Improving the training, competency, and health and safety culture of a microbiology laboratory through the exploration of situated and social learning models.

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A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree

Professional Doctorate in Healthcare Science

School of Health, Education, Policing and Sciences

Version 1 May 2024

Version 2 August 2025

Acknowledgements

I would like to thank my past doctoral supervisors who have played a role in shaping this thesis – Dr Vicki Chalker, Dr Matt Smith, Dr Sarah Williams, Mr Paul Orsmond, Dr Arthur Hosie, Professor Roozbeh Naemi.

My current supervisors Professor Arinola Adefila and Dr Ahmad Haidery who have steered me to completion and offered continuous support and feedback.

My line managers, Dr Sarah Alexander and Sunita Gurung who have supported me undertaking this work and allowed me the freedom to make changes in the laboratory.

I am particularly grateful for the support, mentorship and friendship of Dr Mike Carter who selflessly assisted with the interviews in this study and is always happy to offer advice.

My partner Michael who has allowed me the time and space to complete this thesis and encouraged me to continue when it got too much.

And finally, the whole of the NCTC team, including those who have moved on from the department in recent years. Thank you for letting me change things in the laboratory, hopefully for the better, contributing to the interviews, and providing feedback on my work. I am proud to be able to lead this team.

Abstract

Compliance to health and safety regulations is paramount when working in a microbiology laboratory. Hazards including the handling of infectious agents and using safety-critical equipment mean that staff working in such an environment must be aware of what they are doing and act appropriately. The relationship between training, competence, and safety culture was explored in the National Collection of Type Cultures (NCTC), a microbiology laboratory with 13 staff members.

The aim of this research was to ascertain how laboratory training and technical competence is developed, how it contributes to the overall health and safety culture of the microbiology, what factors influence how staff in a microbiology learn, and what mechanisms should be applied to make a tangible improvement in the approach taken to build a positive safety culture with competent staff.

The research took place during the COVID-19 pandemic in a microbiology in the United Kingdom, after the end of lockdown and during a time of transition back to “business-as-usual,” providing a unique opportunity to evaluate the impact of the pandemic on training and safety culture in a microbiology laboratory, with transferrable practices and idiosyncratic characteristics. A qualitative research methodology was followed, using an iterative action research approach in which the participants were involved in shaping the outcomes of the resources created and implemented during

this research. In total, 24 unique individuals, and 1,190 records featured in the study.

A formative review of incident and training records showed there was potential for improving the laboratory training and competency process to allow for safe practise in NCTC. A critical literature review of 20 research revealed a rapid transition to virtual learning as a result of the COVID-19 pandemic but lacked effectiveness and generalisability to the microbiology setting. The widely used team and problem-based learning, simulation and coproduction, showed the importance of interaction and a collaborative approach to education. These findings aligned with the learning model of Communities of Practice (CoP), providing a potential solution to addressing the link between competence and culture, the influence of leadership and access to tacit knowledge in the workplace. This research reverts to the origins of the CoP theories in its application to an in-person setting.

This is the first known application of Wenger’s value creation framework to evaluate health and safety culture in a microbiology laboratory. It used semi-structured interviews with 10 staff members to explore how information flowed in the workplace what sources staff valued and how leadership and the collective identity of the unit influenced safety culture. Social network analysis to identify information exchange, and triangulation with meeting recordings were also employed to corroborate findings.

The overall findings of this research show that social learning, collaboration and participation are an important contributing factor to the participants’ overall professional competency and should be utilised and incorporated into the laboratory training approach. The competency assessment process was updated to better capture safety training, encouraging involvement at all levels in meetings, establishing feedback on the design of written documentation and decision making and establishing a forward training strategy. The interventions led to a reduction in safety incidents in the laboratory attributed to insufficient training, demonstrating an improvement in the overall safety culture of the laboratory through the integration of social learning, upward feedback and recognition of identity into training frameworks.

The potential impact of this thesis in the wider biomedical community is an alternative approach to effective laboratory training, technical competency and collaborative leadership that moves beyond knowledge and compliance to utilise social interaction to fulfil the training needs of the individuals and build a resilient safety culture across laboratory environments.

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Abbreviations

Abbreviation	Meaning
ACDP	Advisory Committee of Dangerous Pathogens
AI	Appreciative Inquiry
CL	Containment Level
ClassMarker®	https://www.classmarker.com/
CoP	Communities of Practice
COSHH, 2002	Control of Substances Hazardous to Health Regulations, 2002
DOPS	Direct Observation of Procedural Skill
H&S	Health and Safety
HASAWA, 1974	Health and Safety at Work Act, 1974
HG	Hazard Group
HSE	Health and Safety Executive
ISO	International Standard Organisation
MeSH	Medical Subject Headings
MHSWR, 1999	Management of Health and Safety at Work Regulations, 1999
NCTC	The National Collection of Type Cultures
NVivo	A qualitative data analysis computer software package
PD	Professional Doctorate
PHE	Public Health England
PIF	Performance Influencing Factor
QMS	Quality Management System
RA	Risk assessment
RQ	Research question
SAPO, 2008	Specified Animal Pathogen Order, 2008
SCT	Safety-Critical Task
SMART	Specific, Measurable, Achievable, Relevant, Timely
SNA	Social network analysis
SOP	Standard Operating Procedure
STEM	Science, Technology, Engineering, Mathematics
UKAS	United Kingdom Accreditation Service

UKHSA	United Kingdom Health Security Agency
vCoPs	Virtual Communities of Practice

Chapter I

1 Introduction

1.1 Technical Competency, Laboratory Culture, and COVID-19 Pandemic

Health and safety in the microbiology laboratory is paramount to prevent accidents and injuries to the workers and the public. The organisation has a legal duty under the Health and Safety at Work Act 1974, to keep staff members safe from harm and to mitigate risks. This is conducted through appropriate risk assessments, effective training, procedures, policies and reporting structures in the workplace (Health and Safety Executive, 2012).

Microbiology laboratories are governed by additional legislation including, Management of Health and Safety at Work Regulations 1999, Control of Substances Hazardous to Health 2002, Specified Animal Pathogens Order 2008, and Management and Operation of Microbiological Containment Laboratories (Advisory Committee on Dangerous Pathogens, 2019). In the United Kingdom, the Health and Safety Executive (HSE) is the regulatory body tasked with enforcing the law and ensuring employers provide a safe working environment for their employees (Health and Safety Executive, 2022).

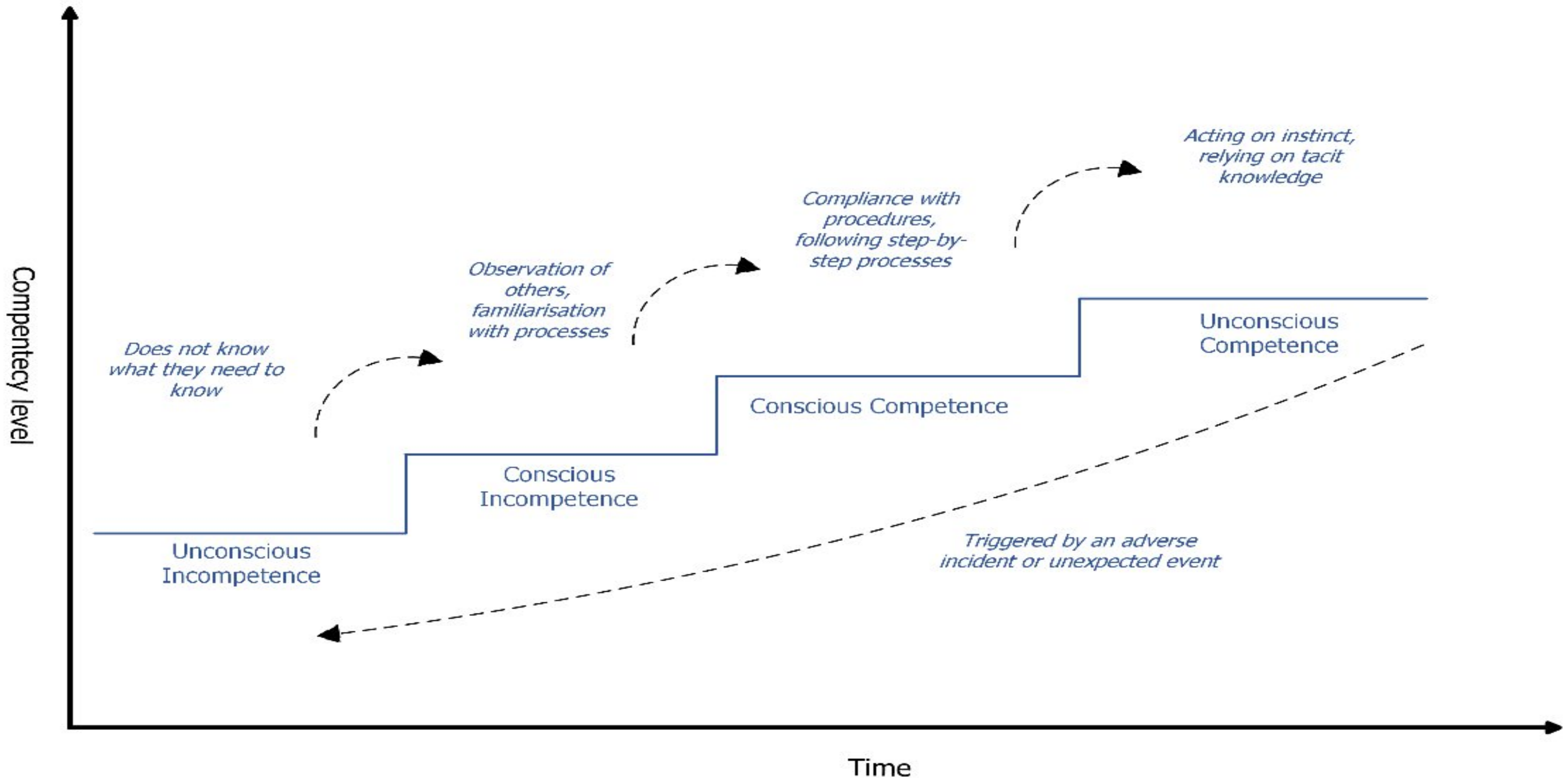
1.1.1 Technical Competency

The Health and Safety Executive describes competence as “*the combination of training, skills, experience and knowledge that a person has and their ability to apply them to perform a task safely. Other factors, such as attitude and physical ability, can also affect someone’s competence*”

(Health and Safety Executive, 2021). A person's competence is grown through training to equip them with the skills, knowledge, and experience to perform the processes effectively and safely.

The first line of control measures are the engineering and mechanical controls aimed to isolate the hazard. Next, procedures with a higher risk must be eliminated or replaced with alternative approaches. Staff are required to undergo training to be able to implement the control measures accurately and consistently.

The conscious competency model of training developed by Noel Burch (Figure 1.1) states that trainees go through four stages to reach mastery. In the unconscious incompetence phase, the trainee is unaware of what they do not know. As training begins, they get a sense of scale of the task and begin to appreciate how much they still need to learn (conscious incompetence). When a trainee is deemed competent, they are acutely aware of the procedure and practise with additional care (conscious competence). Latterly, once technical competency has been mastered, the individual can perform the task without thinking about the specific steps (unconscious competence) (Gordon & Burch, 1974).


Compentecy level
Time
Does not know what they need to know
Observation of others, familiarisation with processes
Compliance with procedures, following step-by-step processes
Acting on instinct, relying on tacit knowledge
Unconscious Incompetence
Conscious Incompetence
Conscious Competence
Unconscious Competence
Triggered by an adverse incident or unexpected event

The stages in which there is a greater risk to health and safety are unconscious incompetence; where the individual may not be aware of the hazards and high risk involved in the working environment and take risks, and unconscious competence; where an individual may perform a task on autopilot without consciously thinking about the procedure and not realise they may make mistakes.

Education and training in a microbiology laboratory must enable the learner to progress through the competence stages to perform tasks safely and consistently whilst learning from adverse incidents to change and improve practice. The conscious-unconscious competence model highlights potential targets for trainers and laboratory managers to intervene to prevent or reduce the impact of a health and safety incident.

Education and training alone is considered a weak health and safety intervention (Russ et al., 2013). Individuals' personality, perceptions of risk and skills play a role in their ability to perform a task safely. To progress to professional competency, a change in behaviour in addition to the acquisition of knowledge is required.

1.1.2 Laboratory Culture

Behaviour change is a function of the person and the environment (Coghlan & Jacobs, 2005), therefore the culture of the workplace influences the health and safety outcomes. In general, culture is defined as collective norms and methods we follow on daily basis. It is the combination of the language, beliefs and habits and shared assumptions of a collective of individuals. Health and safety culture can be defined as "*the way we do things around here*." (Aburumman et al., 2019). Safety culture is an elusive concept, there is no consensus on the elements which form safety culture in the literature (Bisbey et al., 2021).

It is widely acknowledged that safety culture encompass the environmental factors, roles, competencies, attitudes and aptitudes of management and organisation, which will influence the perceptions, attitudes and behaviour of the staff (Bisbey et al., 2021). An organisation with a poor safety culture will have more incidents, whereas positive safety culture is demonstrated by prioritising safety above profits and productivity (Vasconcelos et al., 2018). Therefore, laboratory training must also be effective at changing or influencing a person's behaviour so that they perform tasks in a prescribed manner, not a straightforward undertaking as there is no singular solution for behavioural change.

1.1.3 COVID-19 Pandemic

In March 2020, the United Kingdom entered lockdown due to the COVID-19 pandemic (Gov.uk, 2020). The nation was asked to stay at home; all but essential workers were able to meet face to face, with distancing restrictions in place. Education at all levels was disrupted on a scale not experienced since World War Two. Schools and Universities shifted to online learning and conferences were cancelled. The impact of the COVID-19 pandemic in school age education has resulted in learning deficit in children, particularly from low socio-economic backgrounds (Betthäuser et al., 2023). The impact of the pandemic on safety culture and climate was felt in many fields including aviation and healthcare with reports of a decline in perception of safety climate (Byrnes et al., 2022) and error reporting (Denning et al., 2020). In clinical microbiology laboratories, the majority of work was focussed on testing patient samples for the Sars-CoV-2 virus and routine testing was suspended. Rapid expansion of the laboratory teams with new and inexperienced staff may compromise health and safety in the laboratory setting. The pandemic also expedited the development of the use of technology to facilitate learning and training. Educators had to be creative to deliver the training, ensuring that the objectives were met.

1.2 Research setting

"*If you want truly to understand something, try to change it.*" – Kurt Lewin

As the Operational Lead of a microbiology laboratory, there is a wealth of subjects I need to understand to ensure efficient laboratory operation and reproducible quality service. This can include microbiological understanding of the samples we handle, following restrictive organisational and legislative regulations, or competently managing a diverse team of people in the laboratory. Some of what I am required to know is intangible, such as how people learn, safety culture and defining professional competency. By trying to change and improve these aspects, I hope to gain a deeper understanding of them.

The setting of this research is the microbiology laboratory for which I am the Operational Lead, the National Collection of Type Cultures (NCTC). While NCTC is not directly involved in patient care, it is linked to the protection and improvement of public health. NCTC is operated as part of the Culture Collections department of the UK Health Security Agency (UKHSA). The UKHSA is an executive agency sponsored by the Department of Health and Social Care, with the function of protecting the public from diseases; infections, chemical or radiological (UKHSA, 2023). Culture Collections supports the strategic priorities of the UKHSA by providing high-quality, authenticated biological reference materials to the biomedical community for use in research, diagnostic and testing laboratories, to ensure the reliability and validity of the work (Culture Collections, 2023a). There are four individual Culture Collections focussing on bacteria (NCTC), cell-lines, viruses and fungi, supported by a cross-cutting functional team. In the wider Culture Collections department, there are 80 staff members, we the majority based in Wiltshire. The NCTC unit is based in North-West London.

The NCTC laboratory specialises in the preservation, authentication, and provision of bacterial reference strains of medical or veterinary significance. The collection was established in 1920 by the Medical Research Council who had the foresight to collect and preserve bacterial strains circulating at the time, for future study. The Great War had left an indelible mark on the landscape of the UK and public health; the enteric disease Shigellosis becoming endemic in the trenches on the battlefield (Baker et al., 2014). The importance of further research into these pathogens was recognised at the time and remains the driving purpose behind UKHSA, the Culture Collections and NCTC.

Today the NCTC holds over 6,000 bacterial type and reference strains, consisting of historic strains dating back to the 18th century and representative strains of currently circulating bacteria. The strains are carefully maintained and preserved through freeze-drying, which removes water from the bacterial cells to halt metabolism and keep the bacteria in a state of suspended animation until they are revived by the end user (Culture Collections, 2023b).

Figure 1.2 Equipment used in the freeze-drying process. Constriction of ampoules (left) and loading the secondary freeze-dryer (right)

In addition, the strains in NCTC undergo a rigorous authentication process using current microbiological techniques that are accredited and certified to BS EN ISO/IEC 17025:2017 and BS EN ISO 9001:2015, respectively.

This research project was performed between September 2020 and May 2024, with the majority of data gathered between 2021-2022. With UKHSA being responsible for informing the UK's response to the pandemic, the staff of NCTC faced major disruption to working practices. The research reflects a return to business-as-usual from 2022 onwards with additional social distancing restrictions in place in 2021 and early 2022. The laboratory currently consists of 13 staff members, with data gathered from a total of 24 unique individuals representing past and present NCTC staff.

I have worked for NCTC for over 10 years, starting after completion of my undergraduate degree, as a microbiologist. In the intervening years, I have attained the position of Operational Lead where I now manage the running of the laboratory and a team of 13 people. Working for NCTC has always been a source of pride, confidence and connection to the work undertaken.

I am grateful and proud to be given the opportunity to work with this collection. I am in awe of the rich history of the strains and the research and knowledge they have enabled, and I strive to preserve the collections for future generations of scientists.

NCTC has unique features and working practices however findings from this study would be applicable to other biomedical laboratory settings, providing a framework that influences and shapes the nature of laboratory-based health and safety training.

1.3 Research questions

The original and over-arching research question for this thesis is "***How can laboratory training and professional competency be used effectively to influence health and safety culture?***"

The catalyst for this research question was the rapid shift in working practices during the COVID-19 pandemic. I witnessed first-hand the speed at which laboratory staff were required to learn new techniques or adapt ways of working to accommodate the social distancing measures in place and the increased number of samples requiring testing. I was involved in ensuring the safety precautions in place were updated in line with new guidance and knowledge, and that staff were adhering to them. The social distancing restrictions made it harder to observe and relay information. At the same time, I was responsible for 15 undergraduate placement students, whose experience had been severely disrupted. Some thrived with the opportunity to undertake new laboratory techniques and contribute to the pandemic response, whilst others missed out due to the need to isolate and shield at home. My training techniques had to be adapted to accommodate all 15 of the students working remotely. I had to be inventive and creative to deliver the content to enable them to benefit from the placement experience and be equitable in opportunities and knowledge sharing.

The challenges of training in a laboratory setting during the COVID-19 pandemic made me consider what impact the new training and competency methods arising during the pandemic had on successfully implementing health and safety controls in the microbiology laboratory. Furthermore, my experience with the placement students showed me that any intervention needs to consider the effect on the collective and subsequently culture of a workplace and not just the delivery of knowledge. This presents an opportunity to consolidate the innovations in training from the pandemic and affect meaningful change in the safety culture of a microbiology laboratory.

Through an iterative process of refinement, application of qualitative approaches to research, and consideration of different perspectives, this thesis provides a response to the above question whilst simultaneously expanding and challenging the original definitions and preconceptions. Figure 1.3 details the action research cycle followed throughout this thesis, with each chapter addressing one stage of the cycle.

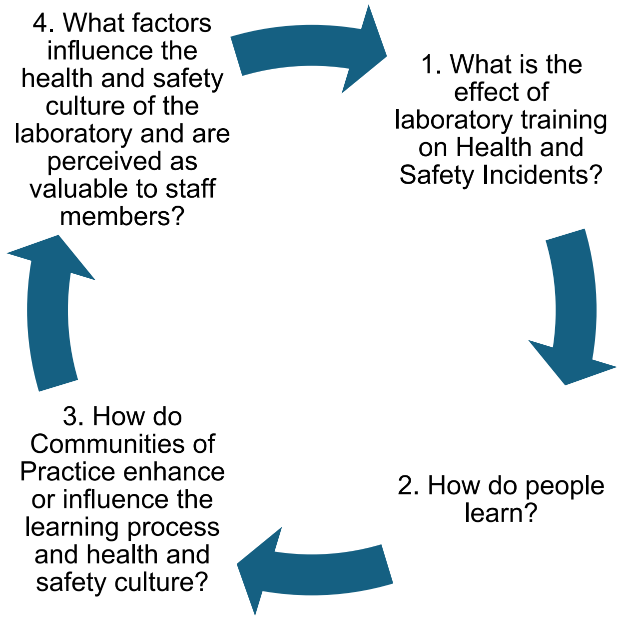


Figure 1.3: Development and progression of research questions presented in action research cycle.

1.4 Research and epistemic approach

Managing change is an essential part of my role as Operational Lead of a Microbiology Laboratory. Change comes in the forms of personnel joining and leaving, updates to processes and regulatory requirements, and changes to the laboratory environment. All require buy-in from those affected by the change to be successful. A figurehead of the change management literature, Kurt Lewin, describes the process of change as three step; Unfreezing (the need for change), moving towards the new, re-freezing (stabilising of the new) (Coghlan & Jacobs, 2005). The opening Lewin quote resonated with me as I enjoy the challenge of implementing changes and improvements to my workplace, whilst wanting to learn more about education, training and development. Lewin is a prominent figure in my thesis development as the primary approach I have utilised is action research, an approach borne out of his work.

My position as a leader in the laboratory means that any interventions will have a direct effect on my team. Therefore, it would be prudent to involve them in the research process by sharing my findings, asking for feedback and making iterative changes throughout the process.

The cyclical phases to the action research approach consist of; identifying a problem; providing evidence; forming and implementing a plan of action; providing further evidence; evaluating effectiveness (Duesbery & Twyman, 2020b). The cycle turns through action and reflection which Lewin described as a spiral of steps, as upon each rotation, a shift in understanding occurs and allows the research to advance (Tripp, 2005).

Action research was chosen as it puts the subjects at the centre of the research. The participants play an active role in addressing the research question or solving an issue in their workplace. Both the researcher and participants will benefit from any improvements made (Duesbery & Twyman, 2020a). This is particularly important when implementing changes to a training programme. The first measurement of successful training is the reaction from the trainees (Kirkpatrick & Kirkpatrick, 2016). They must be satisfied with the training for it to be effective at producing positive results. By taking feedback on changes made as part of the action research cycle, it is more likely to be effective.

When addressing a research question specific to one workplace, action research is a suitable approach as it provides the insider perspective and prevents the disparity between the reality of the situation and what the researcher wants to be happening (Boon, 2017). As the Operational Lead, I consider myself an “insider” to the setting I am studying. The terminology used, the idiosyncratic phrases and processes, are embedded in my knowledge. The value of insider research is contested. On one hand, it offers an insight that may not be afforded to outsiders, as participants may feel more open to share their experience. On the other hand, there is a greater risk of making assumptions and not accurately representing the whole community, just one individual’s perceptions (Dwyer & Buckle, 2009). Rose (1985) as quoted by Dwyer & Buckle (2009) stated “*There is no neutrality. There is only greater or less awareness of one’s biases*.” This is pertinent to the action research approach as it implies that with any researcher, there will be a degree of bias in reporting, no matter their positioning in relation to the community. This is overcome by awareness of self through extensive reflection.

The NCTC laboratory, where my research is conducted, is both unique and universal. There will be terminology and techniques only used within its walls, but readers may find them analogous to their own situation. Parallel to this, there will be situations that have been rendered many times before, across different settings. The reflective nature of this thesis will enable the readers to relate the findings to their own environment to ascertain if a similar approach would be suitable for them.

As outlaid in the introduction, my professional identity and motivation are intrinsically linked with my position as Operational Lead of the NCTC laboratory. In telling the application and outcomes of the research, I am sharing my journey in understanding and growth as a manager and leader. Throughout the thesis I have provided reflective analysis to demonstrate transparency in my reflective thinking. Action research is not all about action. An essential component of the approach is critical reflection. Donald Schön developed the concepts of reflection-in-action and reflection-on-action, the former occurring after an event and the latter whilst it is happening (Schön, 1983). Both these approaches were employed during this research. The written reflections after the completion of each chapter, and continuously as new concepts were encountered, and themes emerged. Reflection-in-action is important as it creates and examines the links between the literature and its applicability to the research setting. It challenges assumptions of both the literature and the setting. In my position, it is crucial that reflection is undertaken as it prevents my own bias from overcoming the interpretation of findings.

The educational theory used to inform interventions and frameworks throughout this thesis is constructivism. This theory originated from cognitivism whereby the learner was put at the centre of teaching rather than the outcome by focussing on the process of learning (Bates, 2016).

The constructivist theories first espoused by Jean Piaget, builds on this by stating that knowledge cannot simply be taught, it is formed by a learner's experience, observations and connections (Filipe et al., 2024). I have leaned towards a constructivist approach due to the desire to involve the subjects, my staff members, in the process of creating an intervention. To do so, I must gain an insight into their understanding and ways of processing information. I feel that this would be a more fruitful approach than implementing interventions based solely on behaviourist theories that focus on the trainer and how they can change behaviour, rather than the needs of the learners. This may not provide motivation for the learners to adopt new practices and have a lack of long-term impact on behaviour change (Lockey et al., 2021).

This doctoral research is an example of the application of qualitative research in science; a style of research I had not had much experience in. When I initially enrolled in the Professional Doctorate programme, I envisaged a more quantitative approach familiar to me from my undergraduate and master's research projects and working in an accredited microbiology laboratory. I foresaw the use of control groups, gathering of measurements before and after the implementation of a new learning platform, taking robust steps to eliminate biases, and performing statistical analysis. However, soon after starting, I realised that this would not be appropriate to what I was trying to achieve. Working with a team of 13 individuals and my position as Operational Lead, it would not be equitable to implement an approach to only half of the team. As the social nature of learning became more apparent as the target for improvements, I began to immerse myself in qualitative literature, at first a daunting prospect but soon providing me with a level of insight and ability to make connection I did not possess before commencing. For example, action research is a cyclical process, but similar to those I am familiar with, such as the Plan, Do, Check, Act cycle used in quality and safety management (Health and Safety Executive, 2013; The Deming Institute, 2024), or the reflective cycle (Kolb & Kolb, 2005). It is a process I carry out all the time in my professional life, but the research has allowed me to take a systematic and structured approach to this. Whilst it is unusual to present a qualitative thesis for a Professional Doctorate in Healthcare Science, qualitative approaches are increasingly utilised in healthcare science to complement and add depth to the scientific advances made (Pope & Mays, 1995). As such, I am proud to present my learning experience of implementing a change in the training approach for health and safety in the laboratory.

Chapter II

2 Health and Safety Practice in the Microbiology Laboratory: The Drivers for Improvement.

2.1 Introduction

The National Collection of Type Cultures (NCTC) currently employs thirteen staff who work in the laboratory, ranging from Supervisors to Support Workers. The NCTC laboratory environment contains risks to the safety of employees if not properly controlled. It involves repetitive actions in dispensing liquid cultures, and manual manipulation of the glass ampoules. Handling a wide range of bacterial strains requires microbiology knowledge to ensure they are cultured in the correct conditions and to be able to identify and differentiate distinct species.

The nature of the work in NCTC creates a high-risk environment; highly concentrated bacterial cultures, handling Advisory Committee of Dangerous Pathogens (ACDP) hazard group two and three strains, and the practice of heating and manipulating glass to create the sealed ampoules. Without appropriate safety control measures in place, there is a chance accidents or other adverse events will occur through causes such as operator error, equipment failure or poor communication. Whilst the challenges faced by NCTC are imitable in other microbiology laboratories, the unique hazards involved with the work makes NCTC an ideal setting to explore and develop laboratory training approaches.

To take into account all the risk factors mentioned above, employers must ensure that they have identified the hazards present, assess how likely the hazards are to cause harm to the business or individual, and put in appropriate control measures to control the risk or remove the hazard. Risk assessments in the workplace are required under The Management of Health and Safety at Work Regulations *(1999*,) The risk assessment is the legal document required for all procedures in a workplace and the findings and controls in the assessment must be incorporated into standard operating procedures (SOPs) and work instructions for the procedure.

UKHSA Health and Safety Guidance HS002A (Public Health England, 2021). states that findings from risk assessments must be communicated to staff through: -

- Training update
- General risk awareness training
- Displaying posters and documents

There should be a record of communication along with feedback from staff to ensure it is understood and to look for further improvement. Periodic refresher training on the processes and risks is also required.

Competency-based training is standard practice in healthcare, driven by quality and regulatory requirements (Brightwell & Grant, 2013). In addition to the legal obligation, NCTC operates under other quality and regulatory policies and standards including the quality standards BS EN ISO/IEC 17025:2017 and 9001:2015, internal quality and safety policies and those relevant to the management of a containment level two and three microbiology laboratories.

The competency assessment process in NCTC is recorded and captured in individual's training records. A new member or staff will undergo a period of training in the laboratory process before they are deemed competent to perform the task independently. The staff working in a microbiology laboratory are knowledgeable about the work they do; however, training others is often an additional task that is expected of competent staff, rather than a skill that is taught. The same is applicable in NCTC, therefore the effectiveness of training may not be consistent and a review of the processes, information recorded and how this aligns with the regulatory requirements will provide an insight into areas of improvement.

2.2 Aims

Following the action research cycle (Duesbery & Twyman, 2020b), data is required to validate the assumption there is a link between training and safety outcomes. A review of the health and safety incidents reported by NCTC staff, and training records was performed to answer the above research questions.

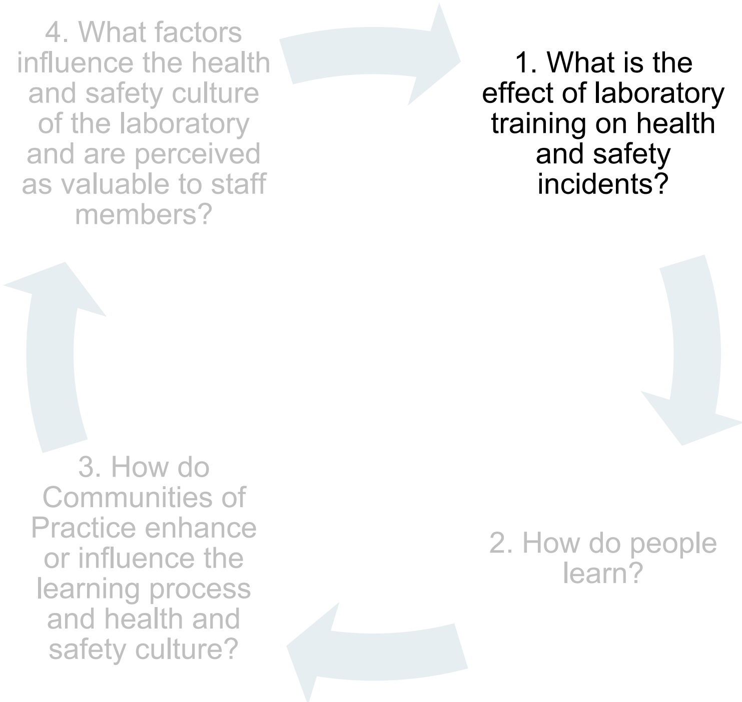


Figure 2.1: Research question one in action research cycle.

To determine the areas for improvement in health and safety training in NCTC, the following research questions will be answered: -

1. **What is the effect of laboratory training on Health and Safety incidents?**
    a. **How effectively does education and training contribute to health and safety compliance and corrective action dissemination in a microbiology laboratory setting?**
    b. **How frequently are health and safety incidents linked to gaps in education or training?**

c. **How are corrective actions from incidents recorded and communicated to laboratory personnel?**
d. **How are regulations, guidance, and procedures integrated into the training process?**
e. **What approaches to training are taken in the NCTC laboratory?**

2.3 Terminology

Table 2.1 details the terminology used in health and safety by NCTC.

Table 2.1 Definition of terms used in health and safety and incident investigation

Term	**Definition**
Accident	An unplanned event that causes injury or ill health (RRC International, 2022).
Near miss	An unplanned event that did not cause harm but had the potential to do so (RRC International, 2022).
Adverse incident	An event that meets the definitions of accident or near miss.
Root cause	The underlying cause of the adverse incident.
Error	An adverse incident not intended by the perpetrator, often the result of poor training, documentation or other job or organisational factors.
Violation	A deliberate infringement of the written procedures.
Corrective	An action implemented to prevent the root cause from

action	reoccurring.

2.4 Methods

2.4.1 Review of H&S incidents

The review was performed in May 2021 using descriptive statistics and narrative synthesis. Adverse incident data held on the Organisation's internal information governance system Trackwise® (Sparta Systems), was obtained for the NCTC unit for the period May 2014 to May 2021 (seven years). The data consists of incident logs completed by NCTC staff including description of the incident, assigned root cause category, analysis of root cause and corrective action taken. The data also includes the interpretation and feedback from the UKHSA-wide Corporate Health and Safety Team whereby additional categorisation on the root cause was applied.

The incident data was analysed for trends in incident type, staff members involved in incident, root cause and corrective actions. Furthermore, coding of the corrective actions was performed to determine how training was applied after an incident. Results are presented in graphical or textual form, summarising the percentage or quantity of measured targets or the themes identified in written evidence.

2.4.2 Review of relevant regulations and guidance

The applicable training and competency guidance were reviewed to extract recommended approaches. Guidance reviewed includes: -

- External safety guidance
  - Human Factors guidance (HSE, 1999)
  - HSE Competency (Health and Safety Executive, 2021)
- Quality standards to which the laboratory is accredited and certified to
  - BS EN ISO/IEC 17025:2017 Testing and calibration laboratories
  - BS EN ISO 9001:2015 Quality Management System
- UKHSA-wide guidance
  - UKHSA health and safety guidance on training and competence (HS001J)
- Departmental-specific guidance
  - Culture Collections Training Manual (ECC74)

2.4.3 Review of training approaches

The competency records of staff held in NCTC were reviewed to determine how well the training records complied to the policies and guidance available in UKHSA and also to establish the methods and techniques used in laboratory training. Based on the near-miss data, eight SOPs were selected related to the freeze-drying process for review. Competency records of 15 staff members trained in the listed processes from February 2014 to June 2021 were reviewed, covering staff at all grades in the unit.

In addition, the training statements on each of the SOPs will be captured to check if they are fit for purpose, and the following documents were reviewed to build a holistic picture of the health and safety culture in the unit: -

- UKAS ISO 17025 audit reports – findings and commendations related to training
- Lloyds ISO 9001 audit reports - findings and commendations related to training
- Internal health and safety audits related to the freeze-drying procedure
- External health and safety audits related to the freeze-drying procedure

Data was extracted by one investigator (me) using a template developed in Microsoft® Forms using the above headings. The full methodology, results and discussion of the review is detailed in Appendix Two.

2.5 Results

2.5.1 Incident reporting in NCTC

In the period May 2014 to May 2021, 111 adverse incidents were recorded by the NCTC laboratory staff: 23 accidents and 88 near misses. Figure 2.2

shows the root cause of the adverse incidents in NCTC. The most common cause cited is education and training factors, with over double the number of incidents attributed to it compared to other root causes (33/111). This indicates that there is potential for improvement in training in the NCTC laboratory.

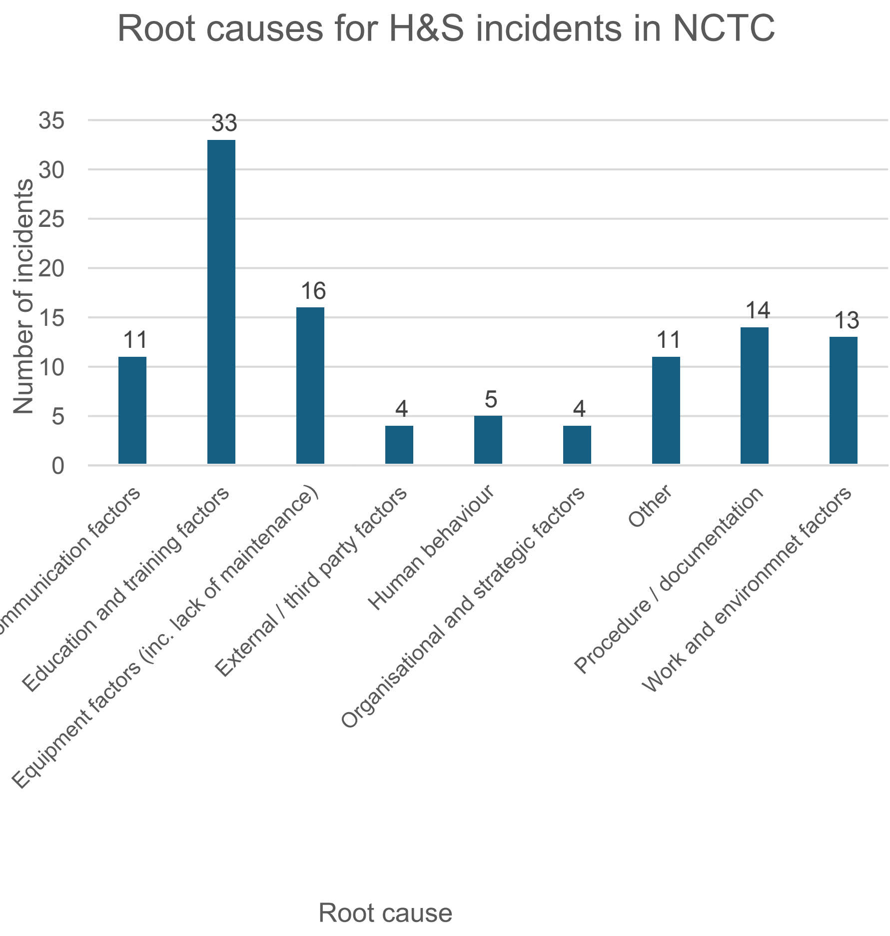


Figure 2.2: Root causes as stated on the information governance system (Trackwise) for the health and safety adverse events occurring in the NCTC laboratory

In addition to the 33 incidents assigned to the root cause of education and training factors, a further 34 records listed education and training of staff as a corrective action or were interpreted to be related to education and training factors by the UKHSA Health and Safety Team, bringing the total number of records in scope of this audit to 67. The full coding of incidents can be found in Appendix One.

Figure 2.3 shows the categorisation of the adverse incidents by the human factor root cause. Human factors are the aspects of human performance that may cause unanticipated events (Russ et al., 2013). The majority (n=56) are errors of which 29 are attributed to lack of knowledge, rather than deliberate violations of the system.

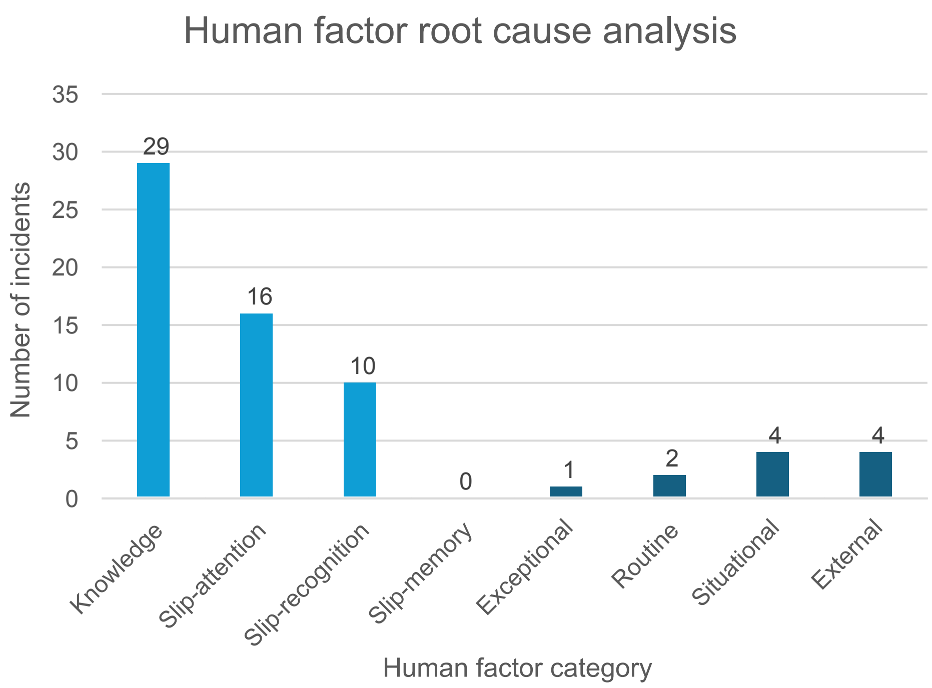


Figure 2.3: Categorisation of root causes of adverse incidents by type of human failure.

The 67 incident records related to education and training were reviewed for patterns, with the nature of the incidents sorted into the categories shown in Figure 2.4.

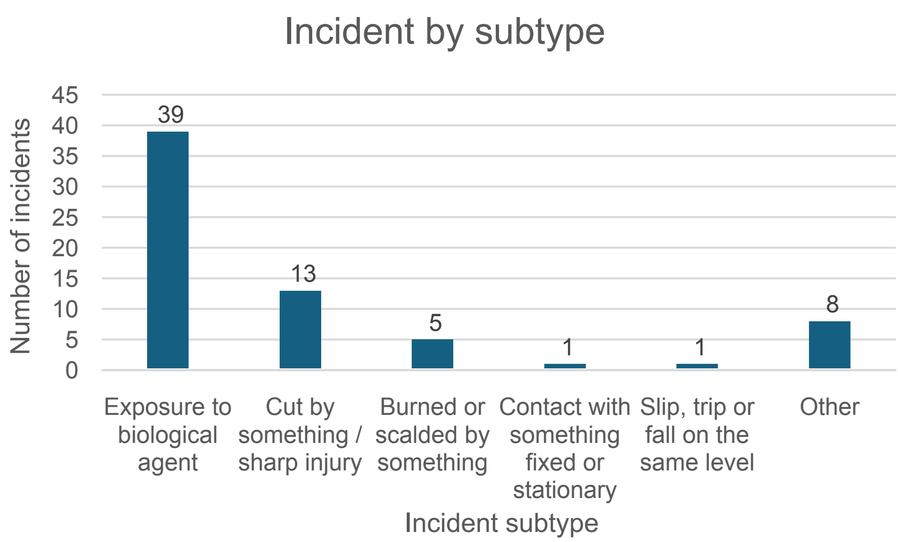


Figure 2.4: Categorisation of adverse events in the NCTC laboratory by pre-defined categories relevant to microbiology laboratories on the information governance system.

The largest incident type is exposure to biological agents, all of which were near misses, the freeze-drying process has given rise to the highest number of incidents among different processes carried out in NCTC accounting for 17 incidents out of 67.

The majority (50/67) records do not state the job title or grade of the staff member involved. Nine records state the staff member was a junior, trainee, student; a greater amount than identify a supervisor (n=1), team manager (n=1) or experienced member of staff (n=1).

Moreover, 39 out of the 67 incidents relating to education and training contain a corrective action involving the re-training or re-education of staff, the majority of which (29/39) was informal rather than documented competency assessments. This figure was derived from reviewing the stated corrective actions for each of the incidents. Examples include:

“Discussion with the team to highlight the incident and prevent further occurrence.”

“Staff urged to take regular breaks.”

“Staff reminded to double check boxes of dry ice before disposing of it.”

“Staff made aware that all incidents and near miss (e.g. plate dropping) are to be reported and acted upon.”

“Student was advised to take care when working in the laboratory.”

2.5.2 The implementation of corrective actions to address the root cause

As the freeze-drying process generated the most training related incidents recorded (n=10), it was selected to review the corrective actions in greater detail. A total of 20 corrective actions were stated in the records.

Figure 2.5 shows the Sankey diagram demonstrating the flow of corrective actions through to tangible outputs. Of the 20 corrective actions identified, four could not be traced at all in the records available, four only resulted in an update to the risk assessment but were not disseminated further, and two were incorporated into the written procedure (SOP) but not explicitly delivered as part of practical or knowledge-based training sessions. Four corrective actions were specifically mentioned in the practical training records for staff. Three in knowledge-based training such as recorded questions and answers, and three were discussed at team meetings.

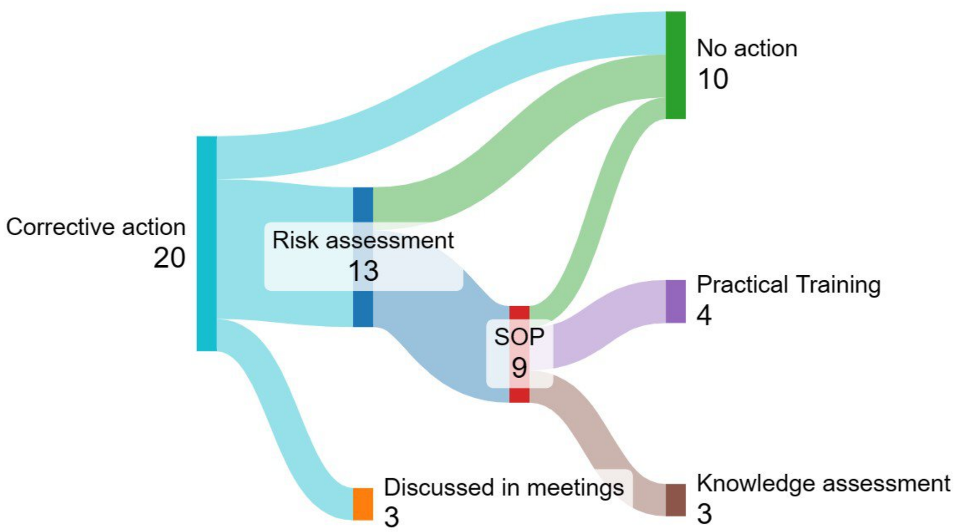


Figure 2.5: Sankey diagram plotting the flow of corrective actions stated for the adverse incidents related to the freeze-drying process.

2.5.3 Regulations and guidance related to technical competency

The six guidance documents were reviewed for recommendations to the approach to training and competency assessment. Table 2.2 summarises the guidance in which recommendations related to training and competency is featured.

The recommendations are arranged in a matrix to highlight similarities and differences. All guidance states that competency expands beyond training and encompasses a person's previous experience, aptitude, and knowledge, whereas the Human Factors guidance on competency contains elements not captured in local training guidance such as more robust training for safety-critical tasks.

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Table 2.2: Matrix of requirements from training guidance applicable to the microbiology laboratory

	Human Factors guidance (HSE, 1999)	**HSE Competency** (Health and Safety Executive, 2021)	**BS EN ISO/IEC 17025:2017**	**BS EN ISO 9001:2015**	**UKHSA health and safety guidance on training and competence (HS001J)**	**Culture Collections Training Manual (ECC74)**
Linked to personal responsibilities	X	X			X	
Competency expands beyond training – encompasses knowledge and experience	X	X	X	X	X	X
Linked to written procedures	X	X	X	X		
Competency assurance system required	X	X	X	X	X	
Training takes into account emergency scenarios	X			X		
More robust training for safety-	X					

	Human Factors guidance (HSE, 1999)	**HSE Competency** (Health and Safety Executive, 2021)	**BS EN ISO/IEC 17025:2017**	**BS EN ISO 9001:2015**	**UKHSA health and safety guidance on training and competence (HS001J)**	**Culture Collections Training Manual (ECC74)**
critical tasks						
Validation and evaluation of training	X	X		X		
Record of activity undertaken						X
Ongoing competency	X	X	X			
Progress of individual tracked		X			X	
Use of a sliding scale of competence.		X			X	
Assessor competent in procedure and assessing		X				X
Set competency criteria		X		X		X

2.5.4 Approaches to laboratory training and technical competency

Personnel

In total, 15 individual training records were reviewed comprising of 120 training events spanning February 2014 to June 2021. Four staffing levels were identified: Supervisors (14 events from 2 trainees), Microbiologists (74 events from 9 trainees), Technologists (22 events from 4 trainees), Support workers (10 events from 2 trainees). Table 2.3 includes a breakdown of the training events per SOP.

Table 2.3: Personnel included in audit based on job role and the numbers for each SOP reviewed.

SOP Title	Supervisor	Microbiologist	Technologist	Support Worker	Total
N2007	1	2	1	0	4
N2312	4	13	3	3	23
N2315	1	7	1	2	11
N2850	4	13	4	3	24
N2857	0	1	1	0	2
N2865	1	11	4	1	17
Total	**14**	**74**	**22**	**9**	**120**

Type of training

Of the 120 training records reviewed, 67 (56%) were initial training records, 43 (36%) were refresher training and 11 (9%) were re-assessments. It appears that the trainers interchangeably used refresher and re-assessment so both types of training have been considered under the heading of on-going competency in this analysis.

Figure 2.6 shows the methods of training utilised in the records as categorised by the HSE. 75% (90/120) training events were accompanied by a competency record. Within NCTC two competence assessment template documents are available for use: ECCW69 for competency assessment and ECCW70 for practical competency assessment.

The second most common method of training was observation with 73% (88/120) of training events featuring some form of observation of the trainee.

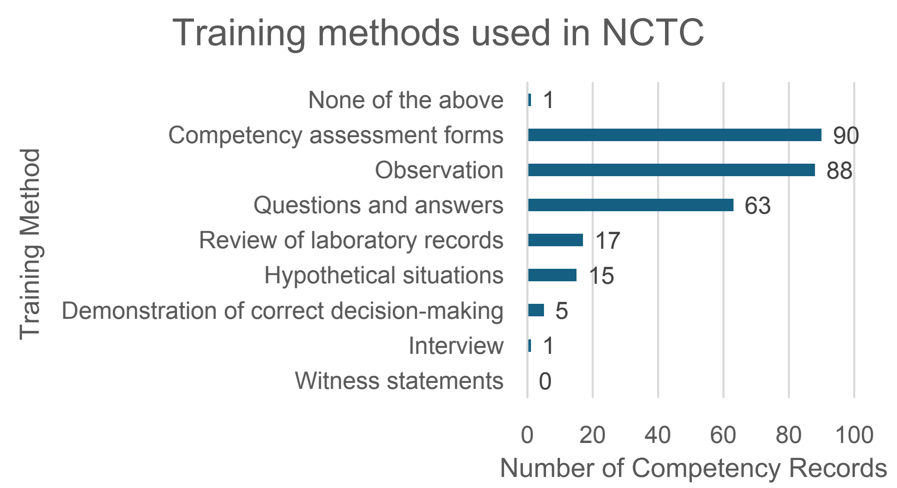


Figure 2.6 Training methods used as inferred from the 120 competency assessment records. Note - a competency record can contain more than one method.

The training records often featured more than one method of training. As shown in Table 2.4, the majority (34% 41/120) of records employ two methods. The most common combination of methods was competence assessment with observation, accounting for 30 (25%) of records (Figure 2.6).

Table 2.4: The number of training methods used in the competency assessment records.

Number of training methods used	Number of training records
1	24
2	41
3	39
4	12
5	3

Length of training period

The average time between the start of training (if noted) and the trainee signed off as competent is 35 days. This is not reflective of the actual time in hours spend training and there is no correlation between length of training and grade of staff (Table 2.5).

Table 2.5: Job roles of NCTC and the average length of training in days.

Trainee staff grade	Average length of training (days)
Support worker	18
Technologist	58
Microbiologist	34
Supervisor	41

Risk awareness

Across the eight procedures reviewed, there are a total of 19 associated risk assessments and eight COSHH associated assessments. The trainees are made aware of the control measures in the assessments through a variety of means, the most frequent being self-declaration that the trainee has “*read and understood*” the risk assessment or procedure, used by 71 (59%) of records including 39 (32%) of records as the only means of conveying awareness. Read and understood consists of the trainee reading the risk assessment and signing and dating their training record that they have understood it.

Figure 2.7 shows the risk awareness methods and their frequency of use. 41 records (34%) contain more than one method.

Figure 2.7: Nature of risk awareness training captured in the competency assessment records.

Audit feedback

Lloyd's Register (LRQA) audit Culture Collections annually as part of the Porton Down certification of the quality management system to ISO 9001. In the period 2014-2021, NCTC staff, processes and training have been included in the audit schedule four times. In addition, The United Kingdom Accreditation Service (UKAS) audit NCTC annually as part of the accreditation to ISO 17025:2017 for the quality control processes. Whilst this is not directly related to the freeze-drying process, comments may provide an insight into the training approach in NCTC. Six UKAS audit reports 2015-2020 were reviewed. 46 comments related to training were identified as part of this review. The majority (22) of comments were regarding how the standard clause was satisfied by the evidence observed. There were 10 general observations and 10 recommendations. In addition, four commendations of NCTC's training process were noted. The majority (14/46) of comments related to the competence records and assessment, commending their appropriateness and suitability for capturing competency. For example, "*Competency assessment is done in a suitable way and requires the trainee to demonstrate a good understanding of the purpose of the test as well to be able to demonstrate they can carry out the test satisfactorily*." Only the earliest audit in 2015 stated the records were not detailed enough and unclear in what constitutes competency. "*Competency for practical training is not fully evident in the training records as it is not clear what competency criteria are being used to assess against*." Another area in which the training in NCTC was deemed suitable was ongoing competency (eight comments). "*On-going assessment of competency is done appropriately*." "*QC processes also provide evidence for continued competency as all are against defined acceptance criteria.*" The external auditors (UKAS) also commented in their final report on the management of training (nine comments) and the induction process (four comments).

Eight internal audits relating to training, or the freeze-drying process were performed between 2015 and 2021. There were five audits performed on training record compliance for staff in Culture Collections, one quality witness audit, one safety witness audit and one laboratory safety checklist performed on the freeze-drying process. A total of 13 findings were raised across all internal audits, with seven requiring follow-up action. The remainder of the findings were positive for example "*[Individual] was very skilled and knowledgeable about the procedures. [They] explained the comprehensive training [they] have received. Control measures in place included: The use of a tray to prevent ampule rolling, lab coat, gloves and lab discipline and training*."

Other methods of knowledge sharing within the NCTC team

In addition to training and competency events, NCTC staff receive information and updates regarding safety and procedures through emails and team meetings. Email communication and informal group meetings (both face-to-face and online), and huddles are out of scope for this audit as no records are available. The minutes of the monthly NCTC Operational and Strategic meetings were reviewed regarding the information on safety provided to staff.

Between March 2014 and March 2021, 39 meetings were held in which health and safety was discussed. These meetings were in-person pre-pandemic and held on Teams during the COVID-19 pandemic (2020 onwards). The most frequently discussed topic was the relaying of incident information, accounting for 28 of the 152 points of discussion. This was followed by risk assessments (16/152), safety audits (13/152), and general incident reporting (12/152).

82/152 discussion points were providing information for staff, 53 topics were instructional, 10 led to further discussion with the team present. Positive feedback to staff was provided six times by the Operational Lead or Supervisor, the majority regarding the reporting of health and safety incidents (3/6). With respect to the incident recorded, 20 were information for staff only, seven required action from staff members and one provoked further discussion during the meeting.

2.6 Discussion

The most cited root cause of health and safety incidents in NCTC is education and training factors (Figure 2.2) which indicates the potential for improvement in the training approach in NCTC. Alternatively, this could be an artefact of the reporting. Root cause analysis requires a systematic approach to ascertain the crux of the issue. In some cases, attributing the incident to a person’s lack of knowledge or experience may mask the true root cause which may be a more systemic organisational or job-related factor.

2.6.1 Unconscious or conscious incompetence?

A theme that emerged during analysis was the reporting of the experience of the person involved in the incident. Whilst the reporting of names and identifiers of specific individuals is discouraged, the job role of the individual is more-commonly stated when the individual is junior, or with additional safeguarding requirements, for example, a placement student. This suggests that it is more likely that an adverse event or near miss will occur during the training phase, when the trainee is inexperienced in a laboratory setting and in the unconscious incompetence stage. Alternatively, it may be the case that an adverse incident is most likely to be reported during the training new inexperienced employees, when the trainee and trainer are more aware of when something is not performed correctly (consciously incompetent) (Figure 1.1, Chapter One). This finding suggests that more focussed intervention in the form of adaptive training is needed at the beginning of a person's journey to laboratory competence and conversely when a person is considered an "expert" to ensure the laboratory protocols are applied as intended.

2.6.2 Training to stimulate behavioural change

Education and training being cited as the most common root cause for incidents in the NCTC laboratory (Figure 2.2) may not be representative of the true picture. From wording of the corrective actions; "*Staff urged to take regular breaks.*" or *"Staff reminded to double check…", "Student was* *advised to take care,"* it can be inferred that what was expected of staff was a change in behaviour.

Returning to the work of Lewin, to implement a change or improvement, one needs to speak to a person's values and behaviour. Behaviour change is a function of the person and the environment (Coghlan & Jacobs, 2005). Improving safety culture cannot be achieved through education and training alone. A person's behaviour must be altered to enable the reduction in human-factor related incidents.

Behaviour change is not simple and there is no magic bullet available to achieve this. Training must be expanded from practical or didactic modes to encompass the socio-cultural experience of the staff. Therefore, any changes would have to consider the safety culture of the laboratory as a whole rather than just the individual performance.

Often, a snapshot of the whole safety culture is measured, known as the safety climate(Alsalem et al., 2018). Safety climate is used as a proxy for the measurement of the culture as a whole, but does not adequately represent the organisational performance (Guldenmund, 2007).

The human factors analysis applied to the incidents showed that 83% are errors, demonstrating a lack of knowledge, a lapse of attention or failure to recognise unsafe practices. Education and training only forms part of the overall safety culture of an organisation and may not be the most effective tool in improving the culture (Hollnagel, 2021). Furthermore, the nature of the risk awareness training used in NCTC being self declaration of understanding does not allow evaluation of behaviour change. There is no mechanism to ensure that reading a document translates to safe practice, a gap for improvement in the competency process.

2.6.3 Informal competence assessment

The audit also highlighted that corrective actions are not always cascaded to staff through documentation or training. It appears that the more informal actions are taken through language such as "*staff urged*," "*made aware*," or "*reminded.*" It is not possible to measure the effectiveness of these informal actions or demonstrate how staff changed their behaviour in relation to these instructions. Leadership and management is considered a major influence on the safety culture of an organisation (Bisbey et al., 2021) the informal language used demonstrate that the laboratory leadership are not adequately providing the support in the form of training, documentation or resources to prevent the incident reoccurring. Incorporating staff feedback is one approach that could be taken to overcome this.

2.6.4 Regulations – the foundation of competency design

Reviewing the policies, procedures and guidance on competency design as part of this review, highlighted that they were not well-implemented in the documentation used to inform training and competency in NCTC. The training manual only covered four of the requirements identified. Looking at the nature of the policies and guidance and how it is implemented in the workplace, there is a clear divide between quality and safety. Whilst there is overlap in what is required from the two systems, there is not one overarching training guidance available encompassing both. The departmental quality manual (2020) is guided by the quality standards and there is no reference to the safety policies utilised in the organisation. As such, the competency assessment approach used in NCTC is purely quality led. The ISO standards offer little direction on how training of staff should be implemented or how competence should be measured. This is due to the standard applying to a wide range of organisations where it would be impossible to harmonise training approaches. As such, the competency assessment method devised for the department by the quality assurance team diverges from the organisation-wide guidance. By not providing staff with stable and evidence-based guidance, they may not be able to comply with all that is required of them, which potentially leads to adverse incidents.

2.6.5 Adapting training for the individual and situation

The length of training captured in the records (Table 2.5) was considered an unreliable metric for review. When competency assessments were introduced in 2014, there were three staff who had already been performing the procedures prior to the introduction, therefore their competency assessments did not reflect their true training journey.

Furthermore, the type of information documented in assessments did not vary between roles of staff. Not all staff roles have the same responsibilities with respect to the freeze-drying process. For example, the support workers may only have needed to recognise potential hazards whereas supervisors required a deeper understanding of the work, compliance and the tasks undertaken by the rest of the team (Sinelnikov et al., 2020). This is not reflected in the records held in NCTC. Sinelnikov et al (2020) present a case for dedicated safety training for supervisory staff as targeting this group has potential to influence safety outcomes at the organisational level, workers attitudes, perceptions of risk and behaviour. Therefore, capturing the additional responsibilities held by supervisors and how they are demonstrated would establish the competency process as a tool of impacting on the overall safety culture of the laboratory.

2.6.6 Effect of COVID-19 on laboratory training in the NCTC laboratory

The effect of the COVID-19 pandemic and subsequent control measures has not been considered as part of this training review. The data used in the review spans from 2015 to 2021. Whilst it covers the period of lockdowns and social distancing, only 30 records included were form this period not allowing a direct comparison of the two eras. This is because in 2020, the freeze-drying activates ceased for staff members to be redeployed to other departments to support the pandemic response. The number of records included when service was resumed only relates to one individual therefore a possible change in approach and evaluation of its effectiveness was not detected. A review of the effect of the COVID-19 pandemic on training would be valuable to ascertain if it resulting in any long-lasting behaviours and practices related to the technical competency process.

2.7 Conclusion

The audit of adverse incidents within the NCTC laboratory unit has shown that education and training factors are frequently linked to gaps in education or training, accounting for a third of adverse incidents that occurred in the laboratory. This includes a direct impact in the form of lack of knowledge or understanding, or indirectly during the training process itself. This figure demonstrates that the raining approach

The technical competency of a person in NCTC is considered on their ability to perform an individual process as per the SOP. This approach whilst satisfactory for quality and regulatory purposes, ignores the wider definition of competency including attitude, experience and behaviours as not all relevant regulations, guidance and procedures are integrated into the training process.

The training in NCTC is expansive, generating thousands of records for each process. It is worth acknowledging that the training and competency process is well managed, making records easily available for review. However, the corrective actions from health and safety incidents could not always be traced to how they were communicated to the laboratory staff, in the form of meetings, SOP updates or training.

The review has revealed that improvements in didactic training will have a role to play in reducing health and safety incidents but may only be part of the solution. The process needs to be adapted to accommodate the requirements from safety regulations through providing additional training and support, and a redesign of the competency assessment forms. Encompassing the wider safety culture of the laboratory and focussing on how information is cascaded to staff, how resources are utilised, and how information is processed rather than the delivery of training may be more effective at influencing behaviour to create a positive health and safety culture and reduce adverse incidents.

Chapter III

3 Training interventions in the times of the COVID-19 pandemic: a narrative literature review

3.1 Introduction

When I commenced this Professional Doctorate, I believed virtual learning would play a large role in the process, potentially as an intervention and method of health and safety training. E-learning has been defined by Moore & Kearsley, (2012) as "*teaching normally occurring in a different place from the learning, requiring communication through technologies as well as special institutional organization."* This broad definition encompasses a wide range of scenarios including, online synchronous or asynchronous lectures, message boards, virtual learning environments, interactive presentation software, or virtual reality. The use of E-learning in all sectors has been accelerated in the past three years due to the COVID-19 pandemic and need to enable learning whilst maintaining social distancing (Connolly & Abdalla, 2022). The previous chapter has established that there is scope for improvement in the training and competency process in the NCTC laboratory. There is also a need to ensure any intervention is able the affect change in behaviour to ensure compliance with stringent health and safety regulations and create a positive culture in the laboratory environment.

The complex requirements for technical competency may not be compatible with the shift to virtual learning. Completing an eLearning module, or attending lectures held via videoconferencing may not confer the understanding or practical skills required to perform duties in a safe manner. The literature in the application of virtual learning in a professional microbiology laboratory is sparse, therefore, to evaluate the appropriate approach to take in the design, implementation and evaluation of a training intervention, a literature review of the wider healthcare literature will provide a foundation for informing the direction to take.

Figure 3.1: Research Question 2 in action research cycle.

Following the action research cycle (Figure 3.1) this chapter is an exploration of how people learn, more specifically:

What learning theories and approaches are applied contemporaneously in healthcare worker education?

a) **how effective are they?**

b) how would these be applied to the NCTC Microbiology Laboratory?

3.2 Objectives

- Determine the training interventions and educational theories applied during the COVID-19 pandemic.
- Establish key features of education and training interventions that made them successful.
- Identify what outcomes are sought in current healthcare education approaches.
- Evaluate which contemporary approaches are applicable to influencing the health and safety culture of a microbiology laboratory.

3.3 Methods

A narrative review of the healthcare training and education literature was performed to determine the contemporary training interventions and educational theories with a focus on those of a constructivist nature.

Literature searches of Medline, Scopus and Education Resource Complete using MeSH headings and free text, targeting the abstracts and titles with keywords “Constructivism,” “training,” “Professional development”, “Pandemic-era education”, “Healthcare professional,” and associated named healthcare professions were combined via Boolean operators. Terminology was adapted for each database. The literature was restricted to only those published between 2020 and 2025 in the English language. The full search terminology can be found in Appendix Three.

The selected population were healthcare workers or healthcare students on a placement in a workplace setting. University-based education and training was excluded except where an intervention was compared to a previous face-to-face workplace setting. These parameters were selected to best reflect the nature of training that may be applicable to the NCTC microbiology setting.

Intervention of any nature were considered for example, face-to-face training or eLearning. Papers describing an intervention and outcomes rather than reviews or opinion pieces were screened for. Study design was not restricted and could include randomised control trials, case studies and uncontrolled before and after studies. This was to best capture the broadest range of interventions applied during the time period selected.

3.3.1 Data extraction and data analysis

Text from the papers identified by the literature search was downloaded to NVivo Pro Version 12 (Lumivero, 2017) and analysed to determine study design, interventions used, and outcomes that were measured. Descriptive information about the research setting, intervention, outcome and participants was extracted. Inductive analysis of the themes around outcomes and reasons for effectiveness of training were analysed through coding on the NVivo 12 software. The codes generated were then ascribed to overarching themes.

3.3.2 Quality assessment

Due to the heterogeneous nature of the studies, an overall risk of bias assessment was not performed. The quality assessment tools developed by the NIH (National Heart Lung and Blood Institute (NHLBI), 2007) were used to assess quality of the content of the studies. The different questions applied to different study designs were tabulated for ease of visualisation.

3.4 Results

All available texts were downloaded to the reference management software Mendeley version 1.19.8, totalling 165 papers. 92 were from Medline, 59 Scopus and 14 from Education Resource Complete.

The abstracts of each text were reviewed, and 19 duplicates removed. Those rejected consist of interventions not in a healthcare work environment (n=57), not a description of a training intervention (n=27), not a full study (n=12), no full text available (n=11), reviews (n=9), not healthcare workers (n=7), intervention occurring pre-COVID-19 pandemic (n=2), and not in English (n=1).

A total of 20 texts remained for inclusion in the narrative review (Figure 3.2).

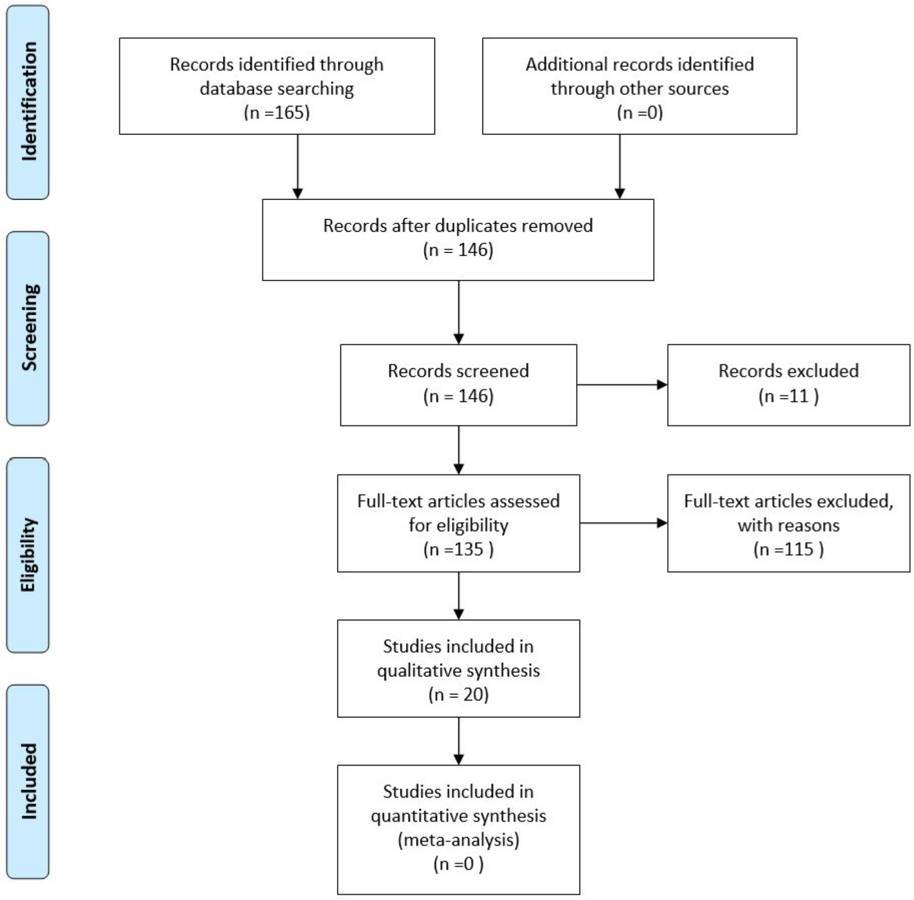


Figure 3.2: PRISMA flow diagram of literature search adapted from (Moher et al., 2009).

3.4.1 Study characteristics

Table 3.1 details the study characteristics of the 20 studies included in the narrative review.

Table 3.1: Study characteristics

Study characteristics	(Alroumi et al., 2021)	(Babenko et al., 2022)	(Bing-Jonsson et al., 2023)
Country and city/province	USA	Canada, Alberta	Norway, Flekkefjord
Setting	Intensive care unit	Family medicine	Nursing homes and a rehabilitation units.
Population	Nurse practitioners	Third-year medical students on clerkship.	Community healthcare nurses
Number of participants and demographics	7 – demographic data not collected, only previous experience in ICU	439 (3 cohorts: 145, 148, 146) Demographic data not collected.	96 completed round 1 (21 RNs, 71 ANs, 4 assistants) 12 completed both rounds (5 RNs, 7 ANs). Extensive demographics captured.
Aims of study	To assess training intervention effect on knowledge and comfort of participants.	To compare collaborative learning outcomes between in-person and online team-based learning.	To identify competence gaps among nursing and implement targeted competence-enhancing activities to improve skills.
Nature of training intervention	Blended learning: synchronous online modules and in-person simulation training. Hosted on Blackboard Coursites Learning Management System	Retrospective comparison in-person clerkships vs. online delivery. Online discussion of clinical case-based scenarios facilitated by clinician.	Targeted blended using learning management system (KS-learning). E-learning, virtual lectures, recorded videos, supervision, vocational training, meetings with supervisor.
Length of intervention	12 weeks, 8 modules, 4 in-person simulation sessions	Not stated	16 months.
Training assessment methods	Multiple choice questions.	Analysis of IRAT and GRAT assessment scores.	Competence mapping using NOP-CET (Nursing Older People—Competence Evaluation Tool)
Training theories applied	Not stated.	Team-based learning.	Not stated.
Study design	Quantitative – descriptive statistics. Pre and post course survey and MCQs	Quantitative, Generalized Estimating Equations (GEE).	Quantitative, cross-sectional design, descriptive statistics
Outcomes	Increase in: - MCQ scores (60% to 73%) Comfort in ICU (3/7 to 5/7) Comfort with ultrasound interpretation (1/7 to 4/7) Decrease in comfort with procedures (3/7 to 2/7)	No significant difference in score improvements across modes; overall mean improvement: 9.30 points (SE = 0.68)	Competence improvement (M = 3.33; p = 0.016) Assistance nurses improved more than Registered Nurses (5.37 points higher; p = 0.014)
Themes identified	Valued interaction with peers and faculty Rated online platform as user-friendly and effective	n/a	n/a
Barriers to success	Simulation limitations during COVID-19 pandemic	Not reported	The assessment was too long resulting in dropouts for

	hinder procedural competence. Issues with data storage on LMS.		round two. Time constraints and competing workload priorities.
Limitations of study	Small sample size. Long-term knowledge retention not assessed.	Only includes one clerkship, Small sample size.	Small sample size (n = 12 for both rounds)
Study characteristics	**(Castro et al., 2021)**	**(Curtin et al., 2021)**	**(Fischbach et al., 2024)**
Country and city/province	USA, multiple	USA, Indiana	USA, Los Angeles
Setting	Community-based residential care homes	Virtual, synchronous medical education program	LA County Department of Public Health
Population	Palliative care (undergraduate students enrolled in palliative care programme).	Paediatric psychiatry students	Newly hired/reassigned public health staff
Number of participants and demographics	126. Gender, age and race demographic data captured.	149. Information on speciality captured.	132 23.5% Hispanic, 17.4% Black, 20.5% Asian, etc
Aims of study	To evaluate the impact of a home-based end-of-life education program on undergraduate students' knowledge, skills, and attitudes	To evaluate the effectiveness of a virtual, multimodal curriculum in teaching medical students and residents about paediatric depression and suicidality.	To evaluate the impact of a virtual Grand Rounds training on outbreak management knowledge and job performance.
Nature of training intervention	Blended experiential learning (online and bedside care).	Virtual, synchronous training - video models, interactive case discussions, and virtual polling.	Virtual sessions conducted through Microsoft Teams. Asynchronous follow up by Microsoft Teams channel (forum).
Length of intervention	Not stated.	60 minutes.	Not stated.
Training assessment methods	Self-assessment surveys, peer feedback, and qualitative reflections from participants	Self-assessment surveys, changes in knowledge, comfort, and attitudes pre- and post-training.	Online post-training survey at end of series.
Training theories applied	Mezirow's Transformative learning theory. Kirkpatrick's Four-Level Training Evaluation Model. Kern's 6-step approach to curriculum development.	Problem-based learning; active learning.	Adult learning; iterative learning; problem-based learning
Study design	Thematic analysis of qualitative feedback. Before and after comparison of self-assessments.	Statistical analysis using Z-scores and Mann-Whitney U tests to compare pre- and post-training data.	Cross-sectional program evaluation, descriptive statistics; Likert-scale responses; qualitative summaries.
Outcomes	Increased empathy, improved communication, comfort with death, self-awareness.	Significant Increase in self-reported comfort with discussing depression and suicidality, increased knowledge of screening tools. Medical students showed greater gain in comfort and knowledge compared to senior residents.	80%+ reported improved job performance; 90% improved understanding; average session rating: 9.13/10
Themes identified	As above	n/a	Peer collaboration, relevance of examples, usefulness of recorded sessions
Barriers to success	n/a	Participants joining from disruptive environments, divided attention of trainees.	Limited access to technology, Surge in workload preventing attendance.

Limitations of study	Lack of control group, self-reporting biases	Limited follow-up, self-reported data, no demographic data collected, small sample size.	Self-reported outcomes; lack of follow-up.
Study characteristics	**(Greenberg et al., 2021)**	**(Ho et al., 2023)**	**(Johnson et al., 2021)**
Country and city/province	USA	Taiwan	Canada, Nationwide.
Setting	Paediatric Anaesthesiology	Radiology	Trauma care
Population	Paediatric anaesthesiology trainees	Post-graduate doctors	Multidisciplinary trauma team.
Number of participants and demographics	2, demographics not stated.	64, demographics not stated.	15, demographics not stated.
Aims of study	To develop and evaluate the effectiveness of a virtual, at-home ultrasound-guided regional block workshop.	To determine the effect of online interactive visual learning on PGY physicians' perceptions of effectiveness and satisfaction with the online learning experience.	To evaluate the effectiveness of a virtual trauma team training course (E-S.T.A.R.T.T.) during COVID-19.
Nature of training intervention	Virtual instruction, video sessions, self-guided at-home ultrasound image acquisition using family members as models.	Online interactive lecture (Google Meeting), exercises using LabelMe software, discussions.	Hybrid delivery. Teleconferencing (Zoom), simulation.
Length of intervention	Not stated.	Two weeks	Not stated.
Training assessment methods	Surveys, informal discussions, debriefs.	Pre- and post-course assessments	Surveys, observation, instructor evaluation
Training theories applied	Adult learning theory.	Process theory	Socratic methods.
Study design	Qualitative evaluation of feedback, trainee performance, and engagement.	Descriptive statistics. Pre-test and post-test assessments and, satisfaction and perception Likert questionnaire.	Qualitative and quantitative analysis of surveys
Outcomes	Improved engagement, increased comfort using ultrasound, enhanced time management, better preparedness for debrief.	Significant increase in post-test scores (median of 4 (1–5) at pre-testing and a median of 5 (2–5)) Satisfaction with teaching methods (Likert scores ≥ 4).	Enhanced learning from observation, increased sense of camaraderie, and valuable feedback from multiple perspectives.
Themes identified	Flexibility in training, value of hands-on practice, enhanced comfort using family as models, and effective time use.	Positive correlation between satisfaction, learning burden, and interest in imaging recognition.	Multidisciplinary collaboration, the value of feedback.
Barriers to success	Lack of access to models and equipment.	Not stated.	Technical difficulties, time zone differences, and

			teachers adjusting to virtual delivery.
Limitations of study	Not stated.	Self-reporting bias, only one centre.	Not stated.
Study characteristics	**(Kelleher et al., 2024)**	**(Koka et al., 2020)**	**(Lee et al., 2021)**
Country and city/province	USA, Texas and Ireland, Dublin.	Switzerland, Geneva	USA
Setting	Texas Children's Hospital and Children's Health Ireland as part of international twinning partnership.	Prehospital emergency medical services, stroke assessment and paramedic training.	Online course focussing on Cross-Cultural Social Work Practice (CCSWP).
Population	paediatric cardiology fellows	Paramedics	Social Worker graduates.
Number of participants and demographics	14 fellows (10 from Texas, 4 from Ireland).	39 (98% completion). Two women in the E-learning group, 10 women in the video group.	Participants and demographics not stated.
Aims of study	To explore the utility and challenges of a joint international educational program in paediatric cardiology fellowship training.	To evaluate the performance of an E-learning module in teaching the National Institutes of Health Stroke Scale (NIHSS), to paramedics.	To develop holistic competence for social justice in social work practice, focusing on social justice, cultural competence, and the effects of virtual learning.
Nature of training intervention	Virtual knowledge sharing sessions	Interactive E-learning module versus subtitled video training. Joomla! 3.9 Learning Management System.	Blended learning (synchronous and asynchronous), teleconferencing (Zoom), digital storytelling, role-playing, simulations, and discussion boards. 3.5-hour long sessions held weekly
Length of intervention	Not stated	Not stated.	Three months
Training assessment methods	Questionnaires – closed and open questions on feedback on the course.	Quiz assessment, time to complete. Participants' satisfaction, perceived course duration, and likelihood of recommending the course.	Graded learner reflections.
Training theories applied	Not stated	Not stated.	Adult learning theories (Knowles).
Study design	Grounded theory, inductive and consensus-based coding to analyse qualitative responses to Likert surveys, descriptive statistics.	Randomized, controlled trial. One group undertake interactive eLearning module, one group to watch training video.	Qualitative analysis of reflections and observation.
Outcomes	93% of fellows found the sessions educationally helpful; 71% agreed the sessions highlighted clinical uncertainty	Participants who followed the E-learning module performed better than those who followed the video—36 (34;37) vs 33 (31;38), P=.04. Satisfaction regarding the learning method was higher in the E-learning group compared to the video group (90% vs 37%, P=.002).	Enhanced critical self-reflection, deeper engagement with cultural humility, and understanding of biases in social work practice.

Themes identified	Variation of practice, managing uncertainty, cognitive overload.	Higher learning engagement, satisfaction, performance improvement and interactivity in E-learning group. E-learning took longer.	Cultural competence, self-awareness, power dynamics, privilege, cross-cultural interactions, biases, and structural oppressions.
Barriers to success	Time management and clinical commitments.	Missing video extracts for some NIHSS items.	Technical issues, lack of in-person interaction, discomfort with reflection.
Limitations of study	Small sample size, questionnaire methodology.	Small sample size, study conducted in one region, only tested learning outcomes, not application of learning.	Not stated.
Study characteristics	**(Mastoras et al., 2022)**	**(Monesi et al., 2022)**	**(Sibrian et al., 2022)**
Country and city/province	Canada, Toronto	Italy, Bologna	USA, California
Setting	Tertiary care hospital - Emergency Medicine, Critical Care, Ethics, and Palliative Care.	Intensive Care Unit hospital	Healthcare centres
Population	Physicians in acute care setting.	ICU Nurses	Newly licensed Registered Nurses
Number of participants and demographics	41, demographics captured include age, sex, experience.	85, demographics not stated.	>50
Aims of study	To improve clinicians' knowledge on best practices for end-of-life care in an acute health crisis. To develop skills in applying clinical decision instruments in the ESC protocol. To foster confidence in communicating triage decisions.	To describe a shortened training program for newly hired ICU nurses using in-situ simulation and evaluate its impact during the COVID-19 pandemic.	To share strategies for a successful transition to virtual learning and demonstrate how a web-based education strategy for NGCNs can replace in-person instruction.
Nature of training intervention	Virtual simulation via Microsoft Teams. recorded lectures.	Short theoretical lectures, hands-on practice, in-situ simulation scenarios, performance assessment using checklists. All in-person.	Virtual learning, clinical case studies, role-playing, small group discussions, development of a learning community and self-reflection. Learning platform with chat, file storage, and videoconferencing capabilities.
Length of intervention	Three weeks.	30 hours (3 days).	10-week programme
Training assessment methods	Self-assessment surveys.	Performance scores via checklists, video recordings, debriefing sessions.	Casey-Fink Graduate Nurse Experience Survey and program evaluations before and after each virtual session.
Training theories applied	Curriculum developed and evaluated with Stufflebeam's Context-Input-Process-Product model. Kirkpatrick level 1 and 2 outcomes.	Team-based learning.	Knowles' theory of adult learning. TeamSTEPPS Kirkpatrick model of evaluation
Study design	Pre- and post-course self-assessment surveys with multiple-choice questions and Likert scale ratings.	Descriptive statistics	Qualitative review of surveys to assess program effectiveness, strengths, and areas for enhancement.

Outcomes	36% Improvement comfort, attitudes on triage and communication. Improvement in test scores from 2.6 to 3.3 out of 5. 95% of respondents agreed or strongly agreed that the objectives were met, the content was relevant, and the program enhanced their knowledge.	67.6% achieved >70% performance, 22% between 60–70%, remainder underperformed and continued training.	Increased learner engagement, satisfaction with virtual learning, and improved application of clinical knowledge. Improved clinical decision-making, enhanced communication skills, better engagement, and increased confidence in patient care.
Themes identified	Enhanced communication skills, appreciation for feedback and practice.	Improved teamwork, situational awareness, communication, confidence, multidisciplinary collaboration, and critical thinking.	Professional role development, critical thinking, communication skills, self-care, stress management, application of knowledge in clinical practice.
Barriers to success	Not stated.	Limited PPE and risk of infection, physical and mental fatigue, time/resource constraints, communication challenges.	Technological issues, online etiquette, some content being less effective in virtual format.
Limitations of study	Small sample size, low Kirkpatrick-level outcomes (reaction and knowledge acquisition),	No long-term follow up, not control group.	Lack of participant demographics. Self-reported findings.
Study characteristics	**(C. R. Smith et al., 2023)**	**(Stippler et al., 2024)**	**(Underhill et al., 2023)**
Country and city/province	USA	USA	USA
Setting	Anaesthesiology residency program at a single healthcare institution	Neurosurgery – online	Academic surgical department
Population	Anaesthesiologists	Postgraduate year 2 neurosurgery residents	Surgeons, fellows, residents, nurses, students.
Number of participants and demographics	54. 63% men, mostly interns (PGY-1), ages ranging from interns to first-year anaesthesiology residents.	122. Demographics not stated.	Total attendees ranged from 23 to 74 per session. Demographics not stated.
Aims of study	To assess the effectiveness of PPE education on donning and doffing adherence.	To assess engagement and attitudes toward active teaching in virtual format. To compare cost and faculty time vs. in-person course.	To assess the effectiveness and engagement of a novel virtual surgical grand rounds format (WWYD), and compare to traditional virtual lecture-based formats
Nature of training intervention	PPE training involving video, in-person demonstration, and immediate feedback after donning and doffing PPE.	Virtual hosted on a website Synchronous and asynchronous reflections, quizzes), instructions, videos, breakout rooms, polls. Use of Zoom for videoconferencing.	Reverse morbidity and mortality rounds. Case-based learning. Moderated virtual discussions, panel experts. Near-peer mentorship and teaching. All held virtually.
Length of intervention	Not stated.	4 hours (previous face-to-face iteration was 8 hours).	24 months.
Training assessment methods	Observation. Comparison of pre- and post-simulation compliance and contamination rates using statistical tests.	Survey of attendees' evaluation of course.	Electronic survey responses,
Training theories applied	Not stated	Kirkpatrick Model Level 1 – Reaction Bloom's Taxonomy	Socratic methods, case-based learning,
Study design	Before-and-after model (pre-simulation vs. post-simulation). Subset included in 8-month follow-up for assessment of long-term retention.	Descriptive statistics; qualitative summaries of attitudes.	Descriptive statistics. Electronic post-session evaluation surveys; end-of-year comparative survey of virtual vs. in-person grand rounds

Outcomes	Significant increases in donning and doffing compliance, reduction in contamination occurrence (P = 0.029), and improved multiple-site contamination (P = 0.013). Long-term doffing compliance decreased from post-simulation (P = 0.008).	Engagement rated good to excellent (73%- 85% of learners). Cognitive load and content good to excellent (75%). Polling content most favourable 90.91% (n = 40) p = 0.0083. Message boards and breakout rooms rated "good" to great" 77% (n = 43) and 70% (n = 30). Reflection most burdensome 23% (n = 10) (p < 0.0001). Presentation most favourable delivery method (89%, n = 39), followed by panel discussion (86%, n = 38).	WWYD vs. traditional sessions; significantly higher in engagement (92.4%), relevance (91.5%), and communication (93.7%), lower mean attendance (60.8 vs. 77.5)
Themes identified	Not stated	Burden of reflection paragraphs, trade-off between cost-effectiveness and hands-on learning, preference for familiar formats	Mentorship and peer learning, Virtual convenience vs. educational quality, Audience diversity impacts experience
Barriers to success	Issues with video technical problems, participant variability in experience.	Inability to replicate hands-on training and informal networking.	Logistical issues such as space and distractions
Limitations of study	Small sample size, single institution setting, limited long-term follow-up, potential inaccuracy in hair/facial hair data.	Kirkpatrick Level 1 only, evaluation tools differed between formats, no comparison with hands-on model.	Single institution; retrospective analysis; incomplete data from some sessions; survey-based data only; no objective measures of engagement;

Study characteristics	**(Walker et al., 2024)**	**(Wan Yunus et al., 2022)**
Country and city/province	United Kingdom, London	Malaysia
Setting	NHS Hospital Trust	Clinical placements for Occupational Therapy students
Population	Healthcare professionals (Mental Health Services) and service users.	Occupational Therapy Students
Number of participants and demographics	11. Demographics not stated.	17 students: 13 females, 4 males. Malay (47.1%), Chinese (47.1%), Indian (5.9%).
Aims of study	To explore participants' experiences in a co-produced experiential learning environment designed to engage creatively with mental health practice.	To investigate the effectiveness and outcomes of online clinical learning and placement in Occupational Therapy during the COVID-19 pandemic.
Nature of training intervention	Drama-led creative workshops to create a film on wellbeing improvement. Workshops held online with face-to-face filming in small groups.	Virtual placement to replace physical placement. Use of videoconferencing (MS Teams). Casse discussions and coursework on learning management system.
Length of intervention	8 x 3-hour weekly workshops	5 weeks
Training assessment methods	Production of short film (output). Training evaluated through semi-structured interviews with participants.	Surveys, interviews and participant observations.
Training theories applied	Co-production, Kolb's theory of experiential learning.	Case-based learning, team-based learning. SPICES-curriculum design.
Study design	Qualitative semi-structured interviews, thematic analysis	Quantitative (Two-way mixed ANOVA, independent t-test) analysis of survey results and Qualitative focus groups.

Outcomes	Enhanced communication, interpersonal skills, creative expression, improved therapeutic alliances, and a greater sense of wellbeing and morale among participants.	No significant differences between full online vs. hybrid learning.
Themes identified	Power dynamics and hierarchy in healthcare Playfulness and safety as facilitators for creativity Group connectedness and support Empathy and understanding through role-playing	Scepticism and acceptance of online learning, Achieving desired competency, peer cooperation.
Barriers to success	Some participants unable to use technology	Miscommunication, internet issues, lack of physical presence, equipment setup.
Limitations of study	Self-selection bias in participants, Limited diversity in participants, long follow-up time, small sample size.	Limited to one setting small sample size, potential bias due to the researcher's involvement.

The 20 papers identified were heterogeneous in location, population, design and intervention. The majority (n=11) of studies took place in the USA, followed by Canada (n=3). The remainder took place across six other countries. One study spanned both the USA and Ireland, describing an international partnership and knowledge exchange (Kelleher et al., 2024).

The population characteristics of the participants also varied across the 20 studies with students and nurses being the most common demographic featuring in four studies respectively. Other professions include physicians with unspecified speciality (n=2), surgeons, neurosurgeons, anaesthesiologists, paramedics and social workers. A breakdown of the exact demographics of the participants was not included in all studies but those that did tended to focus on participants' previous experience such as Mastoras et al., (2022) and Smith et al., (2023).

Further heterogenous factors were the number of participants and length of training intervention. The fewest participants were two in Greenberg et al., (2021), with the largest number featured in Babenko et al., (2022) with a total of 439 participants across three cohorts. The duration of the training intervention was not always clear from the description. It ranged from one hour (Curtin et al., 2021) to 16 months (Bing-Jonsson et al., 2023).

3.4.2 Quality assessment

The diverse nature of the papers identified also reflects in the range of scientific rigor of the studies. Only one randomised control trial was identified (Koka et al., 2020) with the majority being case-cohort or uncontrolled before-and-after studies. Tables 3.2, 3.3 and 3.4 detail the qualitative quality assessment of the papers. Due to the fact most papers were written describing a necessary, unplanned intervention in response to the COVID-19 pandemic, features such as a control group or purposeful sampling were often omitted. Ethical approval was described for 11 of the studies.

Limitations of papers

The self-reported limitations of the studies include, the limited sample size (Alroumi et al., 2021; Babenko et al., 2022; Bing-Jonsson et al., 2023; Ho et al., 2023; Kelleher et al., 2024; C. R. Smith et al., 2023; Wan Yunus et al., 2022), the use of only one institution lacking generalisability (Alroumi et al., 2021; Babenko et al., 2022; Koka et al., 2020; C. R. Smith et al., 2023; Underhill et al., 2023), and the used of self-reporting which may lead to bias (Castro et al., 2021; Curtin et al., 2021; Fischbach et al., 2024; Ho et al., 2023; Sibrian et al., 2022).

CD, cannot determine; NA, not applicable; NR, not reported

Table 3.2: Quality assessment - cohort studies.

	Cohort studies								
	(Babenko et al., 2022)	(Fischbach et al., 2024)	(Greenberg et al., 2021)	(Johnson et al., 2021)	(Kelleher et al., 2024)	(Monesi et al., 2022)	(Sibrian et al., 2022)	(Stippler et al., 2024)	(Walker et al., 2024)
Was the research question or objective in this paper clearly stated?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the study population clearly specified and defined?	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Was the participation rate of eligible persons at least 50%?	Yes	Yes	CD	NR	Yes	NR	NR	Yes	NR
Were all subjects selected or recruited from similar populations and time periods? Were inclusion/exclusion criteria applied uniformly?	Yes	CD	CD	NR	NR	CD	CD	No	NR
Was a sample size justification, power description, or variance and effect estimates provided?	No	No	No	No	No	No	No	Yes	No
Were the exposures measured prior to the outcomes?	CD	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the timeframe sufficient to expect an association?	Yes	Yes	Yes	Yes	CD	Yes	CD	Yes	Yes
Did the study examine different levels of the exposure?	No	No	No	No	No	No	No	CD	Yes
Were the exposure measures clearly defined, valid, reliable, and implemented consistently?	Yes	CD	CD	CD	Yes	CD	Yes	CD	No
Was the exposure assessed more than once over time?	No	No	Yes	No	No	No	No	No	No
Were the outcome measures clearly defined, valid, reliable, and consistently implemented?	Yes	CD	CD	CD	Yes	Yes	Yes	CD	Yes
Were the outcome assessors blinded to exposure status?	NR	NA	No	No	No	No	No	No	NA
Was loss to follow-up after baseline 20% or less?	No	NA	NR	NR	NA	CD	NA	No	No
Were confounders measured and adjusted for statistically?	No	No	No	No	No	No	No	No	NA

Table 3.3: Quality assessment - before and after studies.

Before and after with no control group								
	(Alroumi et al., 2021)	(Bing-Jonsson et al., 2023)	(Castro et al., 2021)	(Curtin et al., 2021)	(Ho et al., 2023)	(Lee et al., 2021)	(Mastoras et al., 2022)	(C. R. Smith et al., 2023)
Was the study question or objective clearly stated?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were eligibility/selection criteria prespecified and clearly described?	CD	CD	Yes	CD	Yes	CD	Yes	Yes
Were participants representative of the general/clinical population of interest?	Yes	Yes	Yes	Yes	CD	Yes	Yes	CD
Were all eligible participants enrolled?	CD	CD	Yes	NR	CD	CD	No	CD
Was the sample size sufficient?	CD	CD	Yes	CD	CD	NR	CD	CD
Was the intervention clearly described and delivered consistently?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were outcome measures valid, reliable, and applied consistently?	Yes	Yes	Yes	Yes	Yes	CD	Yes	Yes
Were outcome assessors blinded?	No	No	No	No	No	No	No	No
Was loss to follow-up <20% and accounted for?	Yes	No	Yes	CD	Yes	NR	Yes	CD
Did statistical methods assess pre/post changes and report p-values?	NR	Yes	NA	Yes	Yes	NA	Yes	Yes
Were outcomes measured multiple times pre- and post-intervention (interrupted time-series design)?	No	No	No	No	No	No	No	No

If group-level intervention, was individual-level data accounted for in group-level analysis?	NA	NA	NA	NA	NA	NA	NA	No

Table 3.4: Quality assessment - case control and controlled studies.

Case control studies			**Controlled intervention studies**	
	(Underhill et al., 2023)	(Wan Yunus et al., 2022)		(Koka et al., 2020)
Was the research question or objective clearly stated and appropriate?	Yes	Yes	Was the study described as randomized, a randomized trial, a randomized clinical trial, or an RCT?	Yes
Was the study population clearly specified and defined?	Yes	Yes	Was the method of randomization adequate (i.e., use of randomly generated assignment)?	Yes
Did the authors include a sample size justification?	No	No	Was the treatment allocation concealed (so that assignments could not be predicted)?	Yes
Were controls selected or recruited from the same or similar population that gave rise to the cases (including the same timeframe)?	Yes	CD	Were study participants and providers blinded to treatment group assignment?	CD
Were the definitions, inclusion and exclusion criteria, algorithms or processes used to identify or select cases and controls valid, reliable, and implemented consistently across all study participants?	CD	Yes	Were the people assessing the outcomes blinded to the participants' group assignments?	Yes
Were the cases clearly defined and differentiated from controls?	Yes	Yes	Were the groups similar at baseline on important characteristics that could affect outcomes (e.g., demographics, risk factors, co-morbid conditions)?	CD
If less than 100 percent of eligible cases and/or controls were selected for the study, were the cases and/or controls randomly selected from those eligible?	NA	NA	Was the overall drop-out rate from the study at endpoint 20% or lower of the number allocated to treatment?	Yes
Was there use of concurrent controls?	Yes	Yes	Was the differential drop-out rate (between treatment groups) at endpoint 15 percentage points or lower?	Yes
Were the investigators able to confirm that the exposure/risk occurred prior to the development of the condition or event that defined a participant as a case?	NA	Yes	Was there high adherence to the intervention protocols for each treatment group?	Yes
Were the measures of exposure/risk clearly defined, valid, reliable, and implemented consistently (including the same time period) across all study participants?	Yes	Yes	Were other interventions avoided or similar in the groups (e.g., similar background treatments)?	Yes
Were the assessors of exposure/risk blinded to the case or control status of participants?	No	No	Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants?	Yes

Were key potential confounding variables measured and adjusted statistically in the analyses? If matching was used, did the investigators account for matching during study analysis?	No	No	Did the authors report that the sample size was sufficiently large to be able to detect a difference in the main outcome between groups with at least 80% power?	Yes
			Were outcomes reported or subgroups analysed prespecified (i.e., identified before analyses were conducted)?	Yes
			Were all randomized participants analysed in the group to which they were originally assigned, i.e., did they use an intention-to-treat analysis?	CD

3.5 Study results

3.5.1 Training interventions

During the COVID-19 pandemic, the majority of training interventions switched to a virtual delivery format, replacing or augmenting in-person training. 14 of the studies described an intervention that was solely virtual. For example, Underhill et al., (2023) describes a virtual setting for case discussions and Wan Yunus et al., (2022) describes a virtual replacement for a previously in-person clinical placement. Seven of the studies feature a blended or hybrid learning environment where virtual and in-person training are combined. Alroumi et al., (2021) used online lectures to complement in-person simulation to train nurses in an intensive care unit (ICU). C. R. Smith et al., (2023) took a similar approach to training healthcare workers how to safely don and doff personal protective equipment. Only one study (Monesi et al., 2022) identified in this review described a wholly in-person training programme for newly appointed nurses in an ICU.

The purpose of the training interventions gives an insight into why the virtual format was favoured during this time period. The training was largely either to replace previously in-person courses that could not take place due to social distancing measures, or as a direct response to the pandemic, to rapidly equip healthcare workers with skills to perform their jobs. Fischbach et al., (2024) and Johnson et al., (2021) introduced new courses on understanding outbreak management and onboarding a new workforce respectively whereas Stippler et al., (2024) and Castro et al., (2021) replace face-to-face training and workplace placements with online alternatives.

The delivery of the virtual training is often multimodal, combining asynchronous delivery in the form of lectures (Ho et al., 2023) and group discussions (Curtin et al., 2021) with synchronous activities such as discussion forums (Fischbach et al., 2024) and prerecorded videos (Bing-Jonsson et al., 2023). Other techniques utilised include quizzing (Stippler et al., 2024) and interactive E-learning modules (Koka et al., 2020). The most commonly-cited tools used to facilitate virtual learning are videoconferencing software such as Zoom (Johnson et al., 2021), Google Meeting (Ho et al., 2023) and Microsoft Teams (Fischbach et al., 2024; Mastoras et al., 2022), and Learning Management Systems such as Blackboard (Alroumi et al., 2021) and Joomla! (Koka et al., 2020).

3.5.2 Educational and training theories

This review searched specifically for papers with constructivist leanings in the search terms to identify techniques and educational theories that would be relevant to the research setting of a microbiology laboratory with diverse staff. Not all of the papers in the literature review stated their theoretical background to the research. As with study design, this may be due to the reactive nature of the interventions.

3.5.3 Training approaches; group problem solving

The most-cited training approaches used were problem-based or case-based learning and team-based learning. The design of these interventions revolved around presenting a real or simulated clinical case to a group of learners for discussion. Wan Yunus et al., (2022) provided a clinical case study via a learning management system for participants to discuss as a group and present their interpretations and proposed treatment plans. Underhill et al., (2023) took a similar approach to replicate ward rounds in a virtual format. (Babenko et al., 2022) introduced virtual team-based learning to develop medical students' clinical decision-marking skills in lieu of an in-person clerkship.

Simulation, role-playing and dramatization were commonly featured techniques in the literature review. Simulation is a fully interactive technique used in lieu of real world experience (Herrera-Aliaga & Estrada, 2022). The techniques employed in the interventions ranged from high to low fidelity. Monesi et al., (2022) used in-person simulation of a realistic ICU scenario for newly-qualified nurses to play out. Lee et al., (2021) used virtual role-playing and simulation as part of a multimodal approach to building social workers' cultural competency. A creative endeavour was undertaken by Walker et al., (2024) in which co-production of short films between healthcare workers and service users helped to gain understanding of the wellbeing needs of mental health patients.

As the papers focussed on the working environment and experiential learning, Knowles' theory of adult learning was cited by (Sibrian et al., 2022) and (Lee et al., 2021) and Kolb's theory of experiential learning (Walker et al., 2024) as a basis for the course design.

Castro et al., (2021) take inspiration from Mezirow's Transformative learning theory, Stippler et al., (2024) utilised Blooms Taxonomy to target their training at the appropriate level, whereas Johnson et al., (2021) and Underhill et al., (2023) base their training in Socratic methods.

3.5.3.1 Measurements and outcomes

Both qualitative and quantitative measurements were utilised across the 22 studies. Kirkpatrick's four-level training evaluation model was quoted by four of the studies (Castro et al., 2021; Mastoras et al., 2022; Sibrian et al., 2022; Stippler et al., 2024) therefore deemed an appropriate framework to evaluate the measurements and outcomes of all studies.

Level 1: Reaction

Eleven of the studies focussed on the reception of the training intervention by the learner rather than the effect on learning. Stippler et al., (2024) assessed the favoured mode of delivery (presentations), self-reported cognitive burden on learners, and how engaging the course was. Koka et al., (2020) evaluated the satisfaction of learners which was significantly greater for the E-learning module than the video (90% vs 37%, P=0.02).

Level 2: Learning

The effectiveness of the training was evaluated by 14 of the studies. Seven used test scores to measure learning with against a control group or compared to the baseline before the intervention. Koka et al., 2020 reported a better average score (36 vs 33 P=0.04) through E-learning over watching a non-interactive training video. Wan Yunus et al., (2022) found no significant difference between performance of students experiencing full online compared to hybrid learning. Ho et al., (2023) compared a single group and found a significant increase in test scores after the intervention (average 4/5 pre-test and 5 post-test).

The second method of evaluating learning applied in the studies is through self-reported feedback from the learners. This method was employed by eight studies and was either quantitative or qualitative. Self-reported learning metrics include an increase in comfort in interpreting ultrasounds (1/7 to 4/7) (Alroumi et al., 2021), increased comfort in discussing depression and suicide (Curtin et al., 2021), and improved understanding (90% participants) (Fischbach et al., 2024).

Self-reported knowledge and skills gained from the training analysed qualitatively includes interpersonal skills (Walker et al., 2024), communication skills (Castro et al., 2021), confidence (Sibrian et al., 2022), and understanding of bias (Lee et al., 2021).

Level 3: Behaviour change

Fewer studies featured evidence of behaviour change as a result of the training intervention. When featured, it relied on self-reported rather than demonstratable evidence, for example, participants in Castro et al., (2021) report greater empathy, Fischbach et al., (2024) improved job performance, and Walker et al., (2024) report enhanced interpersonal skills.

One study that attempted to measure behaviour change is Smith et al., (2023) which evaluated compliance to PPE donning and doffing procedures through measuring contamination. Measurements were taking pre-training, post-training, and for a subset of participants, there was an eight-month follow up to assess long-term skill retention.

Level 4: Organisational change

No study assessed the fourth Kirkpatrick level of organisational change. This may be due to the circumstances in which the training interventions were implemented (during the pandemic) where the opportunity to follow up to measure long-term impact has not yet occurred.

The majority (n=14) of outcomes report were positive in favour of the intervention, including an increase in competence (Bing-Jonsson et al., 2023), test scores (Koka et al., 2020), or increased confidence (Sibrian et al., 2022; Walker et al., 2024). Eight neutral outcomes were reported such as the study by Wan Yunus et al., (2022) finding no significant difference between online or onsite clinical placements, and whilst average test scores were higher for online training than in-person in Babenko et al., (2022), it was not significantly different. Some aspects of the training interventions had negative outcomes. These include a decrease in confidence in course content due to lack of in-person experience (Alroumi et al., 2021), or finding the coursework burdensome (Ho et al., 2023; Stippler et al., 2024).

Due to the variation of outcomes measured, qualitative and non-standardised qualitative methods applied, it is not possible to draw a definitive conclusion about the effectiveness of teaching and training methods implemented during the COVID-19 pandemic.

3.6 Thematic analysis

Flexibility and autonomy

The flexible nature of virtual learning was presented as an advantage of the interventions applied throughout the review. This included the ability to join from differing geographic locations (Kelleher et al., 2024), being able to fit the learning in busy work schedules (Babenko et al., 2022), and being able to catch up on missed content at a convenient time (Fischbach et al., 2024).

A motivational factor to learning during the pandemic was autonomy and responsibility. The interventions designed around problem-solving and cased discussions encouraged learners to take ownership of their learning (Castro et al., 2021). This is a key feature in andragogical learning practice in which adult learners need to feel in control of the learning process and see how can benefit them (Knowles et al., 2020).

Reflection

A training tool commonly used in the studies was critical reflection. Participants were asked to reflect on experiences to build competencies (Lee et al., 2021), mindfulness (Sibrian et al., 2022) or as a group on the experience of the training (Walker et al., 2024). Mastoras et al., (2022) used a structured debriefing model (PEARLS) to encourage feedback and reflection.

The reflective aspect of the interventions was not always appreciated by learners who found it burdensome and time consuming (Stippler et al., 2024).

Social learning

The benefits of learning with and from peers and experts was touted in the interventions that involved group work and discussions. By mandating discussions as part of the training, peer mentorship can be facilitated, as can connections between junior and senior staff that may not have occurred otherwise (Underhill et al., 2023). The interactive nature of the interventions were highly valued by the participants (Fischbach et al., 2024) and through the design of the courses and use of training techniques such as team-based learning, the authors sought to foster a collaborative approach to learning (Kelleher et al., 2024)

It was noted that the virtual-only setting of the training hindered relationship-building and creating group cohesion (Lee et al., 2021). Creative endeavours such as the film-making process undertaken by the participants in Walker et al., (2024) may help to foster bonds between individuals when interacting virtually.

Barriers to learning

The barriers encountered when implementing training interventions during a pandemic ranged from the technical to the personal. The use of virtual platforms meant that learners, teachers and facilitators may experience technical issues such as sound quality and internet connectivity (Johnson et al., 2021; C. R. Smith et al., 2023; Wan Yunus et al., 2022), joining from noisy environments (Curtin et al., 2021), or the inability to share large files with the learners easily (Alroumi et al., 2021). Furthermore, the learners may encounter barriers that prevent them from participating fully such as time constraints and balancing a busy workload (Bing-Jonsson et al., 2023; Kelleher et al., 2024; Underhill et al., 2023) or lack of relevant equipment (Greenberg et al., 2021).

3.7 Discussion and reflective analysis

3.7.1 How do people learn?

Relevant training theories

The literature review has also uncovered potential approaches and theoretical backing to training that would be applicable to the overall research question.

Reflection

Reflection was often drawn upon as part of the training design. Lewin and Schön, it is significant part of the research cycle and training cycle that is often overlooked. Reflection is an essential continuing professional development tool in healthcare, a requirement for many to maintain professional registration and fitness to practice (Bassot, 2015). Reflection is the metacognitive process of analysing the thoughts, emotions and actions taken (Epstein, 2008). The aim of reflective practice is to construct a new understanding that would affect the person’s behaviour and outcomes if a similar situation was encountered again (Mann et al., 2009). Its use in the interventions garnered mixed results. The learners found the reflective activities burdensome which may be a result of poor guidance on how to reflect effectively or using time-consuming methods such as statement writing. Using alternative approaches such as group reflection or creative outputs may make the reflective activities more appealing. As reflection is a key aspect of the constructivist approach to learning and andragogy, it will be considered when designing a training intervention for the NCTC microbiology laboratory.

Two studies were rooted in “Socratic methods.” This is where there is a dialogue between the teacher and the learner generated through questioning that evokes critical thinking and reflection. The use of this technique opens up the subject of appropriate use of questioning in training. Many of the eLearning modules undertaken by the NCTC staff involve taking a question-and-answer assessment as demonstration of understanding. It is unknown at this stage how effective this is and should be evaluated as part of the competency assessment review.

Knowles’ theory of adult learning

Constructivism relies on the learner generating new knowledge through experience and reflection (Lockey et al., 2021). This approach is most suited to adult learners for which Malcom Knowles' andragogy approach was adopted in the design of the training interventions.

The appreciation of autonomy and responsibility by the learners in the review is a key aspect of andragogy. Learners need to have control over their own development (Pelletier et al., 2023). This was emphasised by the implementation of a flipped learning approach in which the responsibility of learning was handed to the participants (Lo & Hew, 2022). The review of the NCTC competency records showed there was a degree of autonomy in place with learners declaring they have "read and understood" the risk assessment. Autonomy may be a motivational factor, but in this form, there is a gap in evaluating the effectiveness of the learning. When designing a training intervention, autonomous learning approaches should be built in with mechanisms to capture and evaluate its effect on behaviour change.

The additional principles of andragogy include the need for an intrinsic motivation to learn, problem-centred learning design, understanding of why the learning is applicable, and being able to draw on previous experience (Knowles et al., 2020). The latter may offer insight into the reasons why more incidents occurred with inexperienced staff members in the NCTC laboratory. It would be prudent to explore the facets of andragogy with the NCTC laboratory staff to involve them in the design of the training and competency process.

The importance of social interaction

The key to a high-performing training experience was to include an element of interactivity and discussion amongst the learners. Knowledge and understanding were constructed as a collective through collaborative activities such as problem solving or case discussions. Jean Lave and Etienne Wenger suggest that learning and understanding is inherently social in nature, which supports the andragogical approach in which traditional didactic modes of classroom teaching as seen as not effective (Lave & Wenger, 1991). The study by Walker et al which employed coproduction of a creative endeavour emphasised the benefits of the social approach: autonomy, responsibility, and identity formation. Up to this point, the social interaction between the workers in NCTC has not been considered a contributing factor for health and safety incidents or progression to competency. Group training for spill scenario discussion has been used in NCTC which would mirror the problem solving or case discussion observed in the literature. Furthermore, the COVID-19 pandemic has limited social interaction, so engineering social learning may be a solution to addressing the gap in knowledge left through lack of contact. Based on these findings, it would be promising to introduce more training of this nature to strengthen the ability to build competency.

3.7.2 Effectiveness of learning theories and approaches identified

Virtual learning

This literature review has highlighted the range of training methods utilised in a healthcare setting during the COVID-19 pandemic. It has shown that the predominant delivery format was virtual using videoconferencing, forums, recorded videos, or learning management software. The outcomes were largely positive but due to the heterogeneous nature of the measurements and lack of long-term follow-up of the effect of interventions, the overall benefits of virtual learning are still inconclusive.

Vaona et al., (2018) performed a review of randomised control trials that evaluated E-learning for healthcare professionals against face-to-face training. Across 16 studies included, they found the E-learning had little to no difference in effect on patient outcomes or worker's behaviours compared to face-to-face courses. Only one of the 16 trials featured in this review had a follow-up period of 12 months or greater, the remaining periods ranged from 3-12 months thus demonstrating short-term impacts only. To date, a more contemporary systematic review covering the same population has not been conducted.

The lack of conclusion in this review can be attributed to the varying quality of the papers identified. This itself is an artefact of the COVID-19 pandemic in which the interventions were a product of necessity rather than design. Furthermore, not enough time has elapsed to follow up on the long-term effects of the learning interventions.

UKHSA, the organisation in which the NCTC laboratory is situated, has also increased the use of virtual learning over the past five years.

Mandatory training and onboarding of new staff involve many interactive presentation packages on topics such as data protection, information governance and sustainability. In relation to health and safety, the Corporate Safety Team have translated the mandatory sessions for all-staff and laboratory workers from face-to-face courses to E-learning packages. In addition, they have created additional packages on specialised topics such as SAPO regulations and transporting dangerous goods. The common advantage identified for virtual learning was flexibility in the timing and extent in which learners could engage with the course. This benefit may not be as applicable to the laboratory setting where learners would need to pick up a practical skill in a timely manner to be able to process high volumes of samples. Using a virtual-only learning platform such as video simulation means that learners lack the hands-on experience essential to develop practical skills required in healthcare (Gomez et al., 2024).

As a result of this literature review and the current situation in the workplace, the blended approached preferred by many of the studies in this review will be taken to include a multimodal approach to training. In addition, it is clear that virtual learning will play a role in any training and competency framework that are developed in the laboratory. However, it will be complemented by face-to-face interactions to create the desired effect on long-term behavioural change in individuals or the organisation-wide shift in culture I am aiming for.

3.7.3 How would the identified training approaches be applied to the NCTC Microbiology Laboratory?

Training evaluation

Performing this review has provided me with an insight into a range of theories of a constructivist nature that I can utilise to design, conduct and assess my training interventions.

I was previously familiar with Bloom's taxonomy of cognitive learning objectives (Bloom, 1956) from using it in objective setting. The taxonomy divides knowledge into six discrete categories of skills requiring an increasing level of cognitive ability (Adams, 2015). The classification system revised in 2001, provides educators with a framework to base objectives dependant on what the desired outcome is. This ranges from remembering – being able to recall and state information, up to creation - in which the learner is expected to use the content of the training course to make something new (Spence, 2019). Using such a framework in the context of competency assessment in a microbiology laboratory can allow the training to be adapted to the trainee, an element missing from the competency records reviewed, and perhaps overcome the higher number of incidents occurring with trainees. Supervisors and those who would be expected to train others will be set objectives to reach the higher taxonomic levels of cognition and psychomotor skills. Using a set of verbs aligned to the taxonomic levels can help laboratory staff construct meaningful training objectives, however, there is no guarantee that this will translate to the trainee's experience (Stanny, 2016).

Evaluation of teaching and training is an expansive field of the education literature, dominated by the work of Kirkpatrick (Kirkpatrick & Kirkpatrick, 2016), who has defined four levels of learning from the initial opinions on the event itself, knowledge gained, through to behaviour change and impact at an organisational level. Its application in this literature review revealed that most training interventions achieved success at the first two levels, but the longer-term impact was not realised. In Chapter Two, the need for improved training in the NCTC laboratory was established, as was the notion that a deeper shift in behaviour and safety culture was required. In a systematic review of workplace interventions for improving safety culture, Aburumman et al., (2019) found that training was the most used intervention although not the most effective. The role of training and competency in safety culture is difficult to define. As discussed in the previous chapter, training and other safety interventions aim to modify a person's behaviour. Hollnagel (2021) argues that there are two desired outcomes to behaviour change; either make things less unsafe by eliminating poor performance, or make things safer by focussing on what works well (Hollnagel, 2021). Training and competency allow for both of these definitions in normal circumstances, but in the event of an emergency, individuals will revert to their natural state. Training often focusses on what to do under ideal operating conditions and not what *not* to do. Therefore, focussing on only the training and competency process will not allow for an overall improvement in safety culture alone. It needs to be considered in conjunction with the organisational factors, teamwork, the nature of the job. Using the Kirkpatrick model of training evaluation will enable any interventions to be evaluated appropriately.

3.7.4 Training intervention framework

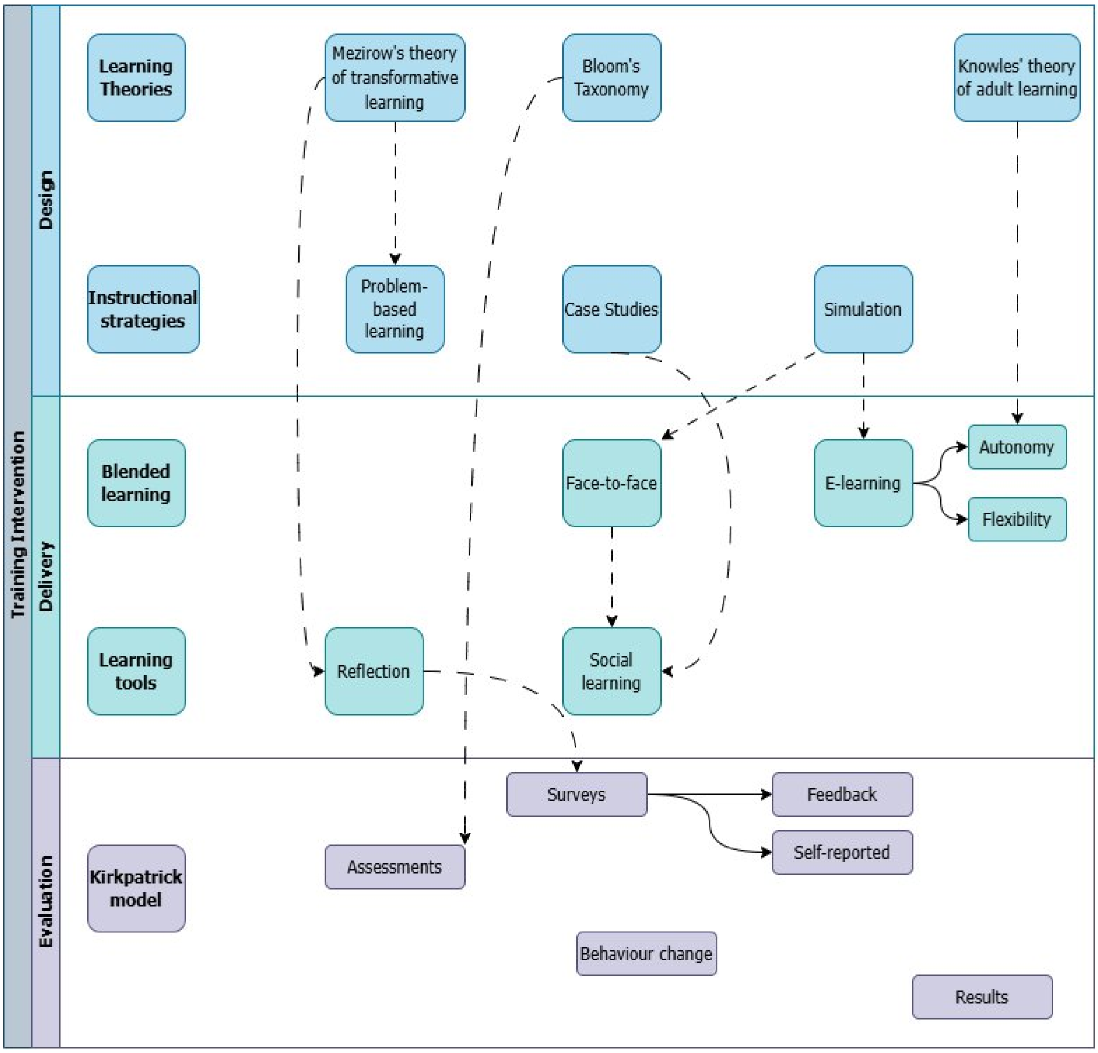


Figure 3.3: Framework for designing a training intervention based on the healthcare literature review.

3.8 Limitations of review

This review was performed by one person, literature searches were not systematically performed and so some key text may not have been identified. The searches focussed on published papers, due to the contemporary nature of the review, more relevant material may have been found in grey literature. A decision was made to focus on a workplace setting which excluded teaching institutions which may have produced a wider range of training and educational interventions. This was to identify training approaches and theories that would be most appropriate to a the NCTC workforce, although no paper matching a similar setting was identified, meaning that some of the themes produced may not be applicable to the research question without further validation.

The review was qualitative in nature meaning that no statistical analysis of the outcomes of education interventions was performed to validate their effectiveness. Qualitative research has its place in healthcare science and is defined by Denzin and Lincoln as a "*situated activity that locates the observer in the world*" (Merriam, 2009). Its use in healthcare has increased as its importance in providing context for quantitative research, providing a valuable insight into the "why" of certain outcomes. As its use has increased, so has the awareness to employ robust and transparent methodologies.

The quality assessment tool used in this review was not high powered. This is due to the resource required to effectively utilise other methods. Other frameworks for qualitative research have been developed by CASP (Critical Appraisal Skills Programme, (2018), GRADE-CERQual (Lewin et al., 2018), as well as checklists such as COREQ (Tong et al., 2007) to guide researchers in formulating and assessing qualitative research. The NHLBI methods were selected due to their accessibility, ease-of-use and ability to cover all study designs identified in this review.

3.9 Conclusion

The purpose of this literature review was to establish how people learn and the effectiveness of training theories and approaches used contemporaneously in healthcare workers. It found that the COVID-19 pandemic has mandated a shift towards the use of virtual learning approaches in healthcare, although there is no strong evidence to its long-term effectiveness. This may be a result of lower quality study design due to the reactive nature of the interventions. A blended approach offers the greatest flexibility to learners whilst retaining hands-on experience essential for development of practical skills required for healthcare roles.

In addition to virtual tools, training approaches that demonstrated effectiveness and would be applicable to the research setting would be problem-based learning, team-based learning, and reflection, the social interaction aspect these approaches provide a possible answer to the question of how people learn. An exploration of social and situational learning literature to identify suitable learning frameworks will follow.

Established theories of a constructivist nature applied in the literature include Kirkpatrick’s model of learning evaluation, Knowles’ theory of adult learning, and social constructivism. These theories will be taken forward to inform the design, implementation, and evaluation of a training intervention to influence competency and positive safety culture in a microbiology laboratory.

Chapter IV

4 Social and situated learning: an introduction and exploration

4.1 Context and overview

Chapter Two highlighted a requirement to review the training and competency approach in the NCTC laboratory to have a positive effect on the safety culture and reduce the number of incidents occurring. The review of the safety incidents also suggested that training and learning takes place outside of formal arrangements, for example, through a conversation in the tearoom, asking a colleague a question, or overhearing another person being trained, but there was no specific mechanism to capture this process, although general processed were proposed. The nature of the competency assessment process used in the laboratory showed room for improvement in adapting the training for the user and role, and in the evaluation of its effectiveness. The training intervention framework designed in Chapter Three (Figure 3.3) has pinpointed approaches and theories that can effectively support health and safety training.

At the centre of these approaches was the idea of learning from peers through discussions, reflection and review of problem-based scenarios. This may be key to ensuring learner engagement and motivation, resulting in behaviour change and safer practice. The social and situated learning theories align with many of the approaches identified in the literature review and may provide enlightenment on why incidents occur and how training can prevent them.

The basis of socio-cultural learning theories emerged with Soviet psychologist Lev Vygotsky establishing the “zone of proximal development” to describe the state between a child's current developmental level, and their potential which could be achieved through interaction with more experienced peers (Vygotsky, 1978).

The theory was echoed in an adult setting by Julian Orr's ethnographic study of Xerox photocopier repair technicians (Brown & Duguid, 1991). New technicians found the comprehensive manual provided by the company lacked relevance in practise. Real-world conditions the photocopiers were placed in e.g. in small, damp cupboards, vibrations from footfall, heavy-handed operator use, were not accounted for. Frustrated technicians started informal meetings over breakfast where they shared stories of unresolved issues and unconventional solutions. Over time, the breakfast meetings became a more valuable tool to the technicians than the manual, allowing them to build a collective knowledge resource that management were not aware of and demonstrating that lone workers thrived when learning socially and collaboratively.

Tacit knowledge is "*that which we know but cannot tell*." Polanyi (1967). It is formed through lived experience and may only become visible during adverse situations, where it is critical for quick decision-making (Eraut, 2000). Orr's work presents me with conflicting thoughts as a laboratory manager. My role is to ensure compliance to standards and regulations through adherence to SOPs, risk assessments and training. I viewed social resources as undermining the quality and safety management system. However, the adverse incidents revealed the depth and breadth of knowledge held by individuals that may not have been revealed as I did not have access to the social spaces. As put by (Brown & Duguid, 2000), managers must balance the process with the practice. Recognising that knowledge is situational and constructed through interaction provides managers with the opportunity to capture and utilise such knowledge in the workplace, and create more insightful documentation and practices. (Brown & Duguid, 1991). In conjunction with improving the formal training processes, in this chapter, I to explored how social learning can contribute to laboratory competence and positively influence the health and safety culture of the laboratory.

The social learning theory I have selected as a framework for designing a training intervention for the NCTC microbiology laboratory is Communities of Practice (CoP). As defined by the originator of the theory Etienne Wenger, a community of practice is "*a group of people who share a concern or a passion for something they do, and learn how to do it better as they interact regularly*" (Wenger & Trayner-Wenger, 2015). This has been selected as the key influencing theory due to the core principles of the learning theory, and the subsequent application of CoP in the healthcare literature, satisfy the training and development needs of the laboratory and provide the elements that create a successful intervention as identified in Figure 3.3 (Chapter Three).

An alternative approach that has developed in parallel with communities of practice from a constructivist background is expansive learning, emerging in the early 1990s from Yrjö Engeström. This approach extends beyond accessing individual's tacit knowledge to utilising collaboration to create new knowledge and understandings. The emphasis on collaboration and social interaction is important but expansive learning focusses on the process of transformation in the times of change with boundary crossing to expand on knowledge and perceptions a key component (Engeström & Sannino, 2010). For this initial exploration into the role of social and situated learning, CoP was the preferred theory to utilise as expansive learning is not insightful on the design of learning, rather, it is more conceptual. It transcends any existing learning theories or didactic forms of learning. Whilst the concept is relevant to the outcomes of this research in capturing where learning occurs outside of set parameters, it does not provide an accessible framework for design, therefore the focus of this chapter is the CoP literature and its applicability to the research question of training interventions to improve professional competency and safety culture in a microbiology laboratory.

Figure 4.1 Research question three in the action research cycle.

This chapter continues to address the question of how do people learn?

The subordinate research question is:-

3. **How do Communities of Practice enhance or influence the learning process and how can this be applied to health and safety culture?**

4.2 Introduction to Communities of Practice

Wenger's concept of Communities of Practice (CoP), first developed with Jean Lave in 1991, states that learning is inherently social, highlighting how newcomers become part of a community by engaging socially with experienced members.

The term "communities of practice" was first used by Wenger in his 1998 book, *Communities of Practice: Learning, Meaning, and Identity*. Here, the ethnographic study conceptualises the theory. A CoP is as defined a group of learners exhibiting mutual engagement, joint enterprise, and a shared repertoire. These definitions are non-prescriptive terms allowing flexibility across contexts. Learning, meaning, and identity are established as fundamental to the function and development of a CoP. The community creates its own internal language and rhythm, which can initially alienate outsiders but, over time, offers a rich platform for shared learning.

Wenger's 2002 work with McDermott and Snyder redefines the core facets of a CoP in more tangible terms: domain (shared purpose and knowledge), community (social interaction), and practice (tools, language, and routines) (Wenger et al., 2002). This text recognised the need for a practical framework to design and implement CoPs as a learning and knowledge management tool. The text presented seven principles for designing CoPs, including designing for evolution, encouraging varying levels of participation, valuing both formal and informal interactions, and maintaining a sustainable rhythm, making the concept more accessible and applicable in a practical setting.

In more recent years, Wenger has focused on the concepts of “constellations” or “landscapes” of practice and the boundary interactions that take place and contribute to the overall community’s development. Boundaries expose the difference between competence and experience. It is important that they do not fully overlap as there is no room for learning but a too greater gap and the opportunity for learning may not be taken (Wenger-Trayner, E. and Wenger-Trayner, 2014) Individuals who participate in multiple CoPs can act as knowledge brokers, helping to share tacit knowledge across boundaries.

4.3 Current application of CoP

From the original conceptualisation by Wenger and collaborators, CoP usage in the business, education and healthcare sectors has evolved significantly in its application.

Presently, knowledge management is the most common application of CoPs in healthcare, bringing together professionals in a specific field working in different geographic locations to share knowledge derived from evidence-based practice and experience. CoPs support personal development and service improvement through sharing ideas, encouraging reflection and peer support (C Alary Gauvreau & Le Dorze, 2022; Giusti et al., 2017; Terry et al., 2020a). CoPs are also used to tackle a specific issue affecting the whole of a profession by members integrating new knowledge into practice to drive innovation and change (Francis-Coad et al., 2018; Jiwa et al., 2009).

Furthermore, the majority of CoP literature generated in the last 10 years utilises technology to connect healthcare workers in virtual communities of practice (vCoPs). Formats used include forums, social media (Alcalde-Rabanal et al., 2018; Lacasta Tintorer et al., 2015; Rolls et al., 2016), blogging (Bertone et al., 2013) , and frequently the use of video conferencing to host meetings (Romero-Mas et al., 2020), this shift in delivery being embraced by Wenger (Farnsworth et al., 2016). vCoPs are easy to establish and break down geographical barriers between groups of people with a shared interest (Barnett et al., 2012). However, the success of such CoPs is not determined. Rolls et al., (2016) found that only a small core group of individuals contributed regularly and vCoPs tended to focus on one discipline; creating boundaries for inclusion of a wider multidisciplinary team. Nevertheless, with the literature trending towards vCoPs, it is clear that technology and online communication is important in the future of communities of practice. This mirrors general shift in the approach to professional training identified in Chapter Three.

The use of CoPs as a knowledge management tool has been widely adopted as it is seen as cost-effective compared to formal learning courses, and a meaningful tool in increasing the sharing of knowledge and information (Busch et al., 2020).

The use of CoPs in practice has diverged from some of the principles it was founded upon. McGrath et al., (2020) found that the CoP label had been misapplied to general professional networks. In their review, it was found that the label was often applied incorrectly or used superficially with only a few using it as an analytical lens. Similarly Smith et al., (2017) found that the CoP framework in the formation of online learning communities was incorrectly or questionably applied in 24 out of 41 studies identified. McGrath et al argue that Communities of Practices is more effectively used as a lens for evaluating learning in a social context than justifying the creation of networks.

4.4 Critical review of Communities of Practice: Key concepts and emerging themes.

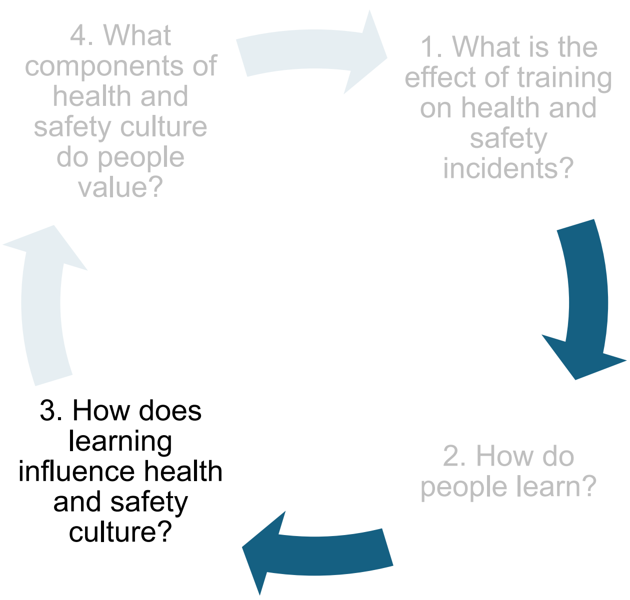


Figure 4.2: Action research cycle, application of findings to answer how learning influences health and safety culture in the microbiology laboratory.

To better understand how Communities of Practice can enhance or influence the learning process and its applicability to improving health and safety culture in a microbiology laboratory, the foundational principles developed by Wenger et al, alongside the application of the concept in the healthcare literature will be reviewed. Critical reflection will accompany the explanation of concepts to elucidate what elements of the practical framework can be improved to apply it to training in the microbiology laboratory.

4.4.1 Domain, community and practice

Exhibiting domain, community, and practice elevates a network to a functioning “community of practice.” Framing the current NCTC laboratory staffing with these concepts may help to realise what can be improved to enable efficient social learning and have a positive impact on health and safety culture.

Wenger et al., (2002 p.29) define the domain as the shared area of interest. The community is the group of people for which the domain is relevant, and the practice encompasses the knowledge, tools, documents, stories told that are available and created by the community.

In the NCTC laboratory, the operational output of maintaining the bacterial collection could be defined as the domain, however, it is unclear with this definition, to what extent health and safety form part of the domain for all the staff members. Understanding how team members define their domain could offer insight into how well their work aligns with the values or the management, organisation, and peers.

Moreover, it is unclear where to draw the boundaries of the NCTC community. There are currently 13 staff members in the core NCTC team of which I manage, but this excludes the wider department, division or organisation. The functions of NCTC differ from the other laboratories on the same site. This would also create boundaries in sharing practices.

Members of NCTC may join from other laboratories and bring with them a new perspective. The COVID-19 pandemic has both hindered the development of a community due to social distancing and minimising interactions within the team, and helped develop it by fostering connections as members assist in other departments in delivery of the pandemic response. With a return towards business-as-usual, there was an opportunity to strengthen the community and embed health and safety into its core identity and interactions.

Practice is defined as the shared resources, tools, routines and experiences of the CoP. NCTC is bound by regulatory demands in the form of legislation and ISO accreditation which are substantially expressed in the laboratory through procedures and training. Lave and Wenger (1991) state that "*Understanding the technology of practice is more than learning to use tools; it is a way to connect with the history of the practice and to participate more directly in its cultural life*." (Lave & Wenger, 1991 p.101). NCTC has a century-long history in which unique methods, language, and understanding has developed. These are only meaningful within the context of NCTC. For relevant health and safety instructions to be embedded effectively, methods of supporting staff in understanding and internalising the practice need to be developed.

4.4.2 Participation and reification

In Wenger's original description of CoPs, the duality of participation and reification were considered essential for sustaining learning. McLoughlin et al., (2018) and Probst & Borzillo, (2008) propose that active participation and collaboration amongst members must be facilitated and encouraged for the CoP to be effective Participation fosters acceptance as members adopt recognised behaviours and viewpoints of the community, essential for gaining access to the wider systems in operation (Jarvis-Selinger et al., 2012).

Reification is described by Wenger as the realisation of abstract concepts into tangible items such as tools, objects, or documents. The resources carry meaning to those in the CoP that may not be fully appreciated by outsiders. The interplay between participation and reification is what sustains the CoP, allowing access to the anecdotal history, documentation, equipment and tools shared across the CoP. As participants engage with these resources, they negotiate the meaning and build their own understanding. Reification was demonstrated in Orr's study of the photocopier technicians. The anecdotal sharing of tips and fixes emerged as a shared resource between the technicians, diverging from what "Management" had intended. In safety culture, this leaves a gap in which both good and poor practice can develop within the laboratory.

Participation has remained a key driver for CoP success; however, the literature has not yet offered a solution to maintain active participation. Wenger's concept of participation encompasses relationship and identity-building in addition to activity. The concept or reification is less explored in the literature. Studies can assign quantitative value to levels of participation, outputs develops such as documents and guidelines

(Wieringa et al., 2018), time saved (Steiner de Benaim, 2008), patient outcomes (Ranmuthugala et al., 2011), or service improvement (J. L. Moore et al., 2021). Qualitative measurements such as sense of belonging (Barry et al., 2017; Terry et al., 2020b),increased job satisfaction (McGrath et al., 2020) have been applied without exploring how participation and reification interplay to achieve these results. Handley et al., (2006) posit that the ambiguity of what participation entails needs further research to answer the question of how to sustain participation within CoPs.

4.4.3 Legitimate Peripheral Participation

An insight into the nature of participation in a CoP is offered in the concept of legitimate peripheral participation (LPP). It describes the standing of new participants to a CoPs as initially on the periphery and accepts that this integral in their learning journey. In this position, learners can still contribute and gain knowledge. It is also recognised that members may move from an integral role in the community to the periphery and back again depending on the current situation.

Being on the periphery of a community is not always a disadvantage. It may mean a person is a member of another community and can act as a broker between the two, sharing information and ideas. Legitimacy is given to the newcomer by existing members which enables them to begin to integrate in the community.

LPP is evident in vCoPs in the literature, where learners are able to engage passively through reading or listening rather than contribution to the conversation (McLoughlin et al., 2018). Ford et al., (2015) observed a low participation but high viewing numbers in a public health forum. The “lurkers” will still benefit from being part to the CoP but may require encouragement to actively participate (Andrew et al., 2008). Norman & Huerta, (2006) included the strengthening of participation in their recommendations for future improvements to their Web-Assisted Tobacco Interventions (WATI) CoP.

The concept of LPP can be explored in the NCTC laboratory through evaluation what barriers are in place to prevent full integration and how staff on the periphery still contribute to the community.

4.4.4 Learning and meaning

Wenger defines “negotiation of meaning” (Wenger, 1998 p.52) as the interaction with others or the resources within a CoP. Negotiation occurs when existing and new knowledge are offset; implying that knowledge is not just acquired but assimilated. Negotiation can take place on an individual or community level, introducing dynamism and evolution to the CoP.

In the microbiology laboratory, health and safety policies should be cascaded from management to laboratory staff. CoP framework offers an insight into why there may be gaps in this process, leading to adverse incidents. If formal safety guidance is inaccessible, staff will construct their own meanings, potentially leading to unsafe practices. Conversely, this process must work in reverse for leadership to utilise innovative approaches. Negotiation of meaning within a CoP is a rich source of study to within a safety-critical environment.

4.4.5 Identity

Wenger has stated that identity is crucial for learning. "*People do not simply learn about; they also learn to be*" (Wenger, 1998 p. 149). Identity is not fixed it is a "trajectory," a continuous process shaped by interaction within and outside the CoPs. It is formed through a combination of lived experience and participation in the community.

Communities of Practice have been widely used in healthcare to determine or influence a person's professional identity. CoPs can provide a "sense of belonging" (Barnett et al., 2012; Barry et al., 2017; Terry et al., 2020b), or be used as a framework for evaluating professional identity (Richard, 2011; Woods et al., 2016).

The CoP view of identity aligns with the wider study identity formation. Gee outlines four factors that shape identity; nature, institution, discourse and affinity (Gee, 2001). Identity is internalised based on how one sees themselves and how others perceive them (Cruess et al., 2019). Identity formation was also an important outcome of social learning identified in the healthcare training literature. The reports of health and safety incidents ascribed to "students" of "trainees" show that these individuals may not be perceived as full members of the community by others. When applying the CoP framework to a training intervention, it will be important to include an evaluation of perceived identity of the individual and wider laboratory to identify factors that contribute to positive health and safety culture.

4.4.6 Reflection

As with the review of the contemporary healthcare learning literature, reflection has emerged as a benefit and outcome of participating in a CoP. Reflection may be embedded into the design of the community, for example, by reflecting on practices (C Alary Gauvreau & Le Dorze, 2022) or to challenge groupthink and contributing to the sustainability of the CoP (de Groot et al., 2014).

Reflection in CoPs can be collective, through storytelling and comparing practices. This aligns with Kolb's experiential learning cycle, where reflection generates new understanding (Kolb & Kolb, 2005). Negotiation of meaning similarly requires members to reconcile existing knowledge with new information obtained from CoP participation. To convert information from tacit individual knowledge to a shared resource, it must be shared, challenging the notion that "lurking," is a form of legitimate peripheral participation, capable of supporting CoP sustainability.

Reflection also shapes identity. As an individual is accepted into a CoP, they begin to view information through both the lens of their identity and the wider CoP they operate in. The process of identity formation should be considered alongside practical training and competency assessment when onboarding new staff in a microbiology laboratory.

4.4.7 Leadership

A key driver in the success and sustainability of a CoP is leadership, especially in the form of facilitation. Li et al., (2009) found facilitation was an essential for a successful healthcare CoP, but there is limited explanation on who should act in this role and their relationship with the organisation. Similarly Probst & Borzillo, (2008) argue for a “strong leader” but provide little detail on what this entails.

Facilitators enable others to complete an action, be it a task or participation in a discussion group. de Carvalho-Filho et al., (2020) described facilitators as “*primus inter pares*” or first among equals, their purpose being coordinating activities, building trust, and providing support. Other papers reiterate the importance of facilitation and encouraging participation (Flogaitis et al., 2012; Jiwa et al., 2009) or keeping focus (Jeffs et al., 2016). This suggests a flat hierarchy in a CoP, in contrast to that experienced in an organisational setting.

Leadership and management qualities such as mediation (Amin & Roberts, 2008), communication, (Driedger et al., 2014), and planning (Conklin et al., 2013) are important for CoP facilitation but it is unclear if facilitators should be in a management position. Probst & Borzillo, (2008) state a leader should be in a position of management to be able to align the CoP with the values of the organisation. Conversely top-down control risks marginalisation of participants (Farnsworth et al., 2016) and reducing engagement (Gleeson, 2010).

Organisational sponsorship is a requirement for a successful CoP. If management is not part of the CoP, buy-in in the form of allowing time, space and financial support (J. L. Moore et al., 2021; Probst & Borzillo, 2008; White, 2010). Roberts suggests that management cannot create a community of practice, only facilitate the emergence of spontaneous CoPs. Lave and Wenger acknowledge CoPs may not always present as a flat hierarchy. Existing members may put barriers in place or withhold information from newcomers, perhaps for fear of being made dispensable or to control the newcomer's journey in becoming a full member. Members need to have trust in each other and management in order to share their knowledge (Roberts, 2006).

In the field of health and safety, Hollnagel, (2021) refers to the gap between "work as imagined" by managers and reality of the implementation of policies and procedures. Managers have the tendency assume staff compliance without considering the perceptions of. In reality, managers and leaders need to consider the perceptions of themselves (Eraut, 2000).

The relationship between laboratory workers and management in the microbiology may affect compliance to policies and procedures. Using CoP as a framework can unravel blockers which may not have come to light in normal working practices.

4.4.8 Motivation

Motivation serves as a factor for success of a CoP and as an outcome of participation. For example, Nesbitt (2013) found nurses in a CoP were more reflective and engaged with research. Francis-Coad et al (2018) observed members of a falls-prevention CoP were more likely to champion fall prevention activities in their workplace. Collective motivation can be generated through dialogues, open communication, aligning with members' needs, and actively contributing to improvements in the workplace (Chalmers & Keown, 2006; Gleeson, 2010; J. L. Moore et al., 2021). Norman & Huerta, (2006) conclude that gathering the member's motives prior to CoP activities increased participation and receptiveness.

Motivational factors identified in the training literature review included autonomy and responsibility. Motivation to learn is also a component of successful adult-learning. Exploring how motivation both to learn and from learning, drives behaviour change is crucial when implementing a training intervention in the laboratory. Moore et al., (2021) applied Michie et al's., (2014) behaviour change wheel which centres on capability, opportunity and motivation as shapers a person's behaviour, which generated an insight into the motivational factors of CoP participation. Whilst motivation, like many facets of CoPs, is difficult to measure, such an insight is required to successfully design a model that perpetuates continued learning and development.

4.4.9 Limitations to CoP

Communities of practice are not a magic bullet to solving professional learning. Critics argue the term "community" implies a harmony, while tension and conflicting opinions may contribute more greatly to the generation of knowledge (Roberts, 2006).

Sustainability and momentum has been identified as challenges to long-term success, due to reduced participation or key members leaving (Adedoyin, 2016; Busch et al., 2020). Contributing factors to sustainability include, adequate leadership (Li et al., 2009), providing diverse and engaging resources (McGrath et al., 2020), organisational support (Probst & Borzillo, 2008).

CoPs may also lack inclusivity. Chalmers & Keown, (2006) found the artificial nature of CoPs prevented accessibility to newcomers. Furthermore a reduced diversity causes groupthink and rigidity (Bertone et al., 2013), curtailing the expression of ideas and opinions.

Building trust and openness is essential for longevity of a CoP and the generation of knowledge (Mcalister, 2016). As shown in the learning literature review, willingness to embrace new formats and technologies played a role in the success of the training intervention.

4.4.10 Evaluating effectiveness

Evaluating the effectiveness of CoPs remains a challenge due to inconsistent methodologies applied across the literature. Studies tend to rely on qualitative approaches such as semi-structured interviews and personal accounts rather than quantifiable data (Li et al., 2009). Ranmuthugala et al., (2011) reviewed 33 studies spanning 1900-2009, found no attempt to empirically assess the impact of CoPs on the desired outcome through quantitative analysis.

Whilst different frameworks have been proposed (Bertone et al., 2013), assessment of lasting impact on organisational culture is not well applied, due to most studies focussing on the initial establishment of a CoP. The lack of evaluation is due to the wide-ranging and evolving application of CoPs, making it difficult to identify elements that drive success (Li et al., 2009; Ranmuthugala, Cunningham, et al., 2011).

Metrics used to measure CoP effectiveness include the level of participation (Christine Alary Gauvreau et al., 2019), resources or outputs generated (Adedoyin, 2016; Bertone et al., 2013), improvement on health outcomes, and participant feedback (Bertone et al., 2013). Evaluative tools used include social network analysis (Helms, 2007; Schenkel A, Teigland R, 2000), surveys (Millen & Fontaine, 2003), measurement of proxy parameters (DiFonzo & Bordia, 1998) and the development of frameworks (Scarso et al., 2009).

Wenger argues the success of a CoP is tied to the value delivered by its existence, or felt by the participants (Wenger et al., 2011). To successfully evaluate the effectiveness of a CoP, one must determine what is considered “valuable” which is inherently subjective. By focussing on value, researchers can analysis how the core elements of CoP identified in this critical review contribute to the overall success and sustainability. This viewpoint echoes that identified in the training literature review of the need to find what is important to the learners to enable effective learning.

4.5 Conclusion and reflective analysis

Reviewing the Communities of Practice in healthcare literature has shown potential in the framework's ability to influence the learning process and subsequently health and safety culture. It has demonstrated that the social learning process extends beyond the barriers of a training intervention and permeates into the wider organisational approach to building a positive health and safety culture, therefore, any interventions will not just focus on training but utilise the wider socio-cultural context of the microbiology laboratory.

The review has highlighted several important factors in the management and sustenance of a successful CoP such as the leadership structure, use of technology and encouraging different forms of participation. It also provided an insight into which of the original concepts within the CoP model were more frequently used; the notion of participation and formation of professional identities proved important in the success of a CoP. It would be useful for me to explore these factors with the NCTC laboratory team. The review demonstrates that CoP as a framework for designing interventions is able to provide a complete package that addresses the questions of how people learn, and how to evaluate effectiveness through focussing on value creation.

The next stage of this research could be to form a community of practice and try to successfully implement the elements identified as crucial for success. This approach would likely fail as unlike many of the CoPs reviewed, the NCTC laboratory is comprised of staff with a mixed level of competency and engagement in the health and safety culture. The logical approach would to be take the CoP framework and use it to evaluate the current safety culture of the NCTC microbiology laboratory through exploring the levels of social interactions, and what staff value in relation to health and safety training.

Chapter V

5 Communities of Practice as a lens to explore health and safety training and culture

It is established that learning must transcend training and the incorporation of the facets of CoP into the competency process may provide framework to achieve this. To examine this hypothesis, involvement of the current staff in NCTC will determine if the components of CoP are present in the unit and how they can be improved to influence safety culture.

Figure 5.1: Action research cycle question four.

To address the above research question, the following subordinate research questions will be addressed: -

a. What is the collective identity of the department?

One of the prominent notions of the CoP theory is that as an individual embeds within a community, they develop an identity (Wenger, 1998). The identity influences the construction of knowledge demonstrated when a boundary is met, and meaning is negotiated. To conceptualise the NCTC as a CoP, it would be beneficial to understand how the members visualise their roles and responsibilities within the unit as well as how the perceive the identity of NCTC in the wider organisation.

b. Where do staff obtain information related to health and safety and which sources are most valued?

What resources and events do NCTC staff have access to? What is the nature of these resources? Are the resources developed inside the CoP? Which ones do staff value the most?

In addition, the connections with other people in and outside of the unit will be determined. Brokers are individuals placed at the boundaries between CoPs who share information and practices. It is important to determine who acts as a broker in NCTC so these connections can be utilised. The research will also determine who are the key connections that provide health and safety information and if certain individuals privileged to information that others are not.

c. What social network is available to staff members?

This will identify how information is cascaded within the CoP. Social network analysis will be performed on the responses given by participants to map out the network, identify potential cliques, key players, and who may be on the periphery. This will help establish which areas of communication need to be strengthened and which individuals act as brokers between other communities and networks. Brokers are essential within a CoP as they enable new information and ways of working to be obtained.

d. What factors influence the health and safety culture?

Using the CoP framework, thematic analysis of the most important factors that influence how staff use safety information and inform their understanding of the requirements in the laboratory will be determined. This will be used to produce a tailored framework for leaders and managers to shape the culture of the laboratory.

5.1 Methods

Semi-structured interviews were held with existing and recently departed NCTC laboratory staff. The interview format was selected as it allows for a deeper exploration of the insider perspective than surveys (Holloway & Galvin, 2017). Perception and emotion can be detected in addition to factual information, which is important for this research as will help elicit the identity aspect of the CoP. Focus groups were considered but dismissed as a data-gathering tool as it may have resulted in “groupthink” and the influence of dominant characters on the responses of others.

Additional data was gathered in the form of “huddle” recordings, bi-weekly informal meetings held with staff to discuss workloads and issues, and monthly operational meeting minutes. This was done as a form of triangulation, to provide evidence that what the participants are saying is representative of the situation, and also as an independent source of information to ensure the researcher was not unduly influencing the outcomes.

The interview schedule was adapted from the value creation framework developed by Wenger et al., (2011). Wenger states "*systematic anecdotal evidence*" through speaking to and observing members is the most effective method of reflect the true value held (Wenger et al., 2002). This framework has been selected as it utilises and expands upon the evaluation of learning model devised by Kirkpatrick, which was identified as a widely used tool in the application of new training interventions in healthcare. The value creation framework expands this model to five cycles of value creation, additionally capturing the sociability aspect of learning, and offers examples and questions that could be used in practice. Furthermore, as the framework is devised by the originators of CoP, it provides an in-depth basis for exploring the different facets such as value, meaning, identity.

The open questions proposed in this schedule address the key areas of interest; where and whom health and safety information is obtained from, what type of methods are valued, how the participant perceives their role in contributing to the health and safety culture of NCTC. In addition, it will offer insight into how knowledge and resources are developed within the team. The interview schedule can be found in Appendix Four.

Additionally, social network analysis (SNA) based on the answers given by participants was used as a method to illuminate the social capital each member had both within and outside of NCTC. SNA is a technique used to explore relationships between individuals or different groups. It can be applied to small familial, workplace settings or to internet-facilitated networks consisting of millions of individuals (Knoke & Yang, 2020). It provides an insight into relationships that qualitative data may not uncover, exposing connections and potential that may not be realised through other methods. Its use to complement the semi-structured interviews and intended to demonstrate who may be the main actors in building and sustaining safety culture in the laboratory.

5.1.1 Theoretical framework

A qualitative descriptive and interpretive approach, driven by phenomenology was taken to gather data and explore the research questions. Participants' perceptions were triangulated with documented evidence to build a model of how health and safety information and resources is used within the NCTC, what meaning participants attached to their experience and how they interpret the information they have available to them.

5.1.2 Participant recruitment and selection

All current laboratory staff (n=7) and former laboratory staff who had moved to different positions within the organisation (n=3) and the outgoing Operational Lead were invited to participate in the interviews. Invitations were sent via email including an information pack detailing the purpose and nature of the research. All but one of the invitees gave written informed consent to take part in the study. No response was received from the invitee via email or follow up. This may be due to the fact they were no longer working for the unit at the time of the invitation.

5.1.3 Data collection

The semi-structured interviews will enable participants to answer the following questions: -

- How do you describe your role in the unit and the role of NCTC in the wider organisation?
- What sources of health and safety information is available to you?
- What connections do you have with individuals inside and outside of the department?
- Picking one example, describe how a resource has been utilised in the department.
- How can health and safety training be improved?

I developed the interview guide independently. The order of the questions was amended by the interviewer after the first interview, but no further adaptations were made.

Once a picture of what type of information and interactions take place within the CoP had been created, further scrutiny into how it is used and to what effect was undertaken. Using the Wenger-Traynor framework for the five levels of value creation, which itself is based upon Kirkpatrick's model for evaluating training, participants will be asked to describe a resource in detail. They will be asked about their thoughts and feelings about the resource, how they used it, did it have any impact personally or within the unit, and since using the resource, have they noticed a change in perceptions and practices within NCTC. This information will illuminate how effective resources are perceived to be, and if there is a need for improvement. The purpose of this approach is to allow the participants to reflect and explore their answers, providing a richer picture of their perceptions.

Interviews were conducted by MC, a retired training manager from UK Health Security Agency. MC has considerable experience in training and mentoring laboratory staff, placing him in a strong position to understand the nature of the research and organisational aspects of the laboratory workplace, whilst remaining independent to the department. MC knew six of the participants from his time in the organisation. Four individuals had joined since his retirement, and they had not met before. An independent interviewer was sought to provide a safe space to participants so they may feel they can answer more freely. I decided not to conduct the interviews as I am the Operational Lead of the unit and line manager to most participants. As such, there is a personal relationship with the participants who were aware of the reasoning behind the research.

Interviews were held over Microsoft® Teams with the interviewer joining from home and participants joining from their work laptops. A private room was booked for each of the participants to use. The set-up of the Teams invites was facilitated by AM, the department's administrative assistant who sent out invites and ensured the technology was functioning. The lead researcher was also invited to the Teams call so the information recorded could be obtained, but they did not join the arranged meeting. During the interview, the interviewer and the participants were asked to turn their cameras on so they could see each other. The interviews were scheduled for one hour. The interview was audio and visually recorded and transcribed using the function within the software. At the end of the interview, MC could no longer access the recording or transcript. No follow-up interviews were required.

15 team huddles held via Microsoft® Teams were audio and visually recorded between 12th April and 17th May 2022. Consent from those present was sought before recording was started.

5.1.4 Ethics

Ethical approval was granted by both Staffordshire University and UKHSA ethics committee.

Written informed consent was obtained from each of the participants. Information gathered was anonymised, kept secure on password protected laptops and not used externally to the study. Participants were made aware that participation in this study was optional and they had the right to withdraw from the research at any stage.

5.1.5 Data analysis

The recordings were transcribed verbatim by the lead researcher using the automated Microsoft® Teams transcript as a guide. The transcript of each interview was emailed to the participant for comment with no corrections being returned. Transcripts were anonymised by assigning each participant with a letter identifier at random.

The transcripts were read twice to familiarise with the content and loaded into NVivo 12 Pro (Lumivero, 2017) to perform coding and thematic analysis. Braun and Clark’s approach was used to guide the thematic analysis of data (Braun & Clarke, 2014). Initial descriptive coding was performed on each of the transcripts followed by axial coding to identify related codes across transcripts and overarching themes. Codes were influenced by concepts explored in the communities of practice literature but were largely inductive as driven by the data.

In addition, deductive analysis using the elements of a successful CoP as identified in the narrative literature review; leadership, level of participation, identity, and value was applied to determine barriers and facilitators for success specific to the NCTC team.

Social network analysis was performed on the responses to the question of whom information related to health and safety was obtained. Binary non-directional matrices were created and mapped using UCINET version 6.365 (Analytic Technologies, 2011).

Team Huddle recordings and minutes from Operation Team Meetings were used to triangulate findings from the interviews. Frequency of discussions related to health and safety were extracted alongside the nature of information (instruction, information, question, praise) and by whom it was raised were used to validate the information provided by the participants and themes identified.

5.2 Results

Ten individuals participated in the interviews; their demographics are detailed in Table 5.1.

Table 5.1: Semi-structured interview participant demographics

Participant	Job role (self described)	Qualification	Time worked for NCTC	Gender
A	Data scientist	MSc	7.5 years	M
B	Media Quality Control Scientist	BSc	1.5 years	M
C	Safety documentation	MSc	8 years	F
D	Supervisor	MSc	4 months	M
E	Support Worker	BSc	6 years	F
F	Senior Molecular Biologist	PhD	7 months	M
G	Microbiologist	MBio	3 months	F
H	Microbiologist	BSc	1 year	F
I	Operations Lead	Masters	5 years	F
J	Microbiologist	BSc	7 years	F

Four of the participants (D, F, G, H) were new to the unit, working in NCTC for a year or less. Two participants (I &J) were currently not working in the unit, having moved to other parts of the organisation at the time of the interview.

5.2.1 The collective identity of the department

Integrated into the CoP literature is the idea that members of a CoP develop an identity as they become an active member. When asked about roles and responsibilities, the NCTC team defined themselves largely by their job title and set responsibilities within the laboratory. There was little discussion about how their role fits into the overall mission of the department. However, the strong theme of collective accountability emerged in regard to health and safety.

On an individual level, participants have largely aligned themselves with the purpose of health and safety. They understand their responsibility to maintain their own safety and the impact they may have on others through feeling responsible for following procedures and keeping others safe.

"*We want a safe working environment for ourselves and our colleagues as well*." – Participant A.

"*I've got that level of oversight over them to make sure the health and safety is being followed."* – Participant D.

"*I would say um, working in a safe and efficient manner*" Participant G.

"*I do feel accountable for everybody in my team. And so, I wouldn't want to put any of them at risk unnecessarily to do something*." Participant I

"*Because if we are not going, if we are not going to do something properly, there is knock on effect of other on other departments*." Participant C.

Discussions showed a collaborative effort in decision making and a willingness to engage in continuous improvement.

"*I'm really quite impressed with the team, because anytime anybody says anything like OK, "actually this is not how we do this or this is the better, this works better this way." They will make the changes*." – Participant E.

"*I think it's my responsibility to work to the highest standard that I can, you know, to always put in as much effort as possible and to ask questions if I'm unsure about something, not to just go in blindly and hope for the best*." – Participant G.

This demonstrates the theme of shared commitment to safety in the workplace. The NCTC laboratory take safety seriously and measures put in place are robust and sufficient. Those participants who have experienced working in other laboratory settings, felt that NCTC had increased health and safety measures in place and was a safe environment to work. In NCTC, compliance to health and safety measures is not just expected but appreciated.

"*I think the department as a whole is quite is really, really very acutely aware of like the importance of health and safety*" – Participant A

The interviews also highlighted that the department was in a period of transition which was causing an unsettled feeling amongst participants affected. Factors that contributed to this were a change in roles and responsibilities.

"*I don't really have an assigned area."* – Participant C

A transition of workflow from developmental to operational;

"*Transitioning the DNA order work from like a research sort of thing into being more routine like the ampule stuff is. So it's been a lot of documentation and stuff and just kind of changing and tweaking things* *because it wasn't really suitable for like widespread use before. So kind of um almost maybe just developing it and making it a bit more user friendly*." – Participant F

And a transition into the department and understanding how existing skills align.

"*Well, I didn't mind it when it started cause it was quite new to me to do that sort of that approach to lab work. I've done like, come from like a research background in academia, so it's very much just do whatever you want. Um and if something catches fire or something, then you just worry about that then."* – Participant F

Some transition is viewed as positive such as the move to the writing of SOPs and risk assessments. Participant J refers to their "*laboratory hat*" and "*documentation hat*," the latter offering a shift in perspective on lab processes and thus contributing to an improved awareness of the implications of safety.

In addition, there are thoughts toward the future and how roles may evolve.

"*I'm going to help out with some of the NCTC work."* – Participant B.

"*I'd say at the moment it's kind of split more towards the lab based, but I 100% expect that to change. I think eventually I'll be more desk based then I will be lab based."* – Participant D

Whilst there is high praise for colleagues and the overall safety culture of the laboratory, participants did not imagine that there was such recognition outside of the department. They felt that there was a lack of understanding about what the unit does and an opinion that the work undertaken by NCTC was not important.

"*I don't think, perhaps they, perhaps they don't even know what we do*." – Participant B

"*I do kind of feel we're always kind of seen as like the lowest rung on the peg kind of thing*." – Participant D

"*That we're quite dated and not really very important*." – Participant F.

The participants view NCTC as a distinct entity from its larger departmental organisation.

"*But they still see themselves as ECACC people, so it's kind of like you put the NCTC with the other culture collections and then just gotta like, oh, we're together now."* – Participant A

5.2.2 Where do NCTC staff get their health and safety information from?

Resources and events

Table 5.2 lists the resources and events that participants stated they receive information relating to health and safety from. Meetings were cited by all participants followed by emails, Q-Pulse (electronic quality management system) and training, mentioned by nine participants each.

Table 5.2: Sources of health and safety information as described by participants of the semi-structured interviews

Source of information	Number of participants	Source of information	Number of participants
Meetings	10	Legislation	2
Emails	9	Spill Drill	2
Q-Pulse	9	Word of mouth	2
Training	9	Signage	2
Risk assessments	7	Training records	2
Face-to-face discussions	7	Audits	2
SOPs, forms, work instructions	6	Internal seminars	1
E-learning	6	Non-conformances	1
Microsoft Teams	4	Diary	1
Hard-copy SOPs	4	Previous experience	1
Risk alerts	3	Safety forms	1
ClassMarker®	3	Trackwise®	1
Observing others	3	Information held on NCTC Strains	1
Online resources	3		

Connections

Table 5.3 details the connections participants have used in relation to health and safety. All but one participant stated that the Interim Operational Lead was their main source of health and safety information. The count of connections themselves does not offer a valuable insight into the flow of the information around the unit, therefore, social network analysis was utilised to elucidate patterns, key players and isolated groups.

Table 5.3: Connections used by participants of the semi-structured interviews to gain health and safety information.

Connection	Number of participants

	citing connection
Interim Operational Lead	9
Microbiologist	8
Head of Department	8
Supervisor	7
Corporate Health and Safety Team	4
Ref Micro Safety Managers	4
Support worker	2
Line Manager	2
FMD	2
Reference Labs	2
Biosecurity lead	1
Customers	1
Occupational Health	1
Central Ops Coordinator	1
Deputy Director	1
Safety Groups and networks	1
Document author	1

Social network analysis

Figure 5.2 demonstrates the binary, non-directed map of the connections used by participants. Participant I cited the most connections and so is central to the community. This is expected as the Operational Lead. Three distinct groups emerged: F&J, B&D and C, E&H. The common linkage between the individuals in a group is that they spend time together in the same laboratory as part of their role. This suggests that there may not be one community of practice but three with the Operational Lead acting as a broker between them.

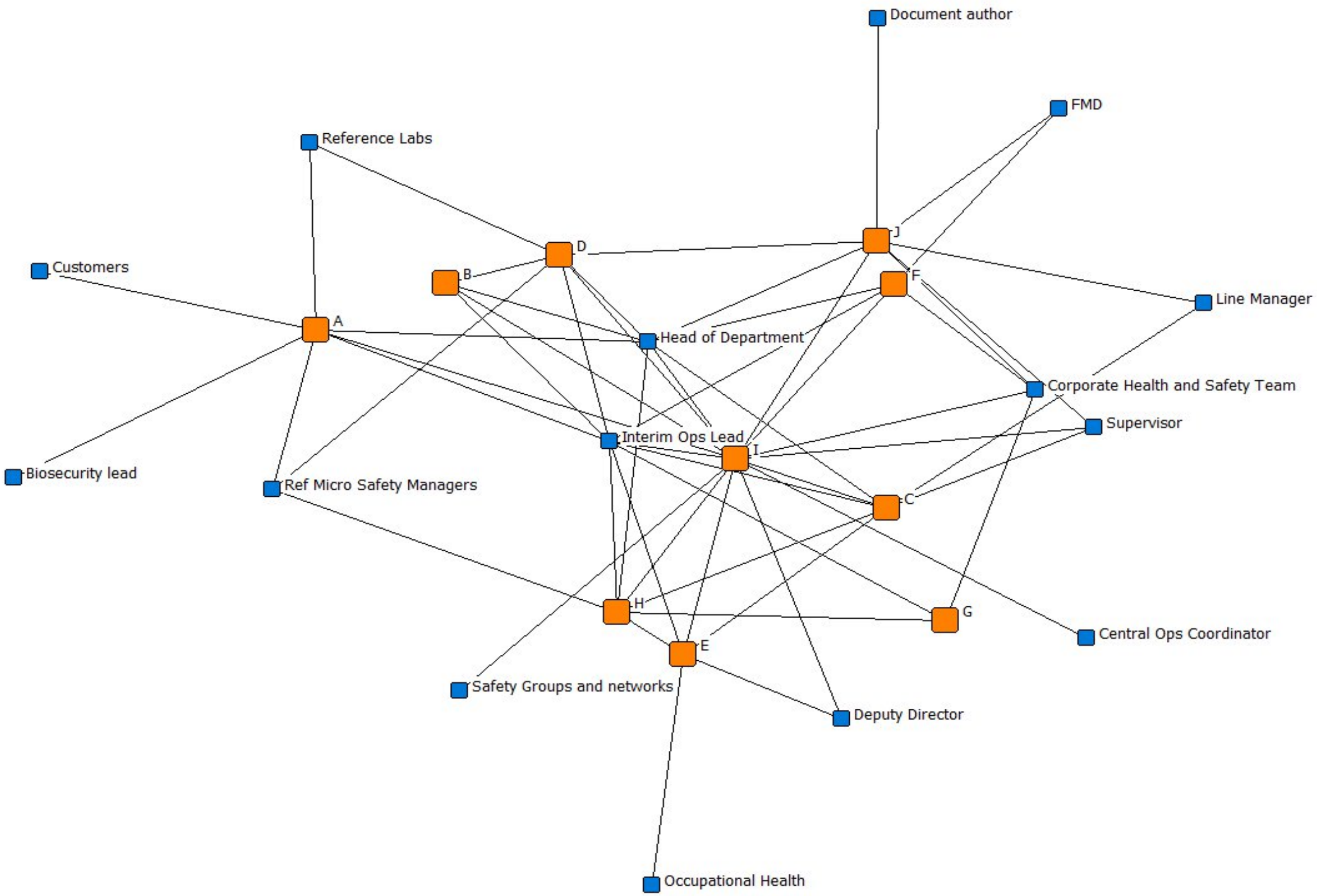


Figure 5.2: Social network analysis of the connections for health and safety information.

When asked who they interact with the most, replies included: -

"*It's always been the person who's doing the QC for the ampule production for NCTC*" Participant B.

"*Would say definitely the staff in freeze drying, so [Participant H] and [Participant E], just because you spend a lot of hours in the lab and particularly me and [Participant E].*" Participant G.

"*My direct colleagues in the laboratory. So about three of us. 3 or 4, three or four people*." Participant H.

"*But mostly it probably would be with those that are within my vicinity*." Participant I.

Most of the communication with teams outside of the immediate unit is handled by the Operations Lead who acts as a broker between the unit.

"*There isn't much of the interaction with the outside team because I think everything is being basically handled by [Interim Operations Lead]".* Participant C.

Furthermore, the two newer members of staff. D and G forged a shared connection and identity over their status as newcomers. Whilst not directly in reference to health and safety, Participant D stated:

"I definitely agree with a colleague once again who's just started, I know she finds it difficult sometimes to find the relevant information that she wants. and she's spoken to me about this before."

"I think the best way would be to look at how well I'm progressing, how well my colleagues progressed and seeing if say she's taking on the training quicker than I have."

5.2.3 What sources of information are most valued by the NCTC team?

The participants have demonstrated they practise and implement safety through the expected system of work; following guidance in SOPs, risk assessments and formal training.

"*Relevant documentation is actually good to start with as well, so it's always good, especially like SOPs, which I think are very good thing, especially a shortened nice and abrupt way to learn*." – Participant D

However, these sources are not held in high regard.

"*Yeah, all the documents just merge into one after a while because you've read so many and then you forget what you read*." – Participant G

"*Yeah. And there's so much documentation. If anything, there's almost too much documentation*." – Participant H

Interestingly, informal discussions, group training and interaction with colleagues are discussed with a greater level of reverence and value to making an impact on working practices. The "huddle" meeting, which is a stand-up informal meeting held bi-weekly to discuss workloads and raise any issues was cited as useful source of information.

"*huddles, um twice a week now, which is like 1/2 an hour just catch up for everybody to uh to be aware of who is doing what and if anything comes up that's being that's being communicated as well……..and that half an hour, it's a really good time to kind of.*
To feed that information back to everybody"– Participant C

"*It would be nice to have everyone cause to have everyone in the NCTC, at the huddles, maybe because I don't think it's much to ask for five to 15 minutes of people's time just to, even for no other reason than we're all visible and we are all present and we all know what that we're all kind of on the same team*." Participant F.

"*So obviously Hannah telling us in the huddles is very useful. I find that's more of a highlight to let us know that something's coming up*." – Participant D.

Face-to-face interaction with colleagues and other members of staff on site is valued more than online interactions.

"*whereas when you're face to face either in a group or a one to one or the huddle, you might get a bit more communication from individuals." –* Participant C

"*With that, if they're not particularly exciting in their subject matter, they it can help being brought to life by a person*." – Participant F

"*I make a conscious effort to meet everybody every day. So even if that means like every day in the morning I do a walk around. So I leave just to say hello, see, you know that way you get a lot of information as to what's going on in the lab as well in informal way."* Participant I

Being able to influence or play an active role in the improvement of processes acts as a motivating factor as is the level of autonomy afforded. Staff feel valued and that they add value to their work.

"*Well, you know that when you completed something and you made the corrections, it's a job well done."* – Participant J.

"I like the variety though, because…..I can plan my day myself." – Participant E

The discussions from the semi-structured interviews focussed on the following general themes; participation, accessibility, trust, the antecedent, leadership, and boundaries. Many of the themes were derived from the CoP literature and reframed for the application to health and safety culture.

5.2.4 Factors that influence health and safety culture

5.2.4.1 Participation

The theme of participation consists of sub-themes; collaborative participation, empowered participation, and passive participation.

Collaborative participation

As already discussed, the NCTC laboratory staff identify and value the collaborative nature of the department. Examples are of those staff who have the opportunity to write SOPs and risk assessments or have been asked to provide feedback for others.

"*I always send it out to whoever is willing to read it because they are very lengthy now and then I do get quite a lot of like a comments if that is correct or that needs to be changed and it's really good because at least I know that those risk assessments, if they are being issued then they, they should be, they should be quite OK for the next three years."* – Participant C

"*Because when you're explaining the procedures to somebody else, it's looking at it from a different aspect from when you're learning it."* – Participant H

"*You want the users to be covered safely because you're responsible for the documentation, whereas if you're following it, you don't know the what else needs to be done*." Participant J

Explaining procedures to others or asking for feedback, provides a different perspective, contributing to a heightened awareness of potential hazards.

Empowered participation

Participating in socially driven training activities within and outside of NCTC is a source of confidence amongst the team. Participants felt confident in asking questions from the colleagues who trained them and appreciated multiple trainers involved as they could see the work from different perspectives.

For the spill scenario training - "*I prefer the kind of scenario training actually, because you're, it's a. It's a more direct way of discussing things*." – Participant B

"*[I] was put to be somebody who doesn't work in your Group, like I was with the guy who works in QC I hardly ever do it, until a few months ago I went to pick up things or drop things so it was somebody from...And then the experience of working in QC in contrast to working in freeze drying*." Participant E

"[Being] observed doing the protocols by a colleague because you might do things that you're kind of unaware that you're doing and then they can pick up on that." Participant G

"*Just as an example, when [Participant F] started and we were doing the heat inactivation with the heating block, [they] had ideas on how to record things properly and then the record sheet was amended to fit*." Participant J

And on the topic of decision-making: "*Then I feel like these things should be kind of resulting consensus, like a conversation between all key stakeholders rather than just two people, is, I think, generally a bit more valuable, informative*." – Participant A

"*I felt more comfortable coming to my colleagues and asking them questions*." Participant B

5.2.4.2 Accessibility and negative impact of the COVID-19 pandemic

Accessibility in multiple forms has emerged as the overarching theme of the interviews. The participants described access or inaccessibility to health and safety information in terms of social capital, inclusiveness, and intuitive resources.

Social capital

A person's social capital in the workplace describes the network of connections a person has available to them that form a potential resource for information or collaboration. The social network analysis has shown that there are disparate groups within NCTC with little overlap or contact. It was noted a result of the current COVID-19 social distancing restrictions limited opportunities for social interaction in the team.

"*So I just it's like we don't we don't go for teas anymore or lunches anymore together which is a big kind of social part of our interactions for being taken out which is a bit of a shame…. we are part of the team, but sometimes it just doesn't feel like it...*" – Participant C

"[Participant F] has been doing paperwork from home for some time now. So [they] hasn't been in enough, but when [they] started coming in, I'd like to go in and have a chat with [them]." – Participant E

There is also a poor connection with the rest of the department who are based on a different site. Participants value the interactions they have with the rest of the Culture Collections staff but identify more with NCTC than the department as a whole.

"*Porton, especially with the fact that we have ECACC and NCPV down there and we have very little contact with them and obviously they're technically in Culture Collections with us." –* Participant D.

"*OK, well, this is supposed to [be] my team, but I don't know who they are*." – Participant G

Participants would value a stronger connection with the rest of the department.

"*The Christmas quiz was the best thing really, you know, uh, where you getting to know people. I mean I didn't know any of them. Well, I knew some of them like the quality people and that the people who directly impinge upon NCTC. But some of them, I didn't know anything about*." – Participant B

"*I liked it because it gets you got to know people that were in your team. Because what? Ohh yeah, you're all culture collections but no idea who they are. But with the meetings like, OK well you are NCPF. OK, well, we're NCPV and then sometimes talk like that came here for training as well*. "– Participant H

"*like culture collections themselves, the other colleagues in the different units. I think that could definitely be strengthened*" – Participant I

Multiple examples were given of when a connection from outside of NCTC was used to gain knowledge or assist in a safety-related event.

"Yeah, me and a colleague did check with the health and safety advisor being like should we be doing this? And apparently it was fine but it really. It gave me a tiny insight into Like the kind of different health and safety cultures in other places of work where because it wasn't like, I don't know, it" – Participant A

"*I bumped into a girl that I knew from the other lab and we kind of, but I met her via friends of a like the girl who used to work in NCTC. So it was like it was, it was very handy to have some sort of connections because we managed to get it sorted and she got the person that I was trying to get through*" – Participant C

"*You'll need help or assistance or support or whatever and you're just trying a couple of different people and then you remember that for next time*." Participant F

5.2.4.3 Inclusiveness

The inclusive aspect of accessibility expands beyond the social capital to encompass individual's learning preferences and feelings of exclusion from certain resources.

Meetings cited as an example where individuals felt unable to participate. Whilst the "huddles" were favoured for their informality, more formal meetings such as the NCTC Operational Meeting were seen as inaccessible.

"*So something that you would could discuss it like the huddle meetings, you wouldn't really bring up in those bigger meetings."* Participant C “*harder to do in a sit down meeting to be able to relate the kind of information they're giving you about health and safety into a like a physical way*.” – Participant D

“*all-staff meetings and operations meetings, but they're much more regimented and you can't really just speak about things you know, you sort of have to have put it in the agenda”* – Participant F

Laboratory-based practical training was named as the most inclusive source of safety information as it appealed to participant’s preferred learning styles.

“*So I think this is also always important to have multiple different ways for different people to learn. So having the SOP there, people who learn well from reading*.” – Participant D

“*observed doing the protocols by a colleague because you might do things that you're kind of unaware that you're doing and then they can pick up on that*.” – Participant G

The augmentation of practical training with online knowledge assessments and eLearning was appreciated but would not be fit as the primary method of training.

“*it's like an online software that you then log into it and it gives you a series of questions that you have to answer and you have to get 100% to pass. And that forms part of your training in that particular SOP that you were doing*.” – Participant H

“I don't know if they're being fully utilized at the moment, but the idea behind kind of getting someone to write out the answer to it, so you can kind of read over and go, yeah, OK, they definitely understand that and it is a very good idea.” – Participant D

“Because you know, the questions are normally based on the most important aspects of the document. So it's just a nice refresher after you read it. Like it kind of summarizes the key information” – Participant G

Intuitive resources

Participants expressed a desire for documentation and laboratory safety instructions that are simple to read and intuitive to follow. The risk assessments in their current form were a barrier to assimilating the information within due to their length and repetitiveness.

“*I mean we open a risk assessment and it's like the one I opened last week was 36 pages long with all things repeated………You're not really going to remember that. It's not in a form that is user friendly to absorb and understand*.” Participant B.

“*The amount of documentation puts them off reading it all cause it's 50 odd pages and it's hard to get, especially when you’re a new starter. So someone’s who straight out of university, never worked in the lab before and they've got 20 odd documents or they're 50 pages long to read on safety manuals and they're just like, “oh God, what is this?” when you know* *what you want them to know is what to do, what not to do, What's safe, What's not safe*." – Participant D

"*Risk assessments lately there's, there's this safety critical, so they become much longer."* – Participant E

5.2.4.4 Top-Down Leadership

The leadership of the NCTC laboratory was a strong source of information. All participants stated that the Interim Operations Lead would be their first point of call for a safety-related query or issue. However, despite the strong themes of collaboration, health and safety information was still seen as something that is cascaded down from above rather than generated and shared within the team with the Operations Lead role acting as a broker between units.

"*So we have a monthly departmental meeting and there's always a section about health and safety within that meeting. So if anything has happened in the last month, we're told about it then."* Participant H.

"*Hannah was dealing with the safety team and like everything was going through, Hannah*." – Participant C

So obviously Hannah telling us in the huddles is very useful. I find that's more of a highlight to let us know that something's coming up that – Participant D

"*There are the operations meetings and the Culture Collections meeting, but they're not really for us to talk to each other. They're sort of. More for us to be spoken at by Management I suppose*." – Participant F

This style of management in relation to health and safety was generally accepted as the correct approach to relaying information.

5.2.4.5 Trust

Evident from the interviews was that a great deal of trust existed amongst the NCTC team. This trust was placed in the overall safety culture of the laboratory, colleagues, and their own abilities. However, the top-down safety leadership did not always reflect the same level of trust in others.

Epistemic trust

Epistemic trust describes the confidence that is required in the trainer and procedure to allow learning to occur effectively.

"*Safety critical steps which we're using now. Those are very good starting place to kind of, cause obviously you can see what steps are critically important and they can kind of get a rough understanding of what the methodology is before they're having to watch it*." – Participant D

"*I think it's very good. and it makes me feel much more relaxed and much more calm because you know that the people like are that are doing it, are experienced and have been here for a very long time and they understand it and you feel like they've kind of got your back…. I think that they go kind* *of above and beyond really. So it makes you feel a lot more secure at work*." – Participant F

"*it's just making sure that I'm following the SOP's, the way that the organization wants it done, even if it's slightly different than what I've done previously*." – Participant G

The outgoing Operational Lead does not have access to what the laboratory staff think about changes implemented or their level of understanding, as it is not shared.

"*A lot of people just do sometimes what they've been told and sometimes they do it without really understanding it, but they will still go and do it*." Participant I

Interviewer – "*Were you seen as the big bad boss then with having to implement this or [did] the people take it on board that it needed to be done?"*

"*Yeah. Possibly I mean, to be honest, even if they did, they wouldn't come and tell me to my face. Yeah, I wouldn't know. I'm pretty sure as human nature, you know, as humans and human behaviour would go. Oh yeah, I'm pretty sure a lot of people weren't very amused by it, and yeah, probably wasn't very popular for that time period, but you know it is what it is*." – Participant I

Self-empowerment

Another source of trust in the laboratory is from oneself. Many participants had a strong belief in their own abilities and knowledge which informs their practise.

"*It's always kind of something I've kind of pride myself on having kind of quite a good awareness of like the kind of different kind of overlapping bits of legislation*." – Participant A

"*Well, I've always been aware that they had the potential to be, you know, more serious and to be careful*." – Participant B

"*I've always understood the dangers that working with pathogens and you know, bacterial agents can cause."* – Participant G

"*I have a good safety understanding, so I understand the requirements of it*." – Participant I.

5.2.4.6 The antecedent

The theme of self-empowerment enables the participants to utilise their previous experience and knowledge to inform. Participants feel that they possess a tacit knowledge of health and safety and the events did not enhance or alter this.

"*It hasn't really changed my perspective no, because I've been, I've been through I suppose I suppose you get to be…..You know the what they say, familiarity breeds contempt…..But I just mean that I'm kind of used to dealing with spills and I feel as long as you basically, know what you're doing, it's not really dangerous*." Participant B.

"*But yeah, in terms of general health and safety knowledge, I would say that it hasn't really changed that much. I think the actual processes were all very similar, so it wasn't really any new skills*" Participant G.

"*I wouldn't say [it's changed my perspective] because I think you've always known it's important to raise all the issues that might be there*." Participant H.

Staff who have worked in NCTC for a longer time accept the practices and the increased level of safety measures as a given. This is recognised by newer staff members who notice a positive difference in working practices in the unit to what they have experienced elsewhere.

"*Because they're used to, they're used to using…………They were sort of bred to the NCTC procedures really*." Participant B.

"*And, you know, it's just making sure that I'm following the SOP's, the way that the organization wants it done, even if it's slightly different than what I've done previously*." Participant G.

"*I think it's very good, actually in NCTC certainly compared to when I was in [previous unit], because we have to do a training specific for every process here. So there's competency assessment and then all of our associated risk assessments, COSHHs, SOPs*." Participant H

5.2.5 Triangulation

The transcripts of the "huddle" meetings and content analysis of the monthly operations meetings support the findings that information is cascaded down from senior staff. The health and safety section of the operations meetings are solely for information only, with little discussion or questioning. Based on the findings related to the value of meetings, participants find the huddle more directly relatable than the formal team meetings, but the chord plots show that there is still a lack of open discussion taking place.

Figure 5.3 shows the flow of information across the staff listed by job role in the huddles. The chord plots show the proportion of each type transmitted by each job role rather than the quantity. Figure 5.4 shows the quantity of each type of communication transmitted. Whilst an equal amount of information is given by each staff group as they share their workload, the remainder of the meeting is driven by senior staff (Team Lead / Interim Operations Lead). Questions are mostly asked to the Team Lead or Operations Lead showing the hierarchal structure of the unit.

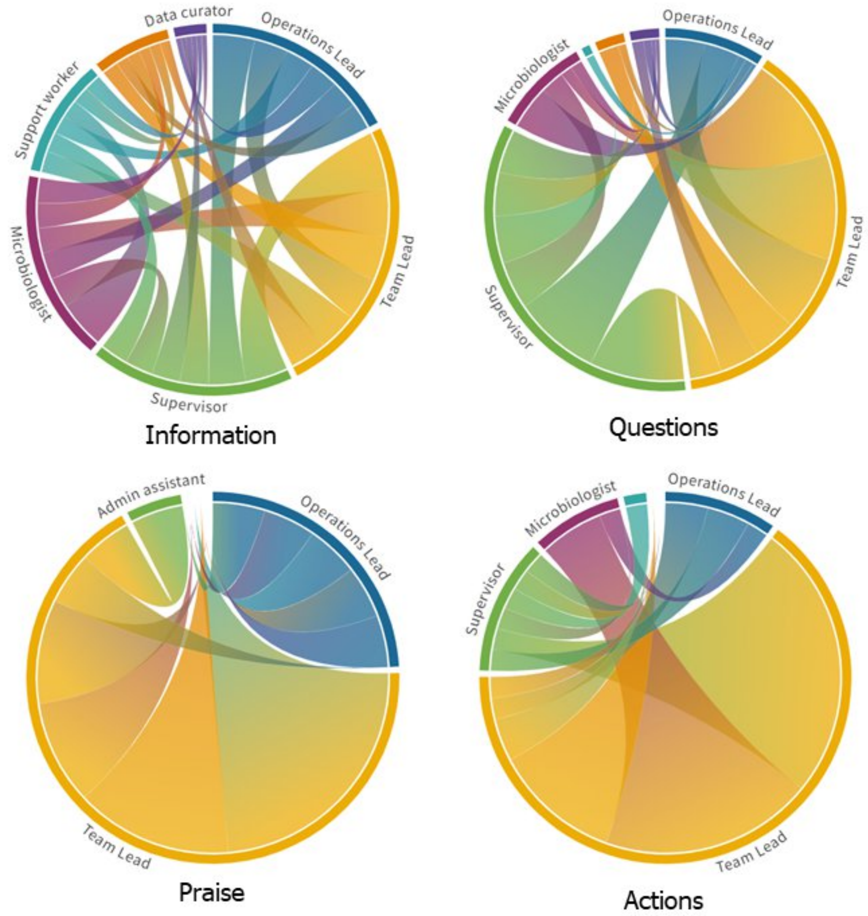


Figure 5.3; Chord plot of discourse during Huddle Team Meetings.

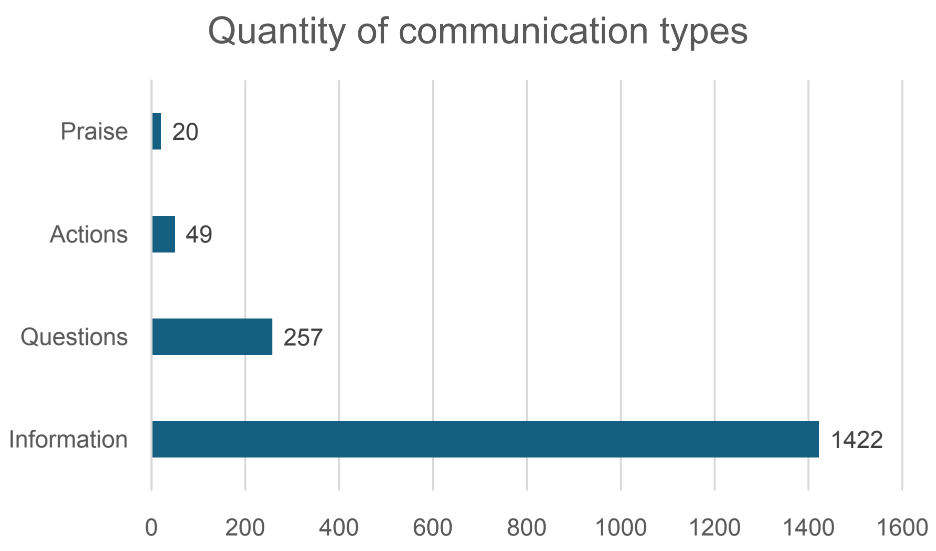


Figure 5.4: Quantity of different communication types during Huddle Team Meetings.

This supports the social network analysis and theme suggesting the Team Lead and Operational Lead provide information in a top-down approach to health and safety.

5.3 Discussion

5.3.1 Health and safety culture: Influencing factors

The transcripts of the semi-structured interviews have provided a clear insight to the enablers and barriers for fostering a positive health and safety culture in a laboratory. The key drivers in the NCTC unit to enable a positive safety culture are collaboration, recognition of previous knowledge and experience, trust, and accessibility. These four factors influence an individual's perception of identity which directs participation and engagement in safety-related activities.

The participants describe a robust, hierarchical health and safety structure in NCTC where information is obtained from the documentation or cascaded through the leadership who are acting as brokers between the wider organisation and the team. However, when discussing particular events where safety information has been utilised, it emerged the social and participatory dimensions of training and everyday interactions carried more reverence in the team. This apparent disconnect between the procedural and the situational supports the findings in Chapter Two that the competency and training records do not capture the whole professional competency of a person. Not only is situational and social learning not captured or utilised as part of training, its significance in a person's development and overall culture of the workplace is not realised.

The remote nature of the individual laboratories precludes the participants from utilising and sharing their tacit knowledge or health and safety. It is clear that the participants take pride in what they know and how they conduct themselves safely in the laboratory. There are very few opportunities to demonstrate and express these skills outside of training another staff-member. The training process can be adapted to capture and celebrate the skills as well as creating opportunities for participants to interact with each other.

In Chapter Two, the lack of feedback from trainees was identified as a barrier to competency, and in the review of training literature reflection emerged as a key driver for sustaining a community of practice. When presented the opportunity to reflect as part of the interview, the participants provide a surface-level reflection, focussing on emotions and descriptions of events. Reflection does not feature heavily in this interview, but it is a key enabler to implementing the other themes of participation, trust, and identity-building.

The interview used the value creation cycle as a framework to discuss health and safety, the type of value described mainly adheres to the first three value creation cycles knowledge and human capital was obtained by seven participants, including how to perform a task safely, improved awareness of risks, how to handle certain emergency scenarios, and where to locate information if needed. Training events led to an increased confidence with performing techniques. Tangible capital generated included physical resources such as the generation of risk assessments or the use of signage to alert others that the laboratory is not safe to enter. The participants have demonstrated some ability to reflect but the use of reflection as a powerful tool in building competency, identity and safety culture has not yet been unlocked. As humans, we reflect every day; when dealing with a new situation, encountering an issue, or ruminating on an upsetting experience. Socrates allegedly said, "*The unexamined life is not worth living.*" If this is the case, why is it difficult for people to demonstrate the deeper levels of reflection and learning? Effective reflection needs to be guided to uncover the tacit and unexplored understanding and perceptions.

5.3.2 The collective identity of the department

Three adjectives to describe the identity of the NCTC laboratory in relation to health and safety would be collaborative, responsible, and insular. The participants had high praise for their own abilities and those of their colleagues but did not believe the same view was reflected externally. Using the communities of practice to explore the identity of a department has provided a framework to recognise synergies and discordance within the team.

According to Wenger, identity within a community of practice requires belonging in the forms of imagination, alignment and engagement (Wenger, 1998 p.174). Most staff have aligned themselves with the current practices demonstrated through using terminology specific to the organisation such as "safety-critical," and "task-based risk assessment." They appreciate the level of engagement from colleagues on safety matters through updating documentation and assessments in response to incidents to improve the safety of work and make the processes suitable to all to follow.

The imagination aspect of Wenger's identity formation has been most enlightening. In general, the staff have perceived that there is a negative external view of the department as unimportant in comparison to others in the building. It would be unlikely that these opinions would have been expressed explicitly, but they have inferred from the minimal interaction opportunities afforded to them. This re-enforces the need to open avenues of connections outside of the team and increase the awareness of the work the NCTC staff undertake. Identity within a community of practice is not fixed and will evolve over time to encompass the individual's lived experience as well as their place within the community. At present, the team are relatively new, with little connection to others within the larger constellation of practice and so, the negative views of the unit are borne of naivety rather than resentment.

Furthermore, the interviews were conducted during a time of upheaval in the department which may have had an effect on the identity of the department. The Operational Lead had recently left for a secondment opportunity and the team were rebuilding after a series of departures. This meant that roles had to be adapted to bridge the change, causing some to lose a sense of belonging. A person will be constantly negotiating their personal and professional identities, according to Ashforth and Schinoff, there is a tension between wanting to be part of the group, and wanting to be unique (Ashforth & Schinoff, 2016). This was demonstrated through the appreciation of autonomy and the desire to occupy a niche in the workplace. A community of practice is often portrayed as a place of equality and harmony (Roberts, 2006) but this is difficult to achieve if members to not have a clearly defined identity and role in the community.

The unit currently operates across three laboratories, each focussing on different activities. Due to the social distancing restrictions, each laboratory will have developed their identities independently rather than as a whole unit. This grants another insight into how the department can be improved.

Leaders should provide a vision and clear roles for staff so they can envisage how they fit in with the department.

Encompassing professional identity into the competency process is established in medical training (Jarvis-Selinger et al., 2012). It is recognised that medical students transition from students, to acting like a doctor, to becoming a doctor through socialisation, negotiation with experiences and existing knowledge, and alignment to a community. The CoP literature and semi-structured interviews have demonstrated that formation of an identity within the workplaces transcends the traditional idea of competency. The potential in such a process must be harnessed by leaders and managers to influence safety culture and produce competent laboratory workers.

5.3.3 Where do staff obtain information related to health and safety and which sources are most valued?

5.3.4 Collaboration and creation as key forms of participation

In Wenger's original description of communities of practice, participation and reification were prerequisites for learning and development. The two acted symbiotically with the development of resources driven by participating in CoPs. Participants bring their previous experience and tacit knowledge, and through participation, construct a new understanding. This cognitive process occurs in groups rather than individually and so is essential for building competency within a CoP (Eraut, 2000).

In NCTC, the collaboration and ownership of creating SOPs, risk assessments and other forms that aid the completion of work in a safe manner elevated a person's level of participation with health and safety. Giving staff the opportunity to write a document or train another member of staff helps to shift their perspective and develop a deeper understanding of the process. The staff in NCTC seem to take this responsibility seriously as they are mindful of the impact on others their actions have. This has provided a clear pathway to enable staff to reach the higher levels of value creation and should be encouraged by the managers of the unit.

Furthermore, encouraging staff to play a role in the creation of resources will help make them more accessible and may lead to better engagement and knowledge transfer. There is a disconnect between the resources available and those appreciated by participants, for example, the risk assessments have become repetitive and lengthy since NCTC switched to a task-based approach as stipulated by the organisational-wide policy. "*Documentation, like machines, will always break down, however well it is designed*" (Brown & Duguid, 1991). Managers have a legal obligation to ensure there is a suitable risk assessment in place for every procedure, but involving staff in their creation and dissemination will not only meet legal duties, but transform the resource into an accessible, value-generating process and make them fit for purpose.

With regards to meetings, there was a preference for the informal nature of the huddles over the rigid and "high-level" Operational Team meetings as the latter were seen as a place where participants were "told" about safety and did not feel able to contribute. As with documentation, formal meetings are an essential part of the management structure of the laboratory. They are necessitated by quality management systems to demonstrate compliance and adequate information cascade. Nevertheless, the style of the meetings can be adjusted to make them more engaging and provide a platform for information to flow upwards as well as down. Managers should also consider creating more semi-structured meetings that offer a safe space for participants to contribute and share. According to the Centre for Disease Control and Prevention, "*laboratory safety is a collaborative effort that, to be successful, should include participation of all persons involved*" (Delany et al., 2011). It appears as if this collaboration is present in NCTC and should be encouraged and facilitated by management.

5.3.5 Legitimate peripheral participation in times of COVID-19

The term "legitimate peripheral participation" is used in CoP literature to denote how a newcomer can become a full member of the CoP. The COVID-19 pandemic has had a negative impact on the way information is shared in the laboratory. At present, there is a disconnect between newcomers and established staff members in relation to their social capital and levels of participation within health and safety. The enduring COVID-19 restrictions was a hindrance in allowing the newcomers to quickly progress to full membership due to the lack of interaction.

5.3.6 The role of trust in sustaining a community of practice

In the literature review of communities of practice in healthcare, CoPs were seen as a space for reflection that motivated and empowered members to make improvements in their workplace. To achieve this, the CoPs must have been seen as a safe space where members feel comfortable and welcomed. Mutual trust between CoP members was critical in allowing learning to occur (Mcalister, 2016).

Trust was a key element in NCTC in sustaining a positive safety culture; expressed in the form of epistemic trust in the procedures and guidance given from the laboratory leadership team. When Terry et al., 2020 reviewed the literature on the use of CoP in nursing education, they found that a sense of belonging was vital for learning and development to occur, enabled by fostering trust amongst members and with mentors. Whilst epistemic trust was present, the lack of trust from senior staff and interaction between members, does not offer a legitimacy of new staff as active members of the team. The presence of trust indicates the presence of mutual understanding and atmosphere of openness in the CoP. (Roberts, 2006). At the worker level the openness was demonstrated through the appreciation of collaboration, showing there is a transfer of knowledge amongst the team, however, there was a clear disconnect with those in management positions.

The detachment between the levels of trust within the team and from leadership may explain why information is seen as top-down. The team do not have the same capabilities and opportunities as leadership to gain information from outside as they are not required to, but there is an untapped potential within the team that is not realised. The NCTC team value their previous experience and organisational knowledge but it is not utilised effectively at present due to a lack of opportunity to communicate, not realising tacit knowledge as an asset or a general apathy towards the health and safety system. Mann et al., (2009) stated that role models and mentors play a key role in shaping identity by facilitating reflection. The lack of quality reflection in the interviews and as part of the training may contribute to the feelings of undervalue in the team. By introducing more opportunities to reflect and voice opinions, senior managers may bridge the gap between trust levels in the team. This could be achieved by creating more opportunities for the tacit knowledge that the team feel they possess to be expressed.

5.3.7 What social network is available to staff members?

Social capital is the actual and potential utilisation of connections available in an individual's network to create resources and knowledge (Steiner de Benaim, 2008). Social capital was obtained through training activities and the opportunity to interact with networks and individuals outside of the laboratory. Those who demonstrated a higher level of social capital did so through utilising a connection to address an issue. They tended to be staff who had worked for the unit for longer than those with little social capital. During the undertaking of the interviews, the UK was at the tail-end of the COVID-19 pandemic. Social distancing restrictions were still in force in the workplace with a limit on the capacity of offices and laboratories. This had an impact on newcomer’s ability to build any social capital, inside and outside of the team. Developing the level of social capital a team has would be beneficial for improving the safety culture. According to Steiner de Benaim (2008), social capital derived from communities of practice increase innovation, prevent reinvention, and decrease the learning curve. With the NCTC team, there is room to improve sociability between team members and also outside connections such as the other units of Culture Collections and laboratories on the Colindale site.

The social network analysis performed showed the leaders in the laboratory cited as a main source of information and guidance and so were placed at the centre of the team. There was a divide with the team based on which laboratory a person spends most of their time; those working in the freeze-drying laboratory sought guidance and support from each other, as did those working in the quality control laboratory. Again, this was likely due to the social distancing measures in place at the time limiting cross-working and sharing of information within the whole of NCTC.

The social network analysis (SNA) performed, whilst only a basic, non-directional matrix, enabled the visualisation of the connections available to the NCTC team and supported the interview thematic analysis on where social capital is attained. SNA has been used in the evaluation and study of CoPs across different disciplines. Jan et al., (2019) performed a systematic review on the use of SNA in higher education to identify CoPs. It found that whilst effective, other qualitative techniques are required to be utilised in conjunction with SNA to reveal more information about the CoP. SNA has proven to be a valuable tool in assessing the knowledge flow of the NCTC laboratory. Directional matrices or further analysis on in-groups and degrees of connections could be utilised in future applications of SNA of laboratory groups by using surveys rather than verbal responses.

5.3.8 Limitations

The findings of the semi-structured interviews and thematic analysis must be considered in conjunction with the knowledge that it was performed and written by a Manager of the NCTC team.

Responses by participants may have been self-censored or adapted as not to affect career prospects or cause offense. To counter this effect, the interviews were conducted by an individual external to the team with no management responsibilities. Participants may have provided answers that are expected of them rather than expressed their true perceptions and opinions.

Interpretation of results may also be biased by the researcher intimately knowing the department and ways of working. As the coding and analysis was performed by one person, there is a risk that personal topics of interest were overstated. Managers have the tendency to see the world as they would like it to be; based on current theories and written protocols (Eraut, 2000). To alleviate this, participants were given the opportunity to discuss the initial findings in group sessions at regular intervals through the analytical process.

The interview has attempted to access the tacit knowledge possessed by the NCTC team. Polanyi, (1967) has described tacit knowledge as "*that which we know but cannot tell*." Why a person "cannot tell" can be due to many reasons for example, they may not have consolidated their feelings to be able to express themselves in words. Some people can "tell" more easily than others (Eraut, 2000). In qualitative interviews, there is a risk that the perceptions of one person who is freer with sharing overshadow those of the other participants. During the compiling of themes and writing, care was taken to ensure representative quotations for each theme was provided from a range of participants to demonstrate saturation.

Furthermore, the findings of this analysis are specific to the contemporary situation in the unit. As the team changes and becomes more established, the dynamic will change. The findings may not translate to other situations and so any reader wishing to apply them to their own department, must do so with care.

5.3.9 Implications of research

This is the first application of the Communities of Practice situational learning framework to assess the safety culture of a microbiology laboratory. The study is in contrast to the formation of CoPs as knowledge management tools prevalent in the literature, as it returns to the original application of the model in an active workplace. It shows that CoP is a viable tool for assessing and improving the safety culture of workplaces. By using the CoP framework, this work attempts to bridge the disconnect between models of safety, and organisational models identified by Bisbey et al., (2021).

According to the HSE, an organisation's safety culture is determined by "*values, attitudes, perceptions, competencies and behaviour*" (Bisbey et al., 2021). Features of a positive safety culture include "*good communication, mutual trust, and shared perceptions of the importance of safety*" (Health and Safety Executive, 2024). Whilst the team believe there is a strong culture of safety in the unit, this research enabled the distillation of the nature of communication, trust and perceptions and provided insights into how these can be improved.

Figure 5.5 provides the framework for how safety culture in a microbiology laboratory can be improved derived from using communities of practice as an evaluative lens, combining the findings of the narrative literature review with the semi-structured interviews.

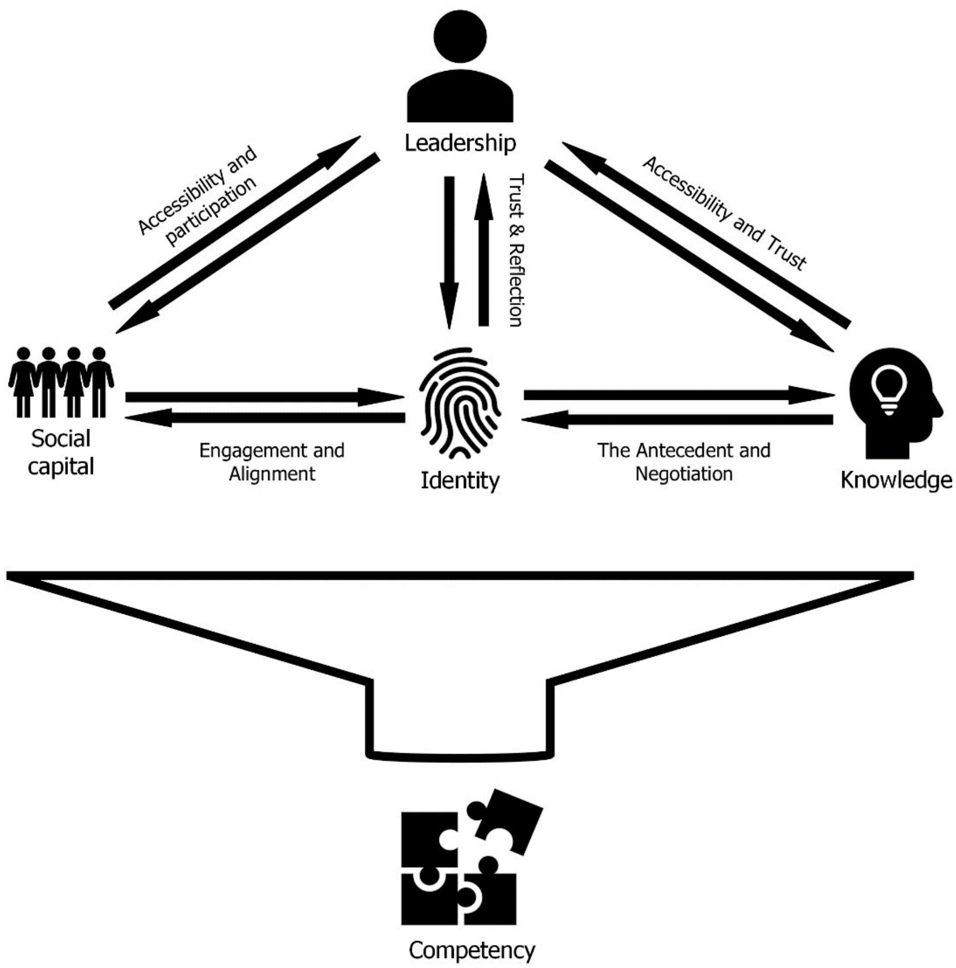


Figure 5.5: Conceptual framework for influencing training, competency, and safety culture.

The factors overlap with those espoused as key features of a positive safety culture such as leadership, trust, empowerment, and communication which provides a source of validity of the use of this approach.

The findings in this research have potential implications for those wishing to implement a health and safety intervention or policy across a whole organisation. Within the small team, intra-communities of practice naturally developed which had access to unique information and development of own sense of what was important. This would be magnified across a whole organisation, leading to different interpretations of the action or guidance.

Multiple tools have been developed for assessing the safety culture and climate of an organisation. A systematic review by (Churruca et al., 2021) found that in a healthcare setting, surveys were the most common method of evaluation safety culture. Whilst this study utilised semi-structured interviews guided by Wenger et al's five cycles of value creation (Wenger et al., 2011) to successfully illuminate strengths and weaknesses in the team, this format may not be suitable for larger groups or pan-organisation application. It should be used as a guide to develop a further framework for evaluation.

Churruca et al., 2021 also found that leadership was the most important factor in maintaining a positive safety culture. This research has shifted the emphasis to situational learning, with strong leadership still shown to be a major contributor to effective health and safety training. Using the value creation framework has proven insightful on where improvements can be made and provides a bottom-up approach to analysing safety culture in a workplace.

5.4 Recommended actions

Based on the findings of the interviews, the following interventions are recommended to managers of any laboratory to enhance and utilise social capital and situated learning.

Link technical operational goals of the team with core values of members. Make these explicit so individuals can see how their work complements that of others and foster a unified team.

Develop collaborative support systems both within and outside of the team to achieve the stated goals and values. Create more opportunities for participation that balance the formal and informal. Encourage engagement, reflection, and challenge to the precedent.

Leaders should foster a bottom-up approach to health and safety. As well as maintaining a top-down flow of information, leaders should ensure there is space to feed upwards to enhance trust and to ensure information has reached all relevant staff and being interpreted as intended.

Expand the training beyond the technical, to encompass the development and recognition of the whole self, including communication and negotiation skills, respect, opportunities to unlearn.

5.5 Conclusion

The application of the communities of practice model and value creation cycles following the original literature by Wenger et al has proven to be a beneficial lens through which to evaluate the factors that influence the health and safety culture of a microbiology laboratory. This was approach is the first of its kind in the CoP healthcare literature. The interviews with staff have provided an insight into the shared identity of the team and how this influences the flow of knowledge and training. Key focus areas for value creation were participation, accessibility, autonomy, the antecedent, and trust. Expressing the culture of the team in these terms has provided tangible objectives for leadership to direct improvements to enhance the health and safety culture of the laboratory. This in turn can be applied to the laboratory training and professional competency process to affect improvements.

Furthermore, it is evident that the COVID-19 pandemic and subsequent shifts in working arrangements such as social distancing and use of virtual communication platforms had a profound negative impact on learning and participation, particularly for newcomers by diminishing the social network available to staff.

Combining the findings of the interviews with the training intervention literature review from Chapter Three will provide a framework in which to redesign and refine the professional competency programme in the laboratory, moving beyond traditional training techniques to utilising socially constructed knowledge. The next step is to implement the findings by updating processes and resources related to health and safety training.

6 Capturing competency: Interventions to improve competency and culture

6.1 Context and overview

Chapter Six details the interventions introduced as a result of this professional doctorate research. The action research approach taken as part of this thesis means iterative and small changes in the training, competency and management approach of the NCTC laboratory have been made over the course of the three-year study. The complex nature of the communities of practice (CoP) model and the elements that form safety culture mean that one magic-bullet solution would not be feasible. Instead, gradual adjustments have been made and introduced as each chapter had been formed, my understanding of the literature grew and perspective as a laboratory manager shifted.

Based on the findings uncovered iteratively throughout this research, Table 6.1 lists the interventions introduced in the NCTC microbiology laboratory with the aim of improving the training and professional competency process, as well as the overall safety culture.

At each stage, the NCTC team were made aware of any changes and the reasoning behind them. I also presented my findings to the Head of Department, Quality Manager and Safety Manager to garner buy-in and support from the Senior Leadership Team.

Table 6.1: Recommendations and interventions proposed as solution to enhance professional competency and overall safety within the laboratory culture

Recommendation	Intervention
Link technical operational goals of the team with core values of members.	• Update to competency assessment form to meet regulatory needs. • Provision of robust training objectives. • Refinement of the use of ClassMarker® for knowledge assessment.
Develop collaborative support systems both within and outside of the team to achieve the stated goals and values.	• Creation of a risk assessment working group. • Creation of the Safety Advocates Community of Practice. • Use of Microsoft Teams® channels to facilitate information sharing and discussion.
Leaders should foster a bottom-up approach to health and safety.	• Provision of comprehensive training guidance. • Update to standard operating procedures (SOPs) and removal of the need to read risk assessments. • Training and development seminar. • Adaptation of meetings to provide opportunities to contribute and reflect.
Expand the training beyond the technical, to encompass the development and recognition of the whole self.	• Update to competency assessment form to capture growth, reflections, experience, and knowledge.

6.2 Capturing competency

In Chapter Two, the review of the training and technical competency process highlighted a gap in the relationship between what is recorded and what is expected. Training in the unit is driven by quality; the manual is explicit in this: "*The description of training for staff in this manual ensures that the Culture Collections meets with the requirements for compliance to ISO 9001:2015 and ISO/IEC 17025:2017* (Brooks, 2018)." There is no mention of health and safety or the associated site-wide corporate guidance which is an oversight considering that there are many units in the department performing procedures of equal or greater risk than the NCTC freeze-drying process. As a result, the nature of the comments captured in training forms are tick-box exercises, providing the minimum requirements of the training manual rather than exploring different methods of training appropriate to the situation.

However, training and competency does not tell the whole story. The absence of information in the competency forms such as feedback and evaluations, does not indicate it is not performed, it is just not seen as worthy of documentation. The absence hints at another form of competency assessment; one that is constructed in the informal, social spaces in the workplace, providing a potentially rich source of information for staff that if better understood by managers, can be exploited to more effectively implement health and safety protocols.

A radical review in approach to training and competency is required to attempt to balance the needs of the department with the needs of the staff. Staff can be equipped with training knowledge such as how to set objectives, how to give feedback, and provided with resources to expand their training repertoire. There is a balance to find between a comprehensive competency record and the time taken complete the process meaningfully. If this balance is met, the training and competency process can play a role in cultivating the overall safety culture of the laboratory by feeding back into improving the processes and empowering staff.

The competency assessment form was updated to better demonstrate compliance to safety and quality guidance on training, demonstrate how the individual is meeting the requirements for the procedure, and capture feedback on performance from the trainer and trainee. The updated version of the competency assessment form is provided in Appendix Four. In addition to demonstrating compliance, the new form is designed to better meet the needs of the individual. By providing feedback and reflection on the performance when learning a new process, the trainee and trainer can identify areas for improvement to benefit the whole department. For example, if a person was struggling with a particular aspect of a process, reflecting on why may provide and alternative approach leading to an update in procedures and ultimately, the competency process plays an active role in improving the health and safety culture of the laboratory. The competency process was updated following the training cycle (Figure 6.1) to ensure a rounded, holistic approach was taken.

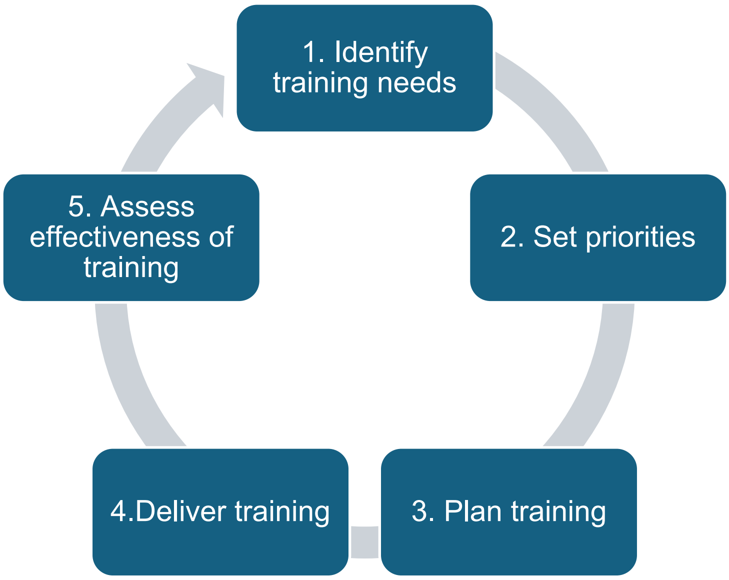


Figure 6.1: The Training Cycle. Adapted from HSE, 2022

1. Identify training needs

6.2.1 Training statements in SOPs

The review of the training records and standard operating procedures (SOPs) identified that the training process ensured a high level of adherence to the training statements contained in the SOPs, with 76 out of 120 meeting the criteria set out in the SOPs. However, the training statements themselves varied in clarity and content, often lacking detail on what constitutes adequate training. For example, only two statements clearly defined the requirements of different staff grades. Statements such as “all NCTC staff must be trained and competent” lack specificity on how this can be achieved. Five of the 23 versions of SOPs permitted previously trained staff to mark the SOPs as “read and understood” in their training record. The inconsistency and lack of specificity will have an impact on ability to conduct training. Setting clear training objectives and outcomes in training statements would enable a benchmarking of the trainee's performance and consistency between the training experience.

To enable assessment of a person's practical training in the laboratory, each SOP has been updated to contain a bespoke set of training objectives which will be incorporated into the competency assessment. The wording of the training objectives will be based on Bloom's taxonomy of cognitive development or other educational classification systems (Bloom, 1956). The classification system revised in 2001, provides educators with a framework to base objectives dependant on what the desired outcome is. This ranges from remembering; being able to recall and state information, up to creation in which the learner is expected to use the content of the training to make something new (Spence, 2019). Using such a framework in the context of competency assessment can allow the training to be adapted to the trainee. Supervisors and those who would be expected to train others, will be set objectives to reach the higher taxonomic levels of cognition and psychomotor skills. Using a set of verbs aligned to the taxonomic levels can help laboratory staff construct meaningful training objectives however, there is no guarantee that this will translate to the trainee's experience (Stanny, 2016). An example of the new-style training objectives is given in Figure 6.2.

- No pre-requisite training is required for this procedure at CL2.

- The trainee must be competent in the catalase test at CL2 to undergo training at CL3.
- Staff performing catalase testing must meet the following training outcomes as part of the competency procedure: -
  - Explain the principle of the procedure
  - Describe the limitations of the procedure
  - Describe the maintenance of equipment used in procedure
  - List the hazards associated with the procedure
  - Perform procedure without deviation from SOP
  - Recognise an unexpected result and what action to take
  - Use control strains, record results and reagent information on QC sheet
  - Interpret results correctly
  - Demonstrate safe working an adherence to safety control measures
  - Appraise a hypothetical scenario and state the best cause of action
- Individuals new to procedure must undergo a period of practical training (Observation, Supervision, Assessment) and recorded on NW5265.
- Individuals signed off in previous version of SOP must undergo a practical competency assessment of the updated sections.
- Knowledge and understanding are assessed through ClassMarker® theoretical questions.
- Supervisors and those involved in training others must be fully competent in the SOP, including troubleshooting.
- Partial competency, for Containment Level Two only, is accepted.
- If the trainee is required to perform procedure at CL3, they must undergo a practical competency assessment for the sections applicable to CL3.
- Ongoing competency assessed on a yearly basis through witness audits and testing of EQA / anonymised samples.

Figure 6.2: Example of new training statement in SOPs.

Clearly defined training objectives provides a measurable metric to assess how well a person is performing in the laboratory and if competency has been achieved. It does not address the social aspect of competency directly but having clear definitions of what constitutes competency reduces the variation in training and negotiation of meaning.

1. Set Priorities

NCTC are strong in the area of ongoing competency, including the use of annual spill scenario training. As it is not possible to assess the performance of staff in an actual emergency (although a simulated spill drill can be held), the discussion of hypothetical situations that are relevant to the department and deciding on a plan or action as a group is a suitable alternative. This approach meets the needs of the HSE competency guidance by including emergency situations into routine training. It is also comparable to successful training approaches such as problem or cased-based learning utilised in the wider healthcare training literature. Furthermore, the interviews with the NCTC staff showed that many found value in this approach to training. Widening the horizons of what laboratory training and professional competency encompass will lead to better participation, collaboration and generation of improvements to procedures (Delany et al., 2011).

Based on these findings, the delivery of training will try to encompass group and collaborative training events where applicable. In addition to the emergency scenario training, other group training events have been introduced, including good SOP writing practices and how to complete non-conformances.

An alternative approach to setting priorities with training and competency assessment is through defining a series of domains, rather than tasks a person must demonstrate their abilities in. This approach is advocated by the CDC for biosafety laboratory competency in which the domains include; potential hazards, controls, and emergency preparedness (Delany et al., 2011). A similar approach is recommended by the Institution of Chemical Engineers for safety competency, with domains defined as; culture, knowledge and competence, human factors, engineering and design, and assurance (IChemE, 2019). This approach has the advantage of deconstructing a person's competency into the constituent elements of safety culture and provides a more rounded approach to assessment. Furthermore, it allows for different methods of assessment. Trainees and trainers can create links to the competency requirement beyond the didactic training delivered. This approach would also help to elucidate what individuals and the laboratory as a community value in terms of the elements of competency; skills, knowledge, experience, attitudes, and physical ability.

At this stage in the research process, the holistic approach to professional competency has not been implemented in the NCTC laboratory. The wider organisation utilises a similar approach for containment level three competency, and I have replicated this form of competency in the wider department within the scope of auditor competencies. Appendix Five demonstrates some of the domains identified for an individual to successfully carry out an audit or inspection. The individual can build their experience over time as they participate in auditing. Evidence of interactions, audits shadowing or report writing will bolster the assessment of competence. Further work on establishing the key domains of laboratory work would be required to enable the holistic style of competency to be implemented across the unit. This was not possible in the timeframe of the research but is a future development that will be explored.

The review of the training and competency process in NCTC revealed the approach was in-line with the quality-lead training manual of the

1. Plan training

records demonstrated ongoing competency, 54/120 competency forms recorded the activity undertaken, and all records were linked to written procedures. The adherence to the wider organisational and national guidance for competency was less well observed. A sliding scale or measurement of assessors' competency was not introduced as stipulated in the HSE guidance (Table 2.2 Chapter Two).

To support the planning of training, a comprehensive training guidance document has been created that provides an explanation of how and why to complete the competency assessment, how ClassMarker® is utilised for questioning, and how training records are maintained. It also provides guidance and signposting to training skills to empower the NCTC staff as trainers. Such as how to set training objectives dependant on the level of competency required, inspired by Bloom's taxonomy. The purpose of the training guidance is to provide a resource staff may wish to utilise to give them the capability through knowledge of why the changes have been implemented and the background training theories that informed the guidance. The document was drafted based on the outcomes of this research, but NCTC staff had the opportunity to input into the design and content in line with the collaborative participation that was valued in the interviews. The training manual is controlled on the document management system and issued to all NCTC staff as a resource.

1. Deliver training

Figure 2.6 in Chapter Two lists the training methods used in NCTC. Observation was the most common method of training used. Observation by a trained member of staff is a valuable tool for assessing competency however, since the criteria for who can assess and what should be observed was vague, it led to inconsistency across the assessment records. Direct observation of procedural skills (DOPS) is an established competency assessment method widely used in the medical field (Ahmed et al., 2011). DOPS involves the trainee being observed performing a procedure by another, who does not have to be an expert themselves, and are scored against set criteria specific for each procedure. Reviews of the use of DOPS in medical training settings reveal that the approach had a positive effect on the trainee's performance but there is little evidence of its impact on long-term behaviour (Aryal et al., 2021; Lörwald et al., 2018). Introducing a DOPS assessment for every procedure in NCTC may be time-consuming and contribute little to the development of staff, however, the introduction of set criteria to assess against in the form of a robust training statement and using a scoring system will better keep track of a trainee’s process and identify areas for improvement.

6.2.2 Use of questioning in training

Questioning was the most common method of risk awareness as featured in 75/120 training records. On average, seven questions were asked per SOP during training. This includes direct questioning and assessments via ClassMarker®, an online quiz platform.

ClassMarker® was introduced by me in 2019, before commencing this research. It has become a key tool for evaluating trainee knowledge, standardising the assessment process, and streamlining marking. In total, 254 unique questions have been asked 1,900 times. These cover SOPs, risk assessments, and COSHH understanding. Notably, 82% of questions relate to health and safety, reflecting its critical importance in laboratory practice.

The nature of the questions used are mostly (116/254) multiple choice e.g., “*What PPE must be worn during this procedure?”* followed by true or false (82), e.g., “*True or false: The microbiological safety cabinet must be within accepted airflow limits before use.”* There are fewer written responses where the trainee has the opportunity to demonstrate the depth of their knowledge. Trainer-led questioning remains a complementary approach, used in over half (65) of the training records. This includes spontaneous questions during sessions, answers documented in assessments, or follow-up discussions. When done well, questioning acts as formative assessment, guiding trainers on how best to tailor instruction (Pylman & Ward, 2020).

In the interviews with NCTC staff, ClassMarker® was seen as a "tick-box" exercise. The number of assessments needed to cover the SOPs and risk assessments lost value in quality over quantity. Beyond its intended function, ClassMarker® enhanced training through the need of the question setters to critically evaluate the procedures, sometimes uncovering inconsistencies, and the learners reflecting and challenging the statements against practice.

To build on the collaborative and reflective training approach, the use of ClassMarker® has been refined to focus on the contents of the procedures and the need to assess understanding of risk assessments has been removed. The NCTC staff acknowledge the need for detailed risk assessments but reading the repetitive statements and increasingly long documents is a chore. The need to read and assess understanding has been removed from the training manual. This is facilitated by ensuring that the relevant content of the risk assessments is incorporated into the SOP.

Furthermore, the questions used in the ClassMarker® assessment are focused on open-ended questioning, to allow exploration of a trainee's reasoning and provide insight into their grasp of both process and implications.

1. Assess effectiveness of training

6.2.3 Feedback

Feedback to the trainee is also an important evaluation metric for the success of the training event. Whereas the competency assessment is summative, feedback throughout the training process is a formative assessment of the learner's performance (Jug et al., 2019). The current training in NCTC appears to be trainer-led with little documented interaction from the trainee, aside from the use of questioning.

Only one of the records indicated that the trainee required further training. It may be that all trainees made satisfactory progress during training; a further 21 records provide positive feedback on how the trainee is complying to the SOP or working safety, but this is a minority. The design of the forms restricts the amount of information the trainer can add. There are only two lines for free text per training phase (Figure 6.3).

3) Assessment phase: Trainee performs the procedure under trainer's close observation								
1st			2nd			3rd		
trainer		date	trainer		date	trainer		date
Comments (including evidence):								
Phase 3 completed satisfactorily			Trainee	Date				
			Trainer	Date				

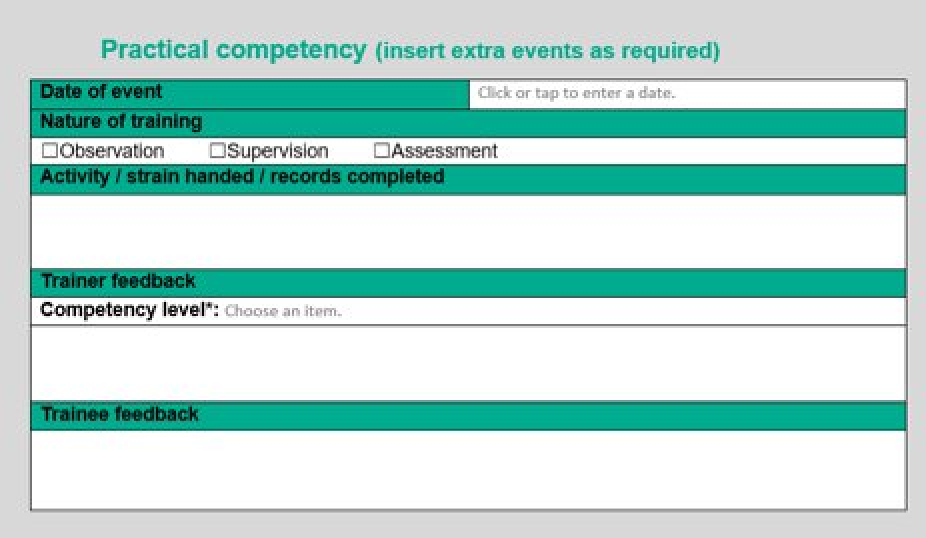
Figure 6.3: Extract from practical competency form currently in use.

It is unclear if feedback is being provided, in what style, or what was said. It may be that the feedback occurs verbally either formally or informally but from the records alone, the format cannot be determined. Effective feedback is a two-way process between trainee and trainer. It should contribute positively to the training which requires the feedback to be delivered tactfully (Jug et al., 2019). Laboratory workers are not formally educated in teaching; it becomes part of the role as experience grows. Thus, there is gaps in knowledge that can be filled with developing awareness of teaching and training techniques along with any new forms and guidance introduced.

Feedback from the trainer and reflection from the trainee should be captured on the competency form. Learning from the Xerox technicians, reflection can be utilised to augment traditional competency models. The competency training in NCTC is evaluated through audits, however, evaluation and feedback from trainees is not captured in training records, meetings or any other source reviewed. Evaluation of a training event is a key component of the training cycle. It enables the trainer to adapt the training to meet the needs of the individual and develop their own training and communication abilities. There is no evidence from the training records of which Kirpatrick level of successful training is being met. If evaluation of the training and trainer is captured in training records or through online forms which all staff have easy access to, it will help with staff personal development as well as ensuring that training is suitable for the individual and organisation. Providing evaluations should not be an onerous task for the trainees but should provide information of value. A balance between ease of completion and detail of feedback must be met.

Individuals operating at the higher levels of cognition, e.g. “expert,” often do not have to refer to the protocols and guidelines. They are acting intuitively, combining tacit knowledge with their deeper understanding of the context (Eraut, 2000). At expert level, the individual is operating unconsciously competent according to the competency model in Chapter One (Figure 1.1). However, it is a fine line between competence and incompetence if the individual does not reflect on their actions or have the opportunity for tacit knowledge to be accessed by others. The Xerox engineers had developed a way of working beyond their competencies. Thus, competency assessment on its own is not sufficient to ensure safe practices. Communities of practice provides a model to access tacit knowledge through reflection and participation. This should be encouraged by prompting and capturing in the competency forms.

As a result, the competency assessment form has been updated from the restrictive template to allow the recording of activity undertaken, and a space for feedback from both trainer and trainee. A new box can be added for as many of each training phase is needed to achieve competency, unlike the previous form, which restricted entry to three events. Figure 6.4 demonstrates the section of the form, with the full competency assessment form available in Appendix Six.



Practical competency (insert extra events as required)

Date of event	Click or tap to enter a date.
Nature of training	
☐Observation ☐Supervision ☐Assessment	
Activity / strain handed / records completed	
Trainer feedback	
Competency level*: Choose an item.	
Trainee feedback	

Figure 6.4: Excerpt of updated competency assessment form. Full form located in Appendix Six.

6.2.4 Recording assessment

Other updates to the competency assessment form include the addition of prompts to provide evidence of understanding and compliance to the procedures, a section to record pre-requisite training and experience, and to record how the trainee meets the safety-critical requirements.

In addition, a grading system was introduced using five outcomes a person could achieve, from not competent, to advanced. The outcomes and a brief explanation are given in Table 6.2.

Table 6.2: Scores assigned as part of the updated competency process

Score	Outcome
Not competent	Insufficient evidence observed to confirm competency in procedure
Awareness	Has theoretical knowledge of subject matter but not able to practically apply this knowledge.
Basic	Has theoretical knowledge of subject matter and

	able to apply practically under direct supervision.
Intermediate	Has applied knowledge of subject matter, competent to perform work unsupervised and able to improvise and adapt working practices in response to events
Advanced	Has applied knowledge of subject matter, competent to perform work unsupervised and able to improvise and adapt working practices in response to events. Has sufficient experience and additional competencies to train, supervise and assess others.

The form is designed to be completed electronically and uploaded to the competency management system (Q-Pulse). Different options for competency management platforms were explored such as using Microsoft® Forms or adapting Q-Pulse, but it was beyond the scope of the project to implement a new system for the organisation. The current form is a compromise between use of resources currently available and creating a process that can be easily used by staff. A Microsoft Word® file with self-explanatory sections that can be expanded is the best compromise available.

6.3 Encouraging collaborative participation

In addition to the changes to the method of capturing competency, resources and tools were adapted and implemented to allow better accessibility to staff and encourage collaboration, reflection and participation of staff.

6.3.1 Update to standard operating procedures (SOPs)

A risk assessment must be created for each process undertaken in the workplace, as legislated by the Health and Safety at Work Act 1974. Due to organisational-wide changes to the risk assessment process, they have become long and repetitive as an effort to capture the end-to-end task, and all hazards and control measures is made. This has been noticed by the NCTC staff as a theme through the interviews was that staff found reading risk assessments a chore and did not feel the task added much value to their training.

As discussed in Section 6.2.2, staff members are no longer assessed against a risk assessment but only the SOP which will contain all relevant control measures, risks, and safety critical tasks. Laboratory staff now only have to read one comprehensive document, providing better accessibility to information.

To prevent the same issue faced in reading the risk assessments transferring to the SOPs, measures to ensure the documents remained accessible were introduced. As part of the human factors toolkit for HSE inspectors, a checklist of document formatting conventions has been developed which has been implemented when reviewing and authorising SOPs in NCTC. The checklist includes: -

- Avoiding long paragraphs;

- Not using all capital letters;
- Consistent, readable font sizing and formatting;
- Use of open space on the page (Health and Safety Executive, 2005).

Furthermore, where applicable, images of equipment and flowchart summaries of the overall process have been incorporated into the SOPs to allow readers to visualise whilst reading the text and consolidate their understanding.

When creating or reviewing an SOP, the authors are encouraged to collaborate with the users by asking for their input into the content and review. This helps foster a sense of ownership and autonomy over the resources used in the laboratory which will feed into the positive safety culture.

6.3.2 Creation of a risk assessment working group

To encourage participation and create opportunities for staff to collaborate in making improvements, a risk assessment working group was formed in November 2021. Membership includes the laboratory supervisors who have the responsibility of risk assessing the processes carried out in their respective areas, but membership is opened to all staff who wish to participate and gain experience in health and safety practices.

The working group meets once a month, any risk assessments due for review are discussed and assigned to an author. It is a space for members to discuss any safety concerns or identify any new risks that need to be incorporated into assessments. The meeting is attended by the NCTC Operational Lead as the chair and the Culture Collections Safety Manager. Whilst there is a structure and actions are assigned, the meeting is semi-formal, and users discuss their own concerns.

During the semi-structured interviews presented in Chapter Five, participants expressed they felt unable to contribute to larger, formal meetings which were seen to be spaces where information was cascaded down to the team. Creating the risk assessment working groups opens an avenue for discussion and upwards feedback. Furthermore, the risk assessment working group provides an opportunity to discuss any incidents or near misses that occurred. A crises or change from the norm is a catalyst for people to share their tacit knowledge (Eraut, 2000). This would help to reframe incidents in a positive light, as a learning tool, encouraging greater reporting.

6.3.3 Creation of the Safety Advocates Community of Practice

A barrier felt by the NCTC team was the geographical separation between NCTC in London, and the rest of the Culture Collections department in Wiltshire. This geographical distance has created a barrier to understanding the culture and operational approaches developed within each microbiology laboratory.

To bridge the gap between the department, I put forward a proposal to the Head of Department to create a “Safety Advocates Community of Practice.”

Based on the modern principles of CoP, a project proposal was submitted in May 2022 outlining the benefits of a safety advocates group and a framework for the management of the group (Appendix Seven).

The purpose of the Safety Advocates CoP is to empower junior members of staff to enact change and share ideas and concerns. This will form part of the bottom-up flow of health and safety information as discussions and outputs will be shared with the Safety Manager of Culture Collections, fostering a level of trust between leadership and staff. Furthermore, the Safety Advocates CoP will provide a forum for social learning and enhance the capability of Culture Collections staff in health and safety matters.

At the time of writing (May 2024), the Safety Advocates CoP has been established for two years. There are currently five voluntary members and meetings are held once a month via Microsoft Teams® video calls. Not all members are able to meet all meetings due to schedulling, but those I have spoken to find attendance worthwhile. Since the Safety Advocates group was set up, there has not been any direction from the more senior leaders of the Culture Collections. As found with the narrative review of the CoP literature, a leader in the group has emerged and is driving the progress of the group forward. Due to time constraints, the effectiveness of the CoP has not been evaluated but it is recommended that a monitoring and evaluation programme is put into place.

6.3.4 Adaptation of meetings to provide opportunities to contribute and reflect

The CoP literature showed that space for reflection is a valued outcome of joining a CoP. To create space for reflection for NCTC staff, the format of the monthly team meetings was changed to make all attendees feel included and able to participate. Each section of NCTC is asked to provide a slide reflecting on the previous month in a SWOT-inspired (Strengths, Weaknesses, Opportunities and Threats) format. The template for the slide is shown in Figure 6.5.

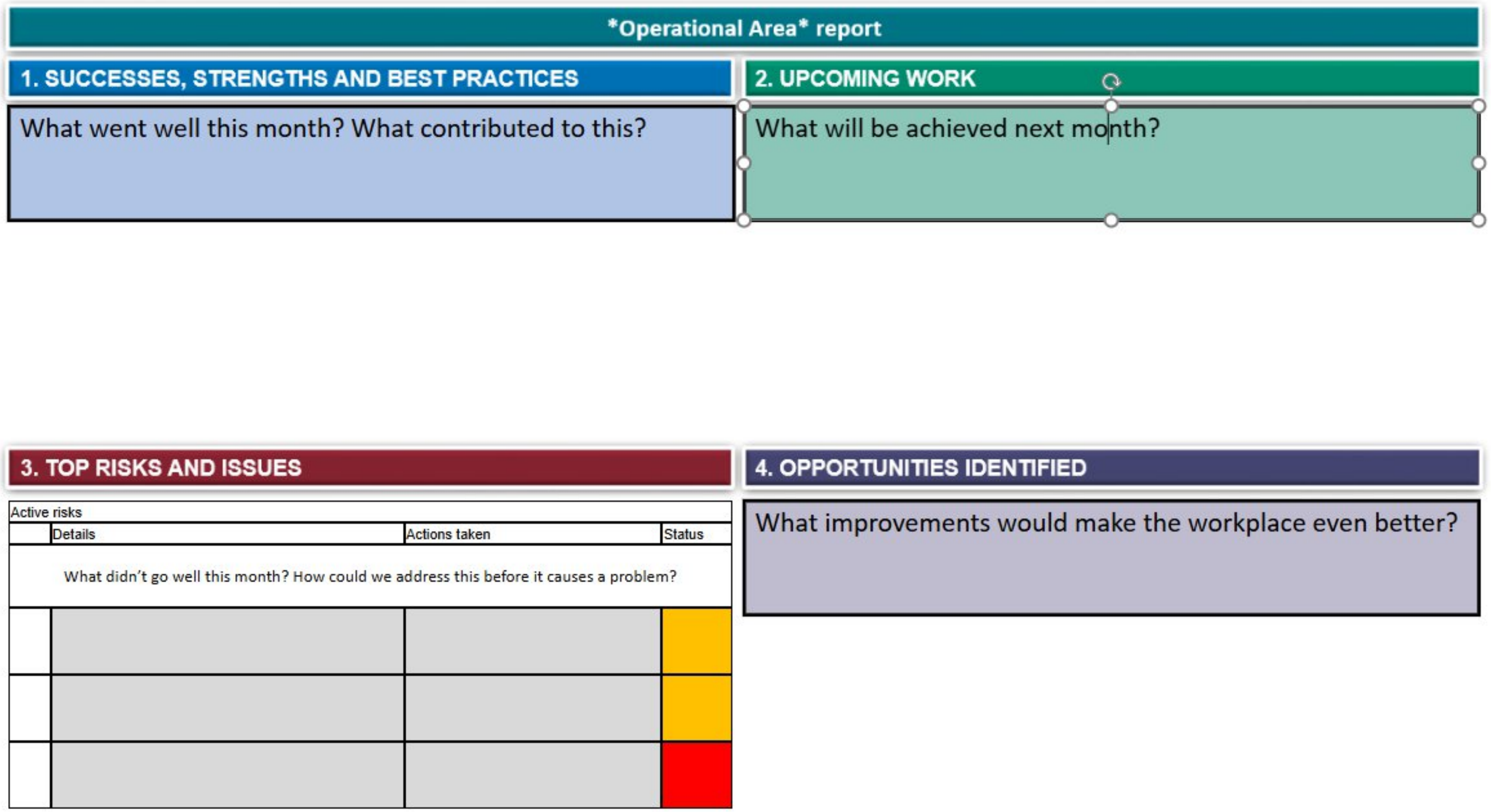


Figure 6.5: Meeting slide template to encourage reflection and participation.

The template encourages staff to consider positive and negative aspects of the previous month's work as well as imagine what could be and what may become a risk in the future. It is important to utilise imagination as it forms part of a person's identity within a CoP which contributes to learning according to (Wenger, 1998 p.175). It has been demonstrated through the semi-structured interviews that making explicit how participants imagined their role in NCTC and NCTC's place in the organisation, allowed any gaps to be identified and rectified.

Trust of the leader and the other members of the team is required to openly share inner thoughts and ideas. The traditional view of feedback as a one-way transmission of information from leader to team is challenged to enable the shared construction of knowledge to solve problems and make improvements (Ossenberg et al., 2019). Guided reflection will be used in group meetings by the chair, or one-to-one meetings between line manager and report to explore the topics raised in detail. Reflection requires guidance to be effective in developing knowledge (Farrell et al., 2021). The method of guided reflection selected for use is based on appreciative inquiry (AI). AI is based on the reflexive construction of ideas through focussing on the positive aspects of the work to generate discussion, ideas, and change. I have chosen this approach as it employs group reflection and imagination to drive innovation. By focusing on positive events that happened in the past, it is thought that people are more likely to contribute ideas for change (Cooperrider & Whitney, 2005). There are four phases;

discovery, dream, design, and destiny that consist of asking positively framed questions that engage participants in thinking about strengths and aspirations. AI has been used in healthcare to drive change and improve patient outcomes. A systematic review of its use by Merriel et al., (2022) identified 17 studies in which AI was used to affect change. They found that although many of the studies lacked scientific rigour, there were examples of improved self-esteem and development of a shared purpose, but no clear evidence of a positive effect on patient outcomes. Detractors of appreciative inquiry say that it causes negative aspects of an organisation to be ignored therefore, cannot be the only approach taken to encourage reflections. I believe it will be beneficial in encouraging participation and collaboration in NCTC and in developing a shared identity.

6.3.5 Training and development seminar

A further avenue for reflection and building capability in the NCTC is the introduction of a one-hour training and development seminar session every two months. The topics of the seminar have been broad ranging so far; leadership, presentation skills, the importance of reflection, and feedback from this research has been covered. To date, only I have delivered presentations but in coming months, other members of the NCTC team will be encouraged to host a session on a piece of work they have completed or a topic that interests them.

The main purpose for organising the seminar sessions is to provide another informal space the team can interact, reflect, and learn. Aside from the bi-weekly team huddles, it is not often the whole team are in the same place at the same time. Facilitating interaction will bring the disparate sections of NCTC together and allow cross-learning among the team.

6.3.6 Use of Microsoft Teams® channels to facilitate information sharing and discussion

As uncovered in the literature review of training for healthcare professionals in Chapter Three and the recent CoP literature, virtual platforms for the facilitation and hosting of communities of practice and learning are the prevalent approach. As such, it would be amiss to ignore the impact of virtual technology on the shaping of learning and safety culture.

Video conferencing, social media and blogs were utilised as part of CoPs to share best practices and develop resources (Barnett et al., 2012). Microsoft Teams® and channels have been implemented as an informal platform to share information. When a staff member has a question or wants to share an article, praise, or piece of information with whole or part of the NCTC team, they are encouraged to post on the MS Teams® Channel rather than email. The advantage using Teams® over email include the potential to generate discussion and learn through passive participation. Using MS Teams® is inclusive as it allows those not directly involved in the conversation to learn from it and gain more insight into the workings of the team. It is easier to facilitate a conversation on Teams® than email as anyone can contribute and new information can come from an unexpected source. The sharing of draft documents for input and review via the channel will encourage inclusivity and collaboration, two highly valued aspects of safety culture valued by the NCTC Team.

Despite the prevalence of technology, in 2022 I decided to shift team meetings back to face-to-face or hybrid where appropriate. The aim of this is to rebuild the connections between the different sections of the laboratory lost during social distancing. It provides dedicated time to listen and learn from colleagues. The literature review in Chapter Three supports the implementation of in-person or blended learning and recognised the importance of physical participation. The interventions applied as a result of this research consider the impact of the social aspect of learning and encourages collaboration first and foremost to generate new knowledge and influence behaviour.

6.4 Discussion: how has this professional doctorate thesis addressed the research questions?

This research has documented an iterative process to improving the training, competency, and health and safety culture of a microbiology laboratory, culminating in the use of situated and social learning models as a framework to build a new competency and culture approach in the National Collection of Type Cultures (NCTC) laboratory.

As part of the action research approach taken, the questions have been re-defined and were emergent throughout the research as new concepts were considered and reflected upon. Figure 6.6 summarises the action research cycle followed as part of this research, and the emergent questions at each stage.

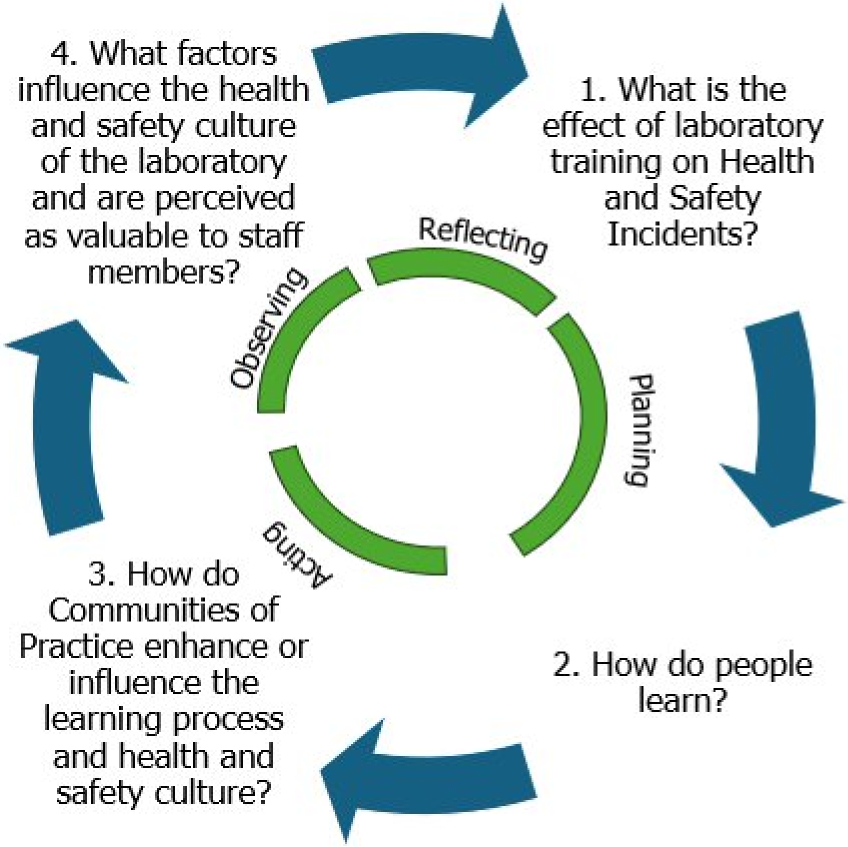


Figure 6.6: Research questions presented in the complete action research cycle.

"How can laboratory training and professional competency be used effectively to influence health and safety culture?"

1. **What is the effect of laboratory training on Health and Safety incidents?**
    a. **How effectively does education and training contribute to health and safety compliance and corrective action dissemination in a microbiology laboratory setting?**
    b. **How frequently are health and safety incidents linked to gaps in education or training?**
    c. **How are corrective actions from incidents recorded and communicated to laboratory personnel?**
    d. **How are regulations, guidance, and procedures integrated into the training process?**
    e. **What approaches to training are taken in the NCTC laboratory?**

Chapter Two established the context and need for change by exploring the concepts of safety culture and the available data on adverse laboratory incidents, to ascertain if there was potential for improvement in the role of education and training plays to reduce incidents. Training and education factors were attributed as the root cause of half of the incidents related to the freeze-drying process however, retraining could not always be traced back through documentation and competency records. The review of recorded incidents demonstrated that education and training is an important intervention for health and safety incidents in the laboratory, but its current application may not realise the full potential for improvements.

The review of incidents provided a snapshot of the safety climate of NCTC and identified areas for improvement. Overall, performing this piece of work demonstrated that the focus of the research should lie with utilising training and competency to address the safety culture of the laboratory as this would be more beneficial in influencing behaviour change and safer practise.

In addition, the review of the competency records and alignment with available guidance showed that whilst record keeping was thorough in the laboratory, the completion of competency forms felt more like a “tick-box exercise” than a valuable process. The records aligned closer with quality assurance than the health and safety requirements of the laboratory and evidence of the application of established training techniques were largely absent. Competency assessment did not cover all facets of competency and focused on knowledge. A person’s previous experience or aptitude was not captured in the records.

The review was useful in illuminating how the current training and competency process in the laboratory was executed, and areas for improvement were identified based on better alignment with the training and evaluation cycle and safety competency guidance. Although the information may not be written down, it may not reflect the actual training experience. This showed that the social aspects of the training process and working in the laboratory in general hold a potential for contributing to a person's competency that was not yet realised. The information not included in training records also provided an insight into the role of competency and training in building a positive safety culture. Training is cited as the root cause of incidents in NCTC and is also the most commonly applied intervention for building a safety culture as identified by Sinelnikov et al., (2020). However, "training" is a misnomer and does not capture the extent to which a person has to align themselves with a workplace, rationalise the meaning of procedures with their tacit knowledge and previous understandings, and interact with the other workers to develop a shared understanding, in order to develop competency. The review hinted that training and competency alone is not sufficient in building a positive safety culture and that wider influences on how individuals learn need to be considered.

How do people learn?

2. **What learning theories and approaches are applied contemporaneously in healthcare worker education?**
    i. **how effective are they?**
    ii. **how would these be applied to the NCTC Microbiology Laboratory?**

The wider healthcare professions were explored to determine what approaches to learning where utilised contemporaneously, and how the COVID-19 pandemic influenced the nature of training.

Virtual or blended approaches, incorporating simulation or problem-based learning was most common, with key theoretical influences of Knowles, Kirkpatrick and Kolb. The overall effectiveness of these approaches was not determined as the quality of the papers identified varied, with many interventions a result of the rapid onset of social distancing required during the pandemic, preventing direct comparison of approaches.

The overall conclusion of the literature review was that virtual training still requires an element of in-person learning and social interaction to be effective in a workplace setting. Framing the review in the context of the microbiology laboratory provided an impetus to explore social learning theories that incorporated the approaches identified. One such approach, communities of practice, aligned with the overall design of training interventions established.

3. **How do Communities of Practice enhance or influence the learning process and how can this be applied to health and safety culture?**

To address this research question, the communities of practice (CoP) model of social and situated learning was selected as an appropriate approach to explore the facets of how people lean and how this could be applied to influence health and safety culture. Emergent themes were that of leadership, the level of participation, role of reflection and motivation, and development of identity. The similarities between the themes from CoP, safety culture and competency were recognised, demonstrating the potential use of CoP to address the research question.

Moreover, the concept of CoPs not just generating knowledge, but generating value provided an assessment method of the current situation of health and safety culture and training in NCTC. Instead of attempting to form a community of practice, the themes emerging from the review of CoP application in healthcare are best used as a framework to apply to the workplace as elements that contribute to a health and safety culture.

4. **What factors influence the health and safety culture of the laboratory and are perceived as valuable to staff members?**
    a) **What is the collective identity of the department*?***
    b) **Where do staff obtain information related to health and safety and which sources are most valued?**
    c) **What social network is available to staff members?**
    d) **What factors influence the health and safety culture of the laboratory?**

Using semi-structured interviews of NCTC staff members designed using the value creation cycles of Wenger, Trayner and de Laat, a picture of where and who staff get their safety information from, what sources are most valued was constructed in order to determine what factors influence the health and safety culture of a microbiology laboratory.

The team placed value in interaction, being able to improve and contribute to process development, working in a place with a robust safety system, and participation in interactive training sessions. The role of documentation and procedures was understood but in the current form, it was felt that they were not accessible as risk assessments contained too much repetitive information. The importance of access to colleagues in the immediate team and wider organisation was emphasised, with the impact of social distancing on preventing the development of connections and limiting interaction expressed across the team.

The roles of leadership and identity were explored, with trust and reflection emerging as key contributing factors to both. Trust in leader's knowledge and abilities, and the invitation to share emotions and experiences through reflection is paramount to ensuring an upward feedback of safety concerns and ideas for improvement. Reflection on events is also important in shaping a person's identity as they reconcile the new learning with past experiences to imagine how things can change in the future.

The NCTC team presented a strong affinity to health and safety, demonstrating a sense of pride in robust systems and continuous improvement. However, the overall optimistic identity did not extend beyond the immediate team. The transitional time, staff changes and lack of access to the wider organisation created an atmosphere of uncertainty in the nature of the role of NCTC.

The semi-structured interviews provided a valuable insight into what is important for a positive safety culture in the NCTC team. This was then translated into interventions aimed at improving the training and competency process to better illicit tacit knowledge.

Concluding remarks

Training will play a role in influencing health and safety culture in the microbiology laboratory, but the traditional images of laboratory training have been expanded to include social interaction through participation and reflection. Training itself is considered a weak intervention to improve human performance as it cannot modify or extract the tacit knowledge and behaviours that individuals often revert to in the event of an unfamiliar or emergency situation. Those responsible for training management in a laboratory should build frameworks that transcend the traditional notions of competency. Safety is more often measured in its absence than its presence, for example, recording and investigating adverse incidents. This makes designing a competency scheme to assess how well a person does not act unsafely difficult (Hollnagel, 2021). The definition of competency used by the Health and Safety Executive, (2021) of "*the combination of training, skills, experience and knowledge that a person has and their ability to apply them to perform a task safely"* should be expanded to include identity and social capital to have a greater effect on the influence of health and safety culture of the laboratory. According to Bisbey et al., (2021), "*safety culture is socially constructed over time and rooted in history*." Communities of practice is a valuable learning concept that has proven to be useful as a tool to explore the safety culture of a microbiology laboratory.

Guldenmund (2007) stated that there are three forces in action within an organisation that influence the behaviour of staff: structure, culture, and processes. I feel that this thesis has addressed all three through the exploration of the structures that govern health and safety in the microbiology laboratory, the social and situated learning that contributes to the establishment of a culture, and the processes which staff value and can be targeted for further development.

The resulting output of this thesis is the generation of a conceptual model that can be applied to similar microbiology laboratories for the leadership team to expand what encompasses laboratory training to encompass relevant themes of communities of practice in order to foster a positive safety culture and better knowledge sharing amongst a team.

Chapter VII

7 Evaluating effectiveness and reflective analysis

7.1 Context and overview

To complete the reflecting stage of the action research question cycle used to design this research project, an evaluation has been conducted to assess if the interventions related to training and competency introduced aligned with the influencing factors on health and safety culture of the microbiology laboratory, and if they were impactful.

Figure 7.1: Starting a new cycle of improvement by evaluating effect of interventions.

7.2 Value creation

The issue with choosing safety culture as an outcome is there is no agreed upon method of measuring it. Any surveys or evaluations used only represent a snapshot of the overall picture, often referred to as safety climate. The desire to measure safety climate has not yet been fulfilled by our current methods of psychometric analysis and understanding of the contributing factors (Alsalem et al., 2018).

The same is true for Communities of Practice. CoPs try to affect motivation, behaviour change or organisational change; all multifaceted and complex spheres with external factors that may also influence change. This is why the focus of research question four was on the influencing factors of health and safety culture, elucidated through the framework of CoP.

The iterative nature of this research means there is not one solution that can be evaluated, nor is there one approach for evaluation. At the time of writing, the initial interventions have been in place for one year. The approach to evaluating their effectiveness I have selected is to return to Wenger's value creation cycle used for the semi-structured interviews. This is because it is founded upon Kirkpatrick's model of evaluation prevalent in the training literature, and value has emerged as a key component of influence the culture of the laboratory.

The evaluation of effectiveness involves a combination of descriptive statistics and reflective analysis of components relevant to the five stages of the value creation cycle. Due to the differing time periods, the depth and coverage of the review of incident and competency records is not as vast as the original review, therefore percentages have been used to demonstrate proportional changes for each factor measured.

I am confident that the interventions I have made have contributed positively to the health and safety culture of the NCTC laboratory, but there are external factors that have also enabled improvements. The majority of the project took place between 2021 and 2022 where COVID-19 pandemic restrictions were still in place. Staff were required to maintain social distancing whilst at work and self-isolate if unwell. This reduced the levels of interaction across the team and contributed to the isolation some participants described in the interviews. As the restrictions were eased, the levels of interaction naturally increased. Furthermore, changes in leadership, addition of experienced laboratory supervisors and recruitment of a Health and Safety Manager for the department also contributed to any change in the culture of the laboratory. I cannot conclusively state that any improvements noted were as a result of the interventions, or the wider change in circumstances in the laboratory, but can consider the evidence holistically in respect of the changing environment.

7.2.1 Cycle 1. Immediate value: Activities and interactions

One metric suggested for use to monitor immediate value is number of interactions between staff in the laboratory. This approach was straight forward during social distancing when I was able to analyse the nature of information exchanged in the “huddle meetings” as it was recorded on Microsoft® Teams. However, now these meetings have returned to in-person, it is not easily accessible as a research metric.

The use of the Teams® channels created for sharing resources and information within the NCTC team to access from different locations and times has shown some traction. Figure 7.2 shows the metrics provided by the platform on user engagement.

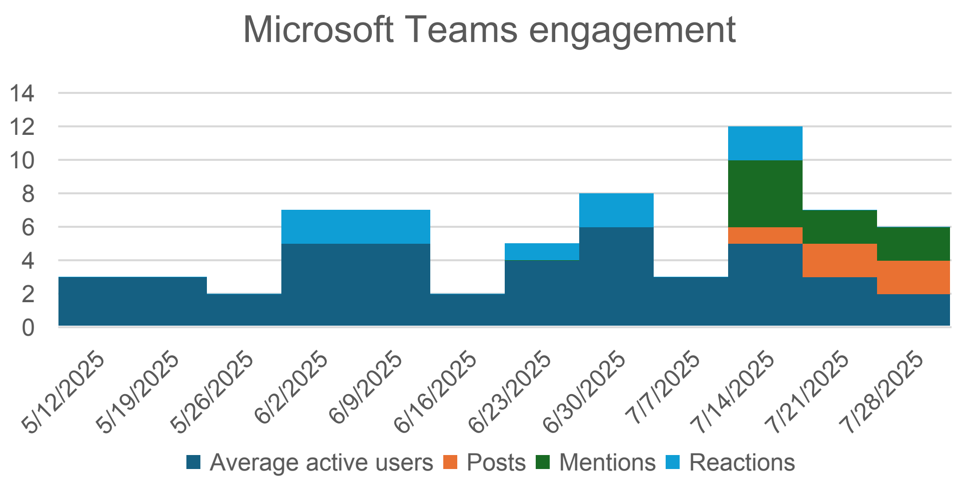


Figure 7.2: Analytic data from Microsoft Teams showing the online engagement in the NCTC team.

Between May and August 2025, there have been 19 active users, 8 posts, 2 replies, 14 reactions and 24 mentions. Use of the platform is sporadic and not consistent, this demonstrates that the adoption of the virtual communication platform has not fully enabled virtual collaboration. This could be that communication is taking place in-person or users are sitting on the periphery, observing the interactions but not participating. The use of Microsoft® Teams will continue as a communication and resource tool. It is hoped that as staff adapt to the platform, its use will increase.

7.2.2 Cycle 2. Potential value: Knowledge capital

To assess the increase in capital gained by the team, the learning, resources and social capital can be reviewed to identify a change or increase.

The change in the use of ClassMarker® can be used as an indication of the learning capital of the team. In the review of training record preceding the research project in Chapter Two, 254 questions related to health and safety understanding were asked. The majority of these (95%) were multiple choice or true or false questions. After the review, the number of H&S related questions asked decreased to 94. This is due to better incorporation of the risk assessments into the standard operating procedures and the cessation of the need for staff to take an assessment of their knowledge of risk assessments. Figures 7.3 and 7.4 show the proportion of question formats used in assessment pre and post intervention. The percentage of multiple-choice questions increased as did the use of other question formats including matching options, demonstration of workings and written answers. This indicates that the use of questioning has shifted to evaluate the higher levels of learning in Bloom's taxonomy – targeting evaluation of synthesis of knowledge beyond simple recall.

Figure 7.3: Proportion of question type pre-intervention

Figure 7.4: Proportion of question type post-intervention

The social capital gained by the NCTC staff could be reanalysed using social network analysis (SNA). The first use of SNA, a simple, non-directional network plot was created. Due to time constraints the activity has not been repeated post-intervention, but I would like to revisit the technique to plot the network across the whole Culture Collections team of about 70 people. To do this, a survey would be a more suitable format than interviews as it would allow the participants to provide quantitative responses. Participants would score a list of potential connection 0-3 based on how often they interacted and how valuable they perceived the interaction would be. From this data, a weighted, directional social network analysis could be created. This would enable the visualisation of pockets of isolation, cliques, and critical nodes that managers could target to ensure knowledge and information was reaching the right people as intended. Furthermore, different nature of the relationships could be analysed. Rather than asking “who do you get your health and safety information from?” As was done in the semi-structured interviews, other factors could be captured such as enabling and blocking relationships. To assess the wider social networks in Culture Collections or in UKHSA laboratories, a survey could be used based on the findings of the interview as a guide for the taxonomy of sources and connections. Extensive validation would be required to ensure the descriptions and discrete groupings were correctly labelled. For example, a line manager and a laboratory supervisor may be the same or separate individuals a person could state. Multiple SNA approaches could be taken such as evaluating a whole network or targeting ego networks. The most appropriate methodology would depend on the size of the network and level of participation. The survey would require the collection of names and so informed consent and ethics approval would need to be sought before implementation.

7.2.3 Resources (tangible capital)

The aim to encourage collaboration in the production of shared resources has been successful. Evidence of the collaborative approach to creating and reviewing documents is shown on the Microsoft Teams Channel where staff members share the draft document and invite comments. This has occurred 29 times in the last 12 months (May 2024 – May 2025).

7.2.4 Cycle 3. Applied value: Changes in practice

To ascertain how the NCTC microbiology staff have changed their practice as a result of this research, a repeat of the training record audit was undertaken. From the period May 2022 to May 2025 when the new process was introduced, only two members of staff were trained in the freeze-drying process of the NCTC bacterial strains, the process originally evaluated in Chapter Two. To gather sufficient data to compare records, competency records from all NCTC microbiology processes that contain safety-critical steps were reviewed. In total, 91 records from eight individuals were identified and included in the review.

Table 7.1 details the number of different training approaches used by proportion pre and post intervention. There is little evidence of an increase in the use of multiple training approaches for each training event with the majority of records 2022-25 using two methods (51%). There is however, an increase in the range of training methods used across all records (Table 7.1).

Table 7.1: Number of training methods used in competency assessment pre and post-intervent.

Number of training methods used	Percentage of records 2014-2021	Percentage of records 2022-2025
1	20%	15%
2	34%	51%
3	33%	18%
4	10%	11%
5	3%	5%

Competency assessment and observation remain the most popular methods of training. In 2014-2021, seven different approaches were utilised. The updated review has identified eleven approaches with an increase in use of review of laboratory records and hypothetical situations, and the introduction of audit, external quality assessment and decision-making.

Figure 7.5: Range of training approaches used and their frequency.

The range of the nature of comments on the forms also increased. Figures 7.6 and 7.7 show the difference between pre- and post-introduction of the new competency assessment form.

The range of comment types increased from 10 to 18. This is due to the prompts included in the revised competency assessment form. Previously, 20% of records contained feedback from the training on performance and 2.5% of records recognised the trainee's previous experience. This has increased to 95% and 34% respectively. The new forms have allowed for greater capturing of competency. Particularly related to the safety-aspects of procedures. This gives greater assurance of the person's overall competency. In addition, 31 records contained feedback from the trainee. This was recorded in the reflection section against each training activity. The update of this feature is lower than I would have expected with only 34% of records containing the reflection. Furthermore, the nature of these comments was most frequently a one-sentence statement amounting to "I feel confident I can perform this procedure independently.” The deeper level of reflection that I am trying to encourage is absent. Based on this, the form may be redesigned to include question prompts to encourage reflection.

Overall, the introduction of the updated competency assessment form and guidance has shown to change practise in the NCTC microbiology laboratory to better capture the competency of staff performing safety-critical tasks.

Chapter VII

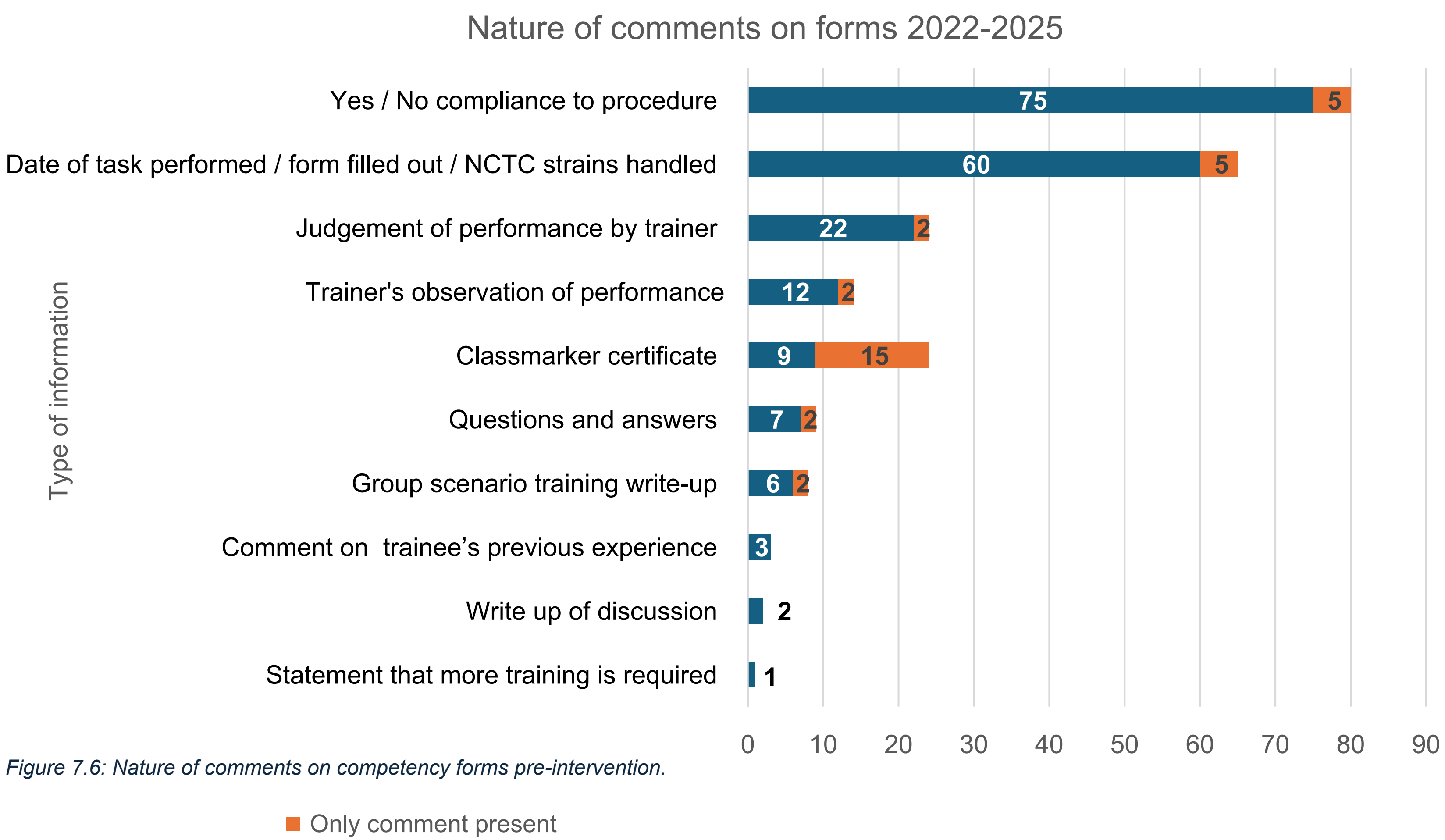


Figure 7.6: Nature of comments on competency forms pre-intervention.

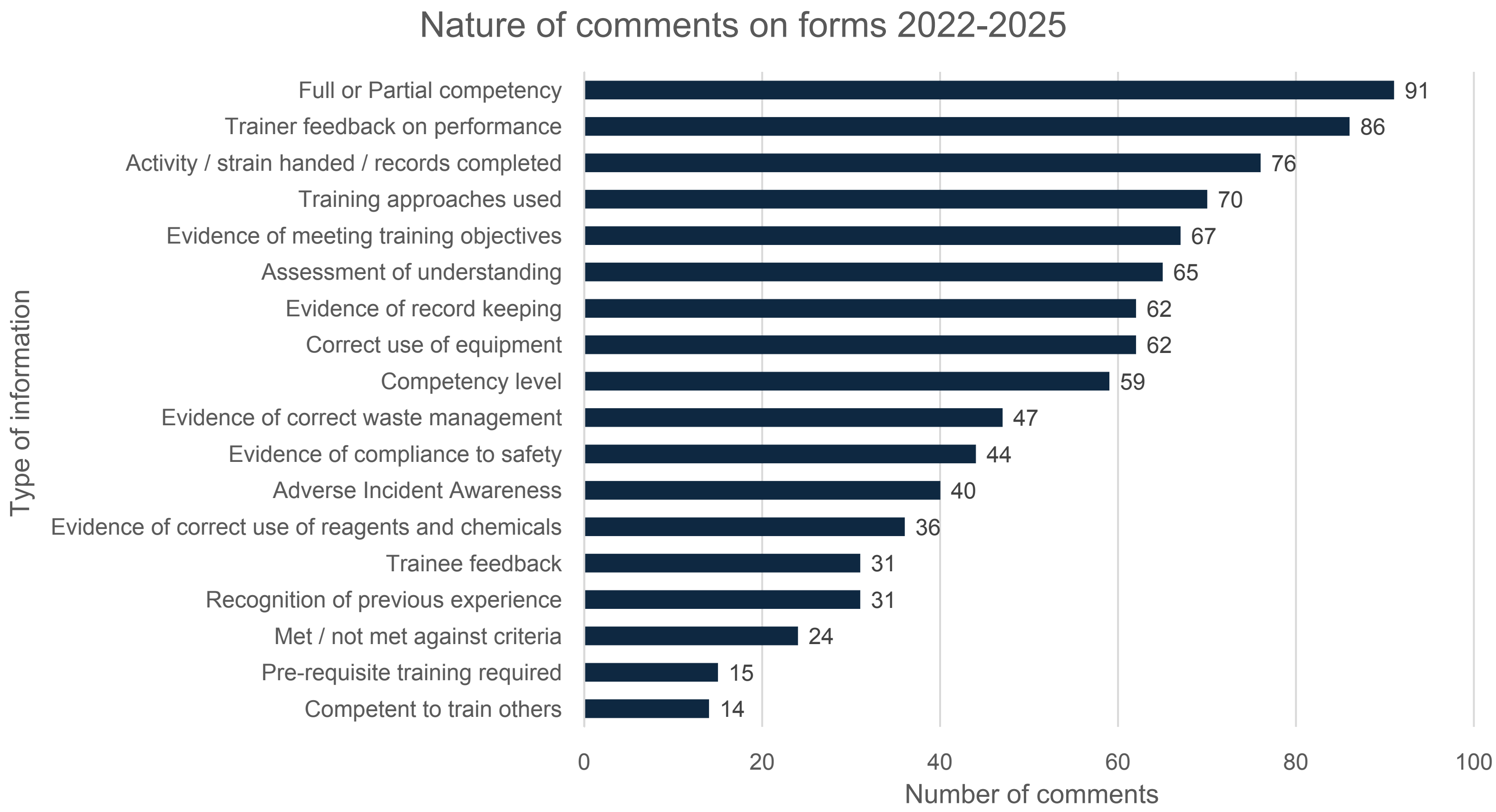


Figure 7.7: Nature of comments on competency forms post-intervention.

7.2.5 Cycle 4. Realized value: Performance improvement

The change in practice in NCTC has also resulted in improvements in performance related to health and safety awareness and reporting.

To assess performance improvement, the records of health and safety incidents from the laboratory were reviewed from May 2022 to May 2025. As with the training records, there were fewer incident logs related to the freeze-drying process, the focus of the original review. Incidents across all areas of the laboratory were used as comparison. In total, there were 49 incidents records in this time period compared to 111 in the pre-intervention review.

Figure 7.8 shows the categorisation of root cause pre- and post-intervention and directional arrows showing and increase or decrease. In 2022-2025, there were six incidents attributed to education and training factors (12%) compared to 33 (30%) in 2014-2021. The decrease in incidents related to education and training indicates an improvement in the laboratory training and technical competency system. It could also indicate an increased engagement of staff in safety culture and an improvement of root cause analysis.

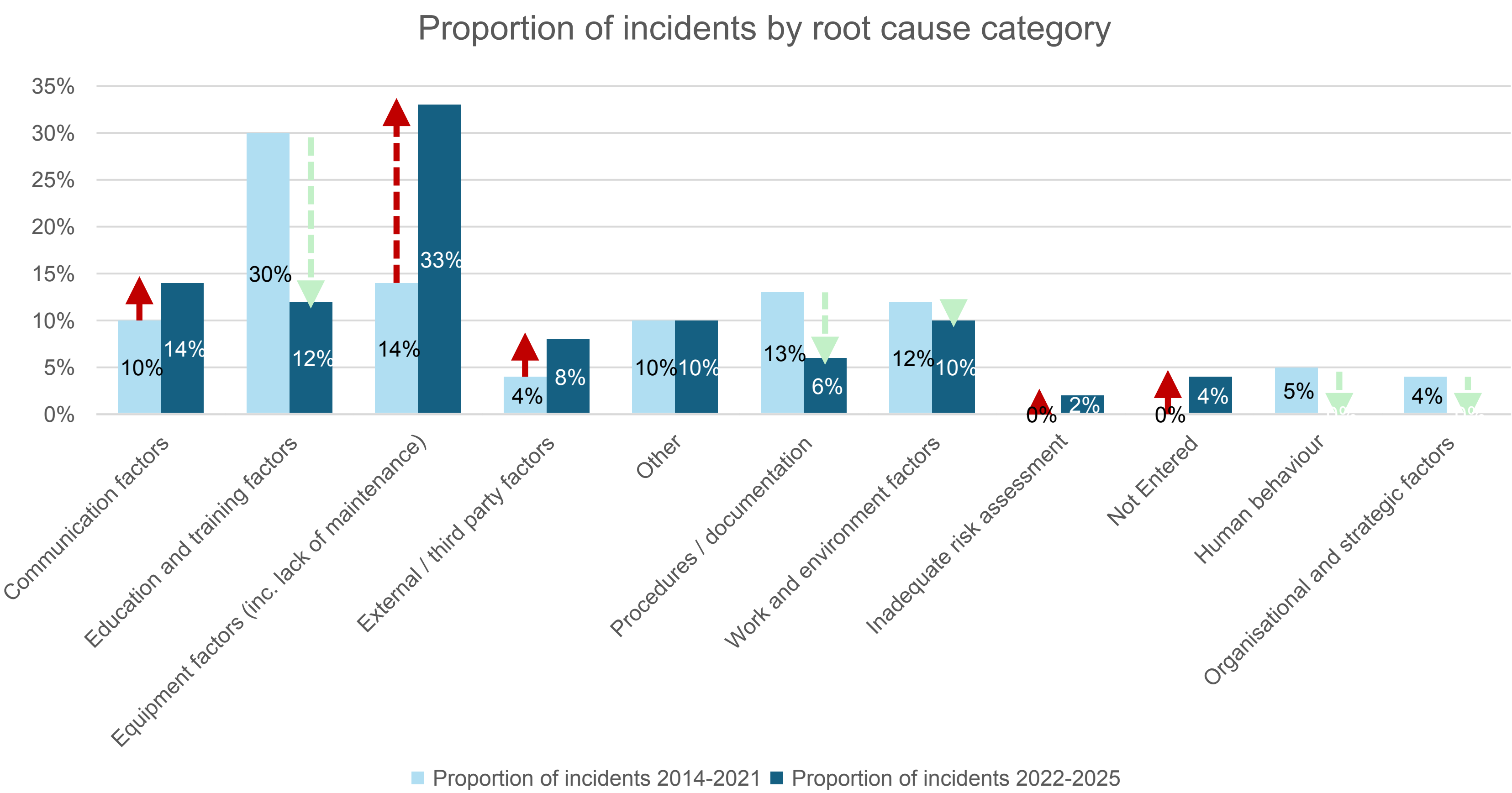


Figure 7.8: Root cause category of H&S incidents. Proportional change

The six incidents attributed to education and training along with a further seven for which the human factors category applied was knowledge-based mistake, were analysed to trace the implementation of corrective action. Figures 7.9 and 7.10 show the Sankey diagrams that visualise the flow of corrective actions into how they were implemented. Pre-implementation, four corrective actions could not be traced to find how they were disseminated to staff. In 2022-2025, all corrective actions could be traced to the risk assessment, discussion in meetings and email communication. All updates to the risk assessments as a result of the incident were incorporated into the associated SOP. Only 6 out of 10 corrective actions could be identified in the training records but were addressed in meeting minutes, which indicates an improvement in dissemination of corrective actions and a proactive approach to learning from incidents.

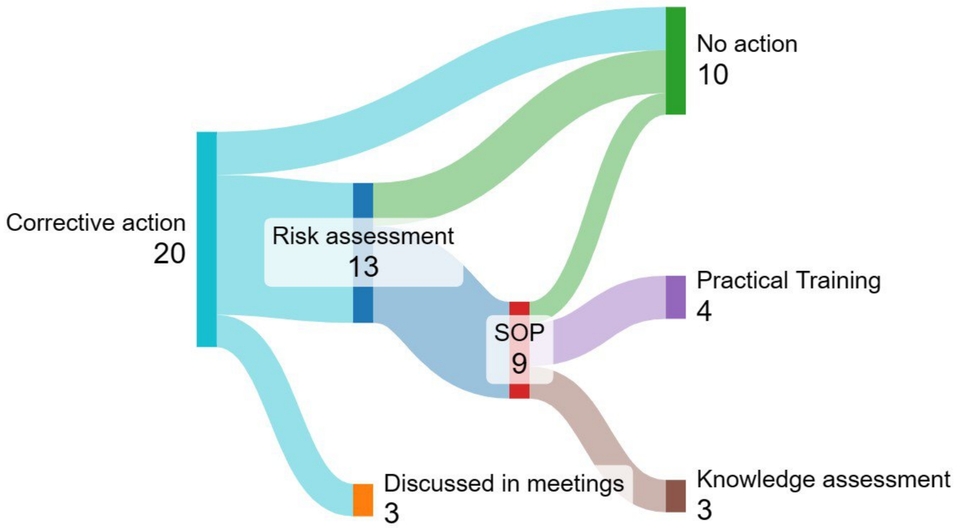


Figure 7.9: Sankey diagram of the flow of corrective actions 2014-2021.

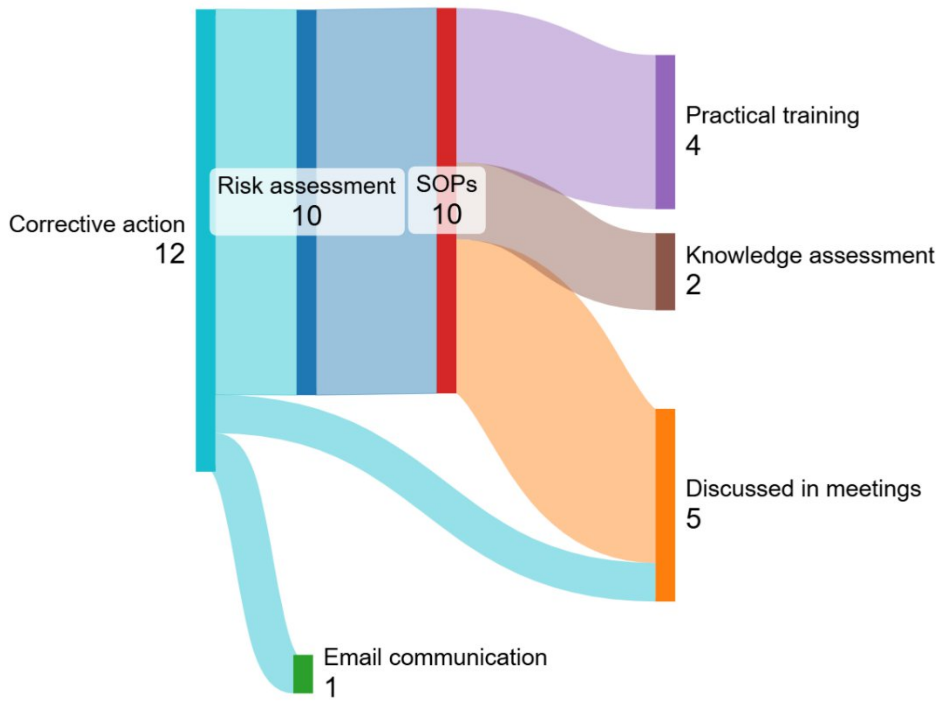


Figure 7.10: Sankey diagram of the flow of corrective actions 2022-2025.

The pre-intervention review of the training records found that the guidance and execution of training was influenced by the quality standards rather than the available safety guidance. The introduction of the updated competency form and training manual has increased the implementation of the required aspects of the competency process according to the internal safety guidance and that of the HSE. Figure 7.11 shows the proportional change of alignment with competency guidelines pre- and post-research project. Across all but one aspect, the percentage of records evidencing compliance has increased or remained the same. There was a 2% decrease in evidence of progress of individual tracked. This was most likely due to the fact that 38% of records being ongoing competency where only one observation of training was made.

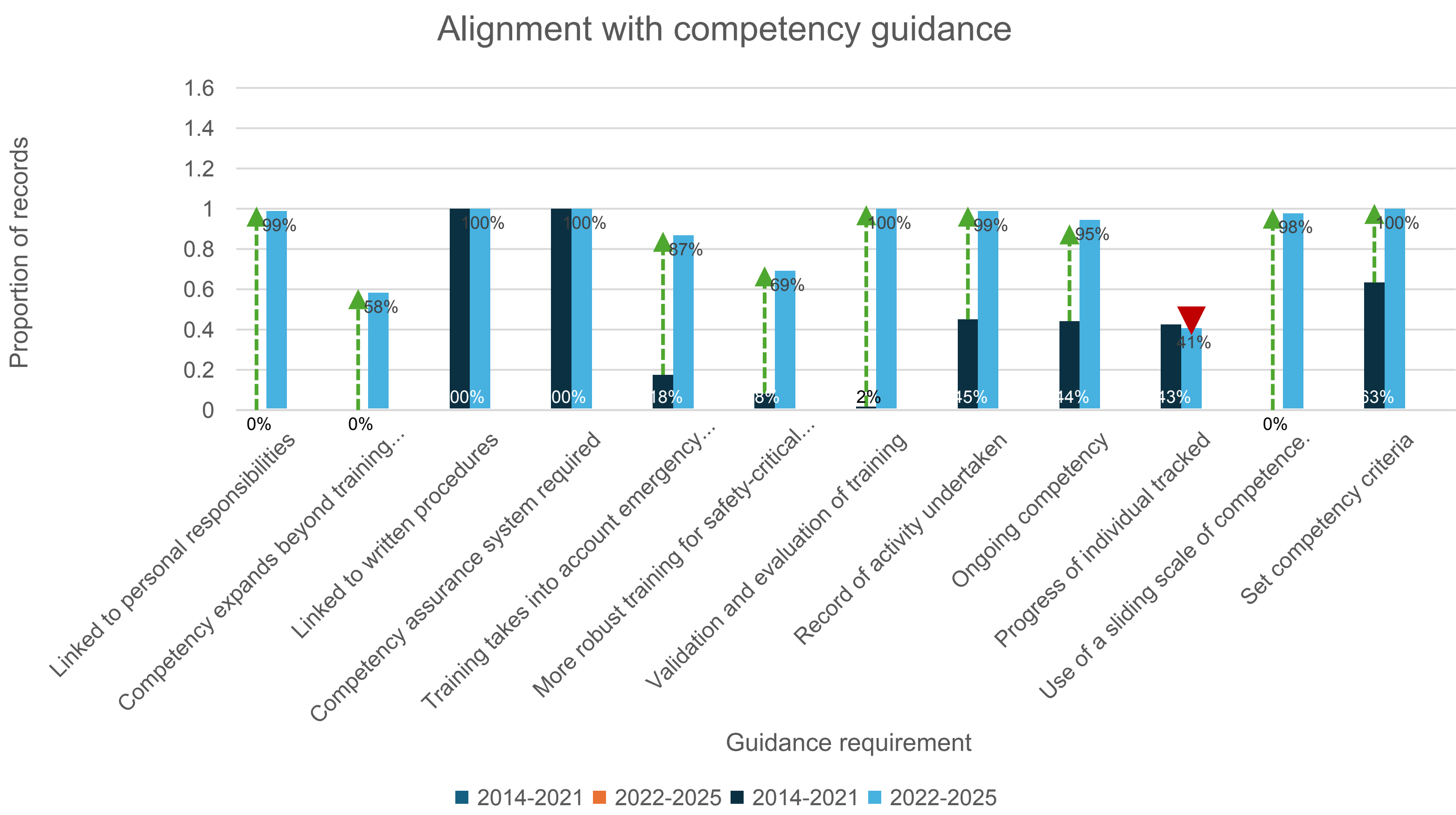


Figure 7.11: Alignment of competency records with competency guidance. Proportional change.

7.2.6 Cycle 5. Reframing value: Redefining success

The final cycle of evaluation involves redefining existing frameworks and what metrics are used to measure success. The nature this research means this will be an ongoing process as new members of the team joins and areas for improvement are identified.

One example of reframing value has occurred during the course of this research. The technical competency form I have implemented as part of the interventions (Appendix Six) aimed to find a balance between compliance and accessibility. Figure 7.11 demonstrates that it is more successful than the previous iteration, however not all laboratory staff are not completing it as intended. This comes back to the “work as imagined” aspect of safety management and highlights the disconnect between management and practice. The laboratory staff worked together to redesign the form to better meet their needs rather than all the expectations of the regulators and guidance. There may never be a harmony between the two, but utilising situated learning has provided a tool for the gaps between work as imagined and in reality, to be addressed.

Another component of the research that may need further evaluation in the future is the nature and role of supervisors and leaders in the situated learning framework. At the time of undertaking this research, I was the most senior person in the team and was directly line managing 10 reports. We did not have any fully trained laboratory supervisors as there was a recent turn-over of staff. The supervisors who took part in the interviews had been in post a matter of months so had not taken on the full role. As such, the other staff members saw them as new and not a full member of the community. The role of supervisors in building the culture and competence of the laboratory is considered to be important (Sinelnikov et al., 2020). Supervisors and mentors are key roles in encouraging and facilitating reflective practice (Mann et al., 2009). I believe that if experienced supervisors were in place, the results of this study would be different. I as the Laboratory Manager would not have been cited as the main contact for safety-related issues if there was a middle-manager between me and the rest of the team. This presents an interesting conundrum in that whilst having supervisors is essential for running a laboratory, allowing for career progression and succession planning, it hinders the upward flow of information and introduces a new layer of interpretation of meaning, creating more examples of work as imagined vs work in reality.

In conclusion, the initial analysis of the interventions as a result of this research has shown a positive effect on the training, competency and safety culture of the laboratory. As the new ways of workings mature and develop, it is hoped that the use of the collaborative approach, social network development, reflection, and competency approaches become part of the identity of the NCTC laboratory and continue to evolve and improve the safety culture of the team.

Chapter VIII

8 Reflective analysis

8.1 Exploring the mystery boxes

Figure 8.1: Mystery Box activity, developed by the Science Museum. Photo credit: https://learning.sciencemuseumgroup.org.uk/wp-content/uploads/2020/04/SMG-Academy-Mystery-Boxes.pdf,

To represent my journey through this professional doctorate, I will use the "Mystery Box" outreach exercise as an analogy for my experience and what I have learned. In the activity, developed by the Science Museum, participants are given a sealed box with an unknown item inside. They are not allowed to open the box, but working in pairs or groups, must use reasoning, scientific deduction and previous knowledge to come up with their best guess of the contents of the box. The aim of the activity is for children to recognise the skills they have that translate to scientific inquiry. The boxes are not opened at the end as an analogy for science being a continuous refinement of theory. I have used this activity on multiple occasions in its intended use as a STEM outreach tool but also in training sessions as ice breakers with colleagues.

The activity is designed to encourage participants to think scientifically, using reasoning and deduction to determine the contents of the box. Coming from a scientific background, I initially envisaged this doctorate to include the approaches I was familiar with, statistical analysis, control groups, repetition and reproducibility. Instead, the doctorate research project has given me the opportunity to explore qualitative research. I have learnt about the different methodologies such as grounded theory, thematic analysis, and content analysis. Performing thematic analysis and coding has provided me with the skills to create connections between discrete items, think more laterally, and see the bigger picture. It has taught me to take time to reflect on the true meaning of someone's words, to act rather than react. These skills have benefitted me as a line manager and in dealing with difficult conversations.

The mystery boxes act as a metaphor for qualitative research. As with scientific inquiry, there is no right answer. It all depends on perceptions and interpretations. We can refine the research through introducing quality assurance and transparency in design and reporting of results, just as we can employ advanced methods such as weighing the box and comparing against a reference over simply shaking and feeling to determine its contents.

The boxes are also an excellent example of social construction and communities of practice in action. The boxes are examined in groups or pairs who discuss the contents. They are not given any clues as to what may be inside, the knowledge is already within them and the interaction assists with bringing it to light. Someone may suggest one potential item, and another builds and refines this until they all feel confident in the correct answer. They draw upon their past experiences to influence the answer. Children may provide a more fantastical answer whereas when I have done this activity with work colleagues, the suggestions of the contents of the boxes are grounded in what I realistically would have access to, such as stationery, coins, or dried food. This demonstrates the importance of previous experiences in shaping knowledge and competency that should be celebrated and included in the training. Furthermore, the mystery boxes invite the expression of identity in the communities of practice context. Participants use imagination, they engage with the practice of guessing and engage with others whilst doing so. As they discuss the potential contents, they begin to align their ideas with the other participants. The mystery boxes activity has also shown me that this process is not easy. Some individuals find it difficult to engage with the activity or even begin to put forward suggestions. The same is true with building competency and refining safety culture using social learning and reflective practice. I have implemented and facilitated additional opportunities but I cannot make someone engage beyond superficial levels.

The final aspect of the doctorate for which the mystery boxes can be used as a metaphor is the outcome. The contents of the boxes are never revealed. Similarly, the cyclical nature of this research means the refinement in practice and advancement of understanding could continue indefinitely. The endpoint reached as part of this thesis provides a satisfactory journey with evidence of a successful refinement of the technical training and professional competency process but in reality, the research is still continuing. Processes are continually reviewed, feedback taken on board and my understanding of safety culture, leadership and training techniques is ever evolving.

By sharing the mystery boxes metaphor, I hope to have demonstrated how I perceive the importance of what this thesis achieves. In a sense, I have presented my inner workings to the mystery box of safety culture and competency. I have applied the knowledge and experiences I have gathered throughout my career to negotiate meaning through the lens of communities of practice.

8.2 *"If you want to truly understand something, try to change it"*

I feel this thesis has delivered on this quote by Lewin, provided in the first chapter. What I have implemented has created a small shift in the way safety is perceived and utilised in NCTC and deepened my own understanding of the topics.

I have learned how to assess research and how to search the literature systematically. I have applied the latter to finding papers in other research areas in my job role. I know what to look for when reading qualitative research. The same critical evaluation can also be applied to reading news articles, internet posts and work-related papers so I no longer take information at face value but consider the viewpoints and stance of the author of such information.

Undertaking the review of the competency processes provided me with a deeper understanding of how training was undertaken and identify gaps in the process that I would not have time and resource to do without the doctorate. Breaking information down and performing gap analysis is a crucial skill for a senior laboratory manager in view of quality and regulatory assurance, and to identify new strategic direction.

I have explored new techniques in social network analysis and read into approaches new to me such as the Behaviour Change Wheel (Michie et al., 2014) that despite not featuring in the thesis, has broadened my training and leadership repertoire.

I have also learned a lot about my self as a person. My position as researcher and laboratory leader required a continuous reflection of why I was assigning various themes to ensure I was transparent with my findings and did not influence them unduly. I have learned about my approach to research and writing. Reflection features heavily throughout the thesis, so it is important I practice what I preach. Giving myself the time and space for reflection enabled me to overcome the emergent nature of the work and shape the direction of the research. The same privilege should be afforded to my staff if I expect them to learn by reflecting.

8.3 Contribution to understanding

The contents of this professional doctorate connect the fields of in occupational safety, education, and psychology to better facilitate professional and technical competency and a positive health and safety culture in a microbiology laboratory. It provides an approach that could bridge the gap between of leadership, accident investigation, training, and human factors. It addresses questions that are not commonly asked when discussing these topics; “Leadership is important for effective health and safety culture, but how does it fit with a bottom-up reporting approach?” “Processes should be designed to minimise human error where possible, but how does one engage with workforce in doing so?”

The setting of the NCTC microbiology laboratory has provided unique and idiosyncratic scenarios, but it is hoped that other laboratory settings, or the broader healthcare community can find insight into the use of communities of practice to influence professional and technical competency and safety culture. The balance between process and management driven structure and a bottom-up constructivist approach to the workplace can be shifted to provide more opportunity for workers to feed into the system and for managers to access the tacit knowledge and resources developed within a community.

8.4 Conclusion

This research project has established a link between the laboratory training and competency process with positively improving health and safety culture. Wenger et al’s framework for value creation has proven to be a suitable tool for evaluating the safety culture of workplace using the lens of communities of practice. Its application has revealed key markers for improvement in laboratory training that will enhance professional competency such as documentation, incorporating in-person training, providing the opportunity to collaborate.

Any approach to competency assessment must consider the person as an individual, as well as the “Community of Practice” they are working within. This can be expanded to include a person’s identity, what they value, and who they have access to. The COVID-19 pandemic has hindered the implementation of these factors but has provided an opportunity to reset and reevaluate the approach to professional competency in the NCTC microbiology laboratory.

Training approaches to facilitate the development of professional competency should include group interaction, collaboration on creating resources, and reflection. Leadership structures must facilitate upward feedback through these means as a way to access and utilise tacit knowledge. In turn, understanding and utilising what collective value, resources and social interaction can have a positive effect on health and safety culture.

9 References

Aburumman, M., Newnam, S., & Fildes, B. (2019). Evaluating the effectiveness of workplace interventions in improving safety culture: A systematic review. *Safety Science*, *115*(December 2017), 376–392. https://doi.org/10.1016/j.ssci.2019.02.027

Adams, N. E. (2015). Bloom’s taxonomy of congnitive learning objectives. *Journal of the Medical Library Association*, *103*(July), 152–153. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4511057/

Adedoyin, A. C. A. (2016). Deploying virtual communities of practice as a digital tool in social work: a rapid review and critique of the literature. *Social Work Education*, *35*(3), 357–370. https://doi.org/10.1080/02615479.2016.1154660

Advisory Committee on Dangerous Pathogens. (2019). *Management and operation of microbiological containment laboratories*. https://www.hse.gov.uk/biosafety/assets/docs/management-containment-labs.pdf

Ahmed, K., Miskovic, D., Darzi, A., Athanasiou, T., & Hanna, G. B. (2011). Observational tools for assessment of procedural skills: A systematic review. *American Journal of Surgery*, *202*(4), 469-480.e6. https://doi.org/10.1016/j.amjsurg.2010.10.020

Alary Gauvreau, C, & Le Dorze, G. (2022). Participant reported outcomes of a community of practice about social participation for speech-language pathologists in aphasia rehabilitation. *Disability and Rehabilitation*, *44*(2), 231–242. https://doi.org/10.1080/09638288.2020.1764116

Alary Gauvreau, Christine, Le Dorze, G., Kairy, D., & Croteau, C. (2019). Evaluation of a community of practice for speech-language pathologists in aphasia rehabilitation: A logic analysis. *BMC Health Services Research*, *19*(1). https://doi.org/10.1186/S12913-019-4338-0

Alcalde-Rabanal, J. E., Becerril-Montekio, V. M., & Langlois, E. V. (2018). Evaluation of Communities of Practice performance developing implementation research to enhance maternal health decision-making in Mexico and Nicaragua. *Implementation Science*, *13*(1). https://doi.org/10.1186/s13012-018-0735-8

Alroumi, F., Cota, D., Chinea, J., Ravikumar, N., Tiru, B., Pinto-Plata, V., & Tidswell, M. (2021). Rapid Intensive Care Unit Onboarding in Response to a Pandemic. In *Journal of medical education and curricular development* (Vol. 8, p. 23821205211020740). SAGE Publications. https://doi.org/10.1177/23821205211020741

Alsalem, G., Bowie, P., & Morrison, J. (2018). Assessing safety climate in acute hospital settings: A systematic review of the adequacy of the psychometric properties of survey measurement tools. *BMC Health Services Research*, *18*(1), 1–14. https://doi.org/10.1186/s12913-018-3167-x

Amin, A., & Roberts, J. (2008). Knowing in action: Beyond communities of practice. *Research Policy*, *37*(2), 353–369. https://doi.org/10.1016/j.respol.2007.11.003

Analytic Technologies. (2011). *UCINET* (6.365). https://sites.google.com/site/ucinetsoftware/downloads

Andrew, N., Tolson, D., & Ferguson, D. (2008). Building on Wenger: Communities of practice in nursing. *Nurse Education Today*, *28*(2), 246–252. https://doi.org/10.1016/j.nedt.2007.05.002

Aryal, K., Hamed, M., & Currow, C. (2021). The usefulness of work-based assessments in higher surgical training: A systematic review. *International Journal of Surgery*, *94*(June), 106127. https://doi.org/10.1016/j.ijsu.2021.106127

Ashforth, B. E., & Schinoff, B. S. (2016). Identity under Construction: How Individuals Come to Define Themselves in Organizations. *Annual Review of Organizational Psychology and Organizational Behavior*, *3*(April 2016), 111–137. https://doi.org/10.1146/annurev-orgpsych-041015-062322

Babenko, O., Ding, M., & Lee, A. S. (2022). In-Person or Online? The Effect of Delivery Mode on Team-Based Learning of Clinical Reasoning in a Family Medicine Clerkship. *Medical Sciences (Basel, Switzerland)*, *10*(3). https://doi.org/10.3390/medsci10030041

Baker, K. S., Mather, A. E., McGregor, H., Coupland, P., Langridge, G. C., Day, M., Deheer-Graham, A., Parkhill, J., Russell, J. E., & Thomson,

N. R. (2014). The extant World War 1 dysentery bacillus NCTC1: a genomic analysis. *The Lancet*, *384*(9955), 1691–1697. https://doi.org/10.1016/S0140-6736(14)61789-X

Barnett, S., Jones, S. C., Bennett, S., Iverson, D., & Bonney, A. (2012). General practice training and virtual communities of practice - A review of the literature. *BMC Family Practice*, *13*, 1–12. https://doi.org/10.1186/1471-2296-13-87

Barry, M., Kuijer-Siebelink, W., Nieuwenhuis, L., & Scherpbier-de Haan, N. (2017). Communities of practice: A means to support occupational therapists' continuing professional development. A literature review. *Australian Occupational Therapy Journal*, *64*(2), 185–193. https://doi.org/10.1111/1440-1630.12334

Bassot, B. (2015). What is reflective practice ? In *The reflective practice guide : An interdisciplinary approach to critical reflection.* (1st Editio, Issue 1, pp. 1–14). Routledge.

Bates, B. (2016). *Learning Theories Simplified* (3rd Editio). SAGE Publications.

Bertone, M. P., Meessen, B., Clarysse, G., Hercot, D., Kelley, A., Kafando, Y., Lange, I., Pfaffmann, J., Ridde, V., Sieleunou, I., & Witter, S. (2013). Assessing communities of practice in health policy: a conceptual framework as a first step towards empirical research. *Health Research Policy and Systems*, *11*(1), 39. https://doi.org/10.1186/1478-4505-11-39

Betthäuser, B. A., Bach-Mortensen, A. M., & Engzell, P. (2023). A systematic review and meta-analysis of the evidence on learning during the COVID-19 pandemic. *Nature Human Behaviour*, *7*(3), 375–385. https://doi.org/10.1038/s41562-022-01506-4

Bing-Jonsson, P. C., Førsund, L. H., Hansen Stålesen, J., Vabo Nesland, B., Lindholm, I. C., & Rugsland Espegren, O. (2023). Lifelong learning in community healthcare: Testing competence after learning activities in a blended learning space. In *Scandinavian journal of caring sciences* (Vol. 37, Issue 4, pp. 1057–1066). Taylor & Francis. https://doi.org/10.1111/scs.13180

Bisbey, T. M., Kilcullen, M. P., Thomas, E. J., Ottosen, M. J., Tsao, K. J., & Salas, E. (2021). Safety Culture: An Integration of Existing Models and a Framework for Understanding Its Development. *Human Factors*, *63*(1), 88–110. https://doi.org/10.1177/0018720819868878

Bloom, B. S. (1956). Taxomony of Educational Objective. In *Taxonomy of educational objectives*.

Boon, A. (2017). *The Action Research Cycle: Exploring Pedagogic Puzzles*. SAGE Publications Ltd. https://doi.org/10.4135/9781473991019

Braun, V., & Clarke, V. (2014). Using thematic analysis in psychology Using thematic analysis in psychology. *Psychiatric Quarterly*, *0887*(1), 37–41. http://www.ncbi.nlm.nih.gov/pubmed/11752478

Brightwell, A., & Grant, J. (2013). *Competency-based training : who bene fi* *ts ? 3*, 107–110. https://doi.org/10.1136/postgradmedj-2012-130881

Brooks, S. (2018). *ECC74 No Culture Collections Training Manual, version 4*. Public Health England.

Brown, J. S., & Duguid, P. (1991). Organizational learning and communities of practice: Toward a Unified View of working, learning, and innovation. *Organization Science*, *2*(1), 40–57. https://doi.org/10.1287/orsc.2.1.40

Brown, J. S., & Duguid, P. (2000). Balancing act: how to capture knowledge without killing it. *Harvard Business Review*, *78*(3), 73–80, 212.

Busch, L., Zonneveld, K., Saini, V., Chartier, K., Leathen, N., Asaro, M., & Feltz, N. (2020). The more we get together: Communities of practice for behaviour analysts. *Canadian Journal of Behavioural Science*, *52*(4), 277–284. https://doi.org/10.1037/cbs0000174

Byrnes, K. P., Rhoades, D. L., Williams, M. J., Arnaud, A. U., & Schneider, A. H. (2022). The effect of a safety crisis on safety culture and safety climate: The resilience of a flight training organization during COVID-19. *Transport Policy*, *117*, 181–191. https://doi.org/10.1016/j.tranpol.2021.11.009

Castro, M. R. H., Calthorpe, L. M., Fogh, S. E., McAllister, S., Johnson, C. L., Isaacs, E. D., Ishizaki, A., Kozas, A., Lo, D., Rennke, S., Davis, J., & Chang, A. (2021). Lessons From Learners: Adapting Medical Student Education During and Post COVID-19. In *Academic* *medicine : journal of the Association of American Medical Colleges* (Vol. 96, Issue 12, pp. 1671–1679). Published for the Association of American Medical Colleges by Lippincott Williams & Wilkins. https://doi.org/10.1097/ACM.0000000000004148

Chalmers, L., & Keown, P. (2006). Communities of practice and professional development. *International Journal of Lifelong Education*, *25*(2), 139–156. https://doi.org/10.1080/02601370500510793

Churruca, K., Ellis, L. A., Pomare, C., Hogden, A., Bierbaum, M., Long, J. C., Olekalns, A., & Braithwaite, J. (2021). Dimensions of safety culture: A systematic review of quantitative, qualitative and mixed methods for assessing safety culture in hospitals. *BMJ Open*, *11*(7), 1–13. https://doi.org/10.1136/bmjopen-2020-043982

Coghlan, D., & Jacobs, C. (2005). Kurt Lewin on Reeducation. *The Journal of Applied Behavioral Science*, *41*(4), 444–457. https://doi.org/10.1177/0021886305277275

Conklin, J., Lusk, E., Harris, M., & Stolee, P. (2013). Knowledge brokers in a knowledge network: The case of Seniors Health Research Transfer Network knowledge brokers. *Implementation Science*, *8*(1). https://doi.org/10.1186/1748-5908-8-7

Connolly, N., & Abdalla, M. E. (2022). Impact of COVID-19 on medical education in different income countries: a scoping review of the literature. *Medical Education Online*, *27*(1). https://doi.org/10.1080/10872981.2022.2040192

Cooperrider, D. L., & Whitney, D. K. (2005). *Appreciative inquiry a positive revolution in change* (1st ed.). Berrett-Koehler.

Critical Appraisal Skills Programme. (2018). *CASP Qualitative Checklist. [online]*. Critical Appraisal Skills Programme. https://casp-uk.net/casp-tools-checklists/

Cruess, S. R., Cruess, R. L., & Steinert, Y. (2019). Supporting the development of a professional identity: General principles. *Medical Teacher*, *41*(6), 641–649. https://doi.org/10.1080/0142159X.2018.1536260

Culture Collections. (2023a). *About us - Culture Collections*. https://www.culturecollections.org.uk/about-us/

Culture Collections. (2023b). *The National Collection of Type Cultures (NCTC)*. https://www.culturecollections.org.uk/about-us/nctc/

Curtin, M., Downs, J., Hunt, A., Coleman, E. R., Enneking, B. A., & McNally Keehn, R. (2021). INteractive Virtual Expert-Led Skills Training: A Multi-Modal Curriculum for Medical Trainees. In *Frontiers in psychiatry* (Vol. 12, p. 671442). Frontiers Research Foundation. https://doi.org/10.3389/fpsyt.2021.671442

de Carvalho-Filho, M. A., Tio, R. A., & Steinert, Y. (2020). Twelve tips for implementing a community of practice for faculty development. *Medical Teacher*, *42*(2), 143–149. https://doi.org/10.1080/0142159X.2018.1552782 de Groot, E., Endedijk, M. D., Jaarsma, A. D. C., Simons, P. R. J., & van Beukelen, P. (2014). Critically reflective dialogues in learning communities of professionals. *Studies in Continuing Education*, *36*(1), 15–37. https://doi.org/10.1080/0158037X.2013.779240

Delany, J. R., Pentella, M. A., Rodriguez, J. A., Shah, K. V., Baxley, K. P., Holmes, D. E., & Centers for Disease Control. (2011). Guidelines for biosafety laboratory competency: CDC and the Association of Public Health Laboratories. *MMWR. Surveillance Summaries : Morbidity and Mortality Weekly Report. Surveillance Summaries / CDC*, *60 Suppl 2*, 1–23.

Denning, M., Goh, E. T., Clarke, J., Almonte, M., Chidambaram, S., Przybylowicz, J., Sounderajah, V., Flott, K., Tan, B., Yalamanchili, S., Winter-Beatty, J., Scott, A., Martin, G., Markar, S., Wells, M., Purkayastha, S., & Kinross, J. (2020). What Has Been the Impact of Covid-19 on Safety Culture? *MedRxiv*, 2020.06.15.20129080.

DiFonzo, N., & Bordia, P. (1998). Reproduced with permission of the copyright owner . Further reproduction prohibited without. *Journal of Allergy and Clinical Immunology*, *130*(2), 556. http://dx.doi.org/10.1016/j.jaci.2012.05.050

Driedger, S. M., Cooper, E. J., & Moghadas, S. M. (2014). Developing model-based public health policy through knowledge translation: The need for a "Communities of Practice." *Public Health*, *128*(6), 561–567. https://doi.org/10.1016/j.puhe.2013.10.009

Duesbery, L., & Twyman, T. (2020a). How Does Action Research Fit in the Health Sciences? *100 Questions (and Answers) About Action Research*, 21–21. https://doi.org/10.4135/9781544305455.n14

Duesbery, L., & Twyman, T. (2020b). What Are the Key Features of Action Research I Should Remember? In *100 Questions (and Answers) About Action Research* (pp. 5–5). SAGE Publications, Inc. https://doi.org/10.4135/9781544305455.n3

Dwyer, S. C., & Buckle, J. L. (2009). The Space Between: On Being an Insider-Outsider in Qualitative Research. In *International Journal of Qualitative Methods* (Vol. 8, Issue 1).

Engeström, Y., & Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review*, *5*(1), 1–24. https://doi.org/10.1016/j.edurev.2009.12.002

Epstein, R. M. (2008). Reflection, perception and the acquisition of wisdom. *Medical Education*, *42*(11), 1048–1050. https://doi.org/10.1111/j.1365-2923.2008.03181.x

Eraut, M. (2000). Non-formal learning and tacit knowledge in professional work. *British Journal of Educational Psychology*, *70*(1), 113–136. https://doi.org/10.1348/000709900158001

Farnsworth, V., Kleanthous, I., & Wenger-Trayner, E. (2016). Communities of Practice as a Social Theory of Learning: A Conversation with Etienne Wenger. *British Journal of Educational Studies*, *64*(2), 139–160. https://doi.org/10.1080/00071005.2015.1133799

Farrell, L., Buydens, S., Bourgeois-Law, G., & Regehr, G. (2021). Experiential learning, collaboration and reflection: key ingredients in longitudinal faculty development. *Canadian Medical Education Journal*, 82–91. https://doi.org/10.36834/cmej.70224

Filipe, H. P., Kostic, M., Lopez, M., & Golnik, K. (2024). Making the case for the evolving role of social media in health professions education and a literature review on the application of some in ophthalmology. *Annals of Eye Science*, *9*. https://doi.org/10.21037/aes-23-74

Fischbach, L., Smith, L. V, King, J., Inkelas, M., & Kuo, T. (2024). Using Grand Rounds to Train and Prepare a Local Public Health Workforce To Manage COVID-19 Outbreaks During the 2020-2021 Pandemic Winter Upsurge. In *Health promotion practice* (Vol. 25, Issue 4, pp. 545–558). Sage Publications. https://doi.org/10.1177/15248399231171952

Flogaitis, E., Nomikou, C., Naoum, E., & Katsenou, C. (2012). Investigating the possibilities of creating a Community of Practice. Action Research in three educational institutions. *Journal for Critical Education Policy Studies*, *10*(1), 217–234.

Ford, J. R., Korjonen, H., Keswani, A., & Hughes, E. (2015). Virtual communities of practice: can they support the prevention agenda in public health? *Online Journal of Public Health Informatics*, *7*(2), 1–12. https://doi.org/10.5210/ojphi.v7i2.6031

Francis-Coad, J., Etherton-Beer, C., Bulsara, C., Blackburn, N., Chivers, P., & Hill, A. M. (2018). Evaluating the impact of a falls prevention community of practice in a residential aged care setting: A realist approach. *BMC Health Services Research*, *18*(1). https://doi.org/10.1186/S12913-017-2790-2

Gee, J. P. (2001). *Identity as an Analytic Lens for Research in Education Author (s): James Paul Gee Source : Review of Research in Education , 2000 - 2001 , Vol . 25 (2000 - 2001), pp . 99-125 Published by : American Educational Research Association Stable URL : https: 25*, 99–125.

Giusti, A., Perra, A., & Lombardo, F. (2017). The experience of a nationwide Community of Practice to set up Regional Prevention Plans in Italy. *Health Research Policy and Systems*, *15*(1). https://doi.org/10.1186/S12961-017-0226-4

Gleeson, C. (2010). Education beyond competencies: A participative approach to professional development. *Medical Education*, *44*(4), 404–411. https://doi.org/10.1111/j.1365-2923.2009.03601.x

Gomez, K., Edwards, H. L., & Kirby, J. (2024). Livestreaming clinical experience to remotely located learners: A critical narrative review. *Medical Education*, *58*(9), 1032–1041. https://doi.org/10.1111/medu.15392

Gordon, T., & Burch, N. (1974). *T.E.T., Teacher Effectiveness Training*. Crown Publishing Group.

Gov.uk. (2020). *Prime Minister’s statement on coronavirus (COVID-19): 23 March 2020 - GOV.UK*. https://www.gov.uk/government/speeches/pm-address-to-the-nation-on-coronavirus-23-march-2020

Greenberg, M. R., Lawrence, M. B., Chen, F., & Ross, E. M. (2021). Piloting a New Curriculum: Guided At-Home Pediatric Regional Anesthesia Education Using a Portable Ultrasound. In *Cureus* (Vol. 13, Issue 9, p. e17933). Cureus, Inc. https://doi.org/10.7759/cureus.17933

Guldenmund, F. W. (2007). The use of questionnaires in safety culture research - an evaluation. *Safety Science*, *45*(6), 723–743. https://doi.org/10.1016/j.ssci.2007.04.006

Handley, K., Sturdy, A., Fincham, R., & Clark, T. (2006). Within and beyond communities of practice: Making sense of learning through participation, identity and practice. *Journal of Management Studies*, *43*(3), 641–653. https://doi.org/10.1111/j.1467-6486.2006.00605.x

Health and Safety Executive. (1999). *HSG 48: Reducing error and influencing behaviour*. https://books.hse.gov.uk/

Health and Safety Executive. (2005). *Core topic 4: Reliability and usability of procedures in Inspectors Toolkit: Human factors in the management of major accident hazards*. Inpectors Toolkit: Human Factors in the Management of Major Accident Hazards. https://www.hse.gov.uk/humanfactors/topics/toolkit.pdf

Health and Safety Executive. (2012). Health and Safety: A Brief Guide. *Government Leaflet*, 1–6. http://www.hse.gov.uk/pubns/indg345.pdf

Health and Safety Executive. (2013). *HSG65: Managing for health and safety*.

Health and Safety Executive. (2021). *What is Competence? - Competence in health and safety*. https://www.hse.gov.uk/competence/what-is-competence.htm

Health and Safety Executive. (2022). *About HSE*. https://www.hse.gov.uk/aboutus/index.htm

Health and Safety Executive. (2024). *Organisational culture: Overview*. https://www.hse.gov.uk/humanfactors/topics/culture.htm

Helms, R. W. (2007). Redesigning communities of practice using knowledge network analysis. *Hands-On Knowledge Co-Creation and Sharing: Practical Methods and Techniques*, 251–274. http://igitur-archive.library.uu.nl/math/2009-0109-200624/UUindex.html

Herrera-Aliaga, E., & Estrada, L. D. (2022). Trends and Innovations of Simulation for Twenty First Century Medical Education. In *Frontiers in public health* (Vol. 10, p. 619769). Frontiers Editorial Office. https://doi.org/10.3389/fpubh.2022.619769

Ho, K.-C., Huang, T.-S., Lin, J.-C., & Chiang, H.-K. (2023). The online interactive visual learning improves learning effectiveness and satisfaction of physicians with postgraduate year during the COVID-19 pandemic in Taiwan. In *BMC medical education* (Vol. 23, Issue 1, p. 713). BioMed Central. https://doi.org/10.1186/s12909-023-04639-w

Hollnagel, E. (2021). Safer systems: People training or system tuning? *European Journal of Investigation in Health, Psychology and Education*, *11*(3), 990–998. https://doi.org/10.3390/ejihpe11030073

Holloway, I., & Galvin, K. (2017). Interviews. In *Qualitative Research in Nursing and Healthcare* (Fourth Edi, pp. 87–107). John Wiley & Sons Ltd.

IChemE. (2019). *IChemE Safety Centre Guidance - supplementary*. *August*.

Jan, S. K., Vlachopoulos, P., & Parsell, M. (2019). Social network analysis and learning communities in higher education online learning: A systematic literature review. *Online Learning Journal*, *23*(1), 249–264. https://doi.org/10.24059/olj.v23i1.1398

Jarvis-Selinger, S., Pratt, D. D., & Regehr, G. (2012). Competency is not enough: Integrating identity formation into the medical education discourse. *Academic Medicine*, *87*(9), 1185–1190. https://doi.org/10.1097/ACM.0b013e3182604968

Jeffs, L., McShane, J., Flintoft, V., White, P., Indar, A., Maione, M., Lopez, A. J., Bookey-Bassett, S., & Scavuzzo, L. (2016). Contextualizing learning to improve care using collaborative communities of practices. *BMC Health Services Research*, *16*(1).

https://doi.org/10.1186/s12913-016-1566-4

Jiwa, M., Deas, K., Ross, J., Shaw, T., Wilcox, H., & Spilsbury, K. (2009). An inclusive approach to raising standards in general practice: Working with a “community of practice” in Western Australia. *BMC Medical Research Methodology*, *9*(1). https://doi.org/10.1186/1471-2288-9-13

Johnson, G. G. R. J., Beaumont, J., Paton-Gay, J. D., Widder, S., & Gillman, L. M. (2021). Multidisciplinary, multisite trauma team training during COVID-19: Lessons from the first virtual E-S.T.A.R.T.T. course. *Canadian Journal of Surgery*, *64*(6), E609–E612. https://doi.org/10.1503/cjs.009921

Jug, R., Jiang, X. S., & Bean, S. M. (2019). Giving and receiving effective feedback a review article and how-to guide. *Archives of Pathology and Laboratory Medicine*, *143*(2), 244–250. https://doi.org/10.5858/arpa.2018-0058-RA

Kelleher, S. T., Kyle, W. B., Penny, D. J., Olsen, J., Nolke, L., Allen, H. D., & McMahon, C. J. (2024). Twinning International Pediatric Cardiology Fellowship Programs: A Transformative Educational Experience for Trainees with Potential for Global Adoption. In *Pediatric cardiology*. Springer Verlag. https://doi.org/10.1007/s00246-024-03469-x

Kirkpatrick, J. D., & Kirkpatrick, W. K. (2016). *Kirkpatrick’s Four Levels of Training Evaluation*. Association for Talent Development.

Knoke, D., & Yang, S. (2020). *Social Network Analysis*. SAGE Publications, Inc. https://doi.org/10.4135/9781506389332

Knowles, M. S., Holton, E. F., & Swanson, R. A. (2020). Introduction to Adult Learning. In *The Adult Learner : The Definitive Classic in Adult Education and Human Resource Development* (8th ed., Issue 2015, pp. 3–7). Taylor & Francis Group.

Koka, A., Suppan, L., Cottet, P., Carrera, E., Stuby, L., & Suppan, M. (2020). Teaching the national institutes of health stroke scale to paramedics (E-Learning vs Video): Randomized controlled trial. *Journal of Medical Internet Research*, *22*(6). https://doi.org/10.2196/18358

Kolb, A. Y., & Kolb, D. A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of Management Learning and Education*, *4*(2), 193–212. https://doi.org/10.5465/AMLE.2005.17268566

Lacasta Tintorer, D., Flayeh Beneyto, S., Manresa, J. M., Torán-Monserrat, P., Jiménez-Zarco, A., Torrent-Sellens, J., & Saigí-Rubió, F. (2015). Understanding the discriminant factors that influence the adoption and use of clinical communities of practice: The ECOPIH case. *BMC Health Services Research*, *15*(1), 1–10. https://doi.org/10.1186/s12913-015-1036-4

Lave, J., & Wenger, E. (1991). *Situated Learning*. Cambridge University Press. https://doi.org/10.1017/CBO9780511815355

Lee, E., Kourgiantakis, T., & Hu, R. (2021). Teaching Note--Teaching Socially Just Culturally Competent Practice Online: Pedagogical Challenges and Lessons Learned During the Pandemic. *Journal of Social Work Education*, *57*, 58–65. https://doi.org/10.1080/10437797.2021.1935367

Lewin, S., Booth, A., Glenton, C., Munthe-Kaas, H., Rashidian, A., Wainwright, M., Bohren, M. A., Tunçalp, Ö., Colvin, C. J., Garside, R., Carlsen, B., Langlois, E. V., & Noyes, J. (2018). Applying GRADE-CERQual to qualitative evidence synthesis findings: Introduction to the series. *Implementation Science*, *13*(1), 1–10. https://doi.org/10.1186/S13012-017-0688-3/TABLES/4

Li, L. C., Grimshaw, J. M., Nielsen, C., Judd, M., Coyte, P. C., & Graham, I. D. (2009). Use of communities of practice in business and health care sectors: A systematic review. *Implementation Science*, *4*(1). https://doi.org/10.1186/1748-5908-4-27

Lo, C. K., & Hew, K. F. (2022). Design principles for fully online flipped learning in health professions education: a systematic review of research during the COVID-19 pandemic. *BMC Medical Education*, *22*(1). https://doi.org/10.1186/s12909-022-03782-0

Lockey, A., Conaghan, P., Bland, A., & Astin, F. (2021). Educational theory and its application to advanced life support courses: a narrative review. *Resuscitation Plus*, *5*. https://doi.org/10.1016/j.resplu.2020.100053

Lörwald, A. C., Lahner, F. M., Nouns, Z. M., Berendonk, C., Norcini, J., Greif, R., & Huwendiek, S. (2018). The educational impact of Mini-Clinical Evaluation Exercise (Mini-CEX) and Direct Observation of Procedural Skills (DOPS) and its association with implementation: A systematic review and meta-analysis. *PLoS ONE*, *13*(6), 1–15. https://doi.org/10.1371/journal.pone.0198009

Lumivero. (2017). *NVivo (Version 12 pro)*. www.lumivero.com

Mann, K., Gordon, J., & MacLeod, A. (2009). Reflection and reflective practice in health professions education: A systematic review. *Advances in Health Sciences Education*, *14*(4), 595–621. https://doi.org/10.1007/s10459-007-9090-2

Mastoras, G., Farooki, N., Willinsky, J., Dharamsi, A., Somers, A., Gray, A., Yaphe, J., Dalseg, T., & O'Connor, E. (2022). Rapid deployment of a virtual simulation curriculum to prepare for critical care triage during the COVID-19 pandemic. *Canadian Journal of Emergency Medicine*, *24*(4), 382–389. https://doi.org/10.1007/s43678-022-00280-6

Mcalister, M. (2016). The Creative Nature of Communities of Practice. *Transformative Dialogues: Teaching & Learning Journal*, *9*(2), 1–7.

McGrath, C., Liljedahl, M., & Palmgren, P. J. (2020). You say it, we say it, but how do we use it? Communities of practice: A critical analysis. *Medical Education*, *54*(3), 188–195. https://doi.org/10.1111/medu.14021

McLoughlin, C., Patel, K. D., O'Callaghan, T., & Reeves, S. (2018). The use of virtual communities of practice to improve interprofessional collaboration and education: findings from an integrated review. *Journal of Interprofessional Care*, *32*(2), 136–142. https://doi.org/10.1080/13561820.2017.1377692

Merriam, S. B. (2009). Chapter 1: What is Qualitative Research? In *Qualitative research: A guide to design and implementation* (3rd Editio, Issue 2009, pp. 3–19). John Wiley & Sons Ltd.

Merriel, A., Wilson, A., Decker, E., Hussein, J., Larkin, M., Barnard, K., O'Dair, M., Costello, A., Malata, A., & Coomarasamy, A. (2022). Systematic review and narrative synthesis of the impact of Appreciative Inquiry in healthcare. *BMJ Open Quality*, *11*(2). https://doi.org/10.1136/bmjoq-2022-001911

Michie, S., Atkins, L., & West, R. (2014). *The Behaviour Change Wheel: A Guide to Designing Interventions* (1st Editio). Silverback Publishing.

Millen, D. R., & Fontaine, M. A. (2003). *Improving individual and organizational performance through communities of practice*. 205–211. https://doi.org/10.1145/958160.958192

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. (2009). The PRISMA Group Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Medicine*, *6*(7). https://doi.org/10.1371/journal.

Monesi, A., Imbriaco, G., Mazzoli, C. A., Giugni, A., & Ferrari, P. (2022). In-Situ Simulation for Intensive Care Nurses During the COVID-19 Pandemic in Italy: Advantages and Challenges. In *Clinical simulation in nursing* (Vol. 62, pp. 52–56). Elsevier. https://doi.org/10.1016/j.ecns.2021.10.005

Moore, J. L., Bjørkli, C., Havdahl, R. T., Lømo, L. L., Midthaug, M., Skjuve, M., Klokkerud, M., & Nordvik, J. E. (2021). A qualitative study exploring contributors to the success of a community of practice in rehabilitation. *BMC Medical Education*, *21*(1). https://doi.org/10.1186/S12909-021-02711-X

Moore, M., & Kearsley, G. (2012). *Distance education: A systems view of online learning.* Wadsworth.

National Heart Lung and Blood Institute (NHLBI). (2007). *Study Quality Assessment Tools*. https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools

Nesbitt, J. (2013). Journal clubs: A two-site case study of nurses' continuing professional development. *Nurse Education Today*, *33*(8), 896–900. https://doi.org/10.1016/j.nedt.2012.08.011

Norman, C. D., & Huerta, T. (2006). Knowledge transfer & exchange through social networks: Building foundations for a community of practice within tobacco control. *Implementation Science*, *1*(1). https://doi.org/10.1186/1748-5908-1-20

Ossenberg, C., Henderson, A., & Mitchell, M. (2019). What attributes guide best practice for effective feedback? A scoping review. *Advances in Health Sciences Education*, *24*(2), 383–401. https://doi.org/10.1007/s10459-018-9854-x

Pelletier, J., Romo, E., Feinstein, B., Smith, C., Pellerito, G., & Croft, A. (2023). Little Patients, Big Tasks - A Pediatric Emergency Medicine Escape Room. In *Journal of education & teaching in emergency medicine* (Vol. 8, Issue 4, pp. SG1–SG19). UC Irvine Health School of Medicine. https://doi.org/10.21980/J89W70

Polanyi, M. (1967). *The tacit dimension.* Doubleday.

Pope, C., & Mays, N. (1995). Qualitative Research: Reaching The parts other methods cannot reach: An introduction to qualitative methods in health and health services research. *Bmj*, *311*(6996), 42. https://doi.org/10.1136/bmj.311.6996.42

Probst, G., & Borzillo, S. (2008). Why communities of practice succeed and why they fail. *European Management Journal*, *26*(5), 335–347. https://doi.org/10.1016/j.emj.2008.05.003

Public Health England. (2021). *4.7 Communication of Risk Assessment Findings in HS002A Health and Safety Procedure and Guidance: Risk Assessment* (p. 12). Director of Corporate Affairs, Public Health England.

Pylman, S., & Ward, A. (2020). 12 Tips for Effective Questioning in Medical

Education. *Medical Teacher*, *42*(12), 1330–1336. https://doi.org/10.1080/0142159X.2020.1749583

Ranmuthugala, G., Cunningham, F. C., Plumb, J. J., Long, J., Georgiou, A., Westbrook, J. I., & Braithwaite, J. (2011). A realist evaluation of the role of communities of practice in changing healthcare practice. *Implementation Science*, *6*(1). https://doi.org/10.1186/1748-5908-6-49

Ranmuthugala, G., Plumb, J. J., Cunningham, F. C., Georgiou, A., Westbrook, J. I., & Braithwaite, J. (2011). How and why are communities of practice established in the healthcare sector? A systematic review of the literature. *BMC Health Services Research*, *11*. https://doi.org/10.1186/1472-6963-11-273

Richard, K. (2011). Working From the Periphery toward Full Participation: Identity Frames and Social Practices that Shape Women as Researchers. *Advancing Women in Leadership*, *31*, 136.

Roberts, J. (2006). Limits to communities of practice. *Journal of Management Studies*, *43*(3), 623–639. https://doi.org/10.1111/j.1467-6486.2006.00618.x

Rolls, K., Hansen, M., Jackson, D., & Elliott, D. (2016). How health care professionals use social media to create virtual communities: An integrative review. *Journal of Medical Internet Research*, *18*(6), e166. https://doi.org/10.2196/jmir.5312

Romero-Mas, M., Gómez-Zúñiga, B., Cox, A. M., & Ramon-Aribau, A.

(2020). Designing virtual communities of practice for informal caregivers of Alzheimer's patients: An integrative review. *Health Informatics Journal*, *26*(4), 2976–2991. https://doi.org/10.1177/1460458220950883

RRC International. (2022). Investigating, Recording and Reporting Incidents. In *Unit NG1: Manangement of Health and Safety RRC Study Text* (Fourth Edi, pp. 4-11-4–25). Rapid Results College.

Russ, A. L., Fairbanks, R. J., Karsh, B. T., Militello, L. G., Saleem, J. J., & Wears, R. L. (2013). The science of human factors: Separating fact from fiction. *BMJ Quality and Safety*, *22*(10), 802–808. https://doi.org/10.1136/bmjqs-2012-001450

Scarso, E., Bolisani, E., & Salvador, L. (2009). A systematic framework for analysing the critical success factors of communities of practice. *Journal of Knowledge Management*, *13*(6), 431–447. https://doi.org/10.1108/13673270910997105

Schenkel A, Teigland R, B. S. (2000). Theorizing Communities of Practice: A Social Network Approach. *In Academy of Management Conference: Organization and Management Theory Division*.

Schön, D. A. (1983). *The Reflective Practitioner*. Basic Books.

Sibrian, J., Hutapea, K., Dunbar, G. B., & Kawar, L. N. (2022). A Virtual World: New Graduate Education in the Era of COVID-19. In *Journal of continuing education in nursing* (Vol. 53, Issue 7, pp. 307–311).

Charles B. Slack, inc. https://doi.org/10.3928/00220124-20220603-06

Sinelnikov, S., Bixler, E. A., & Kolosh, A. (2020). Effectiveness of safety training interventions for supervisors: A systematic review and narrative synthesis. *American Journal of Industrial Medicine*, *63*(10), 878–901. https://doi.org/10.1002/ajim.23163

Smith, C. R., Vasilopoulos, T., Frantz, A. M., LeMaster, T., Martinez, R. A., Gunnett, A. M., & Fahy, B. G. (2023). Staying proper with your personal protective equipment: How to don and doff. In *Journal of clinical anesthesia* (Vol. 86, p. 111057). Elsevier. https://doi.org/10.1016/j.jclinane.2023.111057

Smith, S. U., Hayes, S., & Shea, P. (2017). A critical review of the use of Wenger's community of practice (CoP) theoretical framework in online and blended learning research, 2000-2014. *Online Learning Journal*, *21*(1), 209–237. https://doi.org/10.24059/olj.v21i1.963

Spence, B. (2019). Using Bloom's taxonomy matrix to reach higher-level learning objectives. *Radiologic Technology*, *90*(6), 622–624.

Stanny, C. J. (2016). Reevaluating bloom's taxonomy: What measurable verbs can and cannot say about student learning. *Education Sciences*, *6*(4). https://doi.org/10.3390/educsci6040037

Steiner de Benaim, L. (2008). e-Training to Communities of Practice as a New Key toward Globalization. *Distance Learning*, *5*(1), 75–88.

Stippler, M., Blitz, S. E., Quinsey, C., Limbrick, D., Byrne, R., Zipfel, G., &

Selden, N. R. (2024). Active Teaching Techniques Using Virtual Didactics: Novel Experience From a National Neurosurgery Resident Course. In *Journal of surgical education* (Vol. 81, Issue 2, pp. 312–318). Elsevier. https://doi.org/10.1016/j.jsurg.2023.11.006

Terry, D. R., Nguyen, H., Peck, B., Smith, A., & Phan, H. (2020a). Communities of practice: A systematic review and meta-synthesis of what it means and how it really works among nursing students and novices. In *Journal of clinical nursing* (Vol. 29, Issues 3–4, pp. 370–380). Blackwell Scientific Publications. https://doi.org/10.1111/jocn.15100

Terry, D. R., Nguyen, H., Peck, B., Smith, A., & Phan, H. (2020b). Communities of practice: A systematic review and meta-synthesis of what it means and how it really works among nursing students and novices. *Journal of Clinical Nursing*, *29*(3–4), 370–380. https://doi.org/10.1111/JOCN.15100

The Deming Institute. (2024). *The PDSA Cycle - the W. Edwards Deming Institute*. https://deming.org/explore/pdsa/

The Management of Health and Safety at Work Regulations, (1999).

Tong, A., Sainsbury, P., & Craig, J. (2007). Consolidated criteria for reporting qualitative research (COREQ): A 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care*, *19*(6), 349–357.

Tripp, D. (2005). Action research: a methodological introduction. *Educ. Pesqui.*, *31*(3), 443–466. https://doi.org/dx.doi.org/10.1590/S1517-97022005000300009

UKHSA. (2023). *UKHSA strategic plan 2023 to 2026*. https://www.gov.uk/government/publications/ukhsa-strategic-plan-2023-to-2026

Underhill, J., Poulose, B. K., Harzman, A., & Huang, E. (2023). What would you do (WWYD)? Thinking outside the virtual lecture box during COVID-19 and beyond. In *Global surgical education : journal of the Association for Surgical Education* (Vol. 2, Issue 1, p. 17). Springer. https://doi.org/10.1007/s44186-022-00093-2

Vaona, A., Banzi, R., Kh, K., Rigon, G., Cereda, D., Pecoraro, V., Tramacere, I., & Moja, L. (2018). E-learning for health professionals (Review). *Cochrane Database of Systematic Reviews*, *1*. https://doi.org/10.1002/14651858.CD011736.pub2.www.cochranelibrary.com

Vasconcelos, P. F., Arruda, L. P., Sousa Freire, V. E. C., & Carvalho, R. E. F. L. (2018). Instruments for evaluation of safety culture in primary health care: integrative review of the literature. *Public Health*, *156*, 147–151. https://doi.org/10.1016/j.puhe.2017.12.024

Vygotsky, L. S. (1978). Interaction between learning and development (M. Lopez-Morillas, Trans.). In *Cole M, John-Steiner V, Scribner S, Souberman E, eds. Mind in Society: The Development of Higher*

Psychological Processes. (pp. 79–91.). Harvard University Press.

Walker, T., Jones, T., Grant-Peterkin, H., Dave, R., & Röhricht, F. (2024). Evaluating Outcomes of a Co-Produced Theatre-Based Experiential Learning Project in Psychiatry. In *Journal of medical education and curricular development* (Vol. 11, p. 23821205241278176). SAGE Publications. https://doi.org/10.1177/23821205241278175

Wan Yunus, F., Romli, M. H., Mohd Rasdi, H. F., Harun, D., & Kadar, M. (2022). An innovation on clinical placement for occupational therapy mental health during the COVID-19: A mixed-methods feasibility study. In *Frontiers in medicine* (Vol. 9, p. 967511). Frontiers Media S.A. https://doi.org/10.3389/fmed.2022.967511

Wenger-Trayner, E. and Wenger-Trayner, B. (2014). *Learning in Landscapes of Practice: Boundaries, Identity, and Knowledgeability* (C. K. and B. W.-T. E. Wenger-Trayner, M. Fenton-O'Creevy, S. Hutchinson (ed.)). Routledge.

Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*. Cambridge University Press.

Wenger, E., McDermott, R., & Snyder, W. M. (2002). *Cultivating communities of practice: a guide to managing knowledge.* Business School Press.

Wenger, E., & Trayner-Wenger, B. (2015). Communities of practice: a brief introduction. *Communities of Practice*, *15*(5), 1–8. http://wenger-trayner.com/wp-content/uploads/2015/04/07-Brief-introduction-to-communities-of-practice.pdf

Wenger, E., Trayner, B., & de Laat, M. (2011). Promoting and assessing value creation in communities and networks: a conceptual framework (april). In *Ruud de Moor Centrum* (Vol. 18, Issue August). http://www.open.ou.nl/rslmlt/Wenger_Trayner_DeLaat_Value_creation.pdf

White, C. (2010). A socio-cultural approach to learning in the practice setting. *Nurse Education Today*, *30*(8), 794–797. https://doi.org/10.1016/j.nedt.2010.02.002

Wieringa, S., Engebretsen, E., Heggen, K., & Greenhalgh, T. (2018). How knowledge is constructed and exchanged in virtual communities of physicians: Qualitative study of mindlines online. *Journal of Medical Internet Research*, *20*(2). https://doi.org/10.2196/jmir.8325

Woods, A., Cashin, A., & Stockhausen, L. (2016). Communities of practice and the construction of the professional identities of nurse educators: A review of the literature. *Nurse Education Today*, *37*, 164–169. https://doi.org/10.1016/j.nedt.2015.12.004

10 Appendix 1 - Coding of health and safety incidents related to health and safety

Process	Short Description	Person involved	Near Miss or Adverse Incident	Type of Incident (Pre-defined category)	Root cause	Corrective action	Human factors analysis	Sub-category
Containment level three	Incorrect use of autoclave	Not stated	Near Miss	Exposure to biological agent	Staff did not recognise the autoclave was on the incorrect mode	SOP Updated and staff re-trained	Error	slip - attention
	Faulty microbiological safety cabinet	Team manager		Exposure to biological agent	Alarm checks not performed as cabinets running constantly	Install more prominent light to alert users Engineers to address issues with cabinet	Error	slip - attention
	Flood in CL3	n/a		Exposure to biological agent	Fault with autoclave	Additional checks added at servicing and routine maintenance	Error	Knowledge
	Scheduled H&S inspection carried out incorrectly	Not stated		Other	Unaware of the different forms available	Correct form referenced in COP	Error	Knowledge
	Laboratory door faulty	Not stated			Staff did not recognise maintenance was underway and door left open intentionally	Staff reminded to liaise with engineers before entering laboratory	Error	slip - attention
Facilities	Permit to work not completed correctly	Not stated	Adverse Incident	Other	Insufficient training of staff completing works	Staff reminded to check PTW for completion	Error	slip - attention
Freeze-drying	Flame torch malfunction	Not stated	Near Miss	Burned or scalded by ...	Torch not designed for long-term use	Staff advised to alternate the torches and not to refill a warm torch Staff advised to check torches for	Error	n/a

						damage before use Points added to the SOP and risk assessment		
	Glass ampoule break on the constrictor machine.	Not stated		Burned or scalded by ...	Ampoule removed too quickly Staff distracted by radio in lab	Staff urged to keep discussions whilst using the machine to a minimum when performing task. Staff urged to take regular breaks. Staff encouraged to observe appropriate seating practices.	Error	Slip - attenti on
	Flame torch malfunction	Not stated	Near Miss	Burned or scalded by ...	Only one torch available at time of incident	To purchase more torches. Staff urged to allow torch to cool before refilling	Error	Knowl edge
	Burn from constrictor	Not stated	Adverse Incident	Burned or scalded by ...	Only using two adaptors	Update SOP to state use of more adapters and re-training of staff	Violation	Routi ne
	Cut from glass on secondary dryer	Not stated		Cut by something / sharp injury	Sharps gloves not worn as per risk assessment	Staff reminded that wearing gloves for this task is a requirement	Error	Knowl edge
	Cut from glass on secondary dryer	Trainee		Cut by something / sharp injury	Person in training at time. Not wearing safety gloves	Staff reminded to wear safety gloves Trainer asked to be more alert to issues during	Error	Knowl edge

						training		
	Broken glass found in freeze-dryer	Not stated	Near Miss	Cut by something / sharp injury	Flash freeze stage made ampoules fragile, cracked when placed in metal rack	SOP and risk assessment updated. Staff re-trained	Error	slip - attenti on
	Failure of primary dryer	Not stated		Exposure to biological agent	Loose screw	SOP and work instruction updated to include pre-use checks	Error	slip - recog nition
	Broken glass found in freeze-dryer	Not stated		Exposure to biological agent	Flash freeze stage made ampoules fragile, cracked when placed in metal rack	SOP and risk assessment updated. Staff re-trained	Error	slip - recog nition
	Safety checks incorrectly completed	Not stated		Exposure to biological agent	Staff forgot to check if forms were signed before proceeding	Staff reminded that safety check form must be signed before proceeding	Error	Knowl edge
	Safety checks not completed	Not stated		Exposure to biological agent	Miscommunication, staff did not realise forms were not approved	Set up regular schedule to remind when forms are due	Violation	Situat ional
	Failure of freeze-dryer	Not stated		Exposure to biological agent	Staff not aware how to constrict ampoules suitably	Re-training of staff	Error	Knowl edge
	Strain handled at incorrect containment level	Not stated		Exposure to biological agent	Lack of knowledge of strain and identification platforms	Sent for confirmation with ref lab	Error	Knowl edge
	Glass ampoule break on the constrictor machine.	Not stated		Other	Glass ampoules not checked before use	Training of staff to check and to use more adapters	Error	Knowl edge

	Glass ampoule break on the constrictor machine.	Not stated		Other	Lack of staff rotation High level of noise and distraction in lab	Discussed with staff to keep noise and distraction to a minimum Staff urged to allow ampoule to cool before handling Staff to rotate every 45-60 mins Staff informed to report faulty equipment	Error	Slip - attenti on
Freeze-drying	Strain handled at incorrect containment level	Technic ian	Near Miss		Historical nature of collect. Exact root cause unclear	Inventory reviewed; ampoules discarded appropriately	External	n/a
	Laboratory Ventilation Indicator failure	Not stated			Fault with equipment	Thermostat replaced Procedures reviewed to flag issue earlier	Error	slip - recog nition
Handling of organism s	Strain handled at incorrect containment level	Not stated	Near Miss	Exposure to biological agent	Checking strain before handling did not identify appropriate handling facility	Introduction of a pre-use safety check form to be authorised by Team Manager before handling strains	Error	Knowl edge
	Strain handled at incorrect containment level	Not stated		Exposure to biological agent	Checking strain before handling did not identify appropriate handling facility	Introduction of a pre-use safety check form to be authorised by Team Manager before handling	Error	Knowl edge

						strains		
	Strain handled at incorrect containment level	Not stated		Exposure to biological agent	Lack of knowledge of strain. Lack of communication and information sharing between different teams.	Introduction of a pre-use safety check form to be authorised by Team Manager before handling strains	Error	Knowl edge
	Strain handled at incorrect containment level	Not stated		Exposure to biological agent	Staff knowledge of strain and checking processes	Introduction of a pre-use safety check form to be authorised by Team Manager before handling strains	Error	Knowl edge
	Strain handled at incorrect containment level	Not stated		Exposure to biological agent	Lack of information on strain	Introduction of a pre-use safety check form to be authorised by Team Manager before handling strains	Error	Knowl edge
	Strain handled at incorrect containment level	Not stated		Exposure to biological agent	Lack of communication between laboratories	Introduction of a pre-use safety check form to be authorised by Team Manager before handling strains	Error	slip - attenti on
	Strain handled at incorrect containment level	Not stated		Exposure to biological agent	Lack of information on strain	Introduction of a pre-use safety check form to be authorised by Team Manager	Error	slip - attenti on

						before handling strains		
	Strain handled at incorrect containment level	Not stated		Exposure to biological agent	Lack of knowledge of contents of fridge and awareness of strain's handling conditions	Inventory of fridge created. Staff reminded to check ampoules they are unsure of.	Error	
Handling of organisms	Strain handled at incorrect containment level	Not stated	Near Miss	Exposure to biological agent	No inventory for fridge in place Staff not aware of risk with this strain	Inventory of fridge created. Staff reminded to check ampoules they are unsure of.	Violation	Situational
	Strain handled at incorrect containment level	Not stated	Near Miss	Exposure to biological agent	Operator not aware of strain toxin status	Strain moved to CL3	External	n/a
	Strain handled at incorrect containment level	Supervisor	Near Miss	Exposure to biological agent	Staff member note aware of correct storage of CL3 strains	Risk assessment for culture store updated Access to store controlled and minimised	Error	slip - recognition
	Strain handled at incorrect containment level	Bioinformatics scientist	Near Miss	Exposure to biological agent	Staff did not recognise hazard with strain at time of testing	Strain removed from sale, moved to CL3 laboratory	Error	Knowledge
	Strain handled at incorrect containment level	Not stated	Adverse Incident	Other	Lack of information on safety checklist to prompt staff.	Safety checklist updated Staff made aware in morning huddle	Error	slip - recognition
Housekeeping	Cut handling laboratory furniture	Technician	Adverse Incident	Cut by something / sharp injury	Lack of attention from operator	Risk assessment updated to reflect risk and include control measures	Error	slip - recognition

	Unsafe storage of items	Experience staff member	Near Miss	Exposure to biological agent	Lack of space	Identified alternative storage space Staff advised not to overfill fridge	Error	Slip - attention
QC testing	Equipment used incorrectly	Not stated	Near Miss	Burned or scalded by ...	SOP not followed Attention slip	SOP and risk assessment updated to include safety-critical step	Violation	Routine
	Dropped bacteria culture	Student	Near Miss	Cut by something / sharp injury	Lack of concentration when working	Advised to be more aware of surroundings Supervisor to keep trainee under close observation	Error	slip - attention
	Glass ampoule broken whilst opening	Student	Near Miss	Cut by something / sharp injury	Applied too much pressure when scoring	Staff reminded to hold ampoule higher to prevent egress from MSC if shattered More emphasis to the importance correct technique and different grading of glass is to be given during future training of staff/student.	Error	slip - recognition
QC testing	Cut from equipment	Student	Adverse Incident	Cut by something / sharp injury	Attention slip when performing task	Staff advise to pay more attention when performing task	Error	slip - attention
	Papercut from documents	Trainee	Adverse Incident	Cut by something / sharp injury	Did not know to report to first aider	Staff informed of protocol and made aware of how to	Error	slip - recognition

						contact first aider on duty		
	Cut handling laboratory consumables	Student	Adverse Incident	Cut by something / sharp injury	Unergonomic workspace	Staff advised to use equipment appropriately	Error	slip - attenti on
	Plate drop and finger cut	Student	Adverse Incident	Exposure to biological agent	Cluttered laboratory	Use of racks to store plates where appropriate Informed staff to report dropped plates	Error	Knowl edge
	Agar plate dropped	Student	Near Miss	Exposure to biological agent	Cluttered laboratory	Supervisor to train student in setting up laboratory in safe manner	Error	Knowl edge
	Dropped bacteria culture	Not stated	Near Miss	Exposure to biological agent	Incorrect rack used	Staff told to use correct racks. New racks ordered	Violation	Situat ional
	Dropped bacteria culture	Not stated	Near Miss	Exposure to biological agent	Lack of attention from operator	Staff reminded to use appropriately sized containers	External	n/a
	Cut handling laboratory consumables	Not stated			Attentions slip Incorrect storage conditions	Replace glass with plastic where appropriate Staff reminded to pay more attention	Error	Knowl edge
	Strain handled at incorrect containment level	Not stated			Lack of information on historical strain	Safety checklist introduced	Error	Knowl edge
Receipt of goods	Finger cut whilst handling packaging	Not stated	Adverse Incident	Cut by something / sharp injury	Not using appropriate tools to open box	None stated	Error	Knowl edge
	Finger cut whilst handling	Not stated	Adverse Incident	Cut by something / sharp injury	Use of scissors and lack of attention	Staff reminded to be cautious when	Violation	Situat ional

	packaging					handling boxes Staff reminded to use retractable box cutter		
Research and developm ent	Broken measuring cylinder used	Not stated	Near Miss	Cut by something / sharp injury	Staff not trained in hazard awareness	Staff member trained in incident and near miss reporting. Replace with plastic cylinders	Error	Knowl edge
	Laboratory left in unsatisfactory condition	Not stated	Near Miss	Exposure to biological agent	Training issue	Room users informed of incident and told not to leave lab in unsafe condition	Violation	Exce ptiona l
Research and developm ent	Minor spillage of bacterial culture	Not stated	Near Miss	Exposure to biological agent	Lack of attention from operator	Training of staff in correct pipetting techniques		
	Bacterial cultures unsafely handled	Not stated	Near Miss	Exposure to biological agent	Undetermined where lid was removed	Staff to be more careful and check lids are in place Risk assessment updated	Error	Knowl edge
	Equipment safety checks not completed	Not stated	Near Miss	Exposure to biological agent	Staff did not check equipment before use Equipment records not updated	Staff re-trained in the use and management of laboratory equipment	Error	Knowl edge
	SOP not followed when working in lab	Scientis t	Near Miss	Exposure to biological agent	Deviation from protocol	SOP updated to highlight safety-critical steps	Error	Knowl edge
	Incorrect waste stream used	Untrain ed staff membe r	Near Miss	Other	Staff member unfamiliar with task	Staff reminded that the delivery notes should always be cross checked	Error	Knowl edge

						against the contents of the box Staff reminded to double check boxes of dry ice before disposing of it		
	Freezer left open	Not stated	Near Miss	Slip, trip or fall on the same level	Freezer door left open, lack of maintenance	Reminded staff to clean up immediately	Error	slip - attention
	Injury handling laboratory furniture	Not stated			Unsuitable placement of key press	Attach key press to wall	Error	Knowledge
	Overdue service on MSCs	Not stated			Communication Records not completed with information	Replace MSCs with more suitable models	Error	Knowledge
Shipment of goods	Strain handled at incorrect containment level	Not stated	Near Miss	Exposure to biological agent	Lack of information available and miscommunication between laboratories	Gap analysis of information on strains performed Send unknown strains to reference lab as HG3 for confirmation	Error	Knowledge
	Safety checks not completed	Not stated	Near Miss	Exposure to biological agent	Checking not performed due to staff absence Miscommunication between staff members	Staff informed that form must be completed before work commences	External	n/a
Shipment of goods	Incorrect dispatch of goods	Not stated	Near Miss	Exposure to biological agent	Human error	Staff reminded to be vigilant when dispatching strains	Error	slip - recognition
	Equipment removed without decontamination certificate	Not stated	Near Miss	Other	Staff unaware a decontamination certificate was required	3. Train PRU staff in the decontamination of equipment by April 2015	Error	slip - recognition

						4. Review supervision and training of visiting scientists to the PRU team.		
	Incorrect dispatch of goods	Not stated	Near Miss	Other	Sender unaware to notify recipients before sending	Update SOP to include advance notice of shipments Re-train staff	Error	slip - attenti on

11 Appendix 2 – Full audit of competency records 2014-2021

In total 15 individual's training records were reviewed. A total of 120 training events from February 2014 to June 2021 were captured. Four staffing levels were identified: Supervisors (14 events from 2 trainees), Microbiologists (74 events from 9 trainees), Technologists (22 events from 4 trainees), Support workers (10 events from 2 trainees). Table 11.1 includes a breakdown of the training events per SOP.

Table 11.1: Staff records reviewed per job role

SOP Title	Supervisors	Microbiologists	Technologists	Support Workers	Total
N2007	1	2	1	0	4
N2312	4	13	3	3	23
N2315	1	7	1	2	11
N2850	4	13	4	3	24
N2857	0	1	1	0	2
N2865	1	11	4	1	17
Total	**14**	**74**	**22**	**9**	**120**

The training records for two staff known to be performing freeze-drying during this period were not located and so not included in the audit. For three individuals known to perform all aspects of the freeze-drying procedure, the training records were located but competency forms were not present for all the SOPs.

Type of training

Of the 120 training records reviewed, 67 (56%) are initial training records, 43 (36%) were refresher training and 11 (9%) were re-assessments. It appears that refresher and re-assessment were used interchangeably by the trainers so both types of training will be considered under on-going competency.

Figure 11.1 methods of training utilised as categorised by the HSE. 75% (90/120) training events were accompanied by a competency record. The second most common method of training was observation with 73% (88/120) of training events featuring some form of observation of the trainee.

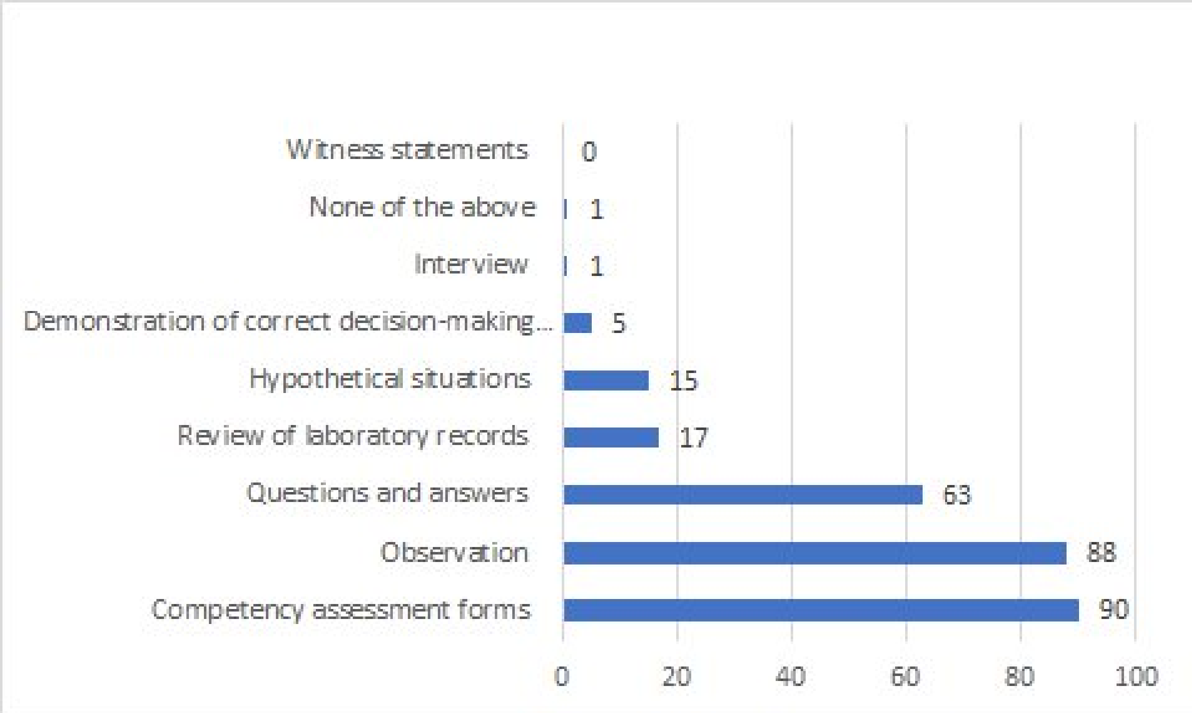


Figure 11.1: Training approaches

The training records often featured more than one method of training. As shown in table 11.2, the majority (34% 41/120) of records employ two methods. The most common combination of methods was competence assessment with observation, accounting for 30 (25%) of records.

Table 11.2: Number of training methods utilised

Number of training methods used	Number of training records
1	24
2	41
3	39
4	12
5	3

The competency assessment form (ECCW69) was completed in conjunction with the practical competency form (ECCW70) for 26 (29%) of records. This increases to 21/58 (36%) when considering initial assessments only.

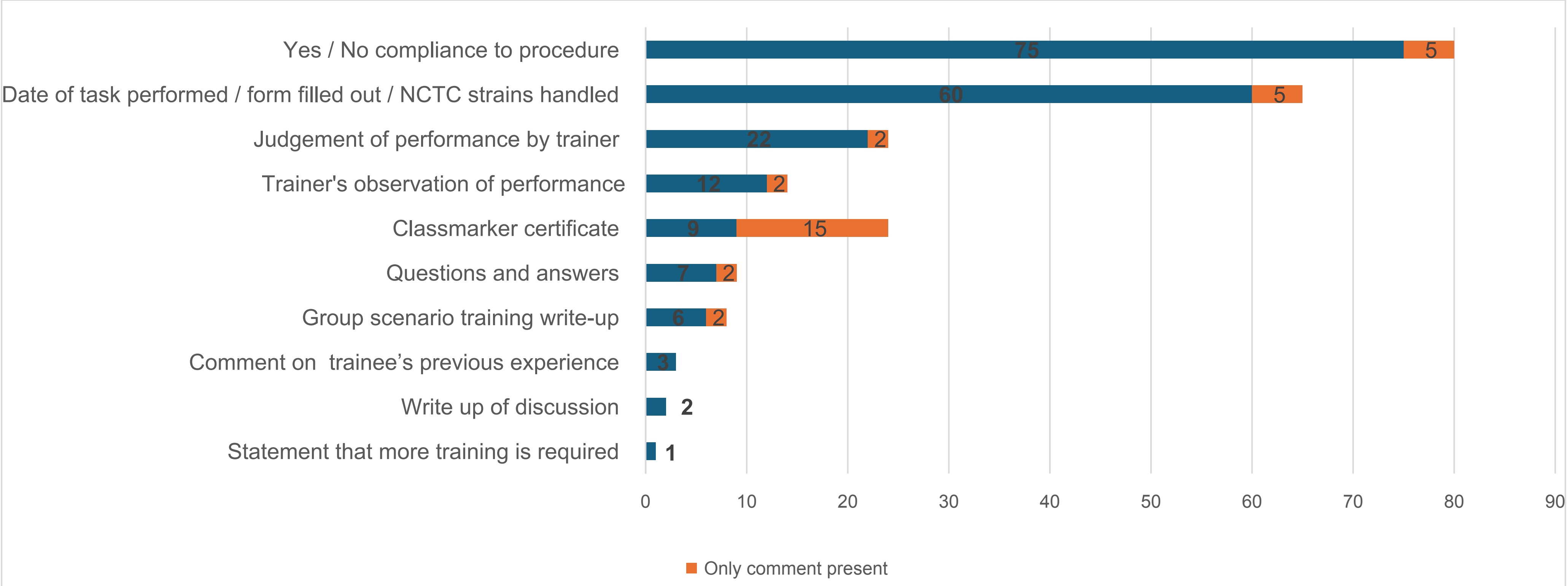
Length of training period

The length of training was reviewed for the 67 initial assessments. The average time between the start of training (if noted) and the trainee signed off as competent is 35 days. There is no correlation between length of training and grade of staff (Table 11.3).

Table 11.3: Length of training by staff grade

Trainee staff grade	Average length of training (days)
Support worker	18
Technologist	58
Microbiologist	34
Supervisor	41

Information contained in training records



The nature of the comments on the training records was reviewed and 11 distinct categories emerged. Figure 11.2 lists these categories and their frequency of occurrence.

Figure 11.2: Information found in training records

A “Yes / No” judgement against pre-defined training statements made by the trainer was present in 80 (67%) of training records. These statements are on the competency form used (ECCW69) and are as follows: -

- Does the member of staff know the location and version of SOP?
- Is there evidence that the member of staff has read and knows the location of all related COSHHs and RAs?
- Is the staff member working safely?
- Observe Procedure. Is the procedure being followed without deviation?
- Is there evidence that work records and equipment monitoring are being completed?
- Is there a good understanding of the procedure by member of staff observed?
- Competency Confirmed?
- Retraining Required?
- Training Record updated?
- Written Assessment Attached?

The most common form of comments present was the “Yes / No” statement with a note of NCTC strains handled and tasks performed on each date, featuring in 49 (41%) of training records. For these records, there is no further elaboration on the trainee’s performance.

The 11 categories of comments in training records are listed in Table 11.4. The frequency of appearance has been broken down by type of assessment (initial or ongoing) and job role of trainee. It appears that a wider range of comments are present in initial assessments than in ongoing competencies, the exception being for ClassMarker® certificates, which are more frequently used in ongoing competency assessment. ClassMarker® is a quiz generating software, introduced in NCTC in 2019. Trainers can set questions and share a link with trainees. If the trainee answers the questions correctly, a certificate is generated stating they have understood the SOP, risk assessment or COSHH.

Table 11.4: Information in training records - initial vs. ongoing assessment

Nature of comments on training record	Initial assessment	Ongoing competency	Support worker	Technologist	Microbiologist	Supervisor	Total
Yes / No compliance to procedure	47	33	7	18	52	3	80
Questions and answers	7	2	3	2	4	0	9
Judgement of performance by trainer	15	9	3	1	18	1	24
Date of task performed / form filled out / NCTC strains handled	38	27	4	14	40	6	65
ClassMarker® certificate	9	15	2	1	16	5	24
Group scenario training write-up	6	2	2	1	4	1	8
Comment on trainee's previous experience	3	0	0	0	2	1	3
Write up of discussion	2	0	0	2	0	0	2
Statement that more training is required	1	0	0	1	0	0	1
Trainer's observation of performance	8	6	0	2	12	0	14

Risk awareness

Across the eight procedures reviewed, there are a total of 19 risk assessments and eight COSHH assessments associated. The trainees are made aware of the control measures in the assessments through a variety of means, the most frequent being “read and understood” used 71 (59%) of record and in 39 (32%) of records as the only means of conveying awareness. Read and understood consists of the trainee reading the risk assessment and signing and dating their training record that they have understood it.

Figure 11.3 shows the risk awareness methods and their frequency of use. 41 records (34%) contain more than one method.

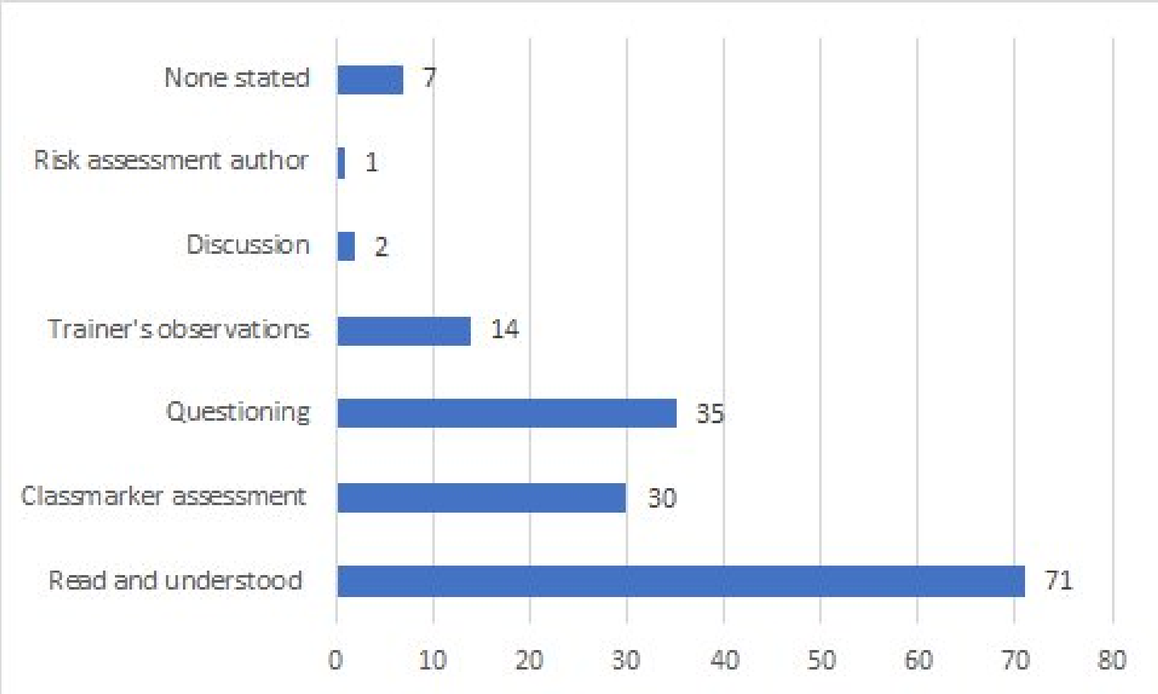


Figure 11.3: Assessment of risk awareness.

Use of questions in training

Questioning was the third most common method used in training for the freeze-drying procedure in NCTC and the second most comment method for risk awareness training. In the training records, questioning takes the form of verbal questions asked, written answers from the trainee or ClassMarker® knowledge assessments. Questioning features directly in 64/120 training records reviewed and indirectly from questions related to associated risk assessments in a further 10 records. On average, seven questions per SOP are asked during training. 56 records contained no evidence of questioning, for six of these records, a ClassMarker® assessment was available but not taken by the trainee.

A total 254 unique questions were asked 1,900 times to the trainees: 89 as part of training to an SOP and 165 as part of risk assessments and COSHH knowledge and understanding. The questions were categorised as related to quality, safety or general comprehension of procedure and documentation. The proportion of questions in each category is shown in Figure 11.4. 82% of all questions were pertaining to health and safety. “Questions” details the questions in relation to health and safety asked when training against an SOP and the associated risk assessments

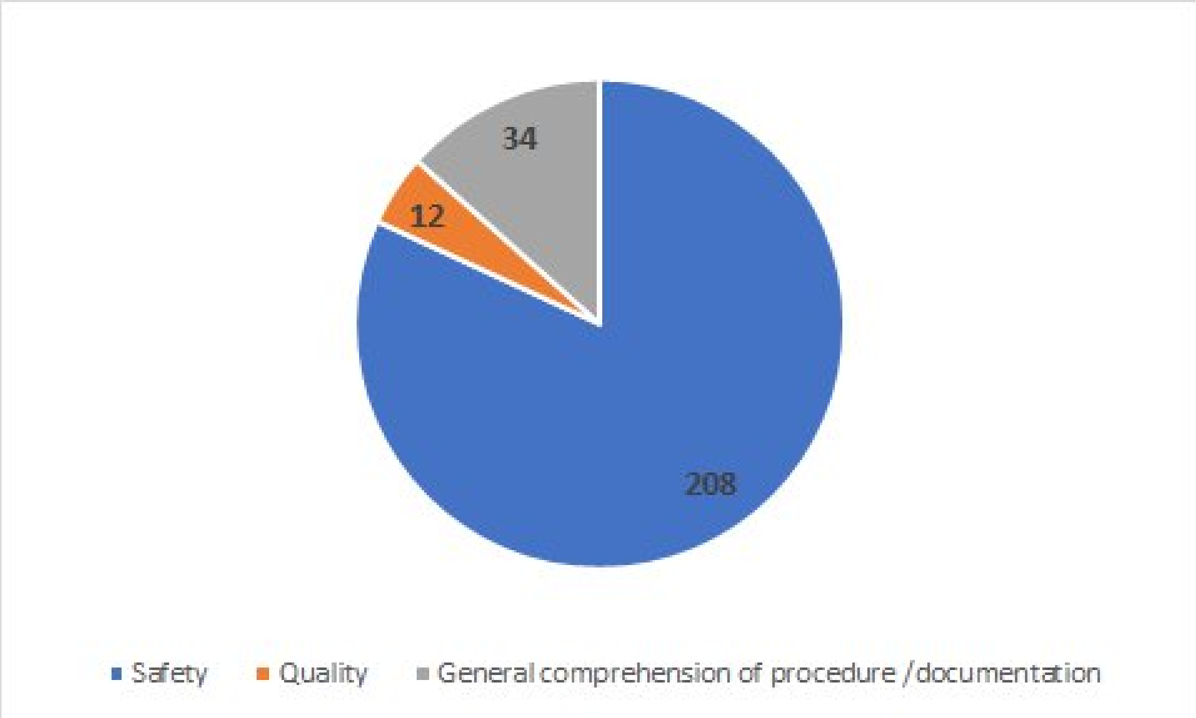


Figure 11.4: Question type by category

Ongoing competency

Of the 15 trainees reviewed, nine have been performing the freeze-drying process for longer than one year.

Ongoing competency was observed for all SOPs with at least one trainee. The SOP where ongoing competency is performed most frequently is N2850 Plugging and constriction of glass ampoules for the secondary drying stage. Table 11.5 details the total ongoing competencies per SOP and Figure 11.5 is the type of ongoing competency. The most common reason for ongoing competency training is upon return to the laboratory after a period of absence with 21 (40%) of records, followed by a new version of the SOP being issued (14 (27%) records).

Table 11.5: Ongoing competency frequency.

Evidence of ongoing competency	Number of ongoing competency records
None	1
N2007	1
N2312	9
N2315	3
N2850	12
N2851	7
N2853	6
N2857	1
N2865	4

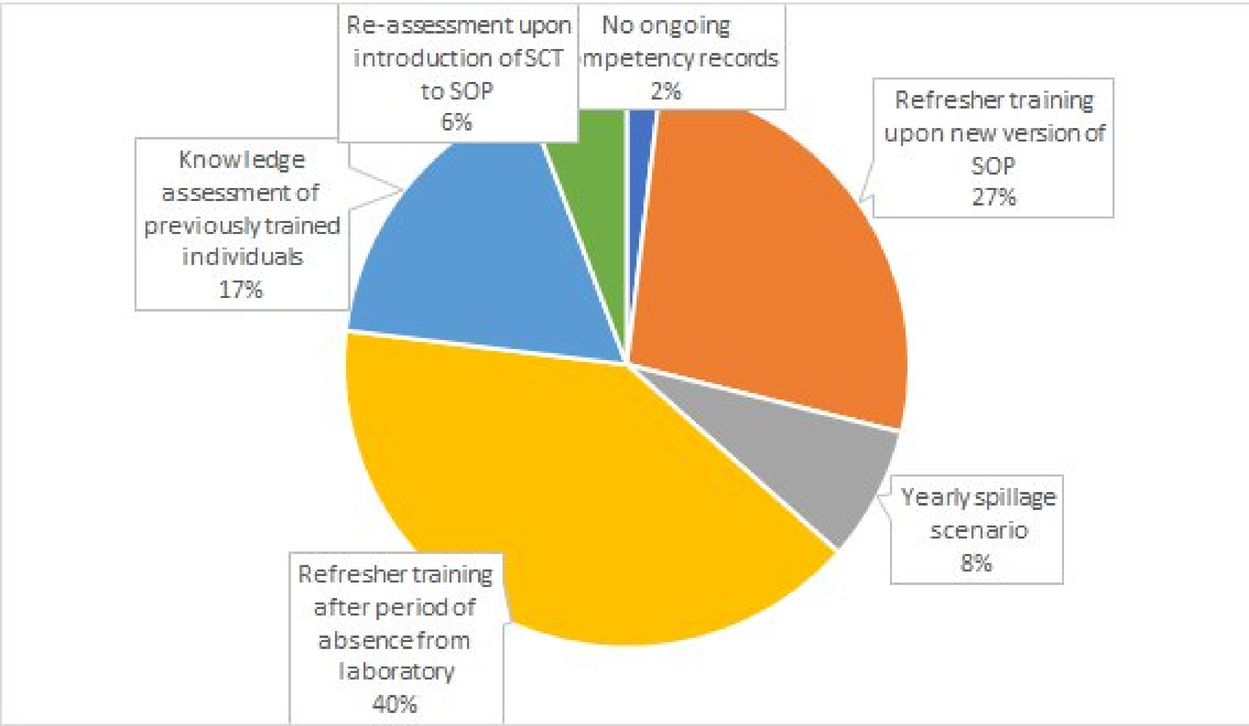


Figure 11.5: Method of assessing ongoing competency.

Compliance to training guidance

Of the four requirements stipulated in ECCW74 Culture Collections Training Manual, only nine (8%) training records met all four whereas 15 (13%) of records reviewed did not meet any of the requirements. The overall compliance rate to the departmental training manual was 50%.

The compliance to the training guidance stipulated by the PHE corporate health and safety team was lower at 17%. One of the training methods stated – use of “Met / Partially met / Not met” was not used in any training records.

Finally, the compliance to the HSE competency principles specified under the Human Factors and Ergonomics topic (6) was 31%. Eight records (7%) did not meet any of the principles and no record met all nine.

Figure 11.6 shows the frequency that each requirement is met by initial and ongoing assessments for each of the requirements of the three guidance document

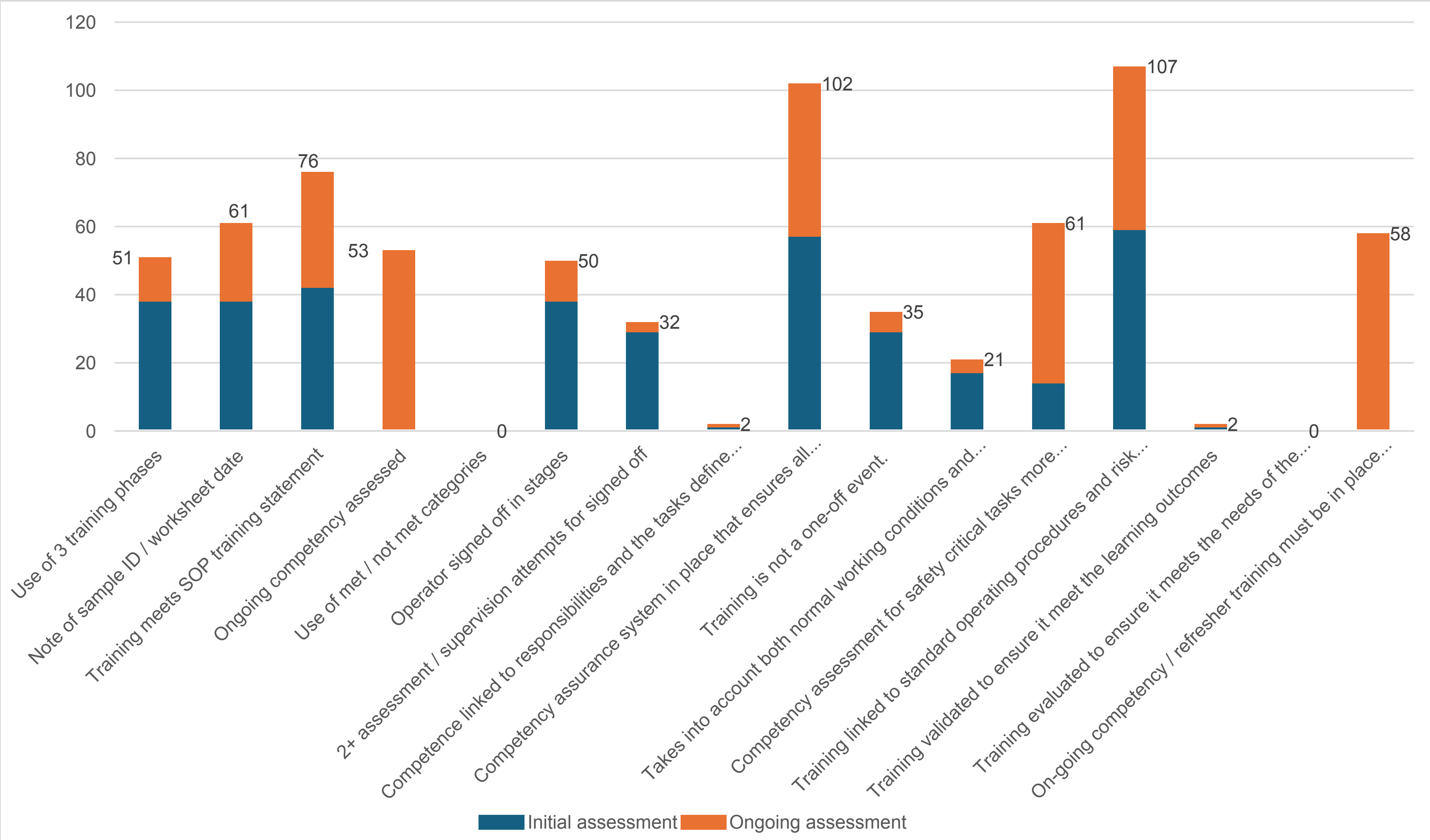


Figure 11.6: Alignment with training guidance.

Training statements in SOPs

Whilst 76 / 120 training records met the training statement in the SOP. Of the eight SOPs reviewed, the trainees were trained across 23 versions. Five SOPs did not contain a training statement. These were all the earliest version of the SOP. Two SOPs stated "all NCTC staff must be trained and be competent in this procedure" without describing what method the training should take.

The most frequently stated method is ClassMarker® assessment of knowledge which is mentioned in eight versions of SOPs. Six SOPs state that new and returning staff and must undergo training by a competent member of staff, with competency assessment completed. A further two SOPs stated a competency assessment must be completed whereas five SOPs stated a practical competency must be completed. Five SOPs stated that staff already trained can record themselves as "read and understood" on the new version of the SOP. Three SOPs (all versions of N2850) stated that staff returning to the procedure after a period of absence must be re-trained by a competent member of staff. Two SOPs defined who could perform the training (author of SOP or supervisor) and differentiated between different grades of staff. The Spillage SOP (N2315) also includes a training statement that staff must take part in a yearly spillage scenario training session.

Audit feedback

Lloyd's Register audit Culture Collections annually as part of the Porton Down certification of the quality management system to ISO 9001. In the time period 2014-2021, NCTC staff, processes and training have been included in the audit schedule four times. In addition, UKAS audit NCTC annually as part of the accreditation to ISO 17025:2017 for the quality control processes. Whilst this is not directly related to the freeze-drying process, comments may provide an insight into the training culture in NCTC. Six UKAS audit reports 2015-2020 were reviewed. 46 comments related to training were identified. The majority (22) of comments were regarding how the standard clause was satisfied by the evidence observed. There were 10 general observations and ten recommendations. In addition, four commendations of NCTC's training process were noted. The majority (14/46) of comments related to the competence records and assessment, commending their appropriateness and suitability for capturing competency. "*Competency assessment is done in a suitable way and requires the trainee to demonstrate a good understanding of the purpose of the test as well to be able to demonstrate they can carry out the test satisfactorily*." Only the earliest audit in 2015 stated the records were not detailed enough and unclear in what constitutes competency. "*Competency for practical training is not fully evident in the training records as it is not clear what competency criteria are being used to assess against*." Another area in which the training in NCTC was deemed suitable was ongoing competency (eight comments). "*On-going assessment of competency is done appropriately*." "*QC processes also provide evidence for continued competency as all are against defined acceptance criteria.*" The external auditors also commented on the management of training (nine comments) and the induction process (four comments).

The "Audit" section contains the commendations, recommendations, and comments from external auditors as categorised by themes elucidated.

Internal audits

Eight internal audits relating to training in general or the freeze-drying process were performed between 2015 and 2021. There were five audits performed on training record compliance for staff in Culture Collections, one quality witness audit, one safety witness audit and one lab safety checklist performed on the freeze-drying process. Table 11.6 details the findings of each of the audits identified.

Table 11.6: Internal audits and findings

Date of audit	Scope	Findings	Comments
2015	Lab safety checklist	• Cabinet procedures take account of fatigue and repetitive actions written in SOPs, repetitive activity in constriction, SOP will be updated to cover this. Risk assessments to reflect this. • Staff trained in techniques used i.e. competent	
2016	Training records	• Only two folders scored over 70% compliance • 63.6% staff completed train the trainer	Audit on all Culture Collections, not specifically NCTC
2017	Training records	• All NCTC staff records reviewed. Each staff member given individual feedback on outstanding training. Audit did not calculate a compliance figure.	
2018	Witness audit - Freeze-drying	• Training records not reviewed due to time	
2018	Training records	• Staff have had verbal training but not captured in competency records • Competency records filled out with detail, sometimes reference numbers are missing	
2019	Training records	• Updates to training records required for all 3 NCTC staff audited	
2019	Safety audit - Freeze-drying	• A review of RA/03676 reveals it to be a very comprehensive and well written RA. • However, it was observed that when plugging the secondary tube sharp-tipped forceps were used. • Staff member very informed and able to explain the safety control measures in place to complete the task safely. • Staff member able to explain the action to take in an emergency. • Staff member very skilled and knowledgeable about the procedures. Explained the comprehensive training she has received. Control measures in place included: The use of a tray to prevent ampule rolling, lab coat, gloves and lab discipline and training.	Audit focuses on tubing of ampoules and spark testing
2021	Training records	• Overall compliance has been demonstrated to be very high across Culture Collections. • Of the 10 training folders reviewed, 1 was 100% compliant, 3 were >90% compliant, 5 were >80% compliant and only 1 was <70% compliant. • All PHE mandatory training showed greater than 80% compliance and all documents controlled by the Culture Collections QA team showed greater than 70% compliance. • All staff were able to provide competency training forms for a SOP specific to their role and all staff were trained to current risk assessments.	Audit on all Culture Collections, not specifically NCTC

Other methods of knowledge sharing within the NCTC team

In addition to training and competency events, NCTC staff receive information and updates regarding safety and procedures through emails and team meetings. Email communication and informal group meetings and huddles are out of scope for this audit as no records are available. The minutes of the monthly NCTC Operational and Strategic meetings were reviewed regarding the information on safety provided to staff.

Between March 2014 and March 2021, 39 meetings were held in which health and safety was discussed. The most frequently discussed topic was the relaying of incident information, accounting for 28 of the 152 points of discussion. This was followed by risk assessments (16/152), safety audits (13/152), and general incident reporting (12/152).

82/152 discussion points were providing information for staff, 53 topics were instructional, 10 led to further discussion with the team present. Positive feedback to staff was provided six times, the majority regarding the reporting of health and safety incidents (3/6). With respect to the incident minuted, 20 were information for staff only, seven required action from staff members and one provoked further discussion during the meeting.

Addressing issues identified in reported safety incidents

Table 11.7 details the corrective actions from health and safety incidents related to the freeze-drying process for which a training intervention was listed, along with where evidence of action was documented. The 10 incidents related to the freeze-drying process generated a total of 17 corrective actions. 13 (76%) of the actions are captured in the risk assessment for the relevant process, nine (53%) are stated in the SOP, four (24%) have been captured in practical training records, three (18%) in knowledge -based training and three (18%) discussed at team meetings.

Table 11.7: Incident and implementation of corrective actions

Incident Description	Corrective action	Evidence of corrective action
Glass ampoule break on the constrictor machine.	Training of staff to check and to use more adapters	Use of multiple adaptors incorporated into SOP and risk assessment 1 x training record (2019) – Trainer observes trainee using multiple adaptors No knowledge-based training assessment
Flame torch malfunction	Staff advised to alternate the torches and not to refill a warm torch Staff advised to check torches for damage before use	Use of multiple torches captured in the SOP and risk assessment Checking equipment for damage not captured in SOP but is control measure in risk assessment No specific training observations Knowledge assessment through questioning
Glass ampoule break on the constrictor machine.	Discussed with staff to keep noise and distraction to a minimum Staff urged to allow ampoule to cool before handling Staff to rotate every 45-60 mins	Allowing ampoule to cool captured in SOP and risk assessment Faulty equipment not mentioned in SOP but equipment maintenance SOP cross-referenced. Captured in risk assessment

Incident Description	Corrective action	Evidence of corrective action
	Staff informed to report faulty equipment	Minimise noise not captured in SOP or risk assessment Staff rotation not captured in SOP but is in and risk assessment No specific training observations No knowledge-based training assessment
Glass ampoule break on the constrictor machine.	Staff urged to keep discussions whilst using the machine to a minimum when performing task. Staff urged to take regular breaks. Staff encouraged to observe appropriate seating practices.	Minimise discussions not captured in SOP or risk assessment Need for regular breaks listed as a SCT in SOP and risk assessment Need for appropriate seating practices a SCT in SOP and risk assessment No specific training observations Knowledge assessment through questioning
Flame torch malfunction	Staff urged to allow torch to cool before refilling	Use of multiple torches captured in the SOP and risk assessment No specific training observations Knowledge assessment through questioning
Cut from glass on secondary dryer	Staff reminded that wearing gloves for this task is a requirement	Use of gloves a SCT in SOP and risk assessment Discussed at team meeting – reminder to wear gloves 1 x training record (2019) – trainer's observation of trainee wearing correct PPE No knowledge-based training assessment
Cut from glass on secondary dryer	Staff reminded to wear safety gloves Trainer asked to be more alert to issues during training	Use of gloves a SCT in SOP and risk assessment Discussed at team meeting – reminder to wear gloves 1 x training record (2019) – trainer's observation of trainee wearing correct PPE No knowledge-based training assessment
Burn from constrictor	Update SOP to state use of more adapters and re-training of staff	Use of multiple adaptors incorporated into SOP and risk assessment 1 x training record (2019) – Trainer observes trainee using multiple adaptors No knowledge-based training assessment
Broken glass found in freeze-dryer	SOP and risk assessment updated. Staff re-trained	Not captured in SOP but control measures implemented in risk assessment Raised at team meeting – no further discussions No specific training observations No knowledge-based training assessment
Failure of freeze-dryer	Re-training of staff in constriction	No specific training observations No knowledge-based training assessment

Questions

Question	Source	Number times question used	Format of question
Fill in the blanks: "Night door of safety cabinet _____"	RA/COSHH ClassMarker ®	8	Multiple choice
Are safety cabinets considered a safety critical equipment?	RA/COSHH ClassMarker ®	8	Multiple choice
Fill in the blanks: Gas connection checks must be performed on a ________ basis and recorded onto NW5066	SOP	1	Multiple choice
Fill in the blanks: Gas leak checks must be recorded on ______ ?	RA/COSHH ClassMarker ®	10	Multiple choice
Fill in the blanks: In CL2, ampoules for QC are separated on the bench where as for CL3......?	SOP	5	Multiple choice
Fill in the blanks: Incidents must be reported on ______ ?	SOP	2	Multiple choice
Fill in the blanks: Laboratory coats and gloves must be worn at all times. _____________ must be worn when opening ampoules.	RA/COSHH ClassMarker ®	10	Multiple choice
Fill in the blanks: The procedure is carried out in a well-ventilated laboratory in order to protect the operator against the release of ____________	RA/COSHH ClassMarker ®	10	Multiple choice
Give 5 examples of when you would raise a near-miss in this procedure?	SOP	1	Written answer
How are spillages reported?	SOP	2	Written answer
Who are the at risk groups of people?	RA/COSHH ClassMarker ®	14	Multiple choice
How can staff prevent a slip, trip or falls injury?	RA/COSHH ClassMarker ®	8	Written answer
How do you dispose of Azowipes?	RA/COSHH ClassMarker ®	15	Multiple choice
How do you maintain and calibration the equipment used in the procedure?	SOP	21	Multiple choice
How frequently does this equipment need to be serviced?	SOP	1	Multiple choice
How is competence in operation of centrifuges proven?	RA/COSHH ClassMarker ®	6	Multiple choice
How many updated safety data sheets were added to safety organiser and incorporated into the COSHH to ensure all information is correct?	RA/COSHH ClassMarker ®	20	Multiple choice
How may a centrifuge become imbalanced?	RA/COSHH ClassMarker ®	6	Multiple choice
How often are centrifuges serviced?	RA/COSHH ClassMarker	6	Multiple choice

Question	Source	Number times question used	Format of question
	®		
How often is the compressor serviced?	RA/COSHH ClassMarker ®	6	Multiple choice
How often is the leakage test is performed	SOP	6	Multiple choice
How should equipment be disinfected in the event of a spillage within the bell chamber?	SOP	1	Multiple choice
How would you check if there is a gas connection leakage?	SOP	1	Multiple choice
Match the following COSHH numbers with their titles:	SOP	5	Match options
Match the Personal protective equipment to the tasks	RA/COSHH ClassMarker ®	8	Match options
On which cabinets does red light flashes below the front panel upon start-up?	RA/COSHH ClassMarker ®	8	Multiple choice
True or false? A safety clearance zone of one metre around centrifuge must be maintained where neither persons nor hazardous materials may be present	RA/COSHH ClassMarker ®	6	True or false
True or false? Alarm will sound on start up. Mute the alarm.	RA/COSHH ClassMarker ®	8	True or false
True or false? All equipment is PAT tested as per site schedule and visual electrical checks are carried out quarterly - This is a control measure for which of the following risks?	RA/COSHH ClassMarker ®	10	True or false
True or false? Any issues with MSC must be reported to Supervisor and cabinet taken out of action, “Faulty Equipment Notice” NW5109 must be attached to the equipment as per SOP N2841 Maintenance and use of equipmen	RA/COSHH ClassMarker ®	8	True or false
True or false? Any shards of glass must be removed using a dustpan or forceps and discarded into sharps bin.	SOP	4	True or false
True or false? Autoclave bins should be taped down before transport out of the laboratory area and an autoclave bin label to be affixed to outside indicating hazard within.	RA/COSHH ClassMarker ®	8	True or false
True or false? Batches of 200 ampoules or batches requiring more than two minutes to spark test should be spark tested less than 10 minutes apart to allow for ozone build up to clear.	SOP	5	True or false
True or false? Beads must only be inoculated within a suitable microbiological safety cabinet (MSC).	RA/COSHH ClassMarker ®	9	True or false
True or false? Both the HAZ-TAB granules and tablets are stable at normal ambient temperatures	RA/COSHH ClassMarker ®	7	True or false
True or false? Butane Gas for Re-fillable Microtorch has long term exposure limit of: WEL 1250 ppm 2180 mg/m³.	RA/COSHH ClassMarker	7	True or false

Question	Source	Number times question used	Format of question
	®		
True or false? Centrifuge rotor and baskets may become heavy when fully loaded with canisters, and rotor may be awkward to lift in to centrifuge. Where a vulnerability may exist, individuals must be assessed on a case-by-case basis by the lab supervisor	RA/COSHH ClassMarker ®	10	True or false
True or false? Chemical waste must be discarded through routes detailed in individual COSHH assessments. Larger volumes of chemicals must be brought to the attention of the NCTC safety officer and be disposed through the Colindale Stores chemical waste route. Used Butane gas canisters should me emptied into the sink with water running and discarded to general waste bin.	SOP	7	True or false
True or false? CL2 autoclave bins must not be overfilled. Ensure lids are secured with autoclave tape. Test load before lifting. Correct handling techniques i.e. good grip and dry hands.	RA/COSHH ClassMarker ®	3	True or false
True or false? COSHH CO/02204 must be read when dealing with the cryopreservation fluid in Protect Anaerobe beads	RA/COSHH ClassMarker ®	1	True or false
True or false? Deep clean is performed at the end of working week	RA/COSHH ClassMarker ®	8	True or false
True or false? Dispo-jars are used for discard of small disposable items for that require autoclaving like plastic pipettes, loops, small glass bottles	SOP	7	True or false
True or false? Do not stack bins on the laboratory floor.	RA/COSHH ClassMarker ®	3	True or false
True or false? During plugging of ampoules, what must be changed between each batch?	SOP	4	True or false
True or false? Eye wash solutions are available in each laboratory by the sink for use in the event of eye exposure.	SOP	2	True or false
True or false? Faulty adaptors does not need segregation and can be used for constriction.	SOP	4	True or false
True or false? For HAZ-TAB tablets, contact with combustible material may cause fire	RA/COSHH ClassMarker ®	7	True or false
True or false? For removal of spillages in confined areas, ensure suitable respiratory protection is worn.	RA/COSHH ClassMarker ®	7	True or false
True or false? For task 02 which requires pushing a trolley with autoclave bins stacked on it what one must do if it is full	RA/COSHH ClassMarker ®	8	True or false
True or false? Full disposal jars must be placed directly into a pre-labelled autoclave bin to avoid content mixing.	RA/COSHH ClassMarker ®	3	True or false
True or false? Glass fragments must be picked up using forceps, dustpan or azo wipe and discarded directly into	RA/COSHH ClassMarker	3	True or false

Question	Source	Number times question used	Format of question
sharps bin.	®		
True or false? Glass tubes are not permitted for use in a centrifuge	RA/COSHH ClassMarker ®	6	True or false
True or false? Hand towels must be discarded into yellow bags after use	SOP	7	True or false
True or false? hazardous materials may be present.	RA/COSHH ClassMarker ®	6	True or false
True or false? Hazards associated with tasks 01, 02 and 03 and 06 are manual handling and biological agents/pathogens	RA/COSHH ClassMarker ®	8	True or false
True or false? If the hand torch runs out of butane, use the same torch to re-fill.	SOP	5	True or false
True or false? If you have a major spillage within the MSC: you should try to stay calm, remove gloves and leave it inside the cabibet, alert others, remove labcoat, evacuate the room and affix do not enter sign on the cabinet as well as the door to prevent entry.	SOP	2	True or false
True or false? In NCTC, we can centrifuge live hazard group 3 material	RA/COSHH ClassMarker ®	6	True or false
True or false? In the event of a minor spill in the laboratory area, liquid working-stock chlorine-based disinfectant can be used to absorb the spill	SOP	2	True or false
True or false? Inoculated beads are classed as infectious material therefore must be treated as biohazardous waste.	RA/COSHH ClassMarker ®	1	True or false
True or false? Instructions for use of the kit are on display in the laboratory for staff to consult when necessary	RA/COSHH ClassMarker ®	7	True or false
True or false? It is acceptable to transport waste through designated clean areas such as the canteen?	RA/COSHH ClassMarker ®	3	True or false
True or false? It is advisable to leave the heat block on, even when not in use	RA/COSHH ClassMarker ®	17	True or false
True or false? It is OK to put sharps such as broken glass directly into the waste bags	RA/COSHH ClassMarker ®	3	True or false
True or false? It is OK to store stacks of inoculated agar plates loose in the fridge	RA/COSHH ClassMarker ®	14	True or false
True or false? Minimise the amount of equipment/ consumables kept in the MSC whilst working and Minimise the movement of hands in and out or the cabinet during a task Are controls against which risk?	RA/COSHH ClassMarker ®	8	True or false
True or false? NW5066 form must be updated every month after the task is performed.	RA/COSHH ClassMarker ®	4	True or false

Question	Source	Number times question used	Format of question
True or false? Personal protection equipment (PPE) used whenever using the product include nitrile gloves, safety glasses and laboratory coat worn	RA/COSHH ClassMarker ®	4	True or false
True or false? Plastics and glass items can be discarded into the same bin.	SOP	7	True or false
True or false? PPE (Laboratory coat and gloves) must be worn when handling infectious waste	RA/COSHH ClassMarker ®	3	True or false
True or false? Pregnant women should not carry out task 01 until a further assessment has been carried out	RA/COSHH ClassMarker ®	8	True or false
True or false? Pregnant women cannot work in the CL2 laboratoryPregnant women and staff with pre-existing conditions should be assessed on a case-by case basis	RA/COSHH ClassMarker ®	35	True or false
True or false? Probe tip of the spark tester must be held at least 2mm away from any object.	SOP	5	True or false
True or false? Racks may be moved to a new location by hand	RA/COSHH ClassMarker ®	10	True or false
True or false? RPE is not required for routine use of the sachets. Respiratory equipment is not recommended in case of insufficient ventilation under emergency circumstances or during large-scale use of the products.	RA/COSHH ClassMarker ®	20	True or false
True or false? Spark testers must only be used on metal surfaces	RA/COSHH ClassMarker ®	10	True or false
True or false? Staff must familiarise themselves with the manufacturers instructions and any risks associated with using the cryopreservation beads prior to use	RA/COSHH ClassMarker ®	1	True or false
True or false? Staff wear suitable PPE at all times including a laboratory coat, gloves and safety glasses for filling the microtorch with the butane fuel.	RA/COSHH ClassMarker ®	7	True or false
True or false? Step by step instructions: All NCTC Staff trained to work at NCTC CL2 must be trained or supervised prior to competency in the following procedure	RA/COSHH ClassMarker ®	3	True or false
True or false? Take regular breaks from sitting and vary tasks to minimise repetition is a control measure for which task?	RA/COSHH ClassMarker ®	8	True or false
True or false? The activities covered by this assessment are the use of chemicals provided in a commercially available biological spill kit for disinfection and cleanup of large-scale microbiological spillages in NCTC laboratory areas.	RA/COSHH ClassMarker ®	7	True or false
True or false? The Ambersil leak detector spray must be protected from sunlight. Do not expose to temperatures exceeding 50°C/122°F.	RA/COSHH ClassMarker ®	4	True or false
True or false? The butane gas canisters are stored in an upright position in a corrosive safety cabinet which is kept locked at all times.	RA/COSHH ClassMarker ®	7	True or false
True or false? The compressor has an in-built automatic	RA/COSHH	6	True or

Question	Source	Number times question used	Format of question
cut-off switch which is activated when enough pressure is obtained.	ClassMarker ®		false
True or false? The effect of the biological hazard associated with task 01 and 03 is that exposure to biological agents either by inhalation, ingestion or by other contact may lead to staff member becoming ill	RA/COSHH ClassMarker ®	8	True or false
True or false? The Haz-TAB granules and HAZ-TAB tablets in the biological spill kit must be used appropriately and in accordance with the manufacturers recommendations and the instructions given in the NCTC biological spillage SOPs: SOP N-2315 (CL3) and SOP N-2029 (CL2)	RA/COSHH ClassMarker ®	7	True or false
True or false? The heat sealer must only be used in a well-ventilated area and for a limited period of time to prevent build-up of fumes.	RA/COSHH ClassMarker ®	17	True or false
True or false? The lab is well ventilated and the inflow of gas can be easily shut off via valves on the piping and on the constrictor machine.	RA/COSHH ClassMarker ®	10	True or false
True or false? The Microbiological safety cabinet must be regularly maintained and within accepted airflow limits before use	RA/COSHH ClassMarker ®	19	True or false
True or false? The product is chemically stable under standard ambient conditions (room temperature) .	RA/COSHH ClassMarker ®	7	True or false
True or false? These products, as supplied, do not contain any hazardous materials with occupational exposure limits established by the region specific regulatory bodies.	RA/COSHH ClassMarker ®	14	True or false
True or false? This SOP covers the procedure for dealing with any spillages in the CL2 laboratory including 2D areas	SOP	2	True or false
True or false? This substance is classified as dangerous according to European Union Legislation.	RA/COSHH ClassMarker ®	7	True or false
True or false? To avoid irritation from cotton fibres, trimming of cotton bungs must be completed in a well-ventilated area and the ampoules must be held at an appropriate distance from operators faces during the procedure.	RA/COSHH ClassMarker ®	10	True or false
True or false? Transport of low risk laboratory waste e.g. black bags and cardboard boxes could result in personal injury due to poor manual handling	RA/COSHH ClassMarker ®	8	True or false
True or false? Using multiple adaptors will allow the adaptors to cool down and prevent any injuries.	SOP	4	True or false
True or false? Waste must be transferred into collection point using a trolley	SOP	7	True or false
True or false? Weekly inflow monitoring to be performed on the first working day of the week. Report any anomalies to Supervisor. Place "Do Not use" sign on any faulty cabinets	RA/COSHH ClassMarker ®	8	True or false
True or false? When dispensing culture into glass ampoules, there is the potential for exposure to blood-borne pathogens in horse serum.	RA/COSHH ClassMarker ®	10	True or false
True or false? When reconstituting an ampoule content, only 0.5ml of broth used to reconstitute culture, therefore	RA/COSHH ClassMarker	10	True or false

Question	Source	Number times question used	Format of question
spillage likely to have minimum impact in terms of exposure.	®		
True or false? When storing freeze-dried ampoules, the presence of a cotton bung in each ampoule helps to prevent exposure if ampoule tips become broken.	RA/COSHH ClassMarker ®	14	True or false
True or false? When transporting any laboratory waste that requires bags, it is essential to ensure that the bags are correctly labelled with the room number and originating laboratory or department in addition to being securely tied	RA/COSHH ClassMarker ®	8	True or false
True or false? When transporting bulky media and reagents from a fridge / freeze to the laboratory, you must us a trolley	RA/COSHH ClassMarker ®	14	True or false
True or false? When working with ampoules containing Mycoplasma, make sure to remove one ampoule at the time as the freeze dried material is very fragile and is easily dislodged.	SOP	4	True or false
True or false? While performing leakage test the gas supply must be turned off.	SOP	6	True or false
True or false? Work surface of cabinets can be lifted up to preform deep clean. This task can be performed by one person.	RA/COSHH ClassMarker ®	8	True or false
True or false? You do not put the night door and switch off the MSC in the event of a major spillage inside MSC cabinet	SOP	2	True or false
True or false?When setting up the spark tester a the mains, the voltage must be set to zero and the power switch set to off to reduce the risk of an electrical shock	RA/COSHH ClassMarker ®	10	True or false
What active ingredient is the DNEL human exposure for both HAZ-TAB granules and HAZ-TAB tablets is based on?	RA/COSHH ClassMarker ®	7	Multiple choice
What additional hazard(s) are associated with the use of the heat sealer?	RA/COSHH ClassMarker ®	17	Multiple choice
What are Class 2 safety cabinets used for the manipluation of in NCTC?	RA/COSHH ClassMarker ®	8	Multiple choice
What are Distel wipes used to clean?	SOP	6	Multiple choice
What are the control measures in place for the leak detector spray?	RA/COSHH ClassMarker ®	4	Multiple choice
What are the control measures listed for "Task 02: Inoculation of media with bacterial cultures stored on Protect cryopreservation beads: general substances"?	RA/COSHH ClassMarker ®	1	Multiple choice
What are the controls in place to mitigate the risk of transferring infectious waste bags to the collection point?	RA/COSHH ClassMarker ®	3	Multiple choice
What are the difference categories of waste and the different disposal routes?	SOP	1	Multiple choice
What are the exposure limits?	RA/COSHH	14	Multiple

Question	Source	Number times question used	Format of question
	ClassMarker ®		choice
What are the Hazard phrases linked to this COSHH?	RA/COSHH ClassMarker ®	7	Multiple choice
What are the hazardous decomposition products of Oxoid CO2Gen, AnaeroGen and CampyGen Sachets?	RA/COSHH ClassMarker ®	14	Multiple choice
What are the hazards and risks associated with the process?	SOP	59	Multiple choice
What are the precautionary statements listed for this COSHH?	RA/COSHH ClassMarker ®	7	Multiple choice
What are the substance hazard categories for this COSHH?	RA/COSHH ClassMarker ®	7	Multiple choice
What checks must be performed during start up operation?	RA/COSHH ClassMarker ®	8	Multiple choice
What colour are the infectious waste bags?	RA/COSHH ClassMarker ®	3	Multiple choice
What conditions must be avoided when using Oxoid CampyGen Gas Sachets?	RA/COSHH ClassMarker ®	14	Multiple choice
What controls are introduced to task 4 hazard: Biological agents/pathogens - General?	RA/COSHH ClassMarker ®	3	Multiple choice
What COSHH assessments are associated with this SOP?	SOP	6	Multiple choice
What disinfects are used in this procedure?	SOP	1	Multiple choice
What does DNEL stand for	RA/COSHH ClassMarker ®	7	Multiple choice
What form must be updated when leakage test and gas checks are completed?	SOP	5	Multiple choice
What form should be updated alongside of the procedure?	SOP	5	Multiple choice
What hazard is controlled by the "Staff must be supervised or trained against N2312 and N2315. Staff carrying out task must wear closed toe shoes"?	RA/COSHH ClassMarker ®	3	Multiple choice
What is the 15 minute workplace exposure limit (WEL) for Azowipes?	RA/COSHH ClassMarker ®	15	Multiple choice
What is the acceptable weight of a filled autocalve bin?	RA/COSHH ClassMarker ®	8	Multiple choice
What is the colour of general waste bags used in the lab?	SOP	3	Multiple

Question	Source	Number times question used	Format of question
			choice
What is the extention number for chemical emergencies/major spill?	SOP	2	Multiple choice
What is the implication of not checking an ampoule after constriction?	SOP	1	Multiple choice
What is the implication of not taking breaks during continuous constriction?	SOP	1	Multiple choice
What is the maximum level a sharps bin can be filled?	RA/COSHH ClassMarker®	3	Multiple choice
What is the maximun amount of autoclave bins that can be loaded onto the trolley?	SOP	3	Multiple choice
What is the most appropriate sign place on the hot plate when in use?	RA/COSHH ClassMarker®	17	Multiple choice
What is the risk and control measure of using the top shelf of a fridge / freezer?	RA/COSHH ClassMarker®	14	Multiple choice
What material is incompatible with the leak detector spray?	RA/COSHH ClassMarker®	4	Multiple choice
What materials should be strongly avoided that could possibly cause hazardous reactions?	RA/COSHH ClassMarker®	7	Multiple choice
What measures are in place to reduce the risk of electrical shock/injury could result if faulty equipment was used by NCTC staff?	RA/COSHH ClassMarker®	14	Multiple choice
What must be assessed before clearing the area of spillage?	SOP	1	Multiple choice
What must you do in the event of a spillage?	RA/COSHH ClassMarker®	19	Multiple choice
What overall controls are listed for use of equipment at high temperature?	RA/COSHH ClassMarker®	17	Multiple choice
What PPE is worn when dealing with spillages?	SOP	1	Multiple choice
What PPE must be worn when performing this procedure?	SOP	30	Multiple choice
What PPE must not to be worn while using constrictor machine?	RA/COSHH ClassMarker®	10	Multiple choice
What precautions are applicable when handling chemical waste?	RA/COSHH ClassMarker®	3	Multiple choice
What precautions should be used for Azowipes?	RA/COSHH ClassMarker®	15	Multiple choice
What RA and COSHH assessments are associated with this RA?	RA/COSHH ClassMarker	8	Multiple choice

Question	Source	Number times question used	Format of question
	®		
What risk assessment must be read and acknowledge by staff when using equipment operating at cold temperatures?	RA/COSHH ClassMarker ®	1	Multiple choice
What risk assessment must be referred to when adding or removing beads from freezer?	RA/COSHH ClassMarker ®	8	Multiple choice
What safety notes are listed in this SOP?	SOP	7	Multiple choice
What safety notices are associated with point 7 of this SOP?	SOP	6	Multiple choice
What safety precautions should be taken while carrying out this procedure?	SOP	5	Multiple choice
What safety tasks are performed in assuring that the electrical risk of using MSC is controlled?	RA/COSHH ClassMarker ®	8	Multiple choice
What segregation of waste should be done?	SOP	3	Written answer
What should be used to remove glass ampoules/fragments that remain in the constrictor after a breakage occurs?	RA/COSHH ClassMarker ®	10	Multiple choice
What SOP outlines the tasks methods of performing the tasks in this risk assessment?	RA/COSHH ClassMarker ®	10	Multiple choice
What SOPs are associated with this RA?	RA/COSHH ClassMarker ®	8	Multiple choice
What to do in various spillage situations?	SOP	1	Written answer
What type of gloves should be worn when removing items from hot equipment?	RA/COSHH ClassMarker ®	17	Multiple choice
What updates are listed in this RA?	RA/COSHH ClassMarker ®	8	Multiple choice
What updates were included in V2 of the RA?	RA/COSHH ClassMarker ®	3	Multiple choice
What would you do for a major and minor spillage?	SOP	1	Written answer
What would you do in the event of an equipment fault? Can you suggest any reason for the failure?	SOP	2	Written answer
When is the review date for this risk assessment?	RA/COSHH ClassMarker ®	6	Multiple choice
When must an autoclave bin be replaced?	SOP	7	Multiple choice
When must safety glasses be worn in the laboratory?	RA/COSHH ClassMarker ®	17	Multiple choice

Question	Source	Number times question used	Format of question
Where can a non-conformance could occur in this process and what would you to do in the event?	SOP	4	Multiple choice
Where is the Waste collection point for 2C36, 2C37 and 2C73?	RA/COSHH ClassMarker ®	3	Multiple choice
Where is weighing out of inositol powder performed?	RA/COSHH ClassMarker ®	7	Multiple choice
Where must broken glass be discarded?	SOP	7	Multiple choice
Where should you open rotors for which you cannot see through the lids?	RA/COSHH ClassMarker ®	6	Multiple choice
Where would find which vaccinations you require?	RA/COSHH ClassMarker ®	3	Multiple choice
Which areas are this risk assessment applicable to?	RA/COSHH ClassMarker ®	3	Multiple choice
Which controls are in place to prevent musculo-skeletal injury when removing the night door?	RA/COSHH ClassMarker ®	8	Multiple choice
Which COSHH assessment should be consulted for information on the cyropreservation fluid?	RA/COSHH ClassMarker ®	8	Multiple choice
Which COSHH is referred to when disinfecting the cabinets?	RA/COSHH ClassMarker ®	8	Multiple choice
Which discard bags/bins must be marked with unit name, room number and date?	SOP	7	Multiple choice
Which harmful substance is present in the cyropreservation fluid?	RA/COSHH ClassMarker ®	8	Multiple choice
Which hazard phrases are included in the COSHH?	RA/COSHH ClassMarker ®	4	Multiple choice
Which hazards are listed in "Task 1 Use of of disinfectants within CL2 laboratories in NCTC"?	RA/COSHH ClassMarker ®	3	Multiple choice
Which hazards are listed on the discard label attached to each autoclave bin?	SOP	7	Multiple choice
Which laboratories is the leak detector spray in NCTC is used to check the gas connections from the main supply to the constrictor machine?	RA/COSHH ClassMarker ®	4	Multiple choice
Which material must Cinbin not be made from?	RA/COSHH ClassMarker ®	8	Multiple choice
Which of the following are considered high temperature equipment?	RA/COSHH ClassMarker ®	17	Multiple choice

Question	Source	Number times question used	Format of question
Which of the following are listed as general working instructions to ensure safe operation of a centrifuge?	RA/COSHH ClassMarker ®	6	Multiple choice
Which of the following controls is NOT used to prevent the risk of contact with sharps?	RA/COSHH ClassMarker ®	10	Multiple choice
Which of the following is not a control measure for Task 02 Plugging of blank ampoules?	RA/COSHH ClassMarker ®	6	Multiple choice
Which of the following is NOT a hazard associated with lifting full autoclave bins onto a trolley within CL2 facility?	RA/COSHH ClassMarker ®	3	Multiple choice
Which of the following is NOT a hazard for Chlorine Tablets?	RA/COSHH ClassMarker ®	15	Multiple choice
Which of the following is NOT covered in this risk assessment?	RA/COSHH ClassMarker ®	8	Multiple choice
Which of the following is prohibited in the laborarory?	RA/COSHH ClassMarker ®	19	Multiple choice
Which risk assessment outlines all hazards associated with HG2 microorganisms?	RA/COSHH ClassMarker ®	10	Multiple choice
Which safety notes are applicable to this SOP?	SOP	2	Multiple choice
Which section of the risk assessment states "Removal of fumigation task as this will now have separate risk assessment"?	RA/COSHH ClassMarker ®	8	Multiple choice
Which SOP describes the preparation of chlorine-release solutions in a well ventilated area away from nakedflames?	RA/COSHH ClassMarker ®	15	Multiple choice
Which tasks are the hazard "slips trips and falls" applicable to?	RA/COSHH ClassMarker ®	3	Multiple choice
Which tasks must Azowipes NOT be used for? (Pick 2)	RA/COSHH ClassMarker ®	15	Multiple choice
Which two of the following are the existing controls for "Task 06 Dispensing culture into glass ampoules: Hazard - repetitive work"?	RA/COSHH ClassMarker ®	10	Multiple choice
Why are Distel wipes (trigene) used?	RA/COSHH ClassMarker ®	15	Multiple choice
Why are multiple adapters used?	SOP	2	Written answer
Why cannot Chloros be used to clean the centrifuge rotor?	RA/COSHH ClassMarker ®	6	Multiple choice

External audits

Topic	Nature	Source	Comment (full)
Competence Records	Commendation	UKAS	Training and competence records were thorough and well maintained.
	Commendation	UKAS	The training of the new member of staff is being done thoroughly with good records.
	Comment	UKAS	Training and competency assessment of QC tests and equipment usage were held. Evidence for the QC tests provided confidence in the training and competency approaches which included both practice observation and verification of knowledge.
	Comment	UKAS	Some questions are also posed on completion of training and recorded within records as objective evidence of training
	Comment	Lloyds	Review of two training records - notes dates of training
	Recommendation	UKAS	Competency for practical training is not fully evident in the training records as it is not clear what competency criteria are being used to assess against
	Recommendation	UKAS	It is not clear why staff have been deemed competent for practical testing.
	Standard cause satisfied	UKAS	Objective evidence to support the scientist's competence was available
	Standard cause satisfied	UKAS	The training records were maintained in accordance with the instructions, with full traceability.
	Standard cause satisfied	UKAS	Some new starters in the lab have also been taken on since the last visit and all staff have a record of training
	Standard cause satisfied	UKAS	[Student's] records provided evidence for training and competency for three QC tests routinely carried out. Evidence for support activity training was also evident.
	Standard cause satisfied	UKAS	Competency assessment is done in a suitable way and requires the trainee to demonstrate a good understanding of the purpose of the test as well to be able to demonstrate they can carry out the test satisfactorily
	Standard cause satisfied	UKAS	Training and competency evidence for VITEK2 identification testing (excluding equipment maintenance) provided confidence in the training approach and depth of practical and knowledge competency assessment.
	Standard cause satisfied	Lloyds	The processes for establishing competence and conducting training were verified in training records sampled.
Training management	Comment	UKAS	NCTC is working towards using the Q pulse system although is restricted currently in terms of resource to upload items.
	Comment	UKAS	Records are retained in Q pulse
	Comment	UKAS	Testing was cross referenced to NCTC strains tested. 'ClassMarker®' software is also used to verify knowledge online.

Topic	Nature	Source	Comment (full)
	Comment	Lloyds	Training requirements and competency are determined through procedure and it is indicated that it is the responsibility of the staff to maintain training records.
	Comment	Lloyds	Training records recently updated to comply with ISO17025 requirements.
	Comment	Lloyds	There is an active program to improve the team structure and provide more direct responsibility for QC. NCTC has already met this.
	Recommendation	UKAS	SOP ECC67/01-13 refers to level 2 and 3 training which is done following an update to a document. Level 2 and 3 training is not defined to show what this relates to and what training is done in practise.
	Recommendation	UKAS	Level 1 training is also done but is not described in the same SOP to make clear that this is also an option.
	Recommendation	Lloyds	The improvement project identifying the improvements required in training records within the Culture Collection department should be progressed as soon as practicable.
Ongoing competency	Recommendation	UKAS	There is no means of keeping track of witnessing audits to ensure the policy of all testing activities being covered annually is being met. For example, it is unclear when the motility, coagulase and VITEK2 were last witnessed.
	Recommendation	UKAS	The lab are conducting on going competency training for all trained staff; however, there is no formal policy for the frequency for this.
	Standard cause satisfied	UKAS	Ongoing competence is assessed annually, through test witnessing, questionnaire's or EQA / IQC participation.
	Standard cause satisfied	UKAS	Evidence for on-going competency for an existing staff member for 2019 was held for QC tests. The same approach was used as for initial training for refresher and on-going competency.
	Standard cause satisfied	UKAS	On-going competency was also evidenced through participation in EQA
	Standard cause satisfied	UKAS	QC processes also provide evidence for continued competency as all are against defined acceptance criteria.
	Standard cause satisfied	UKAS	On-going assessment of competency is done appropriately.
	Standard cause satisfied	UKAS	Test witnessing also provided confidence in training effectiveness although handling practices could be improved upon to reduce risks of potential cross contamination (see recommendation)
Induction process	Commendation	UKAS	Quality inductions are good and the power point presentation for awareness of ISO17025 detailed.
	Commendation	UKAS	Induction processes appear comprehensive including PHE site and NCTC local requirements e.g. H&S, IT, Q-Pulse and quality.
	Standard cause satisfied	UKAS	Induction procedures are in place for new starters and up to date job descriptions are held for all staff including where roles have changed.
	Standard cause	UKAS	A suitable programme of induction is conducted on commencement of work and this includes awareness

Topic	Nature	Source	Comment (full)
	satisfied		training of the quality system and ISO17025
Training plans	Recommendation	UKAS	The training plan held for [staff member] is not up-to-date to show the current status of her training
	Standard cause satisfied	UKAS	Included the completed training plan after her return from maternity leave
	Standard cause satisfied	UKAS	Training is effectively planned using the training matrix which clearly identifies the areas where training is required and this covers all laboratory staff.
	Standard cause satisfied	Lloyds	Training needs of staff are clearly identified and training is given were necessary. Audit criteria is met.
Job descriptions	Standard cause satisfied	UKAS	Job roles are appropriately defined.
	Standard cause satisfied	UKAS	A student training programme is in place and instead of a job description, memoranda of understanding are in place between the student and the organisation.
Mandatory Training	Standard cause satisfied	UKAS	There is a new placement student a Colindale, who's records were reviewed and all necessary mandatory training exercises had been completed.
	Recommendation	UKAS	Training plan for [staff member] includes the familiarisation of such as the QM and NCW procedure these are yet to be read and signed off
Refresher training	Recommendation	UKAS	The policy on retraining after staff absence or break in QC work is also not explained in the procedure
	Standard cause satisfied	UKAS	The new HEO had returned to work after a period of absence. Re-fresher training and competency records were held. The previous HEO was responsible for re-fresher training.
Resilience	Comment	UKAS	There is no plan in place as yet for training further staff in the technical procedures to ensure suitable resource for performance of the tests in line with customer and end user expectations.

12 Appendix 3 - Literature search strategy

MEDLIINE Search Strategy

("Constructivism" OR "Constructivist learning" OR "Constructivist pedagogy" OR "Active learning" OR "Inquiry-based learning" OR "Problem-based learning" OR "Experiential learning" OR "Social constructivism" OR "Collaborative learning")

AND

("Training" OR "Education" OR "Skill development" OR "Professional development" OR "Workplace learning" OR "Adult education" OR "Learning environments")

AND

("Post-COVID" OR "Post-pandemic" OR "COVID-19 pandemic" OR "COVID recovery" OR "Pandemic-era education" OR "COVID-19 and education")

AND

AB(“health worker*” OR “healthcare worker*” OR “healthcare personnel” OR “Health personnel” OR “health profession*” OR “healthcare profession*” OR “healthcare worker” OR “health-care worker*” OR “health-care personnel” OR health-care profession*” OR “medical worker” OR “medical profession*” OR “operating department practitioner*” OR “clinician*” OR “medical technician*” OR “medical assistant*” OR “laboratory worker*” OR biomedical scientist*” OR “bio-medical scientist” OR “chiropodist*” OR “podiatrist*” OR “clinical scientist*” OR “dietician*” OR “ paramedic*” OR “physiotherapist*” OR “prosthetist*” OR “orthotit*” OR “radiographer*” OR “surgeon*” OR “cardiologist*” OR “doctor*” OR “nurse*” OR “nursing staff” OR “midwi*” OR “technologist*” OR “pharmacologist*” OR “phlebotomist*” OR “an#esthetist*” OR “microbiologist*” OR “biochemist*” OR “h#ematologist” OR “histopathologist*” OR “immunologist*” OR “geneticist*” OR “associate practitioner*” OR “emergency medical technician” OR “pathologist*” OR “physician*” OR “general practitioner*” OR “GP*”)

Education Resource Complete Search Strategy

(("Constructivism" OR "Constructivist learning" OR "Constructivist pedagogy" OR "Active learning" OR "Inquiry-based learning" OR "Problem-based learning" OR "Experiential learning" OR "Social constructivism" OR "Collaborative learning")) AND AB (("Training" OR "Education" OR "Skill development" OR "Professional development" OR "Workplace learning" OR "Adult education" OR "Learning environments")) AND AB (("Post-COVID" OR "Post-pandemic" OR "COVID-19 pandemic" OR "COVID recovery" OR "Pandemic-era education" OR "COVID-19 and education")) AND AB ((“health worker*” OR “healthcare worker*” OR “healthcare personnel” OR “Health personnel” OR “health profession*” OR “healthcare profession*” OR “healthcare worker” OR “health-care worker*” OR “health-care personnel” OR health-care profession*” OR “medical worker” OR “medical profession*” OR “operating department practitioner*” OR “clinician*” OR “medical technician*” OR “medical assistant*” OR “laboratory worker*” OR biomedical scientist*” OR “bio-medical scientist” OR “chiropodist*” OR “podiatrist*” OR “clinical scientist*” OR “dietician*” OR “ paramedic*” OR “physiotherapist*” OR “prosthetist*” OR “orthotit*” OR “radiographer*” OR “surgeon*” OR “cardiologist*” OR “doctor*” OR “nurse*” OR “nursing staff” OR “midwi*” OR “technologist*” OR “pharmacologist*” OR “phlebotomist*” OR “an#esthetist*” OR “microbiologist*” OR “biochemist*” OR “h#ematologist” OR “histopathologist*” OR “immunologist*” OR “geneticist*” OR “associate practitioner*” OR “emergency medical technician” OR “pathologist*” OR “physician*” OR “general practitioner*” OR “GP*”))

SCOPUS Search Strategy

(TITLE-ABS-KEY("Constructivism" OR "Constructivist approach" OR "Constructivist learning" OR "Constructivist pedagogy" OR "Active learning" OR "Inquiry-based learning" OR "Problem-based learning" OR "Experiential learning" OR "Social constructivism" OR "Collaborative learning") AND TITLE-ABS-KEY("Training" OR "Education" OR "Skill development" OR "Professional development" OR "Workplace learning" OR "Adult education" OR "Learning environments") AND TITLE-ABS-KEY("Post-COVID" OR "Post-pandemic" OR "COVID-19 pandemic" OR "Remote learning" OR "Online learning" OR "COVID recovery" OR "Pandemic-era education" OR "COVID-19 and education") AND TITLE-ABS-KEY("health worker*" OR "healthcare worker*" OR "healthcare personnel" OR "Health personnel" OR "health profession*" OR "healthcare profession*" OR "healthcare worker" OR "health-care worker*" OR "health-care personnel" OR "health-care AND profession*" OR "medical AND worker" OR "medical AND profession*"))

Limit to Reviews and articles, Subject area medicine, nursing, health professions, dentistry

13 Appendix 4 - Interview schedule

Duration: 60 minutes

Location: Face-to-face in private office at place of work.

Information in blue is question mapping to the five cycles of value creation (Wenger et al., 2011)

Scene setting

- Thank informant for taking the time for the interview.
- Introduce purpose of interview – explore the viewpoints of NCTC staff in relation to health and safety that cannot be discovered by looking at records or observation.
- Reassure informant that discussion is confidential, results will be based on themes that emerge rather than one person's answers.
- State interview is being recorded for accuracy and will not be shared with the team or managers.
- Discuss informed consent – informant will have completed a consent form. Reenforce contents.
- Discuss format of interview – set open questions and prompting where elaboration is required.
- State interview is one hour long, want to capture their opinions and viewpoints, but will redirect to make sure we stay on topic.

Opening questions (establishing identity in NCTC)

1) Describe your role in NCTC.
2) Describe a typical day. What activities do you perform?
3) In relation to NCTC, what are your responsibilities and duties? (engagement)

Topic 1 – Events

1) Can you give examples of events or activities that you have been involved in where you received information, guidance or training related to training?
2) Of the events / activities you have listed, which did you find the most relevant and why? (cycle 1)
3) Picking on event or activity, please describe in more detail? (capture details of event – title, when, where, who etc)
    a. Why did you find this event relevant to you? (cycle 1)
    b. What do you think this event was trying to achieve? (imagination)
    c. What new skill or information did you acquire? (cycle 2)

d. How did this make you think differently about the topic? (cycle 3)
e. Did you make any new connections? If so, who? (cycle 2)
f. Where / when have you used the knowledge / resources obtained at this event? (cycle 3)
g. How did this event affect the feelings toward the work you do? (cycle 2)
h. How has the way your work changed since attending this event? (cycle 4)
i. Have you noticed any changes in others in the NCTC after this event? (cycle 4)
j. How could this event be improved in the future? (cycle 2)
k. After attending this event how was your understanding of what is important changed? (cycle 5)

Topic 2 – connections

1) Who do you interact with the most on a day-to-day basis when at work? (cycle 1)
2) Relating to health and safety, who (individuals or teams, inside or outside of NCTC) do you get your information guidance or training from? (cycle 1)
3) Who is your first point of contact for health and safety advice? (cycle 1)
4) How have you used a connection to accomplish a task? (cycle 3)
5) Do others ask you for help with safety issues in the unit? (cycle 2)
    a. What is the nature of advice you give to others?
    b. Can you give an example?
6) Picking one connection or group of connection who has helped you gain health and safety knowledge. Discuss in more detail.
    a. Who is the connection? What is their role? Where did you meet them? How often do you talk?
    b. What new skills or understanding did they teach you?
    c. How did this interaction change your understanding of Health and Safety? (cycle 3)
    d. How did this interaction affect the feelings toward the work you do? (cycle 4)
    e. What new resources (such as documents, PPE, equipment, forms) came about from this interaction? (cycle 3)
    f. Has this interaction changed anything in the unit? (cycle 5)
7) What connections with other teams or people do you feel could be strengthened in NCTC? (Imagination and alignment)
8) How do you think the NCTC team is viewed by other departments on the Colindale site or by the wider Culture Collections department? (cycle 2)

Follow-up questions

If not, enough detail is provided in the specific event or connection discussion, ask for further examples. Prompt examples include.

- Meetings
- Huddles
- Catch
- Working groups
- 1-2-1 training
- Group training.
- Casual conversations
- Colleagues
- Line-manager
- Unit Lead
- Department Lead
- Corporate Health and Safety Team

1) How effective do you feel current approach to health and safety training is in practice? (alignment)
2) What opportunities could be taken in the future by NCTC (Cycle 2, imagination)
3) How would you change the approaches to health and safety in NCTC? (engagement)

Closing questions

Re-enforce and confirm viewpoints raised by the informant by repeating back key statements

1) How long have you worked for NCTC?
2) Briefly describe your career history before NCTC
3) Can you list your professional qualifications? – note degree titles.

Thank informant for participating.

14 Appendix 5 – Auditor competency form with identified domains

Performance criteria	Competency Level Required	Evidence / Evaluation: How was the competency standard achieved?	Competency assessment			
			Self-assessment	Mentor assessment	Date	Comments
Follows the relevant policies, procedures (including SOPs), guidance and practices.						
Familiar with the Culture Collections Quality Management System.						
Demonstrates awareness of the purpose of audits.						
Demonstrates awareness of regulations, legislation, or standards applicable						

Performance criteria	Competency Level Required	Evidence / Evaluation: How was the competency standard achieved?	Competency assessment			
			Self-assessment	Mentor assessment	Date	Comments
to audit area.						
Correct interpretation of standards, clauses, and principles.						
Can state the similarities and differences between an audit and inspection.						
Can identify the features of a horizontal and vertical audit.						
Can create an audit or inspection plan.						
Links scope of audit to relevant standard and/or clause.						
Selects an						

Performance criteria	Competency Level Required	Evidence / Evaluation: How was the competency standard achieved?	Competency assessment			
			Self-assessment	Mentor assessment	Date	Comments
appropriate sample size for audit.						
Ability to articulate findings clearly, both verbally and in writing.						
Active listening to understand and gather information.						
Negotiates and resolves conflicts tactfully.						
Upholds professionalism when undertaking audit / inspection.						
Effectively communicates with auditees before, during and after the audit.						

Performance criteria	Competency Level Required	Evidence / Evaluation: How was the competency standard achieved?	Competency assessment			
			Self-assessment	Mentor assessment	Date	Comments
Acts with impartiality.						
Able to delegate audit responsibilities to other members of the team.						
Leading complex audits with multiple stakeholders or international scope.						

15 Appendix 6 - Competency assessment form

NCTC Competency Assessment Record

Name of trainee			
SOP Number		**Version**	

SOP Title	
Reason for competency	☐First assessment of procedure ☐New version of SOP ☐Ongoing competency ☐Refresher training ☐Re-assessment due to audit / non-compliance
Type of competency required	☐Practical ☐Knowledge and Understanding
Full / Partial competency (state SOP sections)	☐Full ☐ Partial
Target competency level*	Choose an item.
Trainer(s)	

Training objectives (copy all that apply from training statement of SOP)

Objective	Fully met / Not met	Date	Evidence
		Click or tap to enter a date.	
		Click or tap to enter a date.	
		Click or tap to enter a date.	
		Click or tap to enter a date.	
		Click or tap to enter a date.	
		Click or tap to enter a date.	
		Click or tap to enter a date.	

Training approaches used in competency assessment (select all that apply)

☐ Demonstration of correct decision-making process	☐ Practical observation	☐ Witness statement
☐ Hypothetical scenario	☐ Q&A	☐Other Click or tap here to enter text.
☐ Group training	☐ Inspection	
☐ IQA / EQA	☐ Review of forms and worksheets	

NW5265.02-23 Authorised by Emma Hobbs Effective date: 31.07.2023
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NCTC Competency Assessment Record

Name of trainee			
SOP Number		Version	

Pre-requisite training events for competency (Check training statement)

Training	Date Completed

Safety

Correct use of PPE	Evidence of compliance

Safety instructions and critical tasks in SOP	Evidence of compliance

Adverse Incident Awareness

Relevant adverse incident discussed	Competency level	Evidence
	Choose an item.	
	Choose an item.	

Equipment

Equipment used as part of procedure	Correct operation of equipment level	Understanding of maintenance level	Evidence of training in specific equipment
	Choose an item.	Choose an item.	
	Choose an item.	Choose an item.	

NCTC Competency Assessment Record

Name of trainee			
SOP Number		Version	

Reagents and chemicals

Reagents used as part of procedure	Correct handling of reagents	LOT of reagents recorded	Evidence of training in specific equipment
	☐Fully met ☐ Not met ☐ n/a	☐Fully met ☐ Not met ☐ n/a	
	☐Fully met ☐ Not met ☐ n/a	☐Fully met ☐ Not met ☐ n/a	

Waste management and decontamination

Waste handling or decontamination process	Correct handling of waste / disinfectant	Evidence of training in specific equipment
	☐Fully met ☐ Not met ☐ n/a	
	☐Fully met ☐ Not met ☐ n/a	

Record keeping

Records completed correctly	☐Fully met ☐ Not met ☐ n/a	Evidence:

Assessment of understanding

Attach ClassMarker Assessment or Q&As used for competency

Knowledge area	Fully met / Not met	Evidence
Location of SOP	☐Fully met ☐ Not met ☐ n/a	
Context of procedure	☐Fully met ☐ Not met ☐ n/a	
Principle of procedure	☐Fully met ☐ Not met ☐ n/a	
Reagent control	☐Fully met ☐ Not met ☐ n/a	
Quality control	☐Fully met ☐ Not met ☐ n/a	
Quality assurance	☐Fully met ☐ Not met ☐ n/a	
Safety considerations	☐Fully met ☐ Not met ☐ n/a	

NCTC Competency Assessment Record

Name of trainee			
SOP Number		Version	

Practical competency (insert extra events as required)

Date of event	Click or tap to enter a date.
Nature of training	
☐Observation ☐Supervision ☐Assessment	
Activity / strain handed / records completed	
Trainer feedback	
Competency level*: Choose an item.	
Trainee feedback	

Date of event	Click or tap to enter a date.
Nature of training	
☐Observation ☐Supervision ☐Assessment	
Activity / strain handed / records completed	
Trainer feedback	
Competency level*: Choose an item.	
Trainee feedback	

NCTC Competency Assessment Record

Name of trainee			
SOP Number		Version	

Competency assessment outcome

Overall competency level*:	Choose an item.		
I am confident that I am now fully trained and competent to carry out this/these procedure(s) as written and will abide by all relevant procedural and safety guidance			
	Trainee	**Date**	
I have determined that the trainee (above) has demonstrated satisfactorily that they are competent to carry out this procedure as written and that this has now been recorded in the training record.			
	Trainer	**Date**	

Please save a copy of this competence in the NCTC Shared Drive and send to the Training Administrator for upload to Q-Pulse.

*Level of competence guidelines

Please refer to the NCTC Training guidance for detailed explanation

Score	Outcome
Not competent	Insufficient evidence observed to confirm competency in procedure
Awareness	Has theoretical knowledge of subject matter but not able to practically apply this knowledge.
Basic	Has theoretical knowledge of subject matter and able to apply practically under direct supervision.
Intermediate	Has applied knowledge of subject matter, competent to perform work unsupervised and able to improvise and adapt working practices in response to events
Advanced	Has applied knowledge of subject matter, competent to perform work unsupervised and able to improvise and adapt working practices in response to events. Has sufficient experience and additional competencies to train, supervise and assess others.

16 Appendix 7 - Culture Collections Safety Advocates proposal

Strategic alignment

Creating of the SACoP aligns strongly with the Culture Collections Team Charter and will allow members to demonstrate and achieve the behaviours expected of the department, as shown in Figure three.

Figure 3: Statements on the Culture Collections Team Charter that would be fulfilled by the creation and implementation of a Safety Advocates Community of Practice.

Methodology and strategy

Establishing the SACoP

The methodology for establishing the SACoP is based on the guidance presented by the de Carvalho-Filho et al., (2020) review of the literature.

Page **8** of **17**

Establish a core group from the outset

At present, there are five Culture Collections staff who have volunteered to become Safety Advocates. A further call for volunteers will be circulated by the Head of Culture Collections or Health and Safety Manager.

Keep an open membership

Membership should be fluid and it must be made clear that all staff who are interested in health and safety, at any grade, from any role in the department can join. There should not be an expectation to be active members of the CoP, although participation will be encouraged. Members should be welcome to attend meetings, read the discussions and resources without always actively contributing. It has been shown that CoP "lurkers" still gain knowledge and benefits through their non-participation and may eventually become active participants as their confidence and identity within the group grows (Smith et al., 2017).

Formulate the goals and value of the CoP

An initial meeting will establish the terms of reference for the group; this will consider what individuals are hoping to gain from becoming a safety advocate and what would be expected of them. Members will directly contribute to the name, function, and terms of reference of the group, the latter will be reviewed annually.

Start with a specific project

Subsequent meetings will explore potential targets for intervention; health and safety issues that affect the whole department, or areas in which one unit can learn from another. Each member will have the opportunity to bring forward their ideas and decide upon the key focus areas. Projects and improvement ideas will be decided upon by the CoP members rather than dictated by senior management. They will use existing health and safety data such as Trackwise incident reports and the health and safety performance monitoring tool to identify issues and areas for improvement. It is important that the CoP has objectives and targets as this has proven to be a factor that encourages participation and sustainability (de Carvalho-Filho et al., 2020).

The formation of sub-groups within the CoP targeting one specific area may be required depending on the nature of the topics and projects undertaken. These sub-groups will report into the overall CoP where others can contribute to or learn from the work undertaken. Members will learn skills from each other and where applicable, the Corporate Health and Safety Team or another subject matter expert. Skills may include auditing, communication, report writing, risk assessment or in-depth knowledge of a particular safety issue.

Format of CoP

Use online platforms

The SACoP will primarily be facilitated by Microsoft® Teams. A dedicated channel within the Culture Collections Team will be created. Here, meetings will be scheduled, informal discussions will take place on the discussion board, and resources will be generated and curated using the associated SharePoint. Initial meeting frequency will be once a month, lasting one hour.

Whilst most interactions within the CoP will take place virtually, it is essential that members meet face-to-face periodically to build trust and connections within the group and to sustain the momentum (Ranmuthugala et al., 2011). Biannual face-to-face meetings should occur for the whole group, and members working on a particular project should also meet in person where possible. As members are based across geographically different sites, manager support for dedicated travel time is required.

Synchronous and asynchronous meeting spaces will be used to maximise the benefits of communication. Synchronous meetings will be the main form of communication, although not all members will be able to attend every meeting. To complement this, discussion threads on MS Teams will be used. Whilst the latter method will lack in spontaneous discussion, it will enable all members to participate in their own time and pace (Barry et al., 2017).

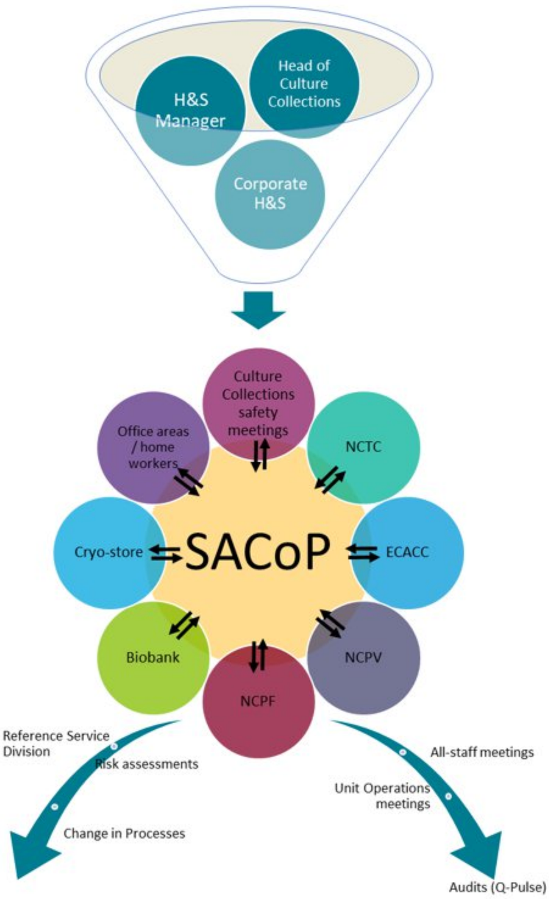
Stakeholders

The involvement of the following stakeholders is required for the success of the Safety Advocate CoP: -

- **Head of Culture Collections** – Buy-in from the Head of Culture Collections is essential for the success of the CoP Barnett et al., (2012). Having strategic oversight of the department can feed into setting the aims and objectives of the CoP and identify projects that will improve the safety culture in the department. To maintain a sense of independence and foster trust within the CoP, the Head of Culture Collections will not partake in CoP meetings directly as McLoughlin et al., (2018) suggest that monitoring of CoP activities by senior management may hinder knowledge sharing.
- **Culture Collections Health and Safety Manager** – Will facilitate and guide the SACoP. Li et al., (2009) and Barnett et al., (2012) found that the facilitator role was essential for sustainability of the CoP. A facilitator, leader or moderator was present in all formal CoPs. This role is best placed to act as a facilitator as they are independent from each of the units, will have extensive knowledge of health and safety and understanding of the needs of the department.
- **Unit leads and line managers** – Success of the CoP is reliant on support from the unit leads in the department. Members will require protected time to participate in CoP meetings and activities which must be allowed by their line managers and unit leads. It should also be recognised by line managers that participating in this CoP is a form of personal development and achievements should be captured at appraisals.
- **Corporate Health and Safety Team** – Will provide support and guidance when required. The Culture Collections Safety Manager will act as a broker between the CoP and the Corporate Team when support or advice is required. In addition, Corporate Health and Safety will provide the training for any member of Culture Collection Staff wishing to become Safety Advocates.
- **Culture Collections Health and Safety Committee** – It is imperative that the achievements of the SACoP is communicated appropriately (de Carvalho-Filho et al., 2020). Members of the SACoP will attend the monthly health and safety committee meetings to feedback progress and report on actions undertaken. The Committee will consist of representatives from each unit, and the individuals identified above. There will be a dedicated agenda point on the meeting for the Advocates to provide an update.

- **Culture Collections staff** – Everyone in the department is welcome to join the SACoP within the department, primarily through All-Staff or unit operational meetings.

Figure four demonstrates the flow of information in and out of the SACoP, and the relationships with the various units within Culture Collections. The SACoP will act as a forum for members to bring health and safety issues, examples of good practice or queries from each of the units within the department. This will directly feed into the Culture Collections Safety Group meeting where information will also be disseminated by the Head of Culture Collections, Operations Leads and the Corporate Health and Safety Team. It is expected that the SACoP will be active in developing new practices, promoting health and safety, or undertaking investigations, therefore will create outputs in which the impact can be measured.



4: Flow of information in and out of the SACoP (Safety Advocates Community of Practice). NCTC= National Collection of Type Cultures, ECACC = European Collection of Authenticated Cell Cultures, NCPV = National Collection of Pathogenic Viruses, NCPF = National Collection of Pathogenic Fungi.

17 Appendix 8 – Informed Content Letters and Information Sheets

STAFFORDSHIRE UNIVERSITY

Version Number 13/02/2022

INFORMATION SHEET FOR PARTICIPANTS

Project Reference Number: SU-21-089-RN

Title of study
Assessing knowledge and value creation in relation to health and safety within a microbiology laboratory.

Invitation Paragraph

I would like to invite you to participate in this research project which forms part of my Professional Doctorate in Healthcare Science research. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information.

What is the purpose of the study?

- To conceptualise the identity of the department
- To determine where staff obtain their information related to health and safety
- To determine what sources of information are available
- To build a picture of the network available to staff members
- To assess how this information is utilised in the laboratory

The findings of this study will inform further research into how health and safety training can be improved.

Why have I been invited to take part?

You have been invited to take part in this interview as I am looking to improve the way health and safety training is delivered and information is disseminated in the unit. To do this, it is important to establish the current situation in the unit and to take into account each staff member's opinions, experience and expertise.

Participation is open to all laboratory-based staff members in NCTC and managers.

An interview format has been selected to enable me to explore the ideas and suggestions you may have in detail.

In addition, I will be recording and transcribing Team Huddles over a 2-month period, to enable me to cross-reference any points that may be raised in the interviews and allow a different perspective to the research.

What will happen if I take part?

If you agree to take part, we will arrange a mutually convenient time to hold the interview. The interviewer may be myself, or a facilitator from elsewhere in the organisation. The interview will be one-to-one and take place in a quiet office or meeting room in Colindale where there will be no other staff present and no disturbances.

The interview will be recorded on a digital voice recorder. This is to allow the researcher to transcribe what was discussed verbatim to ensure accuracy and clarity of what was discussed. You will be given an opportunity to check the transcription to ensure it accurately reflects your experience of the interview before the data is analysed. The recording will only take place with your consent and the facilitator will indicate when the recording has started.

The interview should last about an hour but may be shorter or longer depending on the discussion. It will focus on your role in the unit, examples of health and safety training or information received, your experience with a particular training event, the connections you have made whilst working in NCTC and your opinions on how things can be improved if needed. The questioning will be open to allow for discussion and the interviewer may prompt you for more information on certain topics.

This information will help build a picture of the current practice in the unit and identify areas that could be strengthened. The information you provide will be used in conjunction with other participants to establish recurring themes.

The content of your interview will remain anonymous. It will not be shared or discussed with your colleagues, line manager or Head of Unit / Department, unless significant shortcomings conduct relating to Health and Safety or Organisational Values and Behaviour are revealed. In the write-up of data, only the over-arching themes will be discussed. Direct quotes from you may be used to support the analysis however, these will be anonymised and not attributed to a specific person, job role or any other identifying information.

The Team Huddle recordings, which take place over Microsoft Teams, will be recorded by the software and transcribed verbatim. The themes of topics discussed, rather than individual contributions will be used in the analysis. The information will not be used to identify a particular individual and contributions will not be attributed to them.

The only people who will have access to your data is the researcher (Hannah McGregor) and the facilitator when recording the session.

<u>Do I have to take part?</u>

Participation is completely voluntary. You should only take part if you want to and choosing not to take part will not disadvantage you in anyway. Once you have read the information sheet, please contact me if you have any questions that will help you make a decision about taking part. If you decide to take part I will ask you to sign a consent form and you will be given a copy of this consent form to keep.

<u>What are the possible risks of taking part?</u>

Whilst the information will be kept anonymous, as Team Leader, I have a responsibility to report and act on any information suggesting gross-incompetence or misconduct. In the unlikely event such information comes to light, it will be acted upon following the Organisation's HR or Safety policies as appropriate.

What are the possible benefits of taking part?

There are no intended benefits in taking part.

Data handling and confidentiality

Your data will be processed in accordance with the data protection law and will comply with the General Data Protection Regulation 2016 (GDPR).
The recordings, transcription and data analysis will be stored on the Lead Researcher's UK-HSA issued password-protected laptop on the personal network drive.

Once transcribed, your participation will be anonymised by assigning a numerical code identifier to which the will be referred to throughout analysis, write-up and dissemination of project work.

The audio recordings will be deleted once transcribed and anonymised after you have reviewed content. The anonymised data and analysis will be retained for 10 years before being discarded.

Data will only be shared with a wider research team or third parties with your consent.

No personal data will be shared outside of the EU.

Data Protection Statement

Your data will be processed in accordance with the General Data Protection Regulation 2016 (GDPR).

The data controller for this project will be Staffordshire University. The university will process your personal data for the purpose of the research outlined above. The legal basis for processing your personal data for research purposes under the GDPR is a 'task in the public interest'. You can provide your consent for the use of your personal data in this study by completing the consent form that has been provided to you.

You have the right to access information held about you. Your right of access can be exercised in accordance with the GDPR. You also have other rights including rights of correction, erasure, objection, and data portability. Questions, comments and requests about your personal data can also be sent to the Staffordshire University Data Protection Officer. If you wish to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk.

What if I change my mind about taking part?

You are free withdraw at any point of the study, without having to give a reason. Withdrawing from the study will not affect you in any way. You are able to withdraw your data from the study up until May 2021, after which withdrawal of your data will no longer be possible due as the data will have been anonymised and included as part of the Doctoral Thesis.

If you choose to withdraw from the study we will not retain any information that you have provided us as a part of this study.

What will happen to the results of the study?

The results of the study will form part on my Doctoral thesis on improving training for laboratory workers to reduce the number of adverse health and safety incidents. It will inform the direction and development of an educational framework that could be implemented in the laboratory setting.

At a later date, the results of this study may be incorporated into a publication in a peer revied medical education journal.

Who should I contact for further information?

If you have any questions or require more information about this study, please contact me using the following contact details:
Hannah.McGregor@phe.gov.uk
Tel: 0208 237 6423
Office: Colindale 2C06

Project Supervisor:

Paul Orsmond
Science Centre Building,
Leek Road,
Stoke-on-Trent
Tel: +44 (0)1782 292779
Email: p.orsmond@staffs.ac.uk

What if I have further questions, or if something goes wrong?

If this study has harmed you in any way or if you wish to make a complaint about the conduct of the study you can contact the study supervisor or the Chair of the Staffordshire University Ethics Committee for further advice and information:

Tim Horne
Research, Innovation and Impact Services
Cadman Building, Staffordshire University, College Road Stoke-on-Trent
ST4 2DF
Tim.horne@staffs.ac.uk

+441782295722

Thank you for reading this information sheet and for considering taking part in this research.

RESEARCH PROJECT CONSENT FORM

Title of Project: Assessing knowledge and value creation in relation to health and safety within a microbiology laboratory.

Researcher: Hannah McGregor

I have read and understood the information sheet.	Yes ☐	No ☐
I have been given the opportunity to ask questions.	Yes ☐	No ☐
I have had my questions answered satisfactorily.	Yes ☐	No ☐
I understand that my participation in this study is entirely voluntary and that I can withdraw at any time without having to give an explanation	Yes ☐	No ☐
I understand that I can withdraw my data from the project up to the point of analysis May 2022 without having to give an explanation	Yes ☐	No ☐
I understand that where applicable the interview will be audio-recorded	Yes ☐	No ☐
I consent that data collected could be used for publication in a scientific journals or could be presented in scientific forums (conferences, seminars, workshops) or can be used for teaching purposes and understand that all data will be presented anonymously.	Yes ☐	No ☐
I agree that data will only be used for this project. All data will be sorted safely on a password protected computer (electronic data), or locked away securely (hard copies of data) for 10 years before being destroyed	Yes ☐	No ☐
I hereby give consent to take part in this study	Yes ☐	No ☐

Your data will be processed in accordance with the General Data Protection Regulation 2016 (GDPR).

The data controller for this project will be Staffordshire University. The university will process your personal data for the purpose of the research outlined above. The legal basis for processing your personal data for research purposes under the GDPR is a 'task in the public interest'. You can provide your consent for the use of your personal data in this study by completing the consent form that has been provided to you.

You have the right to access information held about you. Your right of access can be exercised in accordance with the GDPR. You also have other rights including rights of correction, erasure, objection, and data portability. Questions, comments and requests about your personal data can also be sent to *the Staffordshire University Data Protection Officer. If you wish to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk.*

Name Participant (print)	Date	Signature
Name Researcher (print)	Date	Signature

18 Appendix 9 - Ethics approvals

Life Sciences and Education

ETHICAL APPROVAL FEEDBACK

Researcher name:	Hannah McGregor
Title of Study:	Assessing knowledge and value creation in relation to health and safety within a microbiology laboratory.
Status of approval:	Approved

Thank you for addressing the committee's comments. Your research proposal has now been approved by the Ethics Panel and you may commence the implementation phase of your study. You should note that any divergence from the approved procedures and research method will invalidate any insurance and liability cover from the University. You should, therefore, notify the Panel of any significant divergence from this approved proposal.

You should arrange to meet with your supervisor for support during the process of completing your study and writing your dissertation.

When your study is complete, please send the ethics committee an end of study report. A template can be found on the ethics BlackBoard site.

Signed: Prof. Roozbeh Naemi **Date: 24.02.2022**

Ethics Coordinator
School of Life Sciences and Education