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The Role of Interactive Web Broadcasts in Fostering Distance Learning Students' Engagement with Practical Lab and Fieldwork

Thesis

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The role of interactive web broadcasts in fostering distance learning students' engagement with practical lab and fieldwork

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A thesis submitted in partial fulfilment of the requirements of The Open University, for the award of Doctor of Philosophy in the Science, Technology, Engineering and Mathematics Faculty

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Declaration

I hereby declare that the work presented in this thesis has not been submitted for any other degree or professional qualification, and that it is the result of my own independent work.

Venetia Amanda Brown (Candidate)

Date: 3rd March 2022

Abstract

Practical work in science and technology disciplines is crucial for students' understanding and mastery. For educators who teach those disciplines at a distance and for students who learn remotely this endeavour may be challenging.

The study presented in this thesis investigates the use of Interactive Web Broadcasts (IWBs) in five undergraduate practical science and technology modules at The Open University. The study examines the reasons for using IWBs, as well as the strategies and types of interactions that staff and students used to engage and interact with one another. The study gathered perspectives from academics (n=18); associate lecturers (n=10); technical production team (n=3); students (n=88) and an external guest expert about the purposes, strategies and motivations of participating in IWBs. The study used a qualitatively mixed-methods design. An adapted protocol of Flanders's Interaction Analysis Categories was used to analyse the interaction patterns in the web broadcast transcripts and text-chat logs, and a discourse analysis coding scheme was applied to analyse the text-chat. Student online questionnaires were administered towards the end of the modules to capture the student perceptions of IWBs. Student interviews and staff focus group were also conducted to gain a fuller picture of experiences of using and engaging with IWBs.

Findings show that the purposes and aims for using IWBs are to facilitate student engagement, foster a sense of community, and demonstrate an authentic practice of the sciences in real-world contexts. The communicative strategies were primarily affective and met students' interests and expectations. The IWBs mitigated feelings of isolation that are common in distance education environments. IWBs had positive impacts on professional teaching practices, and fostered collegiality and collaboration among staff. The findings are relevant to other distance and traditional campus-based universities that teach practical science and technology, those who teach online using synchronous technology-mediated systems, and who have an interest in student engagement and practical work.

Presentations and publications of this research

Brown, V. and Cayless, A. (2021) Exploring the use of a tutor-briefing labcast to support associate lecturers in a level 2 Physical Sciences module. *eSTEeM. The OU centre for STEM pedagogy: The Open University*, p.23. Available at

https://www.open.ac.uk/esteem-Brown-Cayless-report.pdf

'The Role of Web Broadcasts to Develop Online Learning Communities'. On-demand oral presentation at Advance HE STEM Conference 2021: Rethinking STEM Higher Education. Available online: https://brown-v-youtube.com

'Exploring the use of labcasts to support associate lecturers. Oral presentation at the 9th eSTEeM Annual Conference: Informing Student Success – From Scholarship to Practice. Online via MS Teams. *Abstract online: conference booklet*

'The Role of Interactive Web Broadcasts to Develop Online Learning Communities'. Oral presentation at the 4th Horizons in STEM Higher Education Conference 2019. Kingston University, Kingston, Surrey. Available online: abstract booklet

Fostering a Sense of Community: The Role of Interactive Web Broadcasts in STEM'. Oral presentation at The Online, Open and Flexible Higher Education Conference: Blended and online education within European University Networks. Universidad Nacional de Educación a Distancia (UNED), Madrid, Spain. Available online: programme sessions

Acknowledgements

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Glossary

Assessment: the ways the OU assess how students are progressing during a module. It includes Tutor-Marked assignment and End-of-module assessment.

Associate Lecturer (AL): a tutor who supports students on the module; helps with study materials and marks and comments on student's TMAs and written work.

Asynchronous: communication where the sender and receiver do not have to be online concurrently to interact.

Blended learning: an approach to education that combines some combination of face-to-face learning and online learning, may also be called hybrid learning.

End-of-Module Assessment (EMA): an OU term that relates to essays, projects, portfolio, dissertations or summative assessments which are usually submitted electronically.

Interactive users: individuals who interact with one or more widgets or interact with the text chat during an interactive web broadcast.

Interactive Web Broadcasts (IWBs): live video broadcast over the Internet that has instant chat messaging and audience polling tools to support interaction.

Module Block: a set amount of time in which a main subject or topic area is covered.

Module Team Chair: an academic member of staff who is responsible for a module presentation and/or production.

SXHL288: 'Practical science in biology and health' module.

SXPS288: 'Remote experiments in physics and space' module.

S206/SXF206: 'Environmental science' module.

S315: 'Chemistry: further concepts and applications' module.

Synchronous: communication where the sender and receiver interact simultaneous in real-time.

TM129: 'Technologies in practice' module.

Tutor-Marked Assignment (TMA): an OU term for written assignments that are submitted to a tutor.

Widgets: a graphical user interface that can be embedded within a web page and allows voting; similar to audience polling systems or clickers.

1 Introduction

This PhD thesis investigates the use of Interactive Web Broadcasts (IWBs) in five undergraduate practical science and technology modules at The Open University, United Kingdom (OUUK). The study examines the reasons for using IWBs, as well as the strategies and types of interactions that staff and students used to engage and interact with one another. It also investigates how the IWBs influence students' learning motivation and Sense of Community (SoC).

This chapter starts with the background in Section 1.1. It argues that setting up practical work in a Distance Education (DE) environment can be challenging but that technology has afforded wider opportunities. It then positions engagement and Sense of Belonging (SoB) as key constructs in Higher Education (HE), especially in DE. Section 1.2 outlines the problem statement and presents some of the challenges for the STEM disciplines of not being co-located with others and with scientific equipment. The research aim and central question is discussed in Section 1.3 before discussing the context for this research study. Section 1.5 highlights the use of educational broadcasts and the previous approaches that IWBs built on.

1.1 Background

Practical work is an important component of most science and technology curricula that place investigation, experimentation and demonstration at its core. The implementation processes for those who teach science disciplines at a distance might be challenging. Home experiment kits and occasional intensive face-to-face laboratory sessions were traditionally used to develop practical skills for OU distance learners (MacQueen & Thomas, 2009). However, the ubiquitous nature of the Internet has opened up new possibilities and provided a wider range of supported learning in DE (Harasim, 2000).

Adult distance learners have a unique set of requirements. They need to be in a flexible, learner-centred learning environment with reliable, easy-to-navigate technologies, be provided with appropriate amounts of information and resources, and have opportunities for human connection and social interaction (Palloff & Pratt, 2001).

The lecturer or tutor is tasked with fostering a SoB and keeping students engaged by offering meaningful learning activities. Prompt feedback and acknowledgment are also important in a Distance Learning (DL) context (Bonk & Khoo, 2014). There are a number of interactive learning environments that can help support this endeavour. In particular, webcasting technologies allow students and lecturers to engage in real-time conversations and ask questions in real-time. Web broadcasts are covered in greater detail in Section 1.6 below, but in general, an IWB delivers live video broadcasting to students via their web browser, alongside instant chat messaging and audience polling tools to support interaction.

Student engagement is essential in educational transactions and especially in HE (Thomas, 2012). When a student feels engaged, they are more likely to have self-regulated motivation, participate fully and have an overall positive learning experience (Reeve, 1995). Most students will fluctuate in their engagement, regardless of age, background and educational setting. This is because, as discussed in Section 2.5.1, student engagement is not a stable construct but rather fluctuates based on psychological, personality and social aspects. These factors are further influenced by the institution and wider context (Kahu, 2013). The issue of engagement becomes even more salient in DE environments due to students and lecturers being geographically dispersed, having little or no face-to-face contact.

A sense of belonging to a community is inherently a human endeavour. After physiological and safety needs, individuals aim to meet the social needs of belonging (Maslow, 1999). In traditional on-campus Higher Education Institutions (HEIs), face-to-face communication predominately fosters peoples' ability to develop and maintain relational communication. Students may be influenced by physical proximity, thereby fostering a SoB to location and social environment as they navigate learning communities' spaces, and progress from novices to experts in their field (Lave, 1991). Thomas (2012) argues that a strong SoB is best nurtured through mainstream activities in which all students participate. She further suggests that academic programs offer physical space where students can engage with others and feel like they belong. IWBs provide a virtual space for OU students. More importantly, they are synchronised events which give students the opportunity to access and participate in an Online Learning Community (OLC).

Building student engagement and belonging as a means of retaining students and achieving student success has long been a priority for HEIs (Thomas, 2012). One of the strategic goals of the OUUK's five-year strategy is "success for our students". This goal entails helping students in achieving their goals, whatever and wherever they are, with equitable outcomes that open up new life and job prospects. Part of the commitment to that goal is to "strengthen the sense of community among our students, enhancing how they feel welcomed, supported and heard, including communicating effectively how we have responded to feedback" (*Learn and Live, The Open University's Strategy for 2022-2027*, 2022, p. 6).

1.2   Problem statement

In DL environments, an inherent challenge is the level of separation and lack of physical interaction between educators and students and among students themselves (Holmberg, 1986) This transactional distance phenomenon, a type of psychological and communication space, can lead to remoteness and isolation (Moore, 1989). Studies show that DL students can often experience feelings of isolation (Ali & Smith, 2015; Daviault & Coelho, 2003; Rovai & Wighting, 2005). A persistent educational challenge is motivating and engaging students, improving educational opportunities and meeting the need to make learning environments more accessible to all (Elen & Bishop, 2020).

Moreover, practical science teaching and learning can present further obstacles due to not being co-located with real experimental equipment in laboratory settings (Kennepohl & Shaw, 2010). Remote and virtual laboratories provide alternatives to the latter, enabling students to interact with authentic interfaces and technical instruments. Likewise, pre-recorded video demonstrations of scientific and technological concepts can showcase equipment and working laboratories and has had a long tradition in DE (Bates, 1984). However, conventional video has been critiqued for being a narrative media, resulting in passive learning if not used with other pedagogically designed tools (Laurillard, 2002).

As a way to bridge the gap, synchronous delivery systems have been widely utilised by educators and students to facilitate effective communication between students and educators, and between students and their peers, particularly when face-to-face communication is not available. Irrespective of the types of modalities that support communication and practical activity, questions remain about how geographically

separated educators and students experience engagement, social connectedness, and SoC, all of which require real-time group interaction and a sense of 'being there', which are often lacking in DL environments (Lowenthal & Dennen, 2017).

1.3   Research aim and question

The primary aim of this thesis is to increase an understanding of the ways that IWBs have been applied in STEM modules and to explore how they benefit the stakeholders involved in them. Particular field and laboratory based IWBs, known as Fieldcasts and Labcasts, are investigated across five undergraduate practical science modules. The IWBs are used to enhance student engagement, support practical work and foster a SoC without being co-present in the same place, but at the same time. Thus, IWBs are essential 'synchronous' and 'remote' events. The central research question is therefore:

- **How do interactive web broadcasts foster distance learning students' engagement with practical lab and fieldwork?**

1.4   The setting and context

The OUUK offers accredited and undergraduate and postgraduate degree programmes to adults on a part-time basis. The university is one of the largest in Europe with 205,420 students (*Facts and Figures*, 2017). People study at the OUUK for a variety of reasons, including to update their skills, advance in their careers, gain a qualification or simple for the sake of lifelong learning (*Facts and Figures*, 2017). 70% of students work full-or part-time during their studies and 77% of OU undergraduates had no prior HE qualification when they started (*Facts and Figures*, 2017).

Established in 1969, the university promotes a 'supported open learning' system by providing materials for flexible study, personal tutorials and specialist advisers. Modules are structured to fit the supported learning needs of OU students and are organised around a course calendar. Progression is based on bite-sized learning activities (e.g., 10 to 15 hours of reading and learning activity per week) within module blocks covering the main subject areas. Students across the STEM faculty access their modules and communicate with their peers, lecturers and tutors via a dedicated learning environment. Modules generally contain video and audio clips, animated figures, self-assessment questions, summaries and glossaries to support and reinforce learning. Tutor Marked Assignments (TMA's), Computer Marked Assignments (CMAs),

and End of Module Assessments (EMAs) are used as formative and summative assessments during a module presentation. Several STEM modules have residential or lab schools to facilitate practical skills development at university teaching laboratories or field centres.

1.5   Educational broadcast

Educational broadcasting has a long history at the OU, due to its partnership with the British Broadcasting Corporation (BBC), who offer a wide range of programs designed for study in degree courses (Bates, 1984). Through its initial one-way delivery phase, the OU operated at scale using mass print-based learning materials, educational broadcast and audio-visual resources, which interdisciplinary module teams planned and devised (Mason, 2002). As technology advanced, video cassettes and CD ROMS were used less. IWBs have therefore built on previous broadcast solutions and web-oriented media. IWBs are positioned within the broader field of educational broadcasts. Other uses of live broadcasts for education and general interest purposes are shown in Table 1.1.

Table 1.1: Live broadcasts used for education and general interest.

Genre	Broadcast name (year)	Institution	Format	Purpose	Audience
Education	Seeing with Atoms (2019)	University of Cambridge	Lab-based livestream microphone to facilitate audience questions	Demonstrate scientific apparatus during a science exhibition	General public
	Relationships in an ecosystem (2020)	Field Studies Council	Field-based livestream YouTube live chatbox Catch up video	Support school curricula for fieldwork	Student cohorts
General interest	From Life (2018)	The Royal Academy	Livestream Hybrid audience Twitter	Life drawing	Casual audience ~ 5,000
	Springwatch (2005-2020)	BBC	Live broadcasts Message boards	Charts British wildlife through the seasons	Casual audience ~ 3.41 million

The KMi Stadium, established by the Knowledge Media Institute's (KMi) Marc Eisenstadt and team at the OUUK in the mid-1990s, created large scale one-to-many webcasts on the Websymposia platform (Eisenstadt, 1998). The design philosophy was to create remote telepresence; that is, a sense of 'being there and would help remote audiences experience "the look, feel, excitement and overall sense of presence at an event (…) an enhanced experience using the latest Web-oriented media" (Eisenstadt, 1998, p. 153). As the prototypes improved and different pedagogic activities and events, such as virtual summer schools and live experiments, were supported; the system would later become Stadium Live and be adopted more broadly across the OU. Stadium Live is an in-house hosting platform that allows presenters to set up live events in advance. Table 1.2 outlines the trajectory of large-scale remote events.

Table 1.2: The development of OU large-scale remote events and examples of use adapted from (Collins, 2016).

Prototypes	Example of use	Year
Virtual summer school	A pilot for 12 students supplied with hardware and resources to attend tutorials, lectures and run experiments.	1994
'Maven of the month' Internet talk radio interviews	Live 30-min interviews with a leading researcher or personality with static images, audience questions and sound effects.	1995
KMi Stadium – Large scale telepresence	A Java medium for hosting various distributed events, which include main presentation, live audio, slide show, and custom crowd noises.	1995
Lyceum – Internet voice groupware for DL	Piloted by foreign language students to enable voice conferencing, break out rooms and visual tools.	1999
Stadium Live – Student Hub Live	A live, online interactive platform that delivers extracurricular events such as study-skills workshops.	2014-present
Stadium Live – Labcasts and Fieldcasts	Live, interactive web broadcasts used by STEM faculties for field and lab investigations.	2014-present

1.6 Labcasts and Fieldcasts

As a complement to existing learning support systems, Labcasts and Fieldcasts were set up to provide STEM students with an opportunity to observe and engage in practical science through an interactive experience with lecturers using synchronous methods. The events are broadcast from the OpenScience teaching laboratories on campus and on local field sites to engage students in practical science and technology

in the lab and introduce fieldwork by student-led field investigations. They can accommodate hundreds of students, live stream high-definition video and audio, incorporate interactive audience polling (known as widgets) and real-time text-chat. A technical production team video mixes the live stream and integrate slides, video and live feeds of remote instruments and experiments. The bi-directional flow of communication is represented in Figure 1.1.
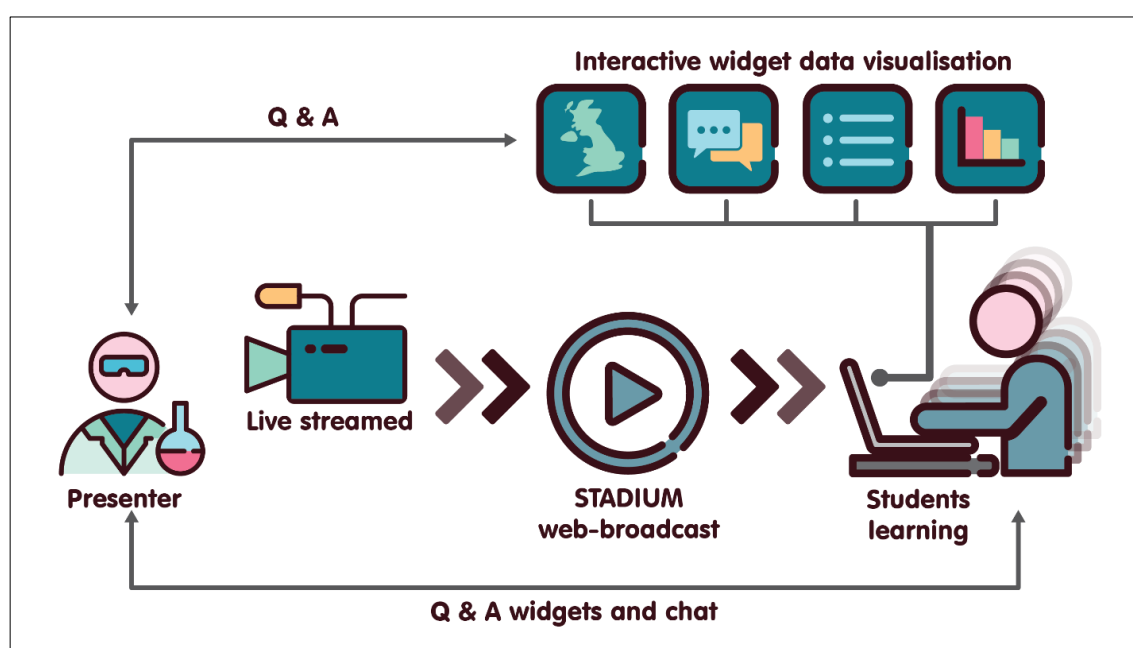
Figure 1.1: An illustration of the bi-directional communication flow in a Stadium Live Labcast (courtesy of Harriett Cornish).

There are challenges of live video production. Balancing production quality and flexibility entails managing high quality video and audio from multiple sources and adapting camera connectivity based on indoor or outdoor broadcasting. Video streaming protocols are required to have reliable and consistent streaming and keep video and audio synchronised. However, these protocol types and discussions are outside the scope of this thesis.

Figure 1.2 below shows the Stadium Live Labcast interface, which is what the students see and interact with. The video window can be expanded to full screen and the widget and chat areas can be moved around. The interface enables interaction and messages sent in the chat box to be seen by everyone. A recording is made available after the live event, but the widgets and text-chat are no longer accessible.
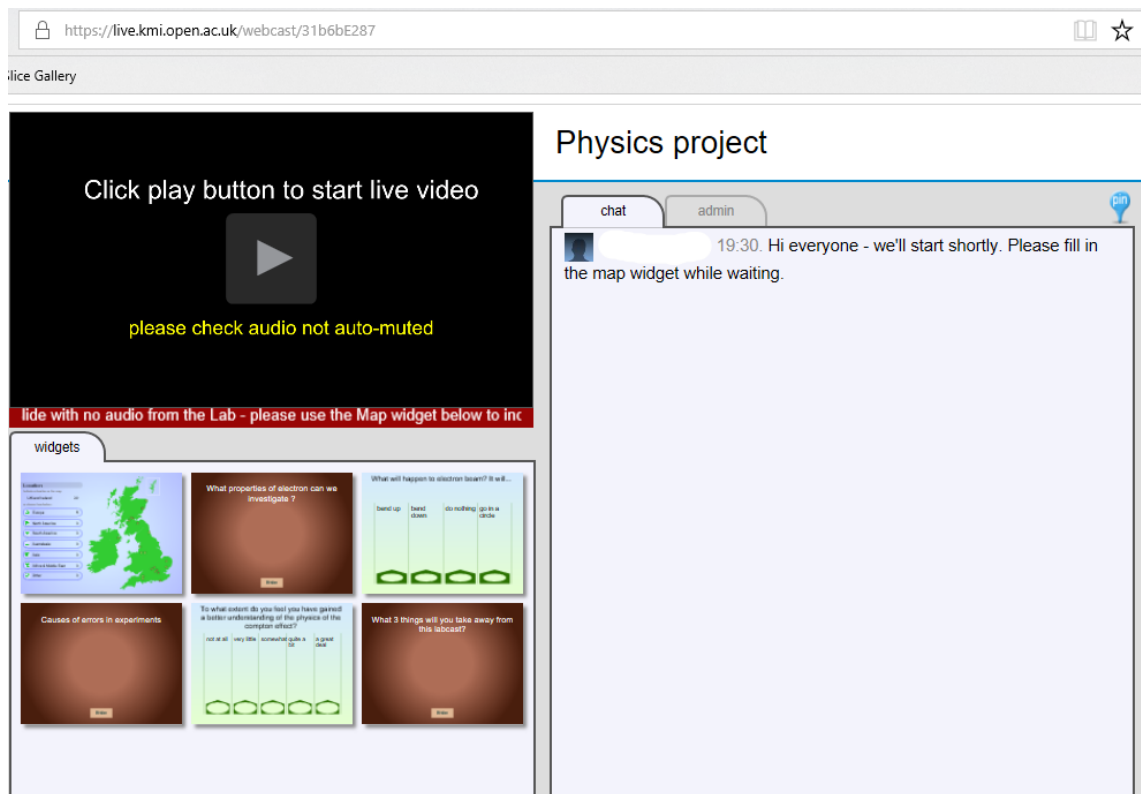
Figure 1.2: Stadium Live Labcast interface (top left); the video window (bottom left); the widgets and the text-chat box (right).

1.7 Thesis structure

Chapter 2 reviews the literature in relation to the problem statement and the research aims and questions. It situates the theoretical framework of the study before discussing some of the central concepts of DE. The issues and challenges related to DE are then reviewed and the pedagogical solutions to address those issues are discussed. Conceptual frameworks and models that support the pedagogical solutions are reviewed. Lastly, the technology-mediated media to support engagement, learning and community are introduced.

Chapter 3 presents the methodological approach used in the study and the data collection methods and analysis to investigate the research questions. It situates the research paradigm and justifies the mixed-methods research approach. Ethics and recruitment procedures are discussed, and the data collection procedures are described and justified. Chapter 4 reports on the qualitative and quantitative findings to answer the research questions. The chapter is divided into four parts: details of the participants, planning web broadcasts, implementation of web broadcasts and the impact of web broadcasts.

Chapter 5 discusses the findings and answers the research questions in the context of the literature. Chapter 6 discusses the conclusions and future work. It presents a summary of the findings and discusses the original contribution made to the state of the art. Limitations are considered and areas or future work are suggested.

The thesis uses the American Psychological Association (APA), 7th Edition style and has some notations. When presenting the data, staff and student comments are presented in a block quotation or within quotation marks within the text. Where ellipsis is used to shorten a sentence or combine two sentences together, this is shown by (…) Square brackets [] are used to clarify meaning.

2 Literature review

Section 2.1 outlines the research questions (RQs) that direct the research in this thesis. The social aspect of learning is discussed in Section 2.2, and it is argued that learning is intrinsically social, even when separated by time and location. Learners socially engage and co-construct knowledge through collaborative discourse and observation of others. This constructivist position builds on the understanding of educational theorists who recognised the role of community to support learning. As a central premise, learning is considered a highly social activity.

Section 2.3 reviews some key concepts in DE and argues that communication is central to DE and discusses its pedagogical roots in conversation and interaction. The challenges of isolation and carrying out practical work is considered in Section 2.4. Some key pedagogical solutions to address those challenges are discussed in Section 2.5. The section argues that student engagement is one of the cornerstones of the student experience and is interconnected with other educational constructs, such as, presence, community, interaction and learning that foster it. The section also reviews the approaches and frameworks that have been used and why they were selected to inform the research design and discuss the findings. Section 2.6 explores the technologies and tools used to support teaching and learning as it relates to the practical STEM subject-matter before summarising the chapter in Section 2.7.

2.1 Research questions in the context of the literature

The problem statement in Chapter 1 highlighted some of the overarching challenges and obstacles of studying at a distance. To answer the main question in Chapter 1, this is further explored through the following six research questions:

- RQ1. What are the module teams' *purposes* for using interactive web broadcasts?
- RQ2. What *strategies* do the presenters and moderators apply to interact and engage with students?
- RQ3. How are students using the widgets to *interact* with the presenters?
- RQ4. How does participating in interactive web broadcasts contribute to *knowledge-building* discourses?
- RQ5. How do interactive web broadcasts support students' learning, and what *motivates* students to engage (or not engage) with the interactive web broadcasts?

- RQ6. In what ways does participating in interactive web broadcasts contribute to students' *sense of community*?

2.2 Learning as a social activity

Learning is a broad notion that encompasses a vast range of specific and distinct elements and processes (Passey, 2014). One of the perspectives in which learning can be considered is through a social lens, which views how learning occurs through social interaction in different settings and circumstances. This constructivist viewpoint emerged in response to criticisms of behaviourism, which asserted that a learner is essentially passive, responding to environmental cues and having their behaviour shaped by positive or negative reinforcement (Delprato & Midgley, 1992).

Social constructivists argue that shared human behaviour creates reality and that knowledge is a product of human creativity constructed through social and cultural processes (Pritchard & Woollard, 2010). Thus, learning is neither simply an individual nor a passive process, but a participatory process where students actively participate (Jonassen et al., 1995). Learners use their prior knowledge as a foundation and build on it to gain new knowledge. Effective learning occurs when an individual engages with people in a social setting and when new or recurrent sensory input (e.g., speech, visuals, demonstrations) is related to pre-existing knowledge and understanding. Learning and understanding are unique due to students' distinct experiences as each learner forms their own representation of knowledge (Pritchard & Woollard, 2010).

A social constructivist approach is broadly based on the work of Lev Vygotsky. A fundamental principle is that learners rely on social interaction with others for stimulus, challenge, and shared activity; which help foster thinking, engagement with ideas and activities, including acquiring knowledge and comprehension (Vygotsky, 1978). Vygotsky also believed that the role of community is vital in making meaning and should engender an active role of the learner. As such, collaborative dialogue through social interaction with the *more knowledgeable other* facilitates learning (Vygotsky, 1978) and is often a social dialogical process between students, their peers and educators.

Similarly, Bandura's social learning theory proposed that learning can occur simply by observing the actions of others in what he termed observational learning (Bandura, 1977). This can be modelled via live, symbolic or verbal instructional modelling. The

theory considers human behaviour to result from interaction with the cognitive, behavioural and environmental influences in one's surroundings. Bandura also noted internal mental states and motivation as essential parts of the learning process as they determine whether a behaviour is learnt or not (Bandura, 1977).

Through his experiential learning cycle, Kolb (1984) theorised learning as transformative experiences. Kolb believed that "learning is the process whereby knowledge is created through the transformation of experience" (1984, p. 38). The experiential learning cycle is typically presented as a cyclical four-stage learning process, including: (1) concrete experience where a learner actively experiences or does an activity like a lab session or field work; (2) reflective observation whereby a learner reflects back on the experience; (3) abstract conceptualisation, where a learner attempts to conceptualise a theory or model of what is observed; and (4) active experimentation, where a learner tests what they have learned in a new situation or environment.

Distance education evolved from cognitive behavioural pedagogical roots and later to social constructivist pedagogy, with its first models derived from forms of traditional education (Pritchard & Woollard, 2010). These approaches also coincided with the evolution of networked, digital technologies and interactive affordances, which enhanced capability, capacity and variety, allowing institutions to lower typical costs associated with interaction for social learning (Wang et al., 2014).

This thesis positions itself within social constructivism as a subset of constructivist learning theory. The study investigates IWBs as one media that attempts to situate scientific and technological practice and learning by providing an online space where social interaction, collaboration and knowledge can be co-constructed by a community of experts, lecturers and learners. In addition, engagement and discourse in a web broadcast environment are viewed in this study as a socio-constructivist process.

2.3 Concepts of distance learning in higher education

Distance education (DE) has traditionally been defined by the quasi-permanent separation of teacher and student (Moore, 1989, 1993). Students are not ordinarily present at an educational institution but benefit from an institution's planning, tuition and guidance. Seminal theorists Holmberg (1986, 2005) and Keegan (1996) have argued that DE is a distinct form of education and academic inquiry, with its

conceptual frameworks and complex set of interrelationships. DE is a multidisciplinary field that is found across various educational sectors.

Central to DE is the concept of communication. Holmberg noted that "the communication element is rightly considered a cornerstone of distance education" (1986, p.54). Communication can be seen to operate in at least two fundamental ways: a one-directional, paper-reliant approach in which learning materials and resources are sent from an institution to students. The other approach is two-directional consisting of interaction between students and the institution. Likewise, interaction has two distinct contexts: the first is an individual isolated activity, in which a student interacts with the material, whether it is text or video; the second is a social activity, in which two or more individuals interact about the learning material. Learning necessitates both types of interaction (Bates, 1984).

Teaching and learning are mediated through two main delivery systems: asynchronous computer-mediated communication (CMC) and synchronous CMC. Synchronous technologies facilitate real-time, simultaneous interaction and communication between individuals. Types of media include videoconferencing, interactive television, instant messaging and student response systems (i.e., polling widgets or clickers). Asynchronous systems are when the student is not in real-time communication with the lecturer or with other students. It includes online discussion forums, electronic mail, as well as traditional methods that use books and videos. Before the emergence of CMC systems, individuals were usually taught as individuals with an absence of the learning group but with the possibility of occasional meetings for both didactic and socialisation purposes (Keegan, 1996). For Keegan (1996), the provision of two-way communication whereby students may benefit from, or even initiate dialogue distinguishes DE from other uses of technology in education.

This two-way communication facilitates stakeholders to establish the educational interactions between learner-teacher, learner-content and learner-to-learner (Anderson, 2003; Holmberg, 1986; Kanuka & Anderson, 1998; Laurillard, 1993a; Moore, 1993). Learner-interface interaction was added by Hillman, Willis and Gunawardena (1994), who described it as a "process of manipulating tools to accomplish a task" (1994, p. 34). The authors argue that this type of interaction was

imperative because "the learner must interact with the technological medium in order to interact with the content, instructor or other learners" (p.33).

As distance learning grew and started to be offered across different educational contexts, Garrison, Anderson and Archer (1999) would later propose the Community of Inquiry (CoI) model to inform the conceptualisation of teaching practice and student learning. The model is a process-oriented one that considers three elements: social presence, teaching presence and cognitive presence. Although the model has received significant attention and has been well researched and modified (Arbaugh et al., 2008; Cooper & Scriven, 2017), it does not fit DE contexts well as it is based on learning collaboratively, which is not the main premise of DE universities.

2.3.1 Conversation theories and models

The first serious theoretical discussions and pedagogical models for DE emerged during the 1960s with Holmberg's conversational approach to course development (Holmberg, 1960). He proposed an *empathy approach* and conversational theory. Underpinning this theory is how dialogue can be supported through the medium of text. Holmberg's guided didactic conversation is presented in written materials and other interactive environments. For Holmberg, the assumption was that interaction is at the heart of teaching, aided in part by materials meant to encourage students. This engagement, which fosters a sense of belonging or rapport with the tutor and organisation, is achieved by employing a "personal, friendly interaction between students and tutors and conversation-like presentations of subject matter" (Holmberg, 1986, p. 38). Second, the student's sense of belonging, pleasure and motivation are all linked. According to Holmberg, learners who develop a favourable relationship with their learning organisation will find their learning more pleasurable, which will boost their motivation and help them learn more effectively. However, one of the limitations of this theory is that Holmberg focused on the individual learner rather than learning as a social activity. Further, by his own admittance, he did not consider the technological developments that occurred in the last few decades of the 20th century. Derek Rowntree (1994) later advocated a similar approach, a 'tutorial-in-print', which acts as a personalised tutor through one-to-one dialogue. The OU has used these dialogic models and feedback loops in their course materials, both print and online.

Another approach, developed by Gordon Pask, also viewed the teacher-student conversation as crucial to the learning process (Pask, 1975, 1976) . His conversational learning model was one of the first attempts to provide learners with an interactive environment that facilitated dialogue and interaction with an expert. In this model, the teacher and the student converse about their respective representations of knowledge. Concerning learning and teaching in science education, Pask views conversation exchanges as having two logical levels: how and why. The former is associated with operation learning. For example, how you 'do' a subject. The latter is concerned with comprehension learning, which requires explanation or justification. Pask considered both as mutually beneficial and necessary for effective learning. Demonstrations occur in the modelling facility or microworld, and the 'how' and 'why' discussion can occur between students and teachers and among students. Transactions happen when the teacher receives or explains a topic. The student responds by asking why questions and can initiate the conversation (Scott, 2001).

Although Pask and Holmberg believe that conversation is fundamental in learning, their ideas are approached entirely differently. For Holmberg, improving the DE student's experience through the unique features of conversation is of primary importance and is more student focused. On the other hand, Pask views conversations to understand the learning process and is, therefore, more teacher focused. Later, an attempt was made to use and enhance Pask's work as a framework for educational technology (Laurillard, 1993a). Like previous theorists and researchers, Laurillard views dialogue as the heart of learning. The learning process, according to Laurillard, consisted of four necessary elements: (1) discursive, which allows students and teachers to discuss a topic; (2) adaptive, where the teacher adapts the student's interaction with the world to allow them to experience it from the teacher's perspective; (3) interactive, where the student interacts with the world and receive feedback on their actions; and (4) reflective, where the student reflects on their experience (Laurillard, 1993a, 2002; Laurillard et al., 2018).

Similar to Pask's model, learning occurs via a communication cycle from teacher-learner and learner-teacher and active generation, modulation or reflection on information or concepts received by the teacher or learner (Laurillard, 2002). The teacher and student discuss a concept, and the teacher reflects on what the student is

doing and adapts the dialogue accordingly. The student iteratively adjusts their activities in response to what the teacher says and evaluates the results until their understanding of the concept matches the teachers. Laurillard offers her framework as a criterion to assess how various media support each component of Pask's conversation theory. She argues that conversation is the crux of the academic teaching process but that most educational media do not support this process (Laurillard, 1993a, 1993b). Laurillard is particularly cautious of broadcast media which, like print, tends to reinforce the information acquisition model of learning if not used with other interactive tools.

Both Pask's and Laurillard's theories are helpful to understanding the functional aspects of the learning process. However, neither consider the more emotive or affective aspects of learning that are inherently part of human communication (Yule, 1985). On the other hand, Holmberg posits that emotions are crucial in the learning process of the DE student, but his theory lacks the details of the functional aspects of the learning process. Another limitation of these theories is that they limit learning to the teacher-student dynamic while ignoring the potential ecologies of learning communities in which students may be involved. This issue is especially relevant in light of current undergraduate practical science modules delivered entirely online or in a hybrid format and may include a variety of groups, fora, and learning environments.

2.3.2 Defining interaction

Interactions play a crucial role in educational activities in DE and are considered a necessary component for a successful learning experience (Bernard et al., 2009; Vrasidas & McIsaac, 1999; Wagner, 1994); student motivation (Mahle, 2011; Saleh et al., 2005) and student satisfaction (Kuo et al., 2013; Swan, 2001). Interaction is a complex and broad concept, and there are several definitions in the literature. Daniel and Marquis (1988) defined interaction as an activity in which a student interacts with one or more individuals in a two-way manner. On the other hand, Simpson and Galbo (1986) argue that the critical trait of interaction is the "reciprocity on actions and responses in an infinite variety of relationships" (1986, p. 38).

A broader perspective was later adopted by Wagner (1994), who expanded the definition as "reciprocal events that require at least two objects and two actions" (1994, p. 8). She suggested that interactions take place when these two objects and

events mutually influence one another. For Wagner, interaction and interactivity are different activities whereby "interaction functions as an attribute of effective instruction while interactivity functions as an attribute of instructional delivery systems" (1994, p. 6). According to Sherry (1995), interaction is students' engagement with fellow students and instructors. Sherry further adds the dimension of connectivity to interactivity, which not only is limited to audio and video or teacher-student interactions but "represents the connectivity the students feel with the distance teacher, the local teachers, aides and facilitators and their peers" (1995, p. 344). Thurmond and Wambach (2004) posit that interactions occur when students are engaged with teachers, other students, the course content and the technological medium utilised in courses. This description best explains interaction in an IWB environment. However, Wagner's distinction of interactivity as a machine feature and interaction due to employing interactive tools and media systems is adopted in this study. Despite the lack of agreement on the definition of interaction, its value in education is emphasised in the literature.

Interactions have long been acknowledged as essential components of science education (Boschmann, 2003; Burke & Greenbowe, 1999; Velasco et al., 2016; Wei et al., 2019). The learning environment in traditional laboratories consists of the students themselves, other students, instructors, laboratory manuals, equipment and computers (Wei et al., 2019). The authors suggest a combination of interaction types common in science laboratories: student-student interaction, student-instructor interaction, student-equipment interaction, and indirect interaction. The next sub-section discusses some of the fundamental issues that can arise in DE teaching and learning.

2.4   Distance education issues

One argument that is made against DE is that it lacks the richness of experience that can be gained in a classroom setting with other students. However, DE can be designed to allow student-student and student-lecturer contact to be comparable to or exceed those found in traditional classrooms (Mehrotra et al., 2001) and much research has shown similar or superior learning outcomes of DE vis-à-vis traditional classrooms (Bernard et al., 2009; Faulconer et al., 2018). Nonetheless, the lack of face-to-face, student-student and student-lecturer interaction continues to be one of the main

barriers to effective learning experiences in DL (Bernard et al., 2009; Lyons et al., 2012; Muilenburg & Berge, 2005). Students tend to be geographically more dispersed than traditional campus-based students and there is evidence within the literature that part-time distance learners have needs and challenges that are different to full-time and campus-based learners (Butcher, 2015; Karal, 2011). It has been widely accepted that feelings of isolation (defined in Section 2.4.1) is a barrier to learning and the wellbeing of students (Rush, 2018; Wegner et al., 1999). Challenges of isolation and carrying out practical work have likewise been reported in the literature, the next sub-sections treat each in detail.

2.4.1 Feelings of isolation

Despite independent learning being at the core of the DE student experience, the psychological and communication gap inherent in DL can often lead to feelings of isolation and disconnection, making the provision of authentic learning experiences challenging. The term isolation has its roots in Sigmund Freud's Psychoanalytical theory. As it relates to human relationships, isolation has been defined as a lack of social integration manifested by fewer and less diverse social interactions (Reis & Sprecher, 2009).

In DE discourse, isolation, loneliness, alienation and remoteness are often used interchangeably (Palloff & Pratt, 2007). Mann (2005) defines alienation in the learning environment as "the experience someone may have in education, by which they feel unable to engage or contribute in ways that are meaningful and productive or the realisation of their own potential and learning requirements" (p.43). As a result, alienation can lead to feelings of social and self-isolation (Rovai & Wighting, 2005). Numerous studies have examined the impact of isolation in DL environments (c.f., Garrison et al., 1999; Rovai & Wighting, 2005; Stodel et al., 2006; Croft et al., Dalton & Grant, 2010; Rush, 2018). Survey data from the 'What Works' project, a three-year programme that considered student retention and success in English HEIs, identified feelings of isolation as one of three key reasons students withdraw (Thomas, 2013).

Feelings of isolation is part of the complex notion of what a 'disengaged' student might feel and may lead to aspects of social and academic attrition (Tinto, 1975). Purvis (1979), in his early review on the OU's teaching and learning, pointed out that isolation may not only be a short-term phenomenon, but might occur over the course of a

qualification as a typical OU undergraduate student spends a minimum of six years studying to obtain a degree. For part-time adult learners, one of the most attractive features of DL is perhaps the convenience and flexibility for students to study at their own pace, in their own time and location. However, Butcher (2015) argues that flexibility is a contentious issue and while many students may require the convenience, it might come at the cost of feeling alienated. On the other hand, Van Ameijde *et al.* (2018) suggest that some OU students choose the institution precisely to study independently without input from others.

Isolation can occur in a variety of forms. Lake (1999) suggests that isolation can manifest as a physical, geographic separation from material or human resources whereas for Daviault and Coelho (2003) the technologies, used to promote connection between spatially distant students, may be the thing to frustrate and alienate students, resulting in feelings of disenfranchisement with effective technology use. On the other hand, researchers Ali and Smith (2015) are more concerned with the relational aspect of technology and believe that our reliance on it has diminished our need for direct communication with others. They further argue that because students spend substantial time alone in the DL environment, they have less opportunities to meet and speak with others, which can lead to social isolation.

Investigations have reported issues such as professional, academic and ethnic otherness (Phirangee & Malec, 2017) and perceived lack of authenticity in developing social relationships (Boling et al., 2012). In a study on a distance MA Built Environment course, Croft et al., (2010) investigated how student learning experiences could be enriched by reducing potential isolation. Using a three-stage mixed-methods research approach (i.e., telephone interviews, participatory workshops and questionnaire surveys), they found that students ranked 'finding out where and who fellow students are' as the least important of potential solutions for overcoming feelings of isolation. Improved tutor contact and sharing experiences and tips with their peers were deemed the most important. The authors go on to summarise several dimensions where isolation can be found such as "social (awareness of others), intellectual/experience (academic ability and life experiences), profession (subject-related expertise), ICT knowledge, sensory (ability to see/feel/hear peers), cultural, and subject - if anyone else is studying the same topic" (Croft et al., 2010, p. 33). Their

study is in agreement with Owens et al., (2009) who found that students from remote regions at an Australian university were looking for opportunities to share their learning experiences with their peers rather than for social reasons. Both Owens et al. (2009) and Croft et al. (2010) highlight certain key factors. That is, feelings of isolation are likely to be subjective and relative to students' needs, expectations and attitudes. Students' motivation, learning styles and previous learning experiences are factors that may influence the extent to which this phenomenon is experienced, if at all.

Historically, HEIs have taken proactive measures to combat isolation by promoting assimilation and familiarisation with the institution and its communities through the development of social groups and organised social events (Mehrotra et al., 2001). Some HEIs that use DL as a part of blended delivery or as a stand-alone course enable socialisation activities, such as virtual pre-arrival activities and welcome groups on social media, as part of a flexible socialisation approach (Gordon, 2014). Others have used pre-induction socialisation MOOCs to facilitate flexible learners' transition into HE (Brunton et al., 2017) and livestream broadcast events for virtual freshers' fairs and academic workshops (Foley & Marr, 2019).

In terms of pedagogical practices, Dickey (2004) found that using blogs as a discourse tool helped prevent feelings of isolation by affording students opportunities to socialise, engage and express their feelings and emotions. Other strategies included assigning email partners and establishing an obligatory discussion group to foster better interpersonal communication. In their study of an online graduate program, Kaufmann and Vallade (2020) found that the lecturers' roles in developing and maintaining rapport and climate were key in alleviating feelings of loneliness in an online classroom.

The need to overcome feelings of isolation and disconnection through effective course design and pedagogical strategies that promote interaction, student engagement and connectedness remains a fundamental agenda for many distance learning providers (Kirkwood & Price, 2013). Fostering engagement, interest and community are paramount to mitigate isolation as will be discussed in Section 2.5. However, another challenge in DE is being able to conduct practical work to which this section turns.

2.4.2 Doing practical work at a distance

Teaching of practical skills in a DL environment is a challenge for both lecturer and student, and poses far more challenges than teaching knowledge and theory (Hampton, 2002). Hampton defines practical skills as, "skills performed by hand or with human intervention using equipment, tools or technology requiring guidance, force or movement" (2002, p. 83). Practical work also necessitates the assistance of skilled personnel, tools and equipment in order to facilitate the development of skills (Hampton, 2002). Furthermore, teaching practical work requires the use of specific instructions and resources to enable learners to follow the process and then repeat the skill to demonstrate competency (Donkor, 2011). However, issues concerning students' use of instructional resources are especially important in the DE setting when students have little or no supervision (Jones & Petre, 1994).

Various courses in the social sciences, humanities and vocational courses are taught in DL environments and usually require some element of practical work. While a history student may have access to archives and an artist to a studio to practice their subject, the wider issue of accessibility, supervision and equipment remains. Traditionally kits and materials have been mailed to students, but the mechanics of transit, size restrictions, cost and the risk of damage to objects (as well as potential delays) can be a challenge (Kennepohl & Shaw, 2010). Students may or may not have access to dedicated work or studio spaces. There is also the matter of assessment, evaluation and academic integrity (Boschmann, 2003). Although written examinations can test knowledge and skills, demonstrating competence through practical performance can be difficult (Hampton, 2002). There is a need for educators to teach and students to follow instruction, as well as demonstrate and practise. Therefore, resources and technologies that support practical work are paramount. This is true in many disciplines, but it is particularly the case in practical STEM-related courses.

2.4.3 Doing practical work in STEM subjects

As previously discussed, practical work is important in courses that have hands-on components. It has been argued that teaching and learning DE science disciplines is particularly challenging due to the practical and applied components of the laboratory or field (Dalgarno et al., 2009; Holmberg & Bakshi, 1982; Kennepohl et al., 2005). Accessibility to equipment, labs and spaces where students can practise their subject

can be an issue. Students with disabilities and those who are not near to an accessible conventional laboratory setting might be disadvantaged (Whalley et al., 2011). Where experimental instruction involves equipment and apparatus that are large, expensive or dangerous, there are usually more restrictions (Bates, 2015). The scientific community deem practical work to be fundamental as it is the link between the real world and scientific ideas (Kennepohl & Shaw, 2010) and according to Coll and Eames (2008) practical work and skill development are an essential part of any undergraduate programme.

Scholars in the field have noted that one of the most challenging aspects is offering a meaningful, practical experience in which students undertake authentic tasks that are reflective of the real-world (Argles et al., 2017; Branan et al., 2016). Even when technology-mediated tools are provided, such as a virtual microscope, Whalley et al. (2011) point out that students may regard the tool as second best, detracting from the genuine experience of gazing down a microscope. The authors also contend if students are solely exposed to a virtual microscope, they may feel intimated or frustrated when confronted with a physical microscope. Another contentious issue is the absence of the instructor or tutor during investigations and laboratory experiments to address queries in real-time (Abdel-Salam et al., 2007; Jones & Petre, 1994).

It has also been reported that carrying out practical computing tasks is challenging (Hilliard et al., 2020; Jones & Petre, 1994). One such area is remote pair programming (RPP) where programmers are co-located and work in pairs to write and check code in a collaborative manner. Adeliyi et al. (2021) investigated the use of remote pair programming (RPP) within first-year and second-year computing modules at The OUUK. The researchers were interested in whether readily available and easy to install collaborative tools, such as Microsoft Teams, Skype and Zoom, could be adopted for RPP and if students could transition from solitary to collaborative programming. Reflective journals and questionnaires were used as methods. Students were requested to work together on non-assessment programming activities that they would have ordinarily done individually as part of their studies. Their study found that the students (n= 24) that were paired randomly struggled to find an appropriate time to accommodate the activity. Other reported issues included partners failing to show up for sessions and technical difficulties. Furthermore, Hilliard et al. (2020) found that

working in an online computing collaborative project caused part-time distance learners to feel doubtful and anxious. Relying on 'unknown others', fear of negative evaluation and concerns about working with non-active group members were among the causes. Both studies indicate the challenges of group work in a DL environment; both from pragmatic (e.g., technical issues, scheduling synchronous activity) and affective (e.g., anxiety, working with others) perspectives. Students might be willing to participate, but that may lie on a continuum of resistance to full participation.

The impact of practical work on student learning is also noted. Scanlon et al. (2002) argue that practical work plays a role in students' knowledge construction in which they gain both conceptual and procedural understanding. The authors view this type of learning as a particularly difficult learning curve for DE students learning science (Scanlon et al., 2002). In addition, there are differences in teaching practices and experiences across STEM disciplines; each have distinct epistemologies and ways of practice (Kennepohl, 2016; Shulman, 2005). As a result, what works well in one area within a DE delivery system may not work well in another. The intricacy of biological models and diagrams, as well as the visual representation of biological concepts across hierarchical levels are two examples. Wright et al. (2016) argue that because so much of biology is taught using complex visual representations, it is vital to include the lecturers' modelling and commentary in the online environment. Whereas, a unique problem for the physics educator might be the constraints of display equipment and the text-handling systems necessary to use math notation in physics teaching (Lambourne & Braithwaite, 2016, p. 69).

In their study of students on two foundation science courses at The Open University of Hong Kong (OUHK), Chan and Shin (2006) investigated students' perspectives on learning science at a distance. Methods employed were in-depth interviews, questionnaire surveys and field observations. The findings revealed that although 97.9% of surveyed students (n=47) thought it was essential for a science course to include practical work, 80% of students did not think computer simulations or other virtual components could replace practical work. When comparing the relative difficulty of learning science through distance education compared to face-to-face education, the surveyed students deemed it to be more challenging than they had anticipated. Comparing perceptions of difficulty on a 1 to 5 scale before and after the

course (with 1 being the easiest and 5 being the most challenging), the mean difficulty increased from 3.21 to 3.64.

In an OU Practical Science course at the OUUK (S288), Argles (2017) reviewed the use of open-source Geographic Information System (GIS) software. Students in the Geoscience, Chemistry, Physics and Environment disciplines performed practical science investigations in the topic 'Remote observations'. The short-time frame for implementing the tool, the variety of scientific content and the low level of presumed GIS knowledge were found to be factors that impacted the teaching style. Forum support on the module was rated as positive by students in discussion forum threads. However, features of the topic, general IT issues, online study and overall workload were rated negatively. Table 2.1 highlights some of the challenges for distance teaching of practical work in comparison to face-to-face GIS practicals.

Table 2.1: Comparison of face-to-face with online distance GIS practicals. Source (Argles, 2017, p. 342).

Feature of practical	Face-to-face	Online distance
Timing	Synchronous; whole cohort present	Asynchronous; cohort fragmented
Study pace	Prescribed or adaptable	Variable
Hardware/Software	Consistent for cohort	Variable across cohort
Demonstrator(s)	Available throughout session	Not always (or ever) available
Problem-solving by instructor	Reactive, targeted	Typically delayed
Issues arising	Familiar, most easily resolved	Unfamiliar, harder/more time-consuming to resolve
Peer support	Available, typically encouraged	May be delayed, requires fostering

Practical work in STEM subjects plays a critical role in students' understanding of scientific and technological concepts. Students improve their observation skills, operational skills and problem-solving abilities through hands-on experiences (Malm et al., 2020). The scientific research and academic communities have long utilised technologies to augment, enhance and support practical work in DE. Equally important is the objectives and aims of practical work and how they might influence the use of a particular academic intervention (MacDonald, 2008). The next section reviews the different pedagogical approaches to address the issues mentioned in the sections above.

2.5 Pedagogical solutions

Improving the student experience can be considered from both the types of technology-mediated tools to support practical work and the pedagogical aims, purposes and strategies that foster students' and staffs' capacity to engage and be engaging. The literature suggests that there is no single aim or purpose for practical work; rather most educational research propose several diverse aims and purposes (e.g., see Scanlon et al., 2002; Hofstein and Lunetta, 2004; Barrie et al., 2015). For example, Hofstein and Lunetta (2004) classify purposes into learning scientific concepts, processes and problem-solving, and motivating learners through interest. Mawn's (2016) 3E model proposes three objectives for an online science laboratory: expectations, experimentation and engagement. Fostering student engagement, according to Mawn, includes providing opportunities to link theory with practice and strengthening students' conceptual understanding (Mawn, 2017, p.97). Scanlon et al. (2002) outline the reasons why practical work is often included in science courses:

a) to illustrate the principles behind a subject, using experiments that introduce, illustrate or reinforce concepts and theories taught in other parts of the course, thereby acting as a focus for reflection.

b) to enable the teaching of procedures or skills training, and to teach skills in experimental design.

c) to introduce students to the world of scientists and engineers in practice (sometimes called the community of practice by educators).

d) to provide a focus for student-student and student-tutor interaction.

e) to motivate students, with the premise being that practical work can be important in influencing the development of positive attitudes to the subject (Scanlon et al., 2002, p. 77).

In a laboratory setting, Abdel-Salam et al. (2007) proposed that the purpose of the laboratory component is to demonstrate the principles learned in the lecture course, acquaint the students with experimental procedures and set-ups, demonstrate use and application of instrumentation, and improve the ability to present and analyse experimental data. Similarly, Woodfield et al. (2005) point to three main goals of any instructional laboratory: relate classroom theory to practice, teach laboratory

techniques, and the cognitive or analytical thinking skills congruent with a discipline. In addition to learning scientific knowledge, Hegarty-Hazel (1990) state that the goals should also include developing scientific attitudes. In their consideration of teaching online biology, Wright et al. (2016) outline four purposes: to illustrate theory and aid conceptual understanding, to highlight scale, to demonstrate connectivity and to develop discipline-specific skills (p.14). These aims span a spectrum of educational purposes; however, authors disagree on their value and to what extent the purposes should be emphasised. For example, Newble and Cannon (1995) place a greater emphasis on general cognitive understanding as well as awareness and knowledge of one's own cognition. Whereas, Barrie et al. (2015) emphasise the necessity of a cognitive-affective balance and autonomy where students take responsibility for their own learning.

Despite some of the challenges previously mentioned, many authors argue that hands-on laboratory experiments and field investigations have tremendous educational value (Fuller, 2006; Kennepohl & Last, 2000; Lambourne, 2007; Scott et al., 2012). Field study, for example, is considered to enable deeper learning and provides opportunities for students to engage in real-world relevant content (Scott et al., 2012) and Fuller (2006) suggests that it enables students to experience geographical and spatial contexts, develop topic knowledge and acquire technical and transferrable skills.

Practical work in DE is supported in a variety of ways. According to Wright et al. (2016), hands-on activities can be categorised into three broad delivery modes:

1. Independent activities such as experimental kits, which can be supplemented with discussion forums and video-based resources.
2. Online activities such as virtual and remote lab experiences
3. Supervised activities such as field trips, residential schools and on-campus activities (p.14).

In any educational setting, both the aims and purposes have a significant impact on student learning, as well as the effectiveness of the instructors or lecturers. There may be differences between lecturers' and students' view of the purposes and aims of practical work. For example, Brass et al. (2003) found that there were different conceptions of students with respect to aspects of learning physics.

In summary, there are various purposes for the use of practical work in laboratory and field-based settings. This study draws on the aims and purposes reviewed in this section to discuss the findings and answer RQ1.

2.5.1 Fostering student engagement

Interaction and engagement are often used interchangeably although there are some distinct differences. Engagement is a broad phenomenon that according to Bryson (2014) represents various research traditions, methodologies, philosophies and disciplines, and is further influenced by location and contexts. Engagement encompasses academic, non-academic and social aspects of the student experience (Krause & Coates, 2008). Because each student's experience is unique, engagement is viewed as something that is in-flux and fluid rather than a stable entity (Bryson, 2014). A student's engagement is also socially constructed and reconstructed through their interactions with others and the learning environment (Bryson, 2014; McMahon, 1997)

Like many educational constructs, the term engagement has evolved over time. For example, Christenson et al. (2012) view engagement as "the glue or mediator that links important contexts (i.e., home, institution, peers and community) to students and, in turn, to outcomes of interest" (p.3). For Reeve (1995), engagement is viewed as "the intentional and emotional quality of a learner's involvement in a task or activity" (p.10). He also positions it as the sustained behaviour, involvement and overall positive affect or emotion on a task, and having continuous interaction with an artefact or person (Reeve, 2013).

Engagement according to Christenson et al. (2012) is "a multidimensional construct involving students' emotion, behaviour and cognition"(p.6). Emotion, behaviour and cognition are three different yet interconnected and mutually supportive features that can be impacted by an intervention or a type of context (Reeve, 2013). The author further expands the characteristics of student engagement:

> "Behavioural engagement refers to how involved the student is in the learning activity in terms of attention, effort, and persistence. Emotional involvement refers to the presence of positive emotions such as interest during task involvement and the absence of negative emotions such as anxiety; and cognitive engagement refers to how strategically the student attempts to learn

in terms of using sophisticated rather than superficial learning strategies" (p.579).

Krause (2005), on the other hand, defines engagement as "the time, energy and resources students devote to activities designed to enhance learning at university" (p.3). Similarly, Kuh (2009) defines student engagement as "the time and effort students devote to activities that are empirically linked to desired outcomes of college and what institutions do to induce students to participate in these activities" (p.683). Kuh's definition implies that engagement necessitates effort from all parties, that is, students, lecturers, tutors and the institution. Although his definition is applicable to all educational contexts, it is especially important for part-time DL student who must navigate the paths of learning and autonomy while also balancing other competing demands in their lives. Lecturers and tutors must likewise develop and foster a learning atmosphere that encourages students' motivation and participation, but according to Krause and Coates (2008), students bear the ultimate responsibility for learning. In DE environments engagement takes on different manifestations, due to the lack of face-to-face contact and the ways in which teaching, and learning is mediated through technology (O' Shea et al., 2015)

Educators Kearsley and Shneiderman (1998) developed engagement theory as a conceptual framework for technology-based learning and teaching and as a result of the authors' experiences teaching in electronic and distance education. The theory underpins the central principle that "students must be meaningfully engaged in learning activities through interaction with others and worthwhile tasks" (p.1). The authors suggest that technology-mediated media can facilitate engagement in ways that are difficult to achieve otherwise. The theory is based on three principles of promoting student engagement in problem-based collaborative learning activities: relate-create-donate. The term "relate" refers to collaborative efforts involving communication, planning and social skills. The "create" principle emphasizes the need to make learning activity purposeful and contextualised, and the "donate' principle refers to making a useful contribution to the wider community, which could be related to occupational or career interests. Because of its emphasis on cooperation, collaboration and a community of learners, the authors suggest that the framework is consistent with constructivist approaches (Kearsley & Shneiderman, 1998).

Sharon Pittaway's (2012) engagement framework takes a slightly different approach to engagement, focusing on 'how' students engage. The framework proposes five non-hierarchical factors that intersect with each other: personal, academic, intellectual, social and professional engagement. The framework can be applied to both face-to-face and online modes. Personal engagement is defined as "the decision to enrol in a university course. This decision is informed by the information students receive before commencing study, which plays an important role in shaping students' expectations and their beliefs about their capacity to succeed at university" (p.41). The second is academic engagement, which refers to the academic traits and skills that students bring and actively develop as they learn. It involves autonomy of learning and becoming acquainted with the academic discourses and writing styles expected in their disciplines.

The third aspect, intellectual engagement, refers to students' engagement with their discipline's ideas and concepts, as well as the socio-political and ethical challenges in wider society from an educational perspective. Students inquire about current events and debates in their field. Effective teachers, according to Pittaway can help create this form of engagement by being passionate about ideas and stimulating student curiosity. Social engagement is the fourth element, in which students appreciate social interaction by getting to know their classmates, making friends and forming positive relationships with lecturers and tutors. Being socially engaged also refers to the informal groups that students organise and run to help them interact with others. As a result, social engagement is linked to all other aspects of engagement. Finally, professional engagement entails participating in professional learning events, workshops and conferences, as well as sharing these types of experiences with other students. Later, Kahu's (2013) conceptual framework considered student engagement as "a psycho-social process influenced by institutional and personal factors and embedded within a wider social context" (p.768).

Empirical studies in online engagement have used different methods to understand the student experience. For example, Armellini et al. (2021) investigated students' perception of their learning and social experiences in the context of an institution-wide pedagogic shift to Active Blended Learning at a British university. Data was collected through six focus groups involving 60 students. Each focus group had between two and

twenty students. The questions explored examples of effective practice and engaging learning experiences. Thematic analysis was conducted on the data. Three main categories emerged: learning experiences, social experiences and support provision. The findings also indicate that staff-student collaborations were central in promoting learner engagement and a sense of belonging, and that students valued regular synchronous and asynchronous interaction with peers above anything else.

In their study on student engagement and emotions, Kahu et al. (2015) investigated 19 mature-aged students throughout their first semester at a DE university. Video diaries and pre- and post-semester interviews were used. The findings indicate that emotions, such as interest and enjoyment, and inhibitors, such as frustration and worry, have different linkages to engagement. The authors concluded that student emotion intersects with institutional factors, such as course design, as well as motivation and background. Second, emotions, engagement and learning are all intertwined and complex, with spirals leading to ideal engagement or disengagement and withdrawal (Kahu et al., 2015)

There are numerous pedagogical practices that promote engagement. Voting and polling (discussed in Section 2.6.1 below) and inviting guest experts to facilitate discussion of issues in a real-time conversation with pre-set questions or spontaneous discussion are two examples (Bonk & Dennen, 2003).

Although the terms motivation and engagement are sometimes used interchangeably, their definitions and meanings are distinct. Motivation is "the extent to which one intends to engage in an activity" (Jones, 2020, p. 5). This definition implies that, like engagement, motivation is on a continuum. Fostering positive faculty-student, lecturer-student and student-student interactions and relationships that lead to engagement has been found to improve student satisfaction, perseverance and academic success (Thomas, 2012; O'Shea et al., 2015).

In considering RQ5, this study draws on the literature reviewed here as a way to discuss the findings on engagement from the perspective of the lecturers and students. Pittaway's framework, in particular, is useful to help answer how students engage (or not engage) with the web broadcasts and how the web broadcast may support their learning.

Students develop in knowledge, confidence, and a sense of belonging as a result of supportive peer relationships and meaningful interactions (Thomas, 2012). Community and sense of belonging emerged from the student engagement narrative. The next sections discuss the interrelated constructs social presence and immediacy, before introducing online learning communities.

2.5.2   Fostering social presence and immediacy

Social presence is one of the most widely used constructs to explain interaction and engagement (Wise et al., 2004). Early communication theorists, Short et al. (1976) initially proposed the concept of social presence by examining and comparing different communication media in regard to their its impact on face-to-face interactions. Short et al. (1976) defined social presence as the "degree of salience of the other in the interaction and the consequent salience of the interpersonal relationships" (p.65). The premise was that some media were better at establishing the quality or state of 'being there' than other media (Lowenthal & Dennen, 2017). The focus of social presence, according to Biocca et al. (2003) must remain "fundamentally a theory of how technology mediates social interaction" (p.474). Presence, according to Biocca *et al.* (2014) is comprised of two interconnected phenomena:

1. Telepresence, the phenomenal sense of "being there" and mental models of mediated space that create the illusion
2. Social presence, the sense of "being together with another" and mental modes of other intelligences (i.e. people, agents) that help us simulate "other minds" (Biocca et al., 2014, p. 2)

Short et al. (1976) also drew on earlier concepts like *immediacy,* which was described by Albert Mehrabian as "the degree of perceived physical or psychological closeness between two people" (Mehrabian, 1971, p. 152). Gorham (1988) went on to expand the concept to include verbal engagement that fostered psychological closeness between teachers and students in a HE context. The media's ability to communicate information about facial expressions, gaze, posture, attire and other nonverbal cues all contribute to a media's social presence (Gunawardena & Zittle, 1997). Immediacy can be conveyed nonverbally through smiles, gesticulations, eye contact and body orientations, as well as verbally through humour, volume control, and self-disclosure,

in which individuals disclose personal information to assist the development of trust (Gorham, 1988; Rourke et al., 1999).

Social connectedness is another related construct that comes from the field of social psychology. According to Mackie et al. (2000), one of the three primary motivational principles that underpin social behaviours, is the desire to feel connected. The terms connectedness and social presence are often used interchangeably (Slagter van Tryon & Bishop, 2012). The term 'e-mmediacy' was coined by the authors to describe the feelings of social connectedness one has with other online class through CMC interactions that simulate perceptions of immediacy. The authors argued that despite the discussions on the importance of social interaction in online learning, few contained specific e-mmediacy strategies for facilitating interactions. (Slagter van Tryon & Bishop, 2006) Three broad categories of expert-recommended strategies for overcoming social connectedness problem were identified: increased interactions, comprehensive technical support and persistent follow-up (Slagter van Tryon & Bishop, 2006, p. 56).

The concept of social presence has been studied in numerous settings. For instance, Lowenthal's (2012) thesis used a mixed methods approach to investigate how social presence emerged in an asynchronous environment among graduate students. Using word counts, content analysis and constant-comparison analysis to examine discussions, he found that small-group discussions had a higher social presence than larger ones. To measure students' perspectives, Sung and Mayer (2012) used a quantitative approach. The researchers created a 19-item Online Social Presence Questionnaire, which was administered to 612 undergraduate students from two South Korean online universities. A series of exploratory and confirmatory factor analyses revealed five variables, which accounted for 58% of the variance, indicating characteristics of social presence, namely: social respect (e.g., prompt responses), social sharing (e.g. sharing knowledge or expressing beliefs), open mind (e.g. expressing agreement or receiving positive feedback), social identity (e.g. being addressed by name) and intimacy - e.g. sharing personal experiences (Sung & Mayer, 2012, p. 1738)

Tu and McIssac (2002) employed qualitative and quantitive methods to investigate students' perceptions of social presence in a web-conferencing environment. They

found that instructors employed a variety of social communication strategies to enhance interactive communications, including initiating conversation, greetings and praise. Improved interaction enhanced social presence, albeit the frequency of engagement did not suggest a high level of social presence. The authors also report social context, online communication and interactivity as aspects of social presence that contributed to the development of a sense of community.

Hackman and Walker's (1990) study investigated the effects of teacher immediacy behaviour and system design on perceived student learning and satisfaction in a televised (one-way video, two-way audio) classroom. They found that clear graphics, interactivity and audio/video transmission, as well as instructors who enhanced presence, had a positive impact on perceived learning and satisfaction.

Shin (2003), on the other hand, questions whether social presence is the best concept for capturing how people perceive others in education settings. Distance students, according to Shin, have more individual demands than "merely identifying one's location, or feeling close to people in terms of sharing time or space" (Shin, 2003, p. 72). Those needs, he believes, are related to connectivity of learning resources and sources of support. Prior to Shin's concerns, Biocca et al. (2001) argue that as the Internet and virtual environments become more social, the necessity for a theory of social presence becomes more essential.

One of the elements of the CoI model is social presence, as described in Section 2.3 above. Rourke et al. (1999) social presence model was examined as a conceptual model. The authors further expounded on social presence (i.e., from the original CoI model) by testing and validating a scheme of content analysis for conferencing transcripts. Content Analysis (CA) is a commonly used qualitative research technique for analysing text-based discussions in CMC environments, as well as for quantifying levels of participation, examining the quality of engagement, and evaluating online learning communities (Hew & Cheung, 2003). Rourke et al. (1999) distinguish three communicative responses that contribute to social presence: affective, interactive and cohesive (Rourke et al., 1999). Affective responses are examples of emotion, feelings and mood. Cohesive refers to any sense of group commitment and use of phatics, salutations and vocatives and interactive responses are examples of interaction among participants that indicate a willingness to maintain contact.

The communicative responses are further defined by twelve indictors as shown in Table 2.2. The template's trustworthiness was determined by analysing transcripts from two graduate level courses that used the FirstClass and WebCT conferencing systems. AtlasTi, a qualitative data analysis programme, was used to analyse the messages. To quantify the frequency of indicators from the coded transcripts, the authors devised a social presence density metric that involved summing the number of instances, dividing by the total number of words and multiplying that figure by 1000. Both transcripts were found to have social presence, but their density ratings differed.

Table 2.2: Social presence model and template. Source (Rourke et al., 1999, p.61).

Category	Indicators	Definitions
Affective responses	Expressions of emotions	Conventional expressions of emotion, or unconventional expressions of emotion
	Use of humour	Teasing, cajoling, irony, understatements, sarcasm.
	Self-disclosure	Presents details of life outside of class or expresses vulnerability
Interactive Responses	Asking questions	Students ask questions of other students or the moderator.
	Complimenting, expressing appreciation	Complimenting others or contents of others' messages
	Expressing agreement	Expressing agreement with others or content of others' messages.
Cohesive Responses	Vocatives	Addressing or referring to participants by name.
	Addresses or refers to the group using inclusive pronouns	Addresses the group as we, us, our, group.

Because of its extrapolative ability to reveal the levels of social presence, the framework has been used in numerous online and distance empirical studies. One advantage of the model is that the framework's initial indicators have been expanded. For example, Swan (2003) added the indicator 'value' which is described as the expression of personal values, beliefs and attitudes. For the Interactive responses' 'acknowledgment', 'disagreement', 'approval', 'invitation' and 'personal advice' were added and for Cohesive responses, 'group reference', 'social sharing' and 'self-reflection' were added (Swan,2003).

The current research used Rourke et al's framework because it is well-suited to understand, adapt and analyse text-based discourse in a web broadcast environment. The framework draws on the principle that social presence will invariably be shaped by the different contexts in which it is applied (Lowenthal, 2012). This research adopts the social presence definition "the ability of participants to project their personal characteristics into the community, thereby presenting themselves to the other participants as real people" (Garrison et al., 2001, pp. 89–90).

2.5.3 Fostering a sense of community and student belonging

Rovai and Jordon (2004) point out that the third primary focus of change in higher education is a greater emphasis on the value of a strong SoC. One way of fostering social presence and addressing the problems of isolation is by building communities of learning that facilitate dialogue and decrease physiological distance (Rovai, 2002a, 2002b; Rovai & Wighting, 2005). A learning community is described as "an intentionally developed community that exists to promote and maximise its members' individual and shared learning. There is ongoing interaction, interplay, and collaboration among the community's members as they strive for specified common learning goals" (Jessup-Anger, 2015, p. 17).

Community, however, is not a unified construct. There are differences in its meaning and how it is formed in online and distance learning settings. For example, community is defined as a sense of belonging (McMillan & Chavis, 1986), interactions and relationships of people with similar interests (Liu et al., 2010) and an environment that facilitates interaction between people in a cohesive, reflective manner (Graves, 1992). In his conceptual paper on course design principles, Rovai (2002a) cites the most central aspects which community revolves around, namely "mutual interdependence among members, sense of belonging, connectedness, spirit, trust, interactivity, common expectations, shared values and goals and overlapping histories among members" (Rovai, 2002a, p. 4).

In a recent study on the lived experiences of chemists in the workplace (e.g., including PhD students and early career chemists), Bond (2021) found "belonging mattered to chemists, belonging at work impacted well-being, belonging impacts innovation, creativity, collaboration, productivity and retention, questions of belonging and experiences of not-belonging are particularly important for people from under-

represented groups in the chemical sciences" (p.6). Although this data is from a workplace setting, it is relevant in the context of part-time adult DE students who may already work in industry or aspire to. Coll and Eames (2008), on the other hand, point out that the learning community in science and engineering in a university context differs from that in the industry. One criticism is that students appear to accumulate knowledge in a mechanistic manner in order to pass exams, rather than acquiring a sense of the culture of science or becoming a scientist. Bond's recent report from the Royal Society of Chemistry and educators Coll and Eames's review suggest that community is complex in both environments and requires unique but possibly collaborative treatment.

In educational settings, a variety of methodologies have been used to measure community. Ellis (2013) states that the approaches include: "directly asking the participants of interest through a semi-structured interview process, direct measurement through an analysis of the content of the interactions among the participant and indirect measurement by tracking some aspect or aspects of communication patterns and indirectly measuring the presence of community through the use of a survey instrument" (Ellis, 2013, p. 62).

In considering an approach to analyse community, this study considered the Psychological Sense of Community (PSOC) as a theoretical framework, which is based on the work of McMillan and Chavis (1986) in the field of community psychology. There are four components to the model:

1. membership (e.g., knowing who's who in the community and setting boundaries).
2. influence (e.g., bi-directional interaction, the ability to influence the group and the group to influence its members).
3. fulfilments of needs (e.g., issues of reinforcement and being part of the 'in crowd'); and
4. emotional connection – for example, identifying with or having a shared history (pgs.9-13).

McMillan and Chavis (1986) claimed that their framework may be applied in non-place-based communities, despite the fact that their research was done in physical neighbourhoods. Dueber and Misanchuk (2001) analysed asynchronous and

synchronous posts of seventeen distance students on an online master's program. Two hundred asynchronous posts and 1,000 comments in the chat were analysed. Findings showed little evidence (e.g., 187 coded utterances in over 20 pages of text) of PSOC categories, namely membership, influence, needs and shared emotional connection. The authors made an interesting observation of the difficulty of differentiating forms of community indicators and polite conversation (Dueber & Misanchuk, 2001, p. 16).

Another approach that was considered was the classroom community scale (CCS) developed by Rovai (2002b). Rovai's work is also influenced by the principles found in MacMillian and Chavis (cf., 2002a). His survey instrument has been used extensively to indirectly measure the presence of SoC in DL environments and HE contexts (Ellis, 2013; Dawson, 2008; Shackleford & Maxwell, 2012). Rovai (2002b) measured 375 graduate students' sense of community enrolled on 28 Blackboard-based online courses by developing a 20-item CCS. The scale reflected connectedness and perceived learning in a course where the connectedness scale measured students' feelings of "cohesion, spirit, trust and interdependence" (p.206). This sub-scale accounted for the bulk of the variance measured by the instrument (42.81%). The learning scale measures, "the degree to which members share values and beliefs concerning the extent to which their educational goals and expectations are being satisfied" (p. 207) and accounted for 11.24% of the variant measured by the instrument. The scale was indicated to have excellent reliability; Cronbach's coefficient α .93. The study found that female students possessed a higher degree of classroom community (M = 57.60, SD = 12.47, n=247) than male students (M = 54.73, SD = 11.7). This difference was significant, t (373) = 2.15, p=.03. He also found that sense of community was moderately related to interactivity via the Blackboard e-learning system (Rovai, 2002b). In addition, Rovai emphasises the importance of dialogue over structure as an important element to SoC in asynchronous courses.

Studies have used the CCS as an evaluative instrument alongside other measures of SoC. A study by Dawson (2008) examined online student behaviours in a CMC environment. He found a significant relationship between students who have frequent communication in a CMC environment (i.e., via email, phone, forum post and chat sessions) and SoC as measured by the CCS. In their quantitative, descriptive study, Shackleford and Maxwell (2012) surveyed 381 (24% response rate) university students

taking graduate web courses. Data sources collected and analysed were the CCS survey and a 32-item interaction survey. The authors reported that the interactions identified in the survey data correlated with the SoC scales. The authors identified several interactions that were most predictive of SoC, namely: introductions, icebreakers, collaborative group projects, exchanging resources and contributing personal experiences. These predictive factors were fairly to moderately correlated with higher CCS scores.

The work presented in this section suggests that the CCS is a valuable instrument to complement qualitative approaches that measure community. As indicated by Dawson (2006), the CCS facilitates scalability and can "gauge and monitor lead indicators of community development" (p. 159). The focus of the current study was on the student engagement and its interconnected constructs such as SoC, therefore an instrument that could be applied at scale (i.e., across five STEM modules) is more appropriate. Although the PCOS framework is insightful, a drawback is its lack of application in educational settings and more so in a DE context (Dueber and Misanchuk, 2001). In addition, the variability in IWBs' interaction and engagement makes the PCOS not suitable for analysing communication patterns.

2.5.4   Interaction and constructing knowledge together

Many scholars have attempted to operationalise the concept of interaction so that patterns of interaction can be identified (cf., Bernard et al., 2009; Wei et al., 2019). Interaction analysis (IA) is one multidisciplinary method of classifying interaction. It considers the investigation of human activities, including discourse, nonverbal interaction, routine practices, artefacts and technologies (Jordan & Henderson, 1995). The usage of video has helped to develop this research area. One of IA's most fundamental underlying assumptions is that knowledge and action have an essentially social origin and are situated in specific social and material ecologies (Jordan & Henderson, 1995). Investigators in video-based research have traditionally approached IA with preconceived coding schemes (Jordan & Henderson, 1995). This study considered the frameworks and models discussed below.

Several studies have examined classroom talk in particular the teacher-student and student-student interactions. For example, Gunawardena et al. (1997) proposed an interaction analysis model, in which they defined interaction as "the process through

which negotiation of meaning and co-creating of knowledge occurs in a constructivist learning environment" (p.406). In a computer conferencing environment, their model investigates the process of social construction of knowledge. The model explains how participants in such a learning environment might achieve a greater degree of critical thinking by interacting with peers at various stages. There are five phases in total: (I) sharing/comparing of information, (II) the discovery and exploration of dissonance or inconsistency among ideas, (III) negotiation of meaning/co-construction of knowledge, (IV) testing and modification of proposed synthesis or co-construction, and (V) agreement/application of newly constructed meaning (p.414)

An earlier framework was Flanders' (1961) Interaction Analysis Protocol (FIAP). The framework was frequently used to investigate verbal interactions between the instructor and students in the classroom. During class, the observer identifies and notes the nature of each interaction between the teacher and students and among and within the students using pre-determined methods (Flanders, 1961).

Flanders (1961) defines teaching as an interactive process where teachers and students participate. The protocol can be adapted for use in other settings, including online learning because it focuses on pedagogical style and events. Indeed, Flanders seemed to have had expectations that technology would change the dynamic of teacher functions and suggested a more flexible approach may be required for more subtle distinctions. Flanders concludes: "Teaching behaviour, by its very nature, exists in a context of social interaction. Techniques for analysing classroom interactions are based on the notion that these reciprocal contacts can be perceived as a series of events, which occur one after another" (1961, pg.1). His system is based on ten categories: teacher-talk (7 categories), student-talk (2 categories) and silence or confusion (1 category). The first seven categories of teacher-talk are divided into indirect talk and direct talk. Students either respond or initiate talk.

FIAP has been applied in various educational contexts. For example, Blank (1996) modified the protocol for use with the ADCAS software programme to assess the percentage of teacher-initiated versus student-initiated discussion. Adaptions have also been made in evaluating modern media, such as videoconferencing, when used to deliver math instruction. For example, to determine the effects of teacher behaviours, Peacock (2005) compared the behaviours of a single teacher who taught maths via

videoconferencing and a traditional classroom setting. The mixed-method study found that the teacher accurately predicted six significant dependencies related to verbal teaching behaviours (Peacock, 2005). Guangbin and Shuyan's (2019) study showed common features of teaching and learning activities in a web-based maths and chemistry course. In another study, Lyon et al. (2014) used an adapted FIAP and student questionnaires in a randomised control study of lecturers from two medical faculties. Results found that the faculty in the intervention group improved significantly in their lectures regarding person-centred teaching behaviour while the control group did not. The authors concluded that person-centred teachers who are more empathic, encourage, praise and ask questions are more effective than those who lecture, give directions and criticise.

Similar to Flanders's research on student and teacher-talk, Mercer's (2004) sociocultural discourse analysis focus on classroom talk. The methodology emphasizes language as a social mode of thinking. Its aim is to understand the distinctive types of dialogues in the teaching-learning process and how they influence how individuals collaborate to build knowledge, develop shared understanding and solve problems (Mercer, 2004). There are three archetypical forms: Disputational, Cumulative and Exploratory. Disagreement and decision-making are characterised as 'Disputational talk'. The term 'Cumulative talk' refers to speakers who establish a common knowledge by building on previous conversations in a positive but uncritical manner. The last form, 'Exploratory talk' occurs when speakers critically but constructively debate each other's ideas (Mercer, 2004, p. 146). The latter form of talk is preferable since it is more related to critical reasoning (Mercer et al., 2004). Although Mercer's research was primarily conducted among primary teachers and pupils in maths and science classrooms, it has been applied in some DL contexts. For example, Ferguson and Shum (2011) investigated exploratory dialogue in Elluminate, a web-conferencing tool. The researchers examined archived synchronous discussions that were part of an online teaching and learning conference. The findings revealed that the periods of time during the conference that was for discussion and keynote speakers were associated with the highest levels of exploratory discourse.

Finally, Knowledge building discourses are part of computer-supported collaborative learning (CSCL) theories (Stahl, 2015). CSCL environments are software systems that

support collaborative distributed learning, aimed at advancing students' discussions from personal opinions to collective knowledge (Stahl, 2015). In knowledge building theory, students' work is primarily valued first and foremost for what it contributes to the community and secondarily for what it reveals about individual students' knowledge and expertise (Scardamalia & Bereiter, 2014). Knowledge building focuses on the community rather than a small group, and in addition to knowledge sharing and construction, it involves sustained inquiry and the pursuit of communal goals (van Aalst, 2009). For example, OpenStudio, an online studio-based environment developed by the OU, enables students to create and upload audio-visual resources and to engage in (asynchronous) dialogue with their peers, tutors and module teams around these resources (Thomas et al., 2016). The learning environment is an example of how interpretations or explanations of the work of others qualify as knowledge creation.

Several studies on Knowledge building have been conducted. The studies usually draw on qualitative or mixed methods to analyse online discourse. Perit Çakır et al. (2009) found that a group co-constructed meaningful chat utterances and inscriptions during a math problem-solving activity meditated by a synchronous multimodal online environment.

Classifications have been developed to identify knowledge building discourses and indicators. For example, van Aalst (2009) developed a classification of discourse patterns in text-based asynchronous discussion forums. The authors found nine discourse patterns students used in collaborative interactions across three modes of discourse: knowledge sharing, knowledge construction and knowledge building. Similarly, Lipponen (2000) found three pedagogically and cognitively different modes of discourse: social-oriented, fact-oriented, and explanation-oriented, to identify collaboration interactions in online discussions. In fact-oriented discourse, there are two types of inquiries: fact-seeking question and questions that seek understanding. Questions or statements that require factual information, such as what, who, how many and when are answered by providing facts about identification, locations, people and times. Why, what for and how come are all forms of questions that cannot be satisfactorily answered without hypotheses, cause-and-effect relationships and justifications. There are two types of explanation-oriented discourse: those that offer factual information and those that are explanatory in nature and include reasons and

cause-effect language. Finally, Lipponen (2000) used social-emotional to refer to affective language that is not part of inquiry but includes greetings and other social comments. Lipponen argues that the modes differ in the nature of the knowledge, which students constructed. Both studies reveal functional classifications. However, these were conducted among primary aged students in a CSCL environment that was pedagogically designed to support practices of inquiry and progressive discourses.

Together, these studies provide important insights into interaction and discourse characteristics in particular learning communities. While Gunawardena et al. (1997) and Mercer's (2004) models are useful for understanding the varieties of talk that promote learning, both models position group activities or pair work as central to its principles. This may not work in an IWB environment, which is not a built collaborative space set up for discussion, although discussion may occur. Further Mercer (2004) points out that the typology of talk was not intended to be used as a coding scheme. Instead, the current research uses Lipponen's (2000) coding scheme as a way to analyse and describe the type of discourses in IWBs text-chat and to answer RQ4. It was also selected because unlike the other classifications reviewed, it includes a social oriented mode of talk. Lipponen's (2000) classification helps to decipher whether text-chat in the IWBs is primarily social in nature or whether there is evidence of more meaningful chat that is representative of knowledge building or knowledge sharing. Also, the study draws on Flanders's (1961) Interaction Analysis as a conceptual framework to analyse and discuss general patterns of interaction and to help answer RQ2.

Overall, there seems to be some evidence to indicate that FIAP can be used in a technology-mediated environment. IWBs, in particular, are designed interactive events that are time-specific and produced on pre-defined conditions. It is an environment in which one-to-many communication occurs. However, Flanders argues that "teachers and students rarely experience thoughtful, shared inquiry" (Flanders, 1970, p. 16). The IWB design allows for and encourages interactivity and bi-directional communication between presenters and students. The FIAP allows for analysis of that one-to-many dynamic; that is, the analysis of what a lecturer is verbally saying and what a moderator and students are saying. Therefore, it does not restrict the interaction patterns to text-chat discussions.

2.6   Technology-mediated media

There are two types of technology-mediated media used in DE courses that enable communication and collaboration: synchronous and asynchronous. Both have their own set of benefits and drawbacks. Surveys such as that conducted by Brandon and Essex (2001) have shown that asynchronous communication can encourage in-depth, more deliberate discussion and reflection. Vonderwell (2003) found that students were more hesitant to contact their peers in asynchronous discussion. Other studies (e.g., Brandon & Essex, 2003; Oztok et al., 2013) have concluded that asynchronous discussion has fewer social cues, lacks immediate feedback, less frequent student engagement and students feel a sense of social disconnection.

Several studies suggest that synchronous media can add value to learning through real-time discussions; instantaneous feedback and enhancement of student connectedness, interest and engagement, and support social learning processes (De Freitas and Neumann, 2009; Hrastinski et al., 2010; Martin et al., 2012). Oztok et al. (2013) examined relationships between students' use of asynchronous discussion and synchronous private messages. They found that those who used private messages were also the most active posters on discussion forums but less likely to read forum notes.

Research has also shown that synchronous environments encourage social presence as teachers and learners benefit from social cues. For example, Kear (2010) explored the views of OU students on an Information and Communication Technologies course. Ten students were interviewed on their perceptions of using online communication. Interview data revealed that students desired to know something about their student peers and reported the benefits they found in real-time communication. Problems of asynchronous tool use such as time lags and message tone were revealed. However, being able to see who had read messages was beneficial. In addition, data showed that the interviewees valued the chat facility, which enabled real-time communication. Asynchronous communication, however, continues to be the dominant form of teaching and learning in the DL environment (Kirkwood & Price, 2013) and is associated with being the medium that facilitates a constructivist-based education (Swan, 2003).

2.6.1 Interactive tools: audience polling

Synchronous media can bridge the gap of being in real-time. However, regardless of media, the challenge is keeping students engaged in the learning process and as Hartwell (2017) points out "it can be challenging for instructors to "reach through the screen" to engage students, who feel a lower sense of presence and a higher sense oof anonymity" (p.39). She further argues that the use of online questions in a synchronous broadcast class can increase student participating and engagement.

Interactive teaching with audience response devices, also known as group response system and clickers, are devices that enable the polling of collective responses from individuals in a group and can aid in the facilitation of dialogue in large face-to-face lectures. They have long been used in campus-based universities and have been found to be effective in engaging students in large classes, encouraging participation and testing comprehension (Caldwell, 2007).

In their conceptual paper, Cutts et al. (2004) draw on Laurillard's framework to understand how the communications flow between teachers and students can be maximised in large lecture groups using group response systems. The authors identify time, learner attention and a lecturer's planned narrative/material that they must get through as impediments to productive dialogue (Cutts et al., 2004). Likewise, Kulkarni and Iwinski (2016) demonstrate how clickers in a lecture capture classroom environment can be transferred into embedded questions for video available for distance students.

Beatty et al. (2006) developed a question cycle for using classroom response systems (CRS) during in-class activity in a physics class. The cycle is organised by presenting a question or problem, allowing time for group discussion, viewing and displaying instant histogram showing the class-wide distribution of responses, moderating a class-wide discussion and evaluating, adding or revising questions. The model, the authors argue, forms the principal of instructional dynamic, which is not to lecture or deliver information but to assist students in exploring, organising, integrating and expanding their knowledge (Beatty et al., 2006). This study uses their question cycle model to understand widgets strategies used by the presenters and to also answer RQ2.

2.7   Chapter summary

To summarise, Chapter 2 introduced existing research and discussed the types of common challenges that exist in DE, and the various design and pedagogical solutions to address some of those issues. Feelings of isolation and doing practical work in science and technology modules are a challenge. To mitigate those two broad issues, the chapter considered the purposes and aims of practical work, both in laboratory and field settings, and discussed the pedagogical strategies that mitigate those challenges. Fostering student engagement is at the heart of the matter. The interconnected constructs of social presence, sense of community, interaction and learning in a way that constructs knowledge were also reviewed.

The chapter considered several conceptual frameworks and models to frame this research. It discussed in detail the concept of engagement and two frameworks and concluded that the reviewed literature and Pittaway's (2012) framework was best suited to understand and draw on in the discussion of the findings. Rourke et al.'s framework (1999) was considered as being suitable to understand social presence in text-based discourse. The chapter offered an analysis of Rovai's (2002b) CCS as a well-suited instrument to measure online learning community and as the most appropriate for the research question (i.e., RQ6) and the research design. The chapter also considered the FIAP framework as best suited to answer RQ2 and provide a coding scheme to analyse interaction patterns between educators and students. It analysed its origins and how the framework has been used in other online contexts. Lastly the chapter considered the theoretical concepts of knowledge building discourses to answer RQ4 and to provide a coding scheme for the analysis of text-chat discourse. The next chapter discusses the research methodology for this study and presents the conceptual frameworks and shows how they were adapted for data analysis.

3   Methodology

This chapter focuses on the methodological approach used in this study and the methods of data collection and analysis used to answer the research questions set out in Chapter 2, Section 2.1. The chapter starts in Section 3.1 by outlining the paradigmatic stance for the study, followed by the selected research approach and research design. It is argued that Pragmatism is better suited to answer the research questions and aligns best with a mixed methods approach and theoretical positioning of this thesis. Section 3.2 outlines the research approach. Section 3.3 justifies using a qualitatively driven mixed-method design and outlines the five modules used in this study. Research methods considered are discussed in Section 3.4. The procedures applied to recruit participants and ensured ethical integrity are outlined in section 3.5. The data collected across modules is summarised in Section 3.6. Data collection procedures are described in Section 3.7, followed by the analytical frameworks used to prepare and analyse data in Section 3.8. The chapter is summarised in Section 3.9 and leads into the findings presented in Chapter 4.

3.1   Research paradigm

A pragmatist research perspective emerged as a middle ground to counteract traditional ontological dualisms - e.g., free will vs determinism, subjectivism vs objectivism (Johnson & Christensen, 2014). While a constructivist view of the social world emerged from criticism of positivistic social research and the traditional structural approach to understanding human-related experience (Cohen et al., 2011), [post] positivists argue that the social world can be studied similarly to the natural world in a way that is value-free and can be used to make informal explanations (Mertens, 2005). Pragmatism, however, acknowledges and values the natural world and the emergent social and psychological constructs, which includes languages, culture, human institutions, and subjective thoughts (Johnson & Onwuegbuzie, 2004).

As a worldview, Pragmatism attempts to overcome the *incompatibility thesis*, a proposition that quantitative and qualitative research cannot be mixed in favour of the *compatibility thesis* that allows the mixing and matching of design components that offer the best chance of answering specific research questions (Onwuegbuzie, 2012). Combining ideas and approaches builds on what we already know. It offers new ways to understand and study our world (Johnson & Onwuegbuzie, 2004), allowing

researchers to be objective and subjective (Tashakkori & Teddlie, 1998). Pragmatists believe that we are historically and socially positioned (Cherryholmes, 1992), whereby the world of human experience in action shapes and influences reality, and knowledge is seen as both constructed and based on the reality of the world we experience and live in (Johnson & Onwuegbuzie, 2004).

Thus the nature of reality in Pragmatism is associated with what is useful and practical, what works in certain situations, and what will best help answer the research questions (Cherryholmes, 1992; Cohen et al., 2018; Creswell, 2018). Taking a pragmatism perspective "theories or programs or actions that are demonstrated to work for particular groups of people are the ones that we should view as currently being the most valid for those people" (Johnson & Christensen, 2014, p. 81). Therefore, the landscape of the context in which this thesis is positioned aligns with Pragmatism. The research was designed in negotiation with academics from four of the six schools in the STEM faculty and considered what worked for them. The paradigm allows for a recognition of the importance of human subjectivities and meaning without altogether rejecting some aspects of objective social inquiry (Hesse-Biber et al., 2015) and lends itself to constructivist theoretical frameworks as discussed in Chapter 1.

As Bryman (2016) points out, social research is influenced by epistemological and theoretical factors and the impact of values and practical considerations. Based on the paradigmatic stance of the thesis, this study will undoubtedly be guided by the researcher's value system, that is, researching what is deemed necessary on the topic. It includes the variables and units of analysis that are appropriate to answer the question (Tashakkori & Teddlie, 1998). As Cherryholmes (1992) argues, a pragmatist looks for the desired consequences (e.g. a type of community) and chooses how and what to research, eliminating, if necessary, other possibilities of what that 'community' might comprise (ibid, p.13).

The researcher's experiences have been shaped by teaching within adult and community, further and higher education institutions, and studying within a distance learning context. The author believes that individuals are active agents with multiple realities. Whether face-to-face or online, teachers and learners bring their identities, learning experiences, motivations, and expectations into the learning environment.

The author also believes that the sociological phenomena of learning, equity, sense of belonging and community at an institution are not fixed but are in-flux and may lay on a continuum. It is anticipated that results will be congruent with this value system.

Online environments designed to foster interactions and engagement from individuals can be addressed through qualitative and quantitative approaches. Therefore, to understand the phenomenon of social interaction, knowledge building, and community in IWBs, both subjective description and exploration and numerical description and prediction are equally valuable (Tashakkori & Teddlie, 2010). Therefore, taking a Pragmatism perspective, a mixed-methods approach is applied to answer the research questions.

3.2   A mixed-methods approach

Seminal authors Tashakkori and Teddlie (1998) broadly define mixed methods as the collection and analysis of both qualitative and quantitative approaches or methods in a single study. There is an integration of findings, which is a crucial concept before inferences are drawn. It is characterised by combining at least one qualitative and one quantitative research component to answer the research question(s) with validity, thereby expanding and strengthening a study's conclusion (Schoonenboom and Johnson, 2017). The rationale for choosing this approach followed the research problem formulation as outlined in Chapter 1, Section 1.1.and the research questions. To address the research questions, a researcher considers the nature of the phenomenon, the aspects it has and what may be right (or wrong) about the phenomenon respectively (Mertens, 2005).

In the context of this study, these question types may be represented by understanding the purposes and affordances of IWBs, how they are used to foster student engagement, learning and SoC and how those factors are perceived. The research questions are both explanatory and exploratory, but a monomethod approach is not suitable to capture the complexity. Elliott and Timulak (2005) suggest that research questions that are open-ended and exploratory are suitable for qualitative inquiry. On the other hand, closed-ended hypotheses and determining differences between groups is helpful to describe the relationships between events and phenomena and may be more suited to measure quantitatively (Mackenzie & Knipe, 2006).

Other approaches commonly employed to understand social phenomena were considered. For example, a qualitative approach using phenomenology can help understand the shared experiences of individuals around a phenomenon and describe social constructs such as the experience of an online learning community. This type of design would require a careful sample of individuals who have experienced the phenomenon in a common way (Creswell, 2018). The variability of IWBs and the multifaceted nature of how learning is mediated point to possible unpredictability. Different Labcast event types and purposes could influence or cause phenomena to occur (i.e., causal conditions). For example, a Labcast tied to assessment protocols and one that is not. Therefore, it may be unlikely that there are mutual experiences.

Case studies aim to produce a first-hand understanding of people and events by presenting a holistic understanding of the complexities and interrelations of the factors in a bounded system. That system can be a program, an event or a person (Creswell, 2018; Hamilton, 2013; Yin et al., 2006). Although a multiple case study could have been used, this was not considered feasible due to the inability to replicate the design and the variability of data collected.

Likewise, grounded theory is helpful to help generate or discover a unified theoretical explanation generated from data from participants who have experienced the process of interaction (Wertz et al., 2011). This could provide a framework of how people are experiencing the phenomenon of IWBs. However, this research design is practical when a theory is unavailable to explain or understand a process. As discussed in Chapter 2, Section 2.5.3 there are various theoretical frameworks and pedagogical practices of online communities articulated in the literature. Moreover, IWBs are a contemporary medium but not a new phenomenon of communication at the OU.

This study is an OU funded research project situated within the institution that uses OU module design and teaching as a blended learning approach. In addition, the study is situated across four schools within a faculty; each discipline having its distinct epistemologies, ways of practice (Kennepohl, 2012) or signature pedagogies which indicate "the personalities, dispositions and cultures of their fields" (Shulman, 2005, p. 52) further positioning and qualifying the suitability of a pragmatic approach. Some participants (i.e., central academics and technical production team) are on-site. Others (i.e., students, associate lecturers, guest speakers) are in the distance. As such, this

study requires mixing at the level of methods, analysis (in some places) and overall interpretation.

Following Greene et al.'s framework (1989), there are five broad rationales for a mixed research study: triangulation, complementarity, development, initiation and expansion. Thus, this research's purpose and empirical outcome is triangulation, in which convergent and corroboration of results from different methods will be used to study the same phenomena and characteristics of student engagement, learning and SoC.

3.3 Qualitatively driven mixed-methods design

This study used a qualitatively driven mixed methods approach to investigate the ways IWBs are used in various STEM modules and the perceptions of the stakeholders who produce, present or participate in IWBs. The rationale for using this design is to use quantitative research methods as an auxiliary component of a primarily qualitative methodology to understand the broader objective context of engagement and interaction in IWBs and contextualise qualitative research on people's experiences of IWBs. A set of quantitative sub-questions and conjectures in various stages of the research assist in elaborating or clarifying the overall core qualitatively driven research questions. The design was used to investigate thirteen different IWBs to explain how interaction occurred (or not). The mixing of data sets at various stages helped to answer the central question: how the IWBs, as a contemporary phenomenon, influence variables of interest, namely student engagement, learning and SoC. Hesse-Biber et al. (2015) point out that a qualitative mixed method design can accommodate the following perspectives:

- To obtain a representative qualitative sample by first conducting quantitative surveys of the researcher's target population.
- To provide options for enhancing the validity and reliability of qualitative findings.
- To obtain a more comprehensive understanding of a phenomenon from differing perspectives.

Morse (1991) offers a notation system to indicate the characteristics of research where the letters qual or QUAL stand for qualitative research and quan or QUANT stands for quantitative research. Capital letters denote priority or increased weight, and lower case denotes the opposite. A plus sign (+) represents a concurrent collection of data.

Using the flexibility that a mixed-methods approach affords the researcher in constructing one's design, this research was conducted in three broad phases over time. In Phases 1 and 2, both qualitative and quantitative components were collected. Data sets were analysed separately and then converged by comparing and contrasting the data en-route to interpretative frameworks. Phase 3 collected qualitative data. The qualitative components were collected for a more extended time and therefore had the primary emphasis. Figure 3.1 below shows the schemata for the phases in the design.
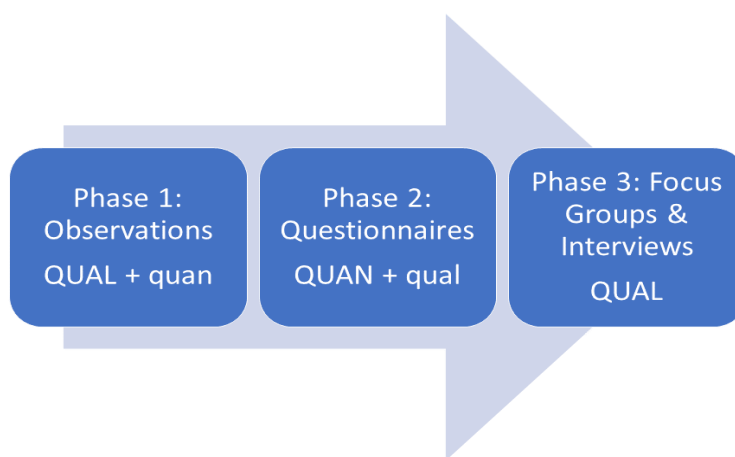
Figure 3.1: Phases in the qualitatively mixed-methods design.

3.3.1 Context

IWBs are optional learning activities that take place during or towards the end of a module block and are currently presented in several undergraduate modules at OU levels 1 – 3 (equivalent to the Framework for Higher Education Qualifications levels 4 – 6) across four schools in the faculty of STEM. The IWBs are produced and filmed in the OpenScience teaching labs at the Open University and in local fields on the campus. The IWBs are presented by, for example, academics from a module team; one or more being a lead presenter, a moderator and other researchers across OU departments. Some modules also invite external speakers to present their research. The university uses Stadium Live as its platform for hosting the IWBs, which can be accessed via a web browser. There are two distinct IWB types:

1. Topic-based Labcasts and Fieldcasts: Field investigation, experimentation and experimental design topics that are related to practical components within a given module. The purpose is to facilitate student preparation for assessments.

2. Discovery-based Labcasts: Labcasts for level 1 students starting or interested in one of the specific discipline streams. The purpose is to explore module progression routes and career pathways.

Five modules were involved in the research activities for this study and are introduced below. Table 3.1 summarises the number of IWBs used in each module across the respective schools during the 19J/20B presentations (the academic year 2019/2020). The IWBs types were topic-based as outlined in list 1 above and were purposively selected because of the research focus on practical lab and fieldwork. Subsequent reference to these modules uses the information in the Module code column.

Table 3.1: Summary table of IWBs used in modules across schools in year 2019/2020.

School	Module	Module Code	Labcast Title	N
School of Computing and Communications	Technologies in practice	TM129	Block 1 Robotics	3
			Block 2 Networking demonstration	
			Block 3 Linux demonstration	
School of Physical Sciences	Remote experiments in physics and space	SXPS288	An interactive introduction to remote experiments in physics and space	4
			Physics project	
			Planetary science project	
			Exploring Mars	
School of Environment, Earth and Ecosystem Sciences	Environmental Sciences	S206/SXF206	Fieldcast 1: Making observations & developing hypotheses	3
			Fieldcast 2: Developing methods & data collection	
			Labcast 3: Analysing data & making conclusions	
School of Life, Health and Chemical Sciences	Practical science: biology and health	SXHL288	The human brain in action	2
			Cells and tissues close-up	
	Chemistry: further concepts and applications	S315	Introduction to the experiment for TMA05	1

3.3.2 Technical production of Labcasts

The technical production team are audio-visual experts responsible for the setup, scripting, filming and editing of the Labcasts and Fieldcasts, which are filmed in the OpenScience teaching-labs and local fields on campus. Storyboard production, planning of studio layout and rehearsals are iterative processes. Figure 3.2 illustrates the types of production activities. Planning happens several weeks or months beforehand. A running order or script exemplar can be found in Appendix L.

Figure 3.2: Technical production team setting up stand-alone cameras (left); vision mixing (top right); supporting presenters in rehearsals (bottom right).

3.3.3 TM129

'Technologies in practice' is a level 1 computing and information technology module (equivalent to UK Framework for Higher Education – FHEQ level 4). The module comprises three blocks of study: Robotics and AI, Networking and Operating Systems; each block is studied over nine weeks (i.e., eight weeks of study materials and one week for assessment). The module has dual presentation (i.e., it starts twice a year in February and October). At the start of the module in 2019/2020, 1,068 and 993 students were registered on the 19J and 20B presentations respectively (starting in October and February). 734 completed the 19J module (69%) and 625 completed the 20B module (63%).

The module consists of practical activities around the three blocks, concluding with a Tutor-Marked Assignment (TMA). In the Robotics and AI block, students carry out

practical programming activities using Robot Lab. The Networking block uses the Cisco Academy learning materials and Packet Tracer, a network simulation tool to practice networking tasks. Block 3, Operating Systems, uses the VirtualBox virtualisation environment for practical activities. Students were not required to submit an EMA for the 19J module due to challenges arising from the pandemic, so their continuous assessment scores informed their module results. Forty-three Associate Lecturers (ALs) deliver tuition on the module. Module content (e.g., interactive study materials, forums, video and interactive assessments) is delivered via the OU's customised virtual learning environment.

Labcasts in TM129 were introduced after the module was produced due to the OpenSTEM Lab Science grant, which allowed the school to purchase a large robot. The Labcasts became part of the broader group tuition policy on the module and offered a way of mediating access to the robot for a large student cohort. As part of the tutorial programme, Labcasts were rolled out across the three blocks and are optional activities as part of module-wide events. The Labcasts involve demonstrations of a large teaching robot, a small network using Raspberry PI computers, and Linux networking. A more recent format includes inviting a guest expert to present their research as it is applied in the real-world. The conversational style presentation is incorporated into the second Labcast on networking. Figure 3.3 illustrates the types of activities in the TM129 Labcasts. The presentations are followed by real-time, question-and-answer sessions with the moderator collating and asking the students' questions from the text-chat and the presenter answering. Open-ended and multiple-choice widgets are used during the broadcast to gauge prior knowledge on Raspberry PI use and predict how a motor may control a robot, for example.

Figure 3.3: TM129 'Technologies in practice' guest presenter discussing his research in a Networking Labcast (left); demonstrating motors and sensors on Baxter robot in Robtics Labcast (top right); split-screen demonstrating Raspberry Pi schematic (bottom right).

3.3.4 SXPS288

'Remote experiments in physics and space' is a practical science level 2 module (i.e., FHEQ level 5) for students on the physical sciences qualifications in either a BSc in Physics or a Natural Science degree with an Astronomy and Planetary Science pathway. The module has three projects in astronomy, physics, and planetary science. The module was rewritten and first delivered in its current form in the 2019J presentation, which includes a new planetary science experimental investigation that takes place in the second half of the module. At the start of the module in October 2019, 210 students were registered and 125 completed and submitted the final EMA (60%).

The module comprises three experimental investigations in projects, such as properties of electrons, planetary atmospheres, and the structure and contents of the Milky Way. The practical investigations include using remote equipment, such as an X-ray spectrometer, radio telescope (ARROW) based in Milton Keynes, and an optical telescope (PIRATE) in Tenerife. Before the module starts, students choose their preferred option in radio or optical astronomy.

The online practical science activities are conducted via the OpenScience Laboratory (OSL). Projects are based around teamwork and collaboration where students develop their skills in observation, hypothesising and reporting. ALs deliver tuition on the

module alongside project specialists, who provide specialist forum support for each experimental project. In the 2019J presentation, there were 10 ALs.

Each project is introduced by a Labcast presented by the module team, a moderator, project specialists and/or other subject experts. These Labcasts involve demonstrations on a workbench, modelling mathematical equations on a whiteboard, live visits to introduce each project's experimental equipment, and a talk with a mission specialist from the National Aeronautics and Space Administration (NASA). Figure 3.4 illustrates the types of activities in the TM129 Labcasts. Widgets are used to hypothesize the direction of an electron or elicit free responses around good experimental design, for example. The Labcasts are optional for students and are part of the module's blended tuition model.
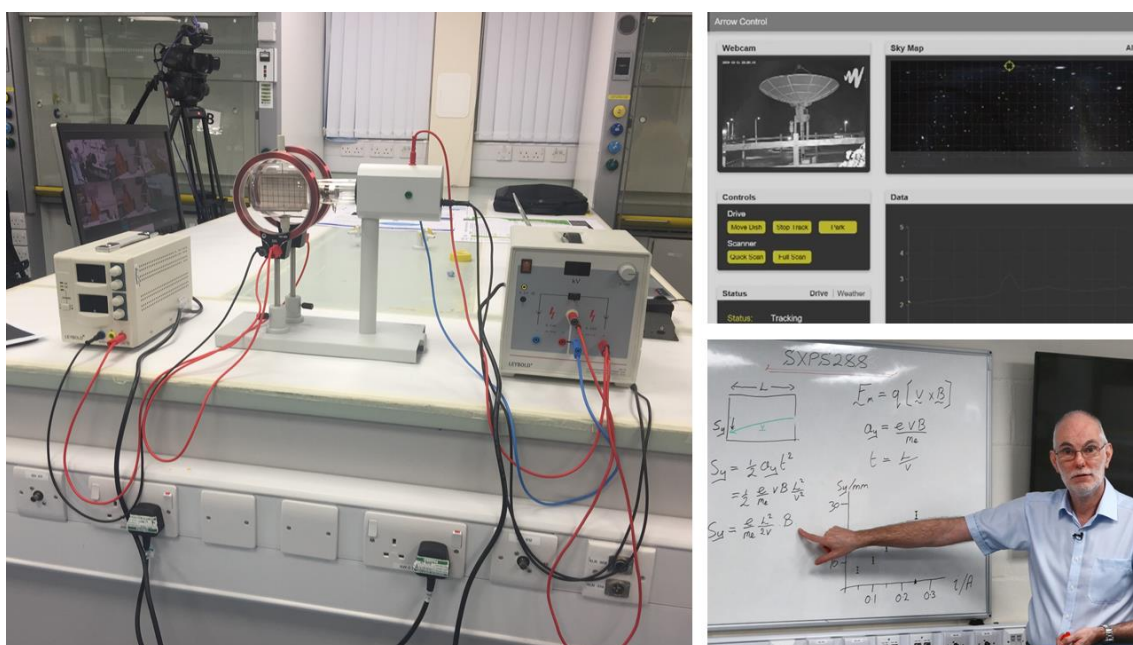
Figure 3.4: SXPS288 'Remote experiments in physics and space' setting up light beam equipment to scatter electrons (left); demonstrating live feed to remote telescope instrument (top right); demonstrating equations to support an experiment (bottom right).

3.3.5 S206/SXF206

'Environmental science' is a level 2 module that leads to either a BSc in Environment Science, an Open degree or a Natural Sciences degree with an Environmental Science Pathway. The module is split into one track (i.e., SXF206) with a compulsory residential field course component and the other (i.e., S206) with a virtual self-directed field course. In response to accreditation requirements for fieldwork, students registered for the BSc in Environmental Science take the residential fieldwork element. In addition, optional field days are offered for both cohorts. Students learn biology,

chemistry, earth science and physics as interconnected topics to study the environment. The main module consists of five blocks: water, air, earth life and cycles. Students on both tracks predominately study the same module; however, different tasks and learning activities occur at various points in the module.

On the S206 track, 364 students started the module and 216 completed the module (59%). For the SXF206 track, 225 started the module and 132 completed (59%). Twenty-three ALs delivered tuition on the module and provided forum support for tuition groups and cluster-wider groups. Five of those ALs were new to the module.

Fieldcasts are compulsory for both cohort groups and are linked to a formative assessment (i.e., TMA04) in which students write a scientific report based on an authentic field investigation. Students are required to either attend the live events or watch the recordings. The Fieldcasts are in their fourth year of production (and third year of assessment) and are broadcast live from local field sites at the OU's Walton Hall Campus in Milton Keynes. The events are presented by the module team to teach biodiversity of species and environmental factors. Fieldcasts are a one-off yearly event that consists of three episodes; two on the same day in the field and a Labcast a few days later.

Students are exposed to a field site during the episodes, and presenters outline what environmental aspects could be investigated. Students are guided through observation, hypothesis, method design and data collection phases of the inquiry. Students drive the investigation using a combination of open-ended and multiple-choice widgets to choose a topic, vote on a hypothesis and choose a sampling strategy. The data is collected on their behalf by the presenters, which starts during the second broadcast and continues after the broadcast has ended. The presenters return to the on-campus laboratory to analyse the data in the final episode. Widgets are used to select the right statistical tests and graphs to present the data. The presenters interpret the relevance of the findings. Students then write a report (i.e., TMA04) based on the episodes about the study and the implications of the findings. Figure 3.5 illustrates the types of activities in the Fieldcasts. The Fieldcasts were broadcast in February 2019 and were fortunately uninterrupted by the pandemic. Most field schools, on the other hand, were cancelled due to the national lockdown affecting largely SXF206 students.

Figure 3.5: S206/SXF206 'Environmental science' teaching team collecting data of vascular plants (left); module team member moderating the text-chat box (top right); demonstrating hypotheses choices (bottom right).

3.3.6   SXHL288

'Practical science in biology and health' is a practical level 2 module course that leads to a Natural Sciences degree in Biology. The module explores topics such as human and animal behaviour, biochemistry and water quality. Students collaborate in designing experiments, collecting and sharing data. At the end of the module, students participate in a multi-disciplinary team project. At the start of the module, 437 students were registered, and 279 completed the module (64%).

The module has three experimental investigations: attention and the brain, animal physiology, and drug metabolism. Online practical activities are carried out via OSL and include rapid visual processing (RVP) tests, sustained attentions tasks and behavioural observations. Project specialists provide specialist forum support, and ALs deliver tuition on the module. On the 19J presentation, there were 16 ALs.

A Labcast supports each investigation to introduce the topics and highlight aspects of experimental design and key considerations associated with performing laboratory-based investigations. The Labcasts involve live visits to a computerised cognitive assessment program, real-time human participants' data, and demonstrations of light and scanning electron microscopes. Figure 3.6 illustrates the types of activities in the Labcasts. Illustrates In addition, widgets are used to hypothesise which gender will perform better on an RVP task and elicit free responses around a question on RVP

performance, for example. Unfortunately, the team could not run a live Labcast for the Labcast supporting topic three due to the coronavirus outbreak. However, a recording from the previous year was made available. In addition, the module team offered additional support for a week via a dedicated thread in a Skills Development Forum to discuss areas relating to the Labcast or the module materials.
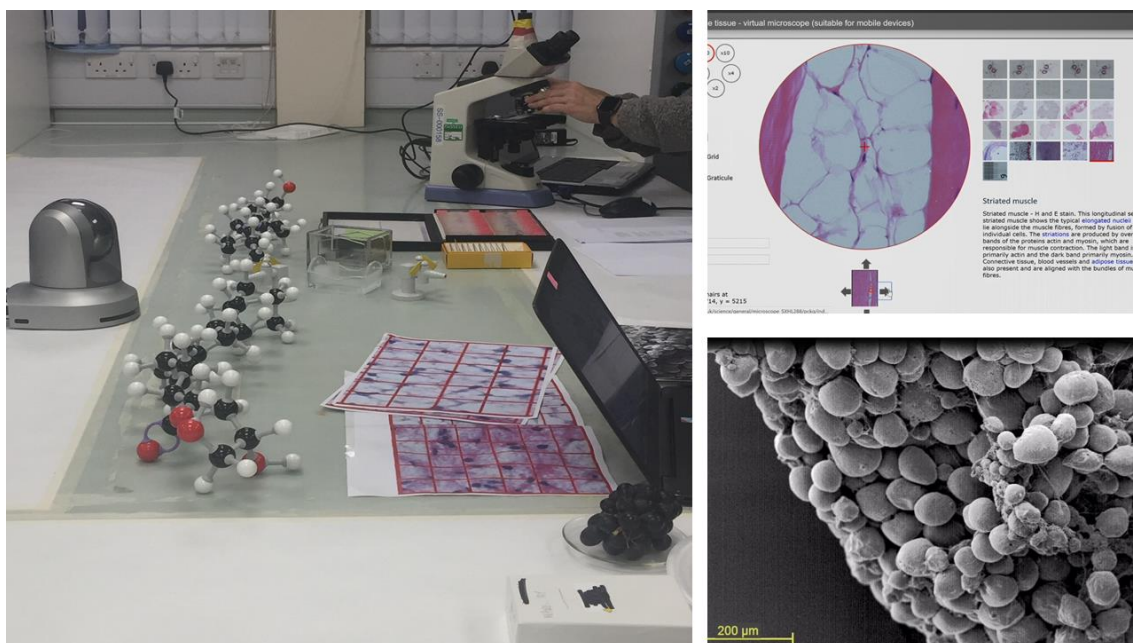
Figure 3.6: SXHL288 'Practical science in biology and health' setting up images in a digital microscope (left); demonstrating adipose tissue in a virtual microscope (top right); demonstrating magnified close up of a cell tissue (bottom right).

3.3.7   S315

'Chemistry: further concepts and applications' is a level 3 module (FHEQ 6) that leads to a BSc in Chemistry or a Natural Sciences degree with a Chemistry pathway. The main components of S315 are the core topics: chemistry in the natural world and chemical reactivity, which are assessed by a TMA and an extended study topic. At the start of the module, 114 students were registered and 89 sat the final exam and completed the module (78%).

The module has three online practical experimental investigations, which are delivered via OSL. Experiment 1 is an experiment to determine the strength of an acid. Experiment 2 is a model cobalt complex for oxygen uptake. The third experiment involves collaborative activities with students' tutor groups and explores drug-drug interactions using LC-MS analysis. Project specialists provide specialist forum support, and ALs deliver tuition on the module.

Each experiment is introduced by a Labcast presented by the module team. The Labcasts involve modelling mathematical equations on a whiteboard, demonstrating and running live experiments on the workbench, and remote access to titration equipment, which accurately measures volumes of chemicals, in the OSL. In the 19J presentation, only the third Labcast ran live to introduce the third experiment and the writing up for TMA05. Figure 3.7 illustrates the types of activities in the Labcasts. Widgets were used to hypothesise whether a solvent would be more or less polar and to choose a range of concentration to be measured during the live experiment.
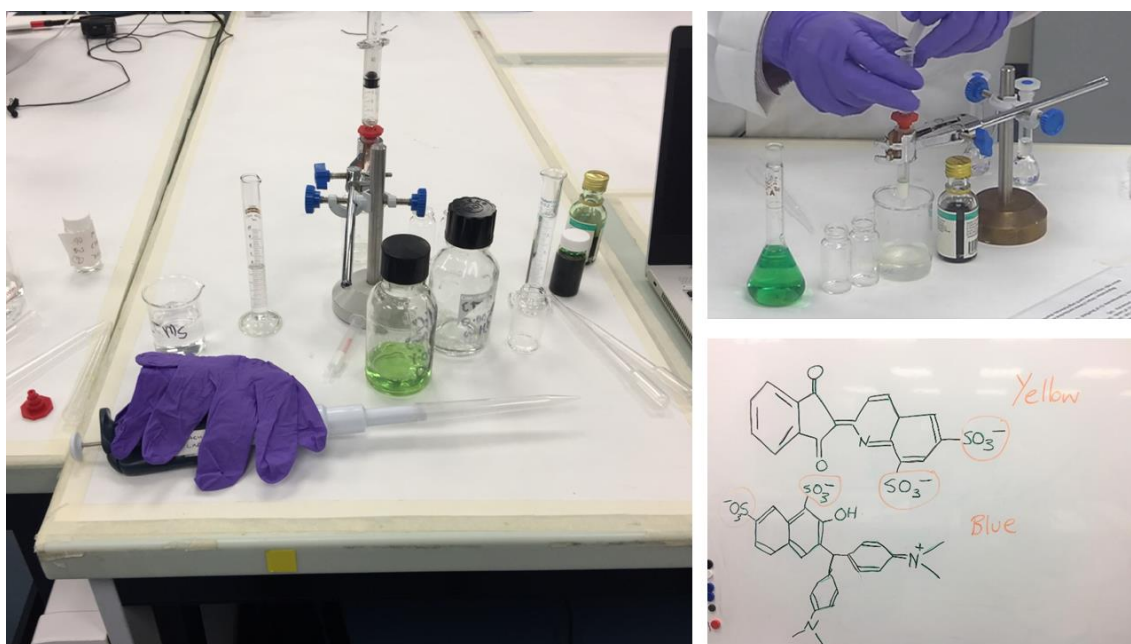
Figure 3.7: S315 'Chemistry: further concepts and applications' setting up equipment and chemicals (left); demonstrating chemical separation techniques (top right); demonstrating molecules interaction on a whiteboard (bottom right).

3.3.8 Summary

Labcasts and Fieldcasts are part of the blended tuition model in the STEM faculty. This study explores the current use of the web broadcasts across five modules within four schools as outlined in Section 3.3.1, Table 3.1. Other faculties and schools use the Stadium Live platform for similar approaches to deliver live events. Four out of the five modules use the IWBs to support investigation, experimentation and experimental design topics and assessments. The 'Technologies in practice' module uses Labcasts as a way to extend the module materials and add points of interest. To investigate how the IWBs are used in the modules and how they are perceived by stakeholders, a qualitatively driven mixed-methods design is adopted. The following section discusses the methods considered to investigate the IWBs.

3.4 Research methods considered

Gaining access to a site and individuals is not exclusively a matter of ethical review boards but also includes negotiating approval from what Hammersley and Atkinson term 'gatekeepers' (Hammersley & Atkinson, 2019) who could provide access and help identify potential participants. In this context, the gatekeepers were the academics (i.e., a module team chair), curriculum managers and the technical production team. Therefore, it was essential to engage with the academics, technical production team, associate lecturers and other staff to situate them into the research and consider the pragmatics of what was possible. Written information about the project, its aims, potential methods and questions to guide the discussions were sent before scheduled meetings.

The author developed research designs in consultation with and approval from the corresponding module team chair. The choice of methods for data collection considered the practicalities of data collection during a presentation (i.e., during a module's semester); the availability and commitments of the relevant groups of people (e.g., module team members, students, technical production staff, associate lecturers, guest presenters) and took into consideration any interests of those who have been involved in the production and presentation of the Labcasts. The meetings resulted in designs for specific modules (see Appendix A). This section outlines the methods proposed to the teams from the five modules summarised in Table 3.1 above.

3.4.1 Observations

Observations are conducive to designs where direct observation of an event can be studied (Yin et al., 2006). Observations facilitate the systematic watching, monitoring, and noting processes, behaviours and activities (Cohen et al., 2018) and are more beneficial when combined with other data collection methods (Tashakkori & Teddlie, 1998). Observations have often been used in researching online communities to gather data on the interactional setting (Lin & Gao, 2020; Liu et al., 2010; Rotman & Preece, 2010). Participant observation entails the researcher as an active participant in a setting where the behaviours and interactions occur. In contrast, nonparticipant is typically a non-intrusive observation of behaviour and making inferences (Tashakkori & Teddlie, 1998).

Observations allow the recording of information as it occurs in situ. It enables an open-ended and inductive approach to understanding contexts and can produce factual information on interactivity, focus on events and behaviours or qualities (Cohen et al., 2018). However, a disadvantage is making inferences on individuals' intentions, motivations and other attributes (Tashakkori & Teddlie, 1998), and the method is time-consuming. It was agreed that observation of live and recorded events would be required to collect data on the production and presentation processes of the Labcasts along with system data logs and text-chat. Collecting usage or data logs facilitate tracking frequencies in online interaction and describing discourse and content (Preece, 2000). In addition, metrics and usage logs complement other methods and gain a fuller picture through triangulation.

3.4.2 Discussion forum threads

Discussion forums are the main communication tools used to foster student interaction within a module. Students post messages asynchronously and discuss ideas, pose questions and solve problems. The hierarchical structure of a forum thread means it is relatively easy to locate, select and sample segments around a research question (Holtz et al., 2012). Likewise, it can facilitate students to voice opinions and reflect on their learning. As students read their peers' opinions and thoughts, it can urge students to compare them with their ideas, understanding and interpretations (Zhu, 1998). However, periods of inactivity and limited student participation can hinder meaningful data (de Lima et al., 2019). A proposed method was to set up a thread on the students' websites to elicit comments and feedback on the Labcasts. This method was deemed inappropriate as additional threads can overwhelm students. STEM modules, in particular, have multiple project specialists and module-wide fora to engage. In addition, content areas on discussion threads and many messages sent do not always indicate the quality of the student experience (Jara et al., 2008).

3.4.3 Questionnaires

Obtaining information from students through survey methods is a common method used in educational research, typically in attitude questionnaires, and is useful for capturing data on students' perceptions, attitudes, preferences and experiences (Cohen et al., 2018; Creswell, 2018). In addition, questionnaires have been recognised to provide convenience, confidentiality and anonymity (Mertens, 2005), encouraging

participants to be more honest in their perceptions and attitudes around their learning and online experiences (Bryman, 2016).

However, shortcomings of survey methods can be due to survey timing, potential poor sampling and low response rates (Creswell, 2014). Therefore, the following surveying tools were suggested:

Feedback widgets were proposed to collect immediate feedback from students at the end of a live Labcast. Closed (multiple-choice) questions were proposed to poll students' feedback or opinions about perceived learning gains. Jara et al. (2008) recommend taking advantage of the technology-in-use as part of effective evaluation and self-assessment. However, this method was not feasible in all instances as some modules already had several widgets incorporated into their Labcast design. Where that was not the case, the use of additional widgets was appropriate and of interest for the presenters to include during a live event.

The option of using Real-Time Student Feedback (RTSF), an in-house tool used on a module's website, to capture feedback from students during their study was not pragmatic as several modules already use this tool as part of their evaluation strategy. Snapshot questionnaires were proposed to collect students' or other groups' responses to a consistent set of questions over time. Administering this type of survey could allow a comparison of changes over time. For example, surveying early during a module can elicit potential anxieties and expectations. Learning experiences and activities are likely to be fresher in the mind of students. However, several issues of the logistics of sampling students arose, namely the proportion of students who drop out early in a course and the issue of oversampling students during a presentation. In addition, there are often competing survey requests at the module and institution levels.

Overall, an end-of-module online questionnaire was deemed appropriate to administer across all five modules and was conducive to answering the research questions. In addition, the end-of-module surveying facilitates a more reflective exercise of experiences and perceived learning outcomes (Jara et al., 2008). Finally, this method would allow cross-comparison and support data triangulation (Bryman, 2006; Creswell, 2014).

3.4.4 Interviews

Interviews, another form of a survey, are appropriate to provide a thicker description of the teaching and learning process. Interviews can help glean particular insights about participants' experiences, motives and opinions (Cohen et al., 2018). It also allows the researcher to probe into previous questionnaire responses. As a result, participants can be more reflective during interviews. However, scale, time and convenience are potential obstacles (Creswell, 2018). Structured interviews require a specific answer or a selection from a prescribed written list of options.

In contrast, unstructured is more open-ended and exploratory, allowing interviewees to answer fully or briefly. However, unstructured interview data can be difficult and time-consuming to analyse. Semi-structured allows for general and pre-planned questions and can be more systematic than open-ended interviewing (Merriam & Tisdell, 2016). Interviews could provide an opportunity to explore the experiences and perspectives of students and other stakeholders, gain feedback on previous observation findings and support triangulation of data (Tashakkori & Teddlie, 2010; Yin, 2018). Except for module TM129, it was agreed that the researcher could recruit available students from the other four modules and that semi-structured interviews (or focus groups) would be appropriate.

3.4.5 Focus group discussions

Focus groups allow for data collection through group interaction and can evaluate existing programs or interventions. It is distinguished from one-to-one interviews or questionnaires because of reflecting on the participants' interactions and collective views. Like the dynamics of discussion forums, focus group participants can listen to the opinions of others before forming their views and build on others' ideas and opinions (Litosseliti, 2003). Focus group methodology can be useful to triangulate with forms of surveying and observations, and might be more economical on time, producing more data in a shorter period (Merriam & Tisdell, 2016). However, group size can often be a drawback; too small and intragroup dynamics can exert a disproportionate effect and too large can be challenging to manage (Cohen et al., 2018).

A proposed strategy was to conduct face-to-face or online focus groups with five or six students (or other groups, e.g., ALs). For module S206/SXF206, face-to-face focus

groups could be conducted during one of the Field Studies Council Centres for residential field schools between 29th March – 3rd April 2020. In addition, an online focus group of five to six students could be conducted for those undertaking the on-screen module (i.e., S206 track). For module S315, two or three face-to-face focus groups could run with approximately 15 students on the 'SS031 – Further laboratory skills' residential school at the Walton Hall campus in mid-November 2019. This method would allow follow up on student questionnaire responses and further elicit student experiences and opinions about the Labcasts. Focus groups were agreed upon and would occur during the mentioned times. For staff, the discussions would be at the end of a module.

3.4.6   Learning diaries

Participants' diaries have been utilised to collect opinions on online communities (Preece, 2000) and can be a valuable tool to gather natural, subjective accounts of an individual's social world (Burgess, 2006) and can increase validity and reliability (Cohen et al., 2018). Participants can undertake the activity at a time convenient for them. For example, reflective questions could be used as prompts in a learning diary to ask students to write reflectively about the social aspects of studying the module and experiences with Labcasts. However, individuals can also get lethargic or forget to enter data; therefore, incentives are usually necessary (Preece, 2000). The researcher proposed recruiting five or six students to keep a diary during the module presentation to be collected at the end of the module. However, the method was not pragmatic out of abundant caution and concerns from module teams around students' workload.

3.4.7   Documentary and visual media

Forms of documentary and visual media can further enrich the understanding of a medium by considering the production of the associated documents, images and artefacts and the audience it was intended for (Cohen et al., 2018). It was negotiated to collect storyboards and scripts (i.e., similar to a lesson plan) to facilitate observations and understanding of the procedures and processes involved. A separate negotiation was made with the curriculum managers for each module to collect module presentation data at the end of the module.

3.5   Ethics and recruitment procedures

Potential cohorts of students and staff participants were identified with the agreement of the module team chair from the five modules. They were purposively selected based on live broadcast events, availability, and student course calendars. Data was collected via the OpenScience teaching laboratories and local field sites at the Open University (UK). The time frame for the data collection phase was between October 2019 and July 2020. However, this was inevitably impacted by the pandemic. Consequently, data collection ran up until November 2020.

3.5.1   Participants and sampling procedures

As mentioned in Chapter 1, IWBs can accommodate hundreds of remote students as such a stratified sampling method was used in this study. Stratified random sampling intends that the sample represents specific subgroups or strata (Bryman, 2016). The researcher conducted data processing to identify samples, including downloading the Stadium Live event connection logs, an automated log generated after a Labcast event. Each entry shows the date and time of when a user connected and whether the connection was before the event going live (pre-event), during a live event, or after the event ended (post-event). A separate field indicates if the user was a known administrator.

The connection logs of all the IWBs were extracted into Excel spreadsheets. Four groups were identified to draw a sample:

1.   students who were 'live users' and watched the recording.
2.   students who were 'live users' but did not watch the recording.
3.   students who were not 'live users' but watched the recording; and
4.   students who neither watched the live or the recording.

The data sets were sent securely via password protected files via ZendTo, a secure file transfer application for confirmation by the Quality Enhancement and Learning Analytics Team. Samples of students were returned according to the four groups who could be approached for research on each module.

Descriptive statistics were used in this study. An Excel data set was created to capture the proportions of available males and females in the above four groups, along with the means and standard deviations of the samples and respondents' age across the

five modules. The mean (i.e., *M =*), which is a measure of central tendency, represents a single number that most accurately sums up an entire set of numbers. Standard deviation (i.e., *SD =*) is a measure of variability and represents the average deviation of the scores within a distribution (Reid, 2014). The relevant tables and figures are shown in Chapter 4. Section 4.2.2.

3.5.2   Recruitment procedures

The research followed the OU ethical procedures for research with human participants and the principles outlined in the British Educational Research Association (BERA). Before data were collected, the researcher addressed the guidelines of responsibility to participants by ensuring that participants' voluntary informed consent was sought and maintained from staff, students and external parties. All participants were informed of the voluntary nature of participating in the research and their right to withdraw. No recompense was offered to individuals who volunteered participation. Students were informed that the research would not affect their progression, assessments or grades. Participants were fully informed about the research study, and permission was sought to publish findings from the study while keeping names confidential. Several documents were relevant for ethical clearance (see Appendices B, C and D).

- Participant information sheet
- An invitation email
- Consent form
- Focus group and interview questions and online survey links

Invitation emails with the attached information sheet were sent on the researcher's behalf by the module team chair and curriculum manager with a live link to the online questionnaire. In addition, an announcement was posted in the News Items area of three of the modules' websites (i.e., TM129, SXPS288, SXHL288). Participant information and consent buttons were added to the questionnaire. At the end of the survey, the students were asked to opt-in and provide their email addresses if they wished to participate further in interviews. Information and consent were emailed directly to staff participants, and Doodle polls were used to schedule convenient times to conduct interviews and focus groups.

3.5.3 Data management and information security

All research data from questionnaires and interviews were managed following the General Data Protection Regulation (GDPR) and the OU's data protection requirements. The researcher also undertook the university's online GDPR training, which provided helpful guidance on managing data and secure workspaces. Data was stored on university equipment and was password protected. Data were anonymised before and during transcription, and audio recording files was securely deleted after transcription. The researcher ensured that collected data from interviews, focus groups and chat exchanges used identifiers to anonymise the participants' identity. The research design was approved by the Human Research Ethics Committee of The Open University (HREC/3413/Brown) and the Student Research Project Panel (2019/133)

3.6 Data collection mapping

The nature of investigating the modules necessitates methods that capture processes, behaviours and attributes, and variables such as frequencies, interactivity, and duration. Table 3.2 shows the negotiated and applied methods in each module to answer the research questions (listed in Chapter 2, Section 2.1, p.10).

Table 3.2: Data collection matrix across the five modules.

Research questions	Data collection methods								
TM129 – Technologies in Practice									
	Staff focus group	Observations	Feedback widgets	Student questionnaire	Student interviews	Other documentary & visual media	Guest interview	AL focus group	Snapshot questionnaire
RQ1. Purposes	●					●			
RQ2. Strategies	●	●							
RQ3. Interaction		●	●						
RQ4. Motivation			●	●					
RQ5.Knowledge		●							
RQ6. Community				●					
SXPS288 – Remote Experiments in Physics and Space									
RQ1. Purposes	●					●	●	●	
RQ2. Strategies	●	●					●	●	

RQ3. Interaction		●	●						
RQ4. Motivation			●	●	●				
RQ5. Knowledge		●			●				
RQ6. Community				●	●				
S206 – Environmental Sciences									
RQ1. Purposes	●					●		●	
RQ2. Strategies	●	●						●	
RQ3. Interaction		●							
RQ4. Motivation				●	●				●
RQ5. Knowledge		●			●				
RQ6. Community				●	●				●
SXHL288 – Practical Science: biology and health									
RQ1. Purposes	●					●			
RQ2. Strategies	●	●							
RQ3. Interaction		●							
RQ4. Motivation				●					
RQ5. Knowledge		●							
RQ6. Community				●					
S315 – Chemistry: further concepts and applications									
RQ1. Purposes	●					●			
RQ2. Strategies	●	●							
RQ3. Interaction		●	●						
RQ4. Motivation			●	●		●			
RQ5. Knowledge		●							
RQ6. Community				●					

3.7 Data collection procedures

Several procedures were used to collect the data summarised in Table 3.2. This section outlines the procedures used to collect data.

3.7.1 Non-participant observations

Observations were conducted in the field and teaching lab and through reviewing the recordings that were made available after the live event. Observation procedures were conducted in three stages: field observation, video observation, and usage data logs. Data were stored, managed and analysed in NVivo 12® a qualitative data analysis

software program designed to manage and analyse text data, such as: interview/focus-group transcripts, documents, multimedia data (e.g., video and audio files) and mixed data (e.g., open and closed questionnaire responses).

The first stage was to observe the planning and production of the Fieldcast or Labcast. Following Derry et al.'s. suggestion to separate observations notes from analytical notes (2010), a template was devised for observation during rehearsals and live events. This was used to note what was observed, how it unfolded, why something happened in a particular way and what it meant. The template also included the physical setting (e.g., the layout of the studio and its organisation), the interactional setting (e.g., the interactions taking place, discussion of turn-taking, linguistic and non-linguistic cues) and the instructional setting (e.g., teaching resources and their organisation, question-and-answer formats, pedagogic styles). The templates and notes were coded in NVivo about the participants' perceptions of the rehearsals and live events. These notes were later cross-referenced with video observation annotations and contributed to the question protocol for the staff focus group discussions to verify the observations.

In the second stage, video recordings of Labcasts were downloaded from the server, transcribed and imported into NVivo. The Labcast and Fieldcast recordings varied from 25 minutes to 90 mins. Once transcribed, files were double-checked, and names were anonymised. A discussion of how the data was analysed is discussed in Section 3.8 below.

The third stage was to collect Stadium Live usage data logs. Usage logs and metrics are routinely used to quantify and describe interaction, engagement and online communities (Ellis, 2013). Data logs were downloaded and collated in Excel as a summary table. Columns selected for analysis were the number of unique users in a live event, interactive users during the event, the number of people posting, the number of text-chat posts and the number of widget responses. Calculations were performed to establish the percentage of people participating across three variables: (1) the participation in chat, (2) responding via the map widget, and (3) participating in chat or responding via widgets.

The text chat logs were also downloaded into Excel to identify the users who participated in text-chat across the Labcasts and analyse messages. The data were

cleaned by removing duplicates, user ID and names and replacing them with an anonymised identifier or pseudonym. This procedure was carried out across a module's Labcasts and Fieldcasts. Messages with personal names or information were also removed and replaced with a pseudonym. The files were then imported into NVivo for analysis.

Data logs from the feedback widgets were collected at the end of Labcasts in modules TM129, SXPS288 and S315. The questions and scales were incorporated into the appropriate widget interface during the rehearsal process, and presenters would poll them towards the end of the live event. Thus, the widgets served as a self-assessment strategy and to get immediate feedback from the students. The questions, devised by the researcher, consisted of five-scale Likert questions and open-ended text-box and polled how much the Labcast had improved understanding of a subject or an experiment or what three things' students took away from the event. The data logs were imported into NVivo, and an inductive approach was used to code the words/phrases producing affective and cognitive themes.

3.7.2 Questionnaires

Web-based questionnaires were devised using the Joint Information Systems Committee (JISC) online survey tool, which provided students with a familiar survey interface and accessibility features. The questionnaire consisted of five-point Likert scale questions and free-text boxes. Types of question categories that were uniform across the modules included: usefulness of live Fieldcasts/ Labcasts and recordings, impact on learning, Labcast formats, motivations for attending (or not), and sense of community. There was some variation of questions due to the interests of each module team chair.

Routing pathways were designed into the survey based on a structured sample of the student cohort across four groups (listed in Section 3.5.1): (1) students who watched the live event and watched the recording; (2) students who watched the live event but not the recording; (3) students who did not watch the live but watched the recording; and (4) students who neither watched the live or the recording. For example, group 1 would be routed to questions of their experiences of attending live and using the widgets, whereas group 3 would be routed to questions around their experiences of using the recordings. In group 4, students were asked to select why they did not attend

live or watch the recordings and what could be made more useful. An invitation to opt-in to discuss their opinions further via interviews was included at the end of the survey. If students selected yes, they were invited to provide an email address for the researcher to contact them. Data were downloaded and analysed using descriptive statistics in Excel. Surveys were also imported into NVivo for thematic analysis of the responses to open-ended questions.

3.7.3 Semi-structured interviews and focus groups

Data was collected through semi-structured interviews and focus groups with individuals. Interview scripts and questioning routes were checked with supervisory teams to assess the order of questions and whether adjustments or further prompts were required.

To recruit students, online Doodle Polls were sent to them with a range of days/times to group them for a focus group discussion. Due to the limited availability of students, individual semi-structured interviews were set up at the end of their modules. Four students from the SXPS288 module participated. Adobe Connect, a web conferencing software, was used to conduct online interviews. This tool was selected because students were familiar with the platform and offered flexibility for both the researcher and the participants. The researcher set up private rooms for each student participant or participant group.

The interviews lasted from 45 mins to 1 hour. Interview scripts, adapted to the module context, were devised around six broad topics for questions. They followed Patton's (2015) suggestion to develop questions around: behaviour or experience, opinion or belief, feelings, knowledge and demographics (see Appendix F). The interviews had a degree of naturalistic inquiry to allow some discussion to unfold naturally and openly. However, there was a predetermined focus on understanding their learning experiences on the module and participating in Labcasts or Fieldcasts. Think back questions were used to take participants to a particular experience, e.g., the first Labcast. Chat exchanges and questionnaire responses, where provided, were probed for further clarity or elaboration.

Module team members, associate lecturers and the technical production team participated in focus group discussions. Three module team members from TM129

participated in a focus group; three module team members from SXPS288; four module team members from S206; and three module team members from S315. One module team member from SXHL288 participated in a semi-structured interview. Three staff members from the technical production team participated in a focus group. The discussions lasted from 1 to 2 hours in one sitting and were all conducted in Adobe Connect. The questioning routes were designed to prompt discussion and elicit comments around staff's IWBs experiences. Questions were devised around five broad themes: teaching students on the module, IWBs as situated in the module, strategies used within IWBs, sense of community and future IWBs. In SXPS288, 3 ALs participated in a focus group and four ALs from S206. Questions were around tutoring students on the module, IWBs as situated in the module, IWBs as supporting assessment and sense of community (see Appendix I). For the technical production team, questioning routes were explored through five broad themes: producing IWBs, maintaining broadcast consistency, strategies used to support presenters, sense of community and future IWBs. A guest presenter from NASA, based in the U.S, was interviewed. The interview script was to elicit comments on their first experience of co-presenting on a Labcast on the SXPS288 module. All staff focus groups and interviews ran on the Adobe Connect platform with the exception of the NASA guest presenter whose interview was conducted in Microsoft Teams.

In one case, the researcher had broadband issues whilst conducting a focus group with the TM129 module team at home and could not get back online. Arrangements were made to continue the discussion a day later, and the researcher had put contingency plans in place (i.e., using a mobile device for a personal hotspot for connectivity). Focus groups and interviews were recorded using the in-built function of Adobe Connect. Audio files were uploaded into transcription software. Once transcribed, files were anonymised and checked for accuracy. The procedures used for analysing the data are discussed below in the order of the data collection procedures outlined in Section 3.8.

3.8   Data analysis procedures

Fieldcasts and Labcasts are designed interactive events where module teams and the technical production team plan the main stages, types of activities and forms of interaction, so the planned running orders or scripts were incorporated into the analysis. The first stage was to import the transcribed video recordings of the 13

Labcasts into NVivo. The software facilitated the researcher's ability to search for and to identify theoretical ideas. These ideas became categories or 'nodes' and formed a hierarchical structure where data segments were coded to each node, becoming coded references (Jackson & Bazeley, 2019; Saldaña, 2016). Three 'cases' - an NVivo term that represents the units of observation in the study were created, these were People (i.e., the participants), All Chatlogs and All Labcasts. The cases allowed all information related to an entity to be held in a case and make comparisons.

3.8.1 Flanders's Interactional Analysis Categories

An adapted protocol of the original ten-category Flanders's Interaction Analysis Categories (FIAC) was used to analyse communicative strategies. The adapted coding scheme was used to explore and classify types of presenter behaviours, how the interaction was initiated and what types of engagement ensued. The coding scheme identifies categories such as initiating, responding, teacher talk and student talk and has been used by researchers in real-time to identify general patterns in classroom interaction (Erickson, 2006). The analysis of initiation and response, which is a characteristic of interaction between two or more individuals, is a key feature of the original categorical system. According to Flanders, initiating means making the first move, leading, and introducing something. Responding to an initiation entails taking action to counter, amplify or react to ideas already expressed (1970). Lecturers, in most situations, are expected to show more initiative than students. The contexts in which the FIAC has been applied has been discussed in Chapter 2, Section 2.5.4, p.38.

For this study, the original categories numbers: 1 – 4 and 6 – 9 were utilised. Category 5 'Lecturing' in which a teacher gives facts or opinions about content or procedures was omitted, in addition to category 10 'Silence/Confusion' which represents a pause in communication or noise and confusion (Flanders, 1970). The web broadcasts' primary communication function is live video transmission, a one-to-many mode, and therefore the category 'Lecturing' would naturally be the highest frequency. Instead, the framework is used to classify interactions and identify what presenters and moderators said and did to advance dialogue and influence participation. The adapted protocol also considers the role that a moderator plays in the text-chat box. Additional categories were therefore added to the student-student interaction dynamic (Moore,

1993). Table 3.3 shows the adapted protocol used to code across the web broadcast transcripts and the associated text-chat transcripts.

Table 3.3: Interaction analysis protocol based on Flanders (1970).

		RESPONSE	Coding notes
Presenter/moderator Talk	Indirect influence	1. Accepts Feeling: accepts and clarifies an attitude or the feeling tone of the students in a non-threatening manner. Feelings may be positive or negative. Predicting and recalling feelings are included.	Requires that the presenter/moderator literally names or otherwise identifies the emotion or feeling, e.g. I'm really happy to see, etc.
		2. Praise student action or behaviour. Jokes that release tension reacts to ideas that have already been expressed or to amplify ideas.	a RESPONSE to the widgets polls or something said in the chat – Examples incl. exclamations such as Right, Good, OK.
		3. Accepts or uses ideas of students. Clarifying or building or developing ideas or suggestions by a student.	NOT FOR WIDGETS Can include acknowledging the students' idea by (a) repeating the nouns and logical connections, (b) modifying the idea, rephrasing it or conceptualising it in the teacher's own words; (c) applying the idea of taking the next step in a logical analysis of a problem (d) comparing the ideas, drawing a relationship.
		4. Asks questions: Asking a question about content or procedure with the intent that a student answer	Code when presenters use question-and-answer widgets or presenters give an opportunity for viewers to ask a live question.
		INITIATION	
	Direct influence	6.Gives directions: Give directions or instructions in which a student is expected to comply	Code when presenter or moderator gives an explicit direction to do something e.g., post questions on the forum or instruction around the interface.
		7. Guide students' thought: Making statements intended to guide a student's thought or research. Can apply to the module materials, assessments or research outside the scope of the module.	
		8. Criticising or justifying authority: statements intended to change student behaviour from non-acceptable to acceptable pattern, stating why the presenter is doing what they are doing. Intended to produce compliance.	

		9. Student-Response. Response to presenter or moderator. To act after an initiation. to counter, to amplify or react to ideas that have already been expressed, to conform or even to comply with the will expressed by others.	Code for most expressions that indicate students are attending to what they are seeing or hearing. Includes students asking questions.
Student talk		10. Student-Initiation: Talk by students in which they initiate their topic, asking thoughtful questions. Deals with independent judgement, higher mental processes and development of own explanations/theories only.	
		11. Student-Talk Responsive: Student response to another student in which it is explicit who is being referenced (e.g., @student12 thanks for the info).	
		12. Student-Talk Initiative: Talk by students which they initiate to another student in which they ask or answer thoughtful questions which develop ideas (e.g., @ student8, I think it's to do with not having enough solar radiation).	

In additional to the categories in the adapted protocol, emerging themes relevant to key constructs such as social presence theory (Rourke et al., 1999); sense of belonging (McMillan & Chavis, 1986); learning community (Liu et al., 2010; Rovai, 2002a) and other pedagogical strategies (Bonk & Khoo, 2014) were also coded. The use of deductive and inductive approaches to interaction analysis was to unify the broadcasts across cases and identify similarities and differences in interaction and communicative strategies.

3.8.2   Interactional analysis and units of meaning

Interactional Analysis was used to analyse and code the various functions of interactional moves and talk by coding the frequencies and patterns within units of meaning. There were four units of meaning:

1. Stages of event
2. Widget cycle
3. Communicative strategies
4. Types of discourse

The units of meanings are parent nodes. Stages of event referred to one of the forms of interaction represented in several or all 13 Labcasts. To analyse the 'interaction' and the 'engagement' elements. For this purpose, 'to interact' referred to the various

planned forms of interaction or stages and 'to engage' analysed the communicative strategies that would enable continuous interaction with an artifact or with a person

The unit of analysis was at the sentence and paragraph levels. A sentence may contain multiple occurrences of a node. For example, all presenters planned to greet and welcome the audience, introduce themselves and orientate the viewers to the interface. These statements and phrases were coded at the child node *establish social connection* and referred to setting up the tone/climate for social interaction as identified in Bonk and Khoo (2014). Other stages of events were identified using an inductive approach and consulting the running orders, which aligned with a generic formula of teaching and learning often reflected in scientific methodology or process. Figure 3.8 shows the parent and child nodes.

Figure 3.8: Stages of event parent node and child nodes; a unit of analysis.

The widget cycle unit referred to how presenters used the widgets to foster student engagement and facilitate feedback. Coding used an adapted question cycle developed by Beatty et al. (2006). The context in which the authors applied the question cycle model is discussed in Chapter 2, Section 2.6.1. The widgets are embedded questions in a live broadcast for distance students. Therefore, aspects of the model were used as a general framework to understand the question-and-answer widgets' role by capturing the stages of how the widgets are used in this context, as shown in Figure 3.9.

Figure 3.9: Widget cycle parent node and child nodes; a unit of analysis.

3.8.3 Discourse analysis coding scheme

After the FIAC was applied to the text-chat transcripts, a content analysis coding scheme developed by Lipponen (2000) was used to code students' discourse patterns and explore whether it represented knowledge-building discourse (see Section 2.5.4, p.38). Lipponen's study analysed the indicators of knowledge building in a computer-mediated discourse on a Computer-Supported Intentional Learning Environment (CSILE). Social-oriented, fact-oriented and explanation-orientated discourse were discovered to be three pedagogically and cognitively distinct modes of discourse. This research expands the definition of social-oriented to capture a broader social-affective theme that relates to indicators of social presence (Rourke et al., 1999) and bridging knowledge, a dimension of sharing resources to enrich community knowledge (van Aalst, 2009). Figure 3.10 shows the unit of analysis for types of discourse.
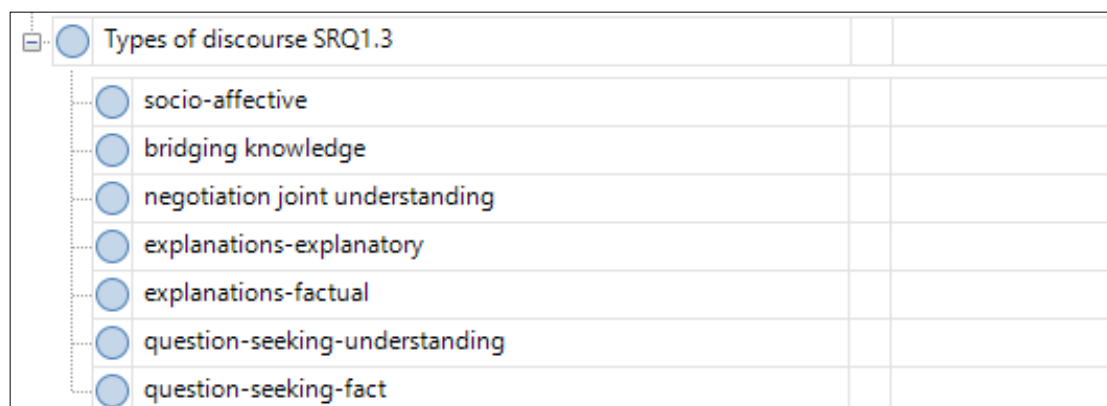
Figure 3.10: Types of discourse parent node and child nodes; a unit of analysis.

3.8.4 Classroom Community Scale

Empirical research in online learning communities has used survey instruments to measure student perceptions. For example, the Classroom Community Scale (CCS) has been used extensively to measure the presence of community (Ellis, 2013; Rovai, 2002b). The contexts in which the CCS has been applied is discussed in Chapter 2,

Section 2.5.3. At the end of the questionnaire, respondents were asked to assess their perceptions of a SoC in their module. The 20-item scale generates classroom community scores and two interpretative factors, 'connectedness' and 'learning'. Respondents select the place on the five-point Likert scale from Strongly disagree to Strongly agree that best reflects their feelings about each item. Examples of questions include *I feel isolated in this module, I do not feel a spirit of community,* and *I feel that I am encouraged to ask questions*. Scores are computed by adding points that are assigned to each of the five-point scales. Items are reverse scored where appropriate to ensure that the most favourable choice is always assigned a value of 4 and the least a value of 0. The overall CCS score adds the values of all 20 items (i.e., a range of 0 to 80). Higher scores reflect a stronger SoC.

3.8.5 Thematic analysis

To analyse interview and focus group data, an inductive approach was used to identify, analyse and interpret patterns of meaning (Clarke & Braun, 2017). The aim was to answer Research Questions 1, 2, 3, 5 and 6, and to analyse whether Labcast purposes and expectations of presenters, ALs and other staff met student needs or expectations. Saldaña (2016) points out that questions that address theories of knowledge and understanding of a phenomenon suggest exploring participants' emotions, values and processes. Matrix coding queries were conducted to enable an intersection between modules and themes.

Emerging themes or categories across the data sets included: pedagogical, socio-emotional, technological and professional development. Process coding, a word or phrase which captures action, was used across the pedagogical theme to code the various teaching and communicative strategies. The names and descriptions of the sub-codes drew from research in the social learning literature. Evaluation coding, which captured words or phrases that assigned judgments about merits, worth or significance of Labcasting as an intervention were used to code types of attitudes (Saldaña, 2016). The NVivo code book can be found in Appendix K. Analytical memos and notes were created to note patterns of similarity, differences and frequency.

3.8.6 Reliability and validity

The researcher used intra-coder reliability as an approach to coder stability for the adapted FIAC. This was achieved by constantly checking coding against the criteria

outlined in the coding notes column in Table 3.3. To apply the adapted coding scheme developed by Lipponen (2000), inter-coder reliability was used to establish the percent agreement between three (including the researcher) raters to compare chat messages and gain clarity on the interpretive lenses. An anonymised spreadsheet of a text-chat transcription was sent to two independent raters. A discourse description tab was added with the seven types of discourse and their descriptions. The raters were asked to read each message, which totalled 198, and insert an 'X' in the cell which they felt represented the discourse patterns across seven columns.

Once completed, additional columns for the combinations of the raters were added. For each combination of raters, a "1" was inserted for agreement and "0" for disagreement and the mean was established. For rater1/rater2 the average agreement = 0.77; rater1/rater3 = 0.86 and rater2/rater3 = 0.77. The overall inter-rater reliability for the sample text-chat was 83%. Although no universally known criterion for what constitutes acceptable reliability in qualitative research exists, Jackson and Bazeley (2019) propose an 80 percent agreement level.

For interview and focus group data, detailed codes were assigned inductively and then brought together through aggregation for the themes and sub-themes to ensure coherence between the levels. Constant comparison was carried out by running matrix queries and ensuring all the data at a code had cohesiveness and equivalence and being discussed in the same 'positive' way or not, for example. Codes were also conceptually checked by referring to the literature and definitions of concepts used. An example of the codebook can be seen in Appendix K.

3.9   Chapter summary

This chapter focused on the methodological approach used in this study. It discussed Pragmatism as a paradigm in which the thesis would be best positioned and argued that a qualitatively driven mixed-methods approach was best suited to answer the research questions. Data collection and analytical procedures were discussed. The researcher explored the differences and similarities within and across the web broadcasts and participant cases in the data analysis phase. Chapter 4 presents the findings of the research across the five modules.

4 Results

Chapter four reports on the qualitative and quantitative findings to answer the six research questions outlined in Chapter 2, Section 2.1, p.10. As the previous chapters have outlined, the study presented in this thesis investigated how IWBs are used in five STEM undergraduate modules and explored the perceptions of stakeholders who produce, present, promote, and participate in IWBs.

4.1 Data collected across modules

The data was collected across methods. Table 4.1 summarises the different types and number of data collected across modules and the technical production team.

Table 4.1: Summary table of data collected across the modules and the technical production team.

Modules	Data collected											
	Running order/scripts	IWB recordings	Usage data logs	Text-chat posts	Widgets logs	Feedback widgets	Student questionnaires	Student interviews	Guest interviews	AL focus group	Staff interview	Staff focus group
TM129 – 'Technologies in practice'	2	4	4	849	27	3	27	0	0	0	0	1
SXPS288 – 'Remote experiments in physics and space'	4	4	4	444	23	4	15	4	1	1	0	1
S206/SXF206 – 'Environmental sciences'	3	3	3	675	16	0	29	3	0	2	0	1
SXHL288 – 'Practical science: biology and health'	2	2	2	350	11	0	9	0	0	0	1	0
S315 – 'Chemistry: further concepts and applications'	1	1	1	46	6	1	3	0	0	0	0	1
Technical production team	0	0	0	0	0	0	0	0	0	0	0	1

4.2   Participants

The participants in this study were from a range of staff and student participants across the five modules. Participants are represented by an associated module code and a generic descriptor. For example, TM129-MT1 refers to a module team member on the TM129 'Technologies in practice' module. Following a similar pattern, the descriptor GP refers to a guest presenter, GM guest moderator, AL for an Associate Lecturer, S for a student. PROD is for a member of the technical production team but is not prefixed with a module code.

Staff participants (i.e., module teams, guest presenters, technical production team) produced, edited, presented or moderated an IWB during 2019/2020 and included those who contributed to previous IWBs. As an umbrella term, staff participants include associate lecturers (ALs) who deliver tuition on the modules and sometimes promoted, moderated or attended IWBs and therefore had a perspective on them.

Two guest presenters are among the staff participants. TM129-GP1 is a lecturer and researcher in the Institute of Educational Technology (IET) at The Open University, whose research interests include mobile learning, widening participation and inquiry learning. The MAZI project, which involves constructing a DIY networking toolkit for location-based collective awareness was presented in a TM129 'Technologies in practice' Labcast. SXPS288-GP1 is a NASA Mission specialist based at NASA's Goddard Space Flight Centre in the United States, whose research focuses on mass spectrometers development for spaceflight. The presenter discussed the Rovers that are working on Mars and the future of Mars exploration as part of an SXPS288 'Remote experiments in physics and space' Labcast.

Student participants were from the five modules in the 2019/2020 academic year. The students vary in their engagement with IWBs and are categorised into four groups: (1) those that attended the live events only; (2) those that attended the live events and watched the replays; (3) those that watched the replays only and (4) those who neither attended a live event nor watched a replay.

4.2.1 Staff

One of the research objectives was to engage with various stakeholders who directly or indirectly have been involved with IWBs. Table 4.2 shows the numbers of staff invited to participate and the response rates.

Table 4.2: Staff response rates across the modules.

Participants	Sent to	Responses received and (response rate)
TM129 module team	4	4 (100%)
S206/SXF206 module team	4	4 (100%)
S206/SXF206 ALs	11	4 (36%)
SXPS288 module team	6	4 (66%)
SXPS288 ALs	6	3 (50%)
SXHL288 module team	5	1 (20%)
S315 module team	4	4 (100%)
Technical production team	3	3 (100%)

Table 4.3 summarises the staff demographics across the five modules. The data source column refers to how data was collected. A prefix distinguishes types of data sources. For example, CH signifies text-chat; INT is the interview; LC or FC means Labcast or Fieldcast observation; FG indicates focus groups, and SUR refers to survey data. Demographic data was captured from the OU's Quality Enhancement and Learning Analytics department, multiple-choice survey questions, during preliminary questions in focus group discussions and interviews or from secondary data (e.g., faculty website) where applicable. Focus groups and interviews were conducted with staff across five modules.

Table 4.3: Staff demographics across the modules.

Identifier	Length of service (years)	Gender (M/F)	Job Title	Labcast experience (years)	Labcast role	Data source
TM129 – Technologies in practice						
TM129-MT1	4 - 7	M	Senior Lecturer & Module Chair	1 - 3	Moderator	FG, LC, CH
TM129-MT2	20 +	M	Senior Lecturer	4 - 7	Presenter	FG, LC
TM129-GP1	10 - 15	M	Senior Lecturer	1 - 3	Guest presenter	FG, LC
TM129-GM1	10 - 15	F	Senior Lecturer	Less than 6 months	Guest moderator	LC, CH
SXPS288- Remote experiments in physics and space						
SXPS288-MT1	20 +	M	Senior Lecturer & Module Chair	4 - 7	Presenter	FG, LC, CH
SXPS288-MT2	16 -18	F	Lecturer	1 - 3	Presenter	FG, LC
SXPS288-MT3	6 - 12 months	M	Lecturer	less than 6 months	Presenter	FG, LC
SXPS288-MT5	4-7	F	Visiting Fellow & Topic Subject Specialist	1 -3	Presenter	LC
SXPS288-GP1	-	F	NASA Mission Specialist	less than 6 months	Guest Presenter	LC, INT
SXPS288-AL1	20 +	F	Associate Lecturer	-	-	SUR
SXPS288-AL2	5-10	F	Associate Lecturer	-	-	SUR, FG
SXPS288-AL3	5-10	M	Associate Lecturer	-	-	SUR
SXPS288-AL4	11 – 20	F	Associate Lecturer	-	-	SUR, FG
SXPS288-AL5	20 +	F	Associate Lecturer	-	-	SUR, FG
SXPS288-AL6	11- 20	F	Associate Lecturer	-	-	SUR

S206/SXF206 – Environmental Sciences						
S206-MT1	4 - 7	F	Senior Lecturer	4 - 7	Presenter	FG, FC
S206-MT2	4 - 7	M	Senior Lecturer	1 - 3	Moderator	FG, FC, CH
S206-MT3	4 - 7	M	Senior Lecturer & Module Chairperson	4 - 7	Presenter	FG, FC
S206-MT4	10 - 15	F	Senior Lecturer	4 - 7	Presenter	FG, FC
S206-AL1	10-15	M	Associate Lecturer	-	-	FG
S206-AL2	10—15	F	Associate Lecturer	-	-	FG
S206-AL3	20 +	F	Associate Lecturer	-	-	FG
S206-AL4	10-15	M	Associate Lecturer	-	-	FG
SXHL288 – Practical science: biology and health						
SXHL288-MT1	20 +	M	Senior Lecturer	4 - 7	Presenter	INT, LC
SXHL288-MT2	4 – 7	F	Senior Lecturer & Module Chairperson	4 – 7	Presenter	LC
S315 – Chemistry: further concepts and applications						
S315-MT1	19 - 20	M	Laboratory Manager	4 - 7	Presenter	FG, LC
S315-MT2	4 - 7	M	Senior Lecturer	4 - 7	Presenter	FG, LC
S315-MT3	4 - 7	M	Lecturer & Module Chairperson	4 - 7	Not Applicable	FG
S315-MT4	20 +	F	Senior Lecturer	4 – 7	Moderator	LC, CH
Technical production team						
PROD-1	20 +	M	Project Officer in Multimedia Technologies	4 – 7	Vision mixer	FG, CH
PROD-2	20 +	F	Media Development Manager	4 – 7	Producer/ camera operator	FG, CH
PROD-3	4 – 7	M	Software Development Manager	4-7	Camera operator/m oderator	FG, CH

4.2.2 Students

Students were recruited by first conducting quantitative surveys on the researcher's target population. Recruitment procedures are discussed in Chapter 3, Section 3.5.2. Table 4.4 shows the population available for research (N), the response rates (n) and the means and standard deviation for age in both genders across the modules.

Table 4.4: The population, response rates and age distributions across module cohorts.

Module	Available females n/N (%)	Respondents females	Available males	Respondents males	Sample Mean age	Sample SD age	Respondents Mean age	Respondents SD age
TM129-19J	83/527 (16%)	3/18 (17%)	444/527 (84%)	15/18 (83%)	33.10	9.20	37.11	13.75
TM129-20B	106/537 (20%)	4/9 (44%)	431/537 (80%)	5/9 (56%)	32.50	8.86	39.00	13.56
SXPS288-19J	16/83 (19%)	2/15 (13%)	67/83 (81%)	13/15 (87%)	35.80	8.48	45.27	14.03
SXHL288-19J	91/116 (78%)	7/9 (78%)	25/116 (22%)	2/9 (22%)	33.40	8.97	41.78	10.74
S206 / SXF206-19J	157/305 (51%)	14/29 (48%)	148/305 (49%)	15/29 (52%)	34.63	11.49	39.72	14.73
S315-19J	29/47 (62%)	0/3 (0%)	18/47 (38%)	3/3 (100%)	31.83	8.56	33.33	12.66

Figure 4.1 shows the distribution of the samples and respondents' age across the modules. The data shows a comparable spread of age between the groups in TM129-19J, TM129-20B, SXHL288-19J, S206-19J and S315-19J. However, the data in SXPS288-19J is more dispersed.
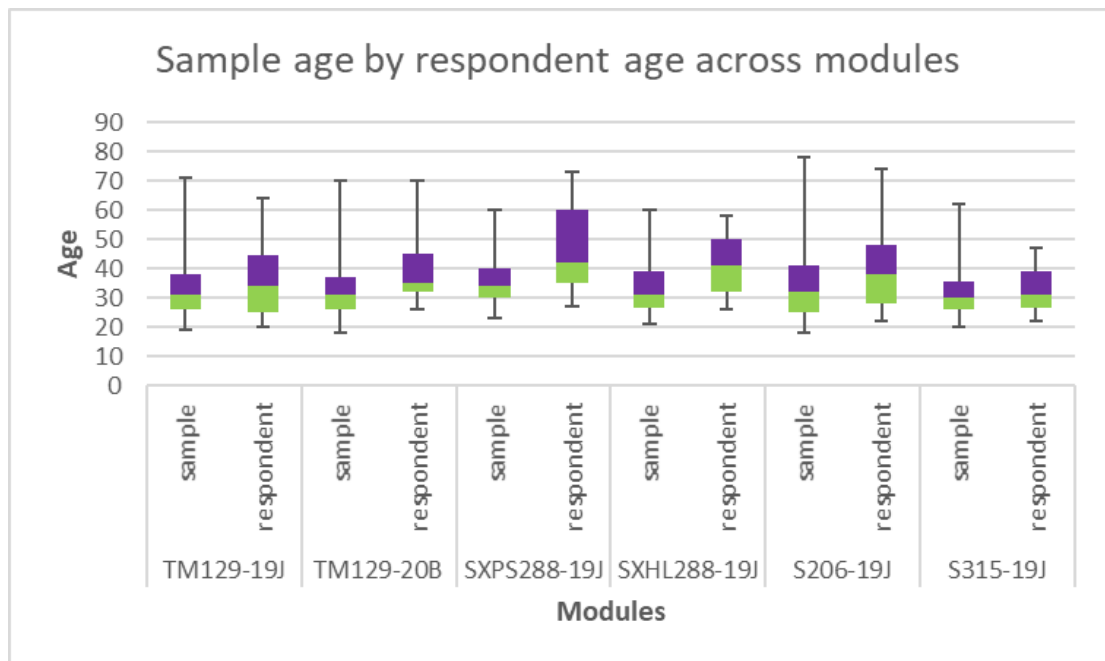
Figure 4.1: The distribution of the samples and respondents age across the modules.

Figure 4.2 shows the comparisons of the proportion of available students and respondents of both genders across the modules. The data shows similar proportions of gender in TM129-19J but a difference in TM129-20B. Likewise, there are similar proportions in SXHL288-19J and S206/SXF206-19J but a difference in SXPS288-19J. Although the sample sizes are not large and the number of responses are low, there is representation across both genders in all modules, with the exception of S315-19J which does not have female respondents.
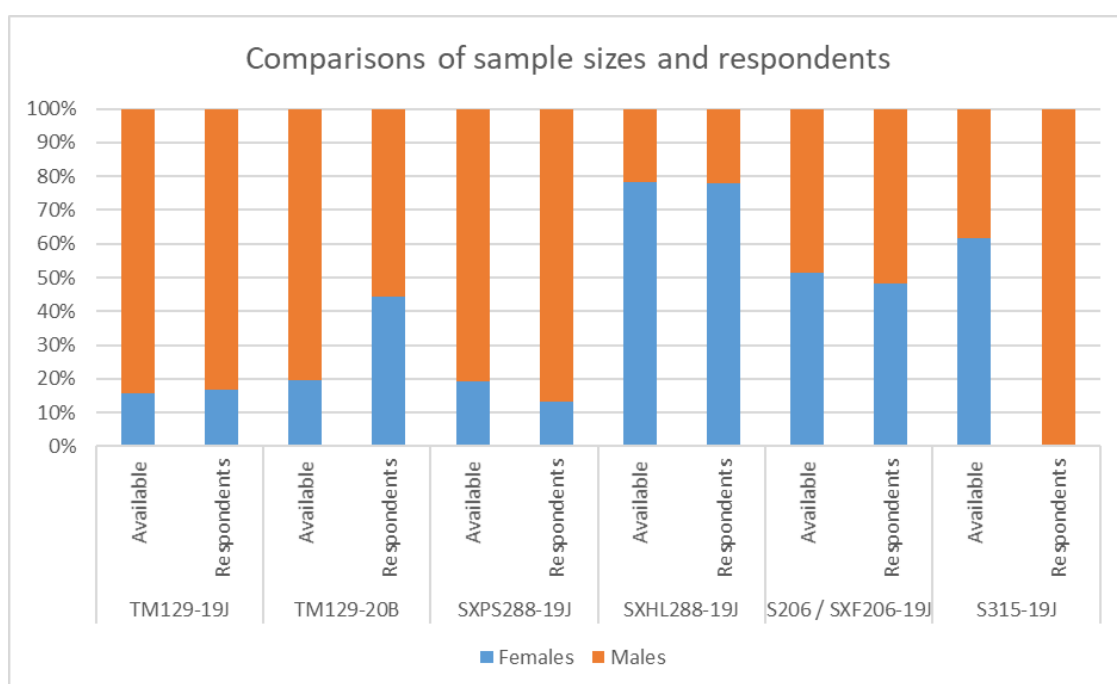
Figure 4.2: The comparison of sample sizes and respondents by gender across the modules.

Table 4.5 summarises the demographics of the seven students from two modules who volunteered to discuss their perspectives on IWBs. Out of 15 survey response rates in SXPS288, four students volunteered for interviews. The mean age was (40.64). Out of 29 survey response rates in S206/SXF206, three students volunteered. The mean age was (39.60).

The Labcast group column in Table 4.5 refers to the four categories identified from the connection logs (Chapter 3, section 3.5.1). For instance, LNR refers to students who were 'live users' but did not watch the recording; RNL signifies those who were not 'live users' but watched the recording, and LAR means students who were 'live users' and watched the recording. Demographic data was captured during preliminary questions in interviews. Protected characteristics such as gender, age and ethnicity were collected from sample data provided by the university's Quality Enhancement and Learning Analytics Team. The S315 module ran a residential school on campus in November 2019. The research objectives and invitation to voluntarily participate in a focus group discussion was extended in person during a briefing session however there was no take-up in participation.

Table 4.5: Student interviewee demographics across two modules.

Participants	Labcast group	Gender	Age	Ethnicity	Length of OU study (years)	Data source
SXPS288- Remote experiments in physics and space						
SXPS288-S05	LNR	Male	42	White	7 >	INT, SUR, CH
SXPS288-S07	LNR	Male	60	White	3 – 4	INT, SUR, CH
SXPS288-S09	LNR	Male	62	White	1 – 2	INT, SUR, CH
SXP288-S14	RNL	Male	43	White	5 – 6	INT, SUR
S206/SXF206 – Environmental sciences						
S206-S03	LAR	Female	26	White	1-2	INT, SUR
SXF206-S10	LAR	Male	58	White	3-4	INT, SUR, CH
SXF206-S13	LAR	Female	39	White	3 -4	INT, SUR

4.3 Planning IWBs

This section focuses on the aims and objectives of the module teams that used IWBs within practical science and technology modules. It presents the data for research question one: *What are the module teams' purposes for using interactive web broadcasts?* The focus groups and semi-structured interviews conducted towards the end of the module provided a reflection point. During focus group discussions and interviews, staff participants from multiple schools (see Section 3.7.3) discussed their perceptions and experiences with the web broadcasts and the extent to which they supported student learning and assessment.

As mentioned in Chapter 3, Section 3.8.5, an inductive approach was used to explore participants' opinions on IWBs. Focus group and interview transcripts were coded at the sentence and paragraph levels to capture a summative, salient attribute. Nodes ranged from descriptive (e.g., "We wanted to have an engaging and interactive way of introducing the projects"- SXPS288-MT1) to convey what was intended (i.e., *facilitating student engagement*), to more conceptual and analytical themes (e.g., "Seeing how that's done with all the wires, the lenses and bits and pieces hanging out all over the lab" – SXPS288-MT1) to convey *authenticity* and *sense of presence*. Coding was gathered at the next level down to aggregate respective child nodes to parent codes as a theme (e.g., *authenticity* to *socio-emotional* as a theme). This was done

systematically across the data sets, to enable checking a node as a theme and looking at the related child nodes. Figure 4.3 shows a sample of a focus group transcript with thematic codes to illustrate the coding.
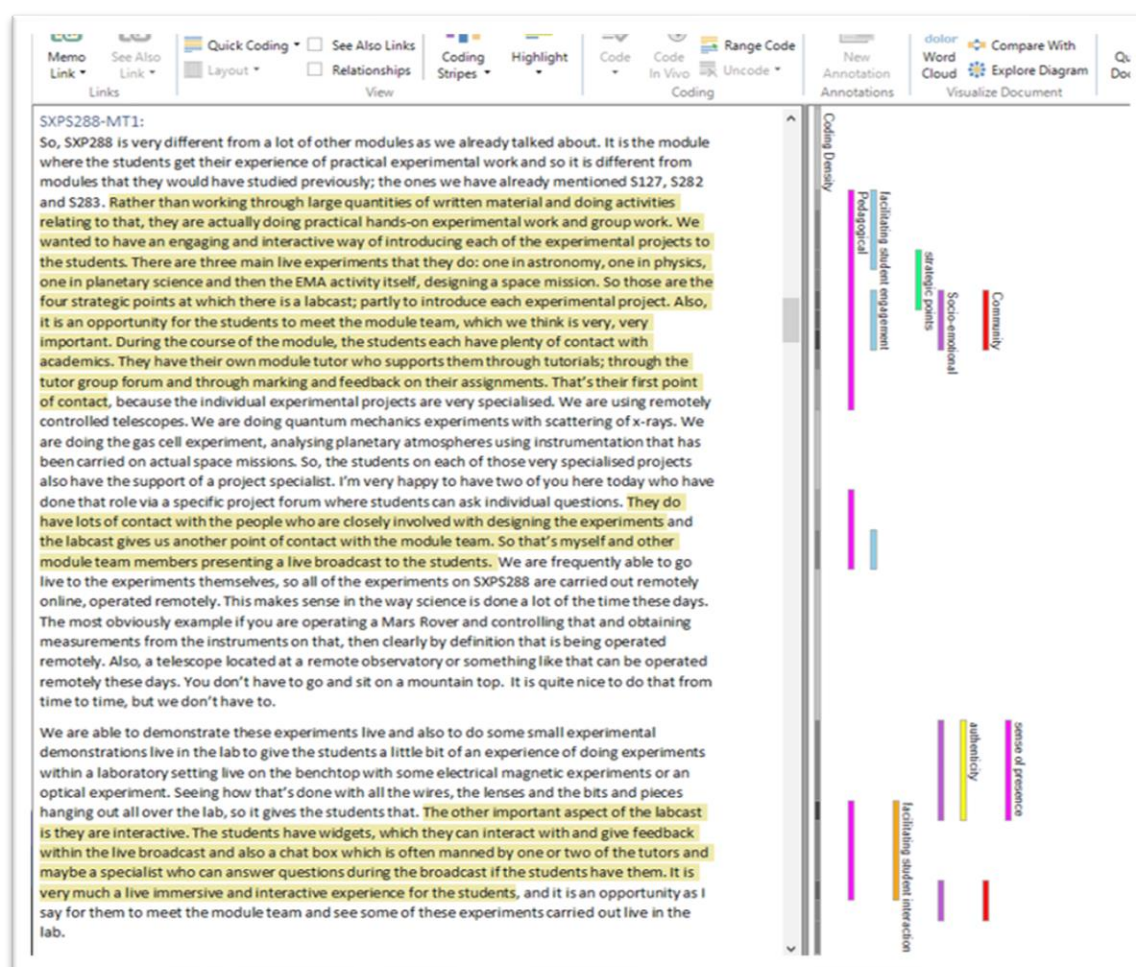
Figure 4.3: A sample of thematic coding on a focus group transcript.

The data show three main themes that emerged across the staff-related data sets: pedagogical, socio-emotional and technological. Five prominent sub-themes emerged on the reasons for using web broadcasts across the modules: *facilitating student engagement, introducing real-world contexts, planning strategic points, authenticity* and *sense of community*.

Table 4.6 summarises the coded themes identified from the data. The number represents the coded references. Where a theme was not identified in a particular module, a dash symbol represents silence on that theme. In Section 4.2.1 onwards, staff comments are presented in a block quotation or within quotation marks within the text. Where an ellipsis is used to shorten a sentence or combine two sentences, this is shown by (…). Square brackets [ ] are used to clarify meaning.

Table 4.6:Number of coded references and main purposes for using IWBs across focus groups and an interview.

Themes	Sub-themes	Focus groups and interview					
		TM129	SXPS288	S206	SXHL288	S315	PROD
Pedagogical	facilitating student engagement	5	1	6	2	4	__
	planning strategic points	1	1	__	2	2	2
	introducing real-world contexts	5	2	__	__	1	__
	supporting remedial work	__	__	__	__	__	1
	exploring module pathways	__	__	__	__	__	2
Socio-emotional	authenticity	1	6	2	__	__	__
	sense of community	__	10	5	__	2	2
	telepresence	__	1	__	__	__	1
Technological	scalability	__	__	__	__	__	3
	affordances	__	__	__	__	__	2

4.3.1 Pedagogical

An emerging theme was pedagogical. Pedagogical as a concept refers to comments on teaching objectives, principles and strategies. Three sub-themes of the parent theme pedagogical occurred across modules teams, and two sub-themes emerged from the technical production team. The most common purpose across all five modules was using IWBs *to facilitate student engagement*.

The module teams described IWBs as a means to "enthuse", "motivate", "encourage", "excite", "meet the module team" and "engage" students. For example, a module team member from TM129 commented:

> One of the big purposes was always this idea about maybe exciting and enthusing students. To go a step beyond shows them where they're going, some possible trajectory, something that might be interesting in the future. So those, I think, are the kind of top-level things. Labcasts were always to sort of motivate students to get them excited and engaged in the block (TM129-MT2).

The data show that different pedagogical concerns often determined module teams' purposes. For example, one SXHL288 team member reported that the Labcasts were used as a way to "engage students more in response to replacing wet labs, residential

schools and face-to-face teaching. It was felt that having a face behind the science would help students relate to what they were learning" (SXHL288-MT1). In contrast, an S206 participant mentioned the importance of independent learning as he states, "we wanted to identify the importance of uncertainty in fieldwork and knowledge and have students engage in their research activities" (S206-MT3).

SXPS288-MT1 and S315-MT3 agreed that Labcasts served to support the experimental projects. For example, S315-MT3 mentioned that the Labcasts "helped to promote the experimental experience (…) I think as well, we wanted to underline some fundamentals in their preparations for doing each of these experiments and the TMAs associated with it". Similarly, SXPS288-MT1 stated "we wanted to have an engaging and interactive way of introducing each of the experimental project and introduce them to perhaps a very different kind of experiment that they have been used to".

When discussing objectives, a similar sentiment was expressed by both an S315 and TM129 team member on altering the Labcast formats. For example, one member stated the common proverb, "don't mess with what's not broken" (S315-MT2), and another commented, "we sort of stuck to the formula. If it ain't broke, don't fix it. It works, and we believe it works" (TM129-MT1).

The data show that one AL from SXPS288 and three S206 ALs also perceived the IWBs to *facilitate student engagement*. For example, SXPS288-AL2 mentioned that she would often attend the students Labcasts and encourage students to do so. S206-AL1 reported that the Fieldcasts helped maintain a certain level of interest and that students appeared to be enthusiastic about attending, especially after joining the first Fieldcast. S206-AL2 commented, "I certainly try to engage them. I always send an encouraging email telling mine to go. And I always tell them, look, it's not just like a normal tutorial. It's actually really interactive". S206-AL4 agreed that Fieldcasts had the effect of attracting students to participate. He also commented on Fieldcasts supporting retention at a point when students may be struggling:

> I think the Fieldcast has the effect of pulling in people to engage. Students often do 120 points a year in the new regime, and they're doing far too much. They fall behind, and they're always in catch up mode. The Fieldcast is a point, certainly on S206, where they can actually do some catching up and get back up to date again (S206-AL4).

Module teams from TM129, SXPS288, SXHL288 and S315 mentioned using Labcasts at *strategic points* within the module. For example, TM129-MT2 mentioned that the three types of Labcasts were planned around the three blocks of the module to get students interested in each of the module's blocks. Except for TM129, there was a commonly held view that the *strategic points* were to introduce and support experimental projects or to emphasise the importance of an upcoming TMA. For example, SXPS288-MT1 stated, "There are three main live experiments that they do: one in astronomy, one in physics, one in planetary science and then the EMA activity itself, designing a space mission. So those are the four strategic points at which there is a Labcast". SXHL288-MT1 mentioned using each Labcast towards supporting the three summative reports that students write on a practical study. Another team member from the same school suggested *planning strategic points* as a means to create a focus, where the upcoming practical work is brought to the fore:

> I think they were also sort of put in particular points in terms of timing so some kind of like flagstones. This is the start of the module; here's a Labcast. Yes, this is a titrate. Similarly, we did one with HPLC, like here's a really important TMA. But I think it just made a big thing on particular points in the module. We did one once on NMR, but we've only done that once. The reason we did that was again come back after Christmas; here's a big thing that's going on. Alongside the teaching, it's like here's a big event, here's a Labcast (S315-MT2).

Similarly, the technical production team described one of the purposes of IWBs to support *strategic points* in a module. PROD-2 stated that "the broadcasts supported the introductions to projects that students undertook during the module, including teamwork or introducing them to a particular concept and demonstrating it with an experiment. At various points in the module the Labcasts help students become familiar with scientific processes" (PROD-2).

A recurrent theme in the focus groups was a sense amongst participants that Labcasts facilitated an introduction to *real-world contexts*. Three module teams (i.e., TM129, SXPS288 and S315) commented on the intent to *introduce real-world contexts* via Labcasts. Statements were coded at this node where there was a reference to exposing students to real-contextualised environments, experts or researchers in the

field. In TM129, a module team member and guest presenter reflect on their intent in using a Labcast for a networking demonstration, as seen in this example:

I can look to both [TM129-MT1] and [TM129-MT2], who might also reflect on why they invited me what they were hoping to get out of it. My impression or understanding is that the students spent several weeks learning some sort of technique. Basically, learning some code and that might be pretty dry in itself and to illustrate its value or its reason for use in the real world (…) I think the intention there is to bring the materials to life a little bit (TM129-GP1).

Yes, I'd agree with that. So, by bringing [TM129-GP1] into the Labcasts, we give that more applied context to the students that balances out the technical aspects of the demonstration (TM129-MT1).

Similarly, an SXPS288 academic commented on the opportunity to provide real-contextualised environments with experts from the field:

We were very fortunate to have [SXPS288-MOD01's] colleagues and contacts in NASA. To have a NASA expert from Goddard Spaceflight Centre to talk live to the students was a fantastic opportunity (…) So again, highlighting one of the main themes of the module. This idea of remote working not only in remotely operated experiments but also in remote cooperation and collaboration with people working in different countries being able to work together on a project (SXPS288-MT1).

A S315 team member commented on the importance of providing students with meaningful and concrete experiences:

These remote experiments involve an auto Titrater and a tutor led, remote HPLC, so it's [the Labcast] to introduce the technique in some ways, which is probably new to them. They must have an understanding because we're quite concerned that people might go into these remote experiments, and if they've had no preparation or no understanding, then it becomes more of a video game than actually gaining anything useful from the experiment (S315-MT1).

The technical production team discussed their perspectives on producing and using IWBs across the modules. Two discrete reasons emerged from the data. First, a

differentiation between discovery-based and topic-based Labcasts (cf. Chapter 3, Section 3.3.1). For example, one team member commented on the purpose of the level 1 discovery-based Labcasts as a means to "explore module progression routes and career pathways, giving students a sense of the scope of their possible degree routes and to get a real sense of the scientific community" (PROD-2). Second, an insight into one of the original purposes of using Labcasts that of remedial support:

> The idea was that Labcasts could provide a tool that the course teams could use to potentially address weak areas where there was an important concept that the course material or the module material didn't address well enough. And again, I think some of the third-level chemistry stuff, for example, has tried to address that. However, remedial could also be used in the more traditional sense of remedial session to students whereby you have a session that encourages students to come along who are having trouble maybe in certain areas. However, I don't think we've had any sessions that have been specifically designed in that manner (PROD-1).

4.3.2 Socio-emotional

Two sub-themes related to the parent theme socio-emotional were coded. Socio-emotional refers to socially and emotionally charged statements and may relate to beliefs, values, and other attitudes.

A widely accepted view that emerged across three module teams (i.e., TM129, S206, and SXPS288) was the sense of *authenticity*. Authenticity refers to comments around personality, behaviour and communication that imply being approachable, attentive, capable, adaptable and knowledgeable (Johnson & LaBelle, 2017). It also represents the real-data, authentic glitches and equipment observed in working laboratories or the field (Argles et al., 2017). An S206 participant expressed, "I think we get to just sort of show up and have a personality in the Fieldcast" (S206-MT2). Another team member described their experiences of adapting to unpredictable conditions, for instance:

> We were trying to recreate what it feels like to teach in the field for students, and we sort of wanted to be making mistakes and being challenged with things. When someone asks you a question, you've got to pull on absolutely

everything, you know, to answer it as well as you can. We wanted to show that and make it as realistic as possible to put you on the spot because that happens in the field. Somebody says, why is that like that? Why does this do that? Where will I find this? You just have to manage as a presenter. That's what's lovely about the field is it is unexpected (S206-MT1).

In the SXPS288 and TM129 Labcasts, however, authenticity was described as practice with the actual instruments and equipment involved, as in the following example:

We can demonstrate these experiments live and do some small experimental demonstrations in the lab. We want to give the students some experience doing experiments within a laboratory setting, live on the benchtop with some electrical, magnetic experiments or an optical experiment. Seeing how that's done with all the wires, lenses, and bits and pieces hanging out all over the lab gives the students that (SXPS288-MT1).

Similarly, in the case of a networking demonstration Labcast, termed 'homecast', which was broadcast live from a TM129 team member's home during the lockdown, the concept of authentic practice with equipment was mentioned:

I think [the networking Labcast] had power by doing it at home. I thought there was maybe something in it for the students and us. It was quite amusing, all our kinds of health and safety rigs and the lights going up in our respective rooms. For me, I could see a student looking at your desk presentation going that could be my kitchen table. There's a suspension of the theatre that the students would recognise that they wouldn't necessarily have light rigs, and there were probably additional wires hanging out around you. Still, this kind of trajectory from theory to practice and this kind of believable step of the type of the course material, you know, this is how you do Ping [a network connection test]. And I thought it made it believable. I could imagine students going, I can do this (TM129-GP1).

Turning to the Associate Lecturers, a comparison of the SXPS288 module team and the SXPS288 ALs shows that both groups perceived the Labcasts as demonstrating *a sense of authenticity* related to observing equipment in a working laboratory. For example, an SXPS288 AL who attended a live Labcast reported that "it was nice to hear the

equipment going clunk in the room and feel that I was in a lab, and it was nice to see the academics there speaking to you and getting the atmosphere" (SXPS288-AL2). Another AL agreed stating, "I will agree with [SXPS288-AL2], it was really nice to hear things conking away in the background and things actually working. That was good" (SXPS288-AL4).

Two (i.e., SXPS288 and S315) out of the five module teams perceived the purpose of Labcasts was to foster a *sense of community.* A commonality between SXPS288 and S315 team members was the notion of direct communication, the possibility of meeting and a sense of belonging, which was actualised through bi-directional communication and synchronous tools:

> The students have an opportunity to meet the module team, some of the specialists and the people involved in designing these experiments. But it was also for the students to be doing something together with each other. So, there's a sense that this is a live event. They are all taking part in it at the same time. There is that overall atmosphere, which I hope again comes across to the students and gives it that sense of immediacy and community and that we are talking to each other directly, even if over a distance (SXPS288-MT1).

> They're getting an opportunity to meet the academics behind the module. So that's probably an opportunity to get to know that there are people on the other side, and they're not just going through a machine learning process. Let them put names to faces. Also, I'm thinking of communicating directly with a student; we don't have many opportunities to do that. A live Labcast does that to a certain extent, I would think as well. There's also the inclusivity thing about it too. You're all a part of this. That community sense (S315-MT3).

ALs from both S206 and SXP288 modules perceived that the purpose of Labcasts and Fieldcasts was to foster a *sense of community*. Tutors referred to the synchronous tools to enhance student connectedness and engagement. For example, S206-AL2 suggested that taking part in the polls (i.e., the widgets), which drove the decision making, could contribute to a sense of community. An AL from SXPS288 expressed the view that the text-chat facilitated interaction:

I feel on the student Labcast; it is really lovely. I do feel like I am part of the student community there. I find that they are all communicating with each other via the chatbox, and that is generally how students prefer to communicate in tutorials. I very much watch the students interact in real-time, and I occasionally say something (SXPS288-AL2).

The data show that ALs consider community building not just in the context of Labcasts but also in how it is fostered in the module itself and across different platforms. One AL reflected on the effects of size number in the tutorials:

The other thing is I would say is some of the national tutorials, the module-wide ones run by the module team. I've looked in on some recordings, and maybe because of the critical mass of numbers, there is a bit more banter around. A bit more jolliness, a bit more students are chatting amongst themselves, which of course is that community thing. It may be because the numbers are much higher, whereas you'll get four students in a tutoring group tutorial (S206-AL4).

The technical production team also discussed socio-emotional themes. For example, one team member mentioned that the IWBs gave the module teams a "connection to the students" (PROD-3). Both PROD-1 and PROD-2 agreed that the IWBs were used to humanise the learning experience as one member said:

I think it was to add a human dimension to module presentations and more particularly for the module team who were delivering it to the students in contrast to ALs. That was very much the view because online courses have potentially become quite cold in the sense that, OK, it might have video recorded in it, but it was very much online material that you had to read (PROD-1).

Another theme to emerge from the data from the technical production team was a *sense of presence* or telepresence. One member stated that the Labcast was an extension where students could see a lecturer demonstrating live and ask questions as if they were in the room (PROD-3). Another referred to Labcasts as supporting a s*ense of community* which helped to stimulate dialogue between the module team and students (PROD-2).

4.3.3 Technological

Two sub-themes related to the parent theme technological were coded. Technological refer to technical aspects of the medium, its design and applications and the affordances associated with web broadcasts.

The technical team mentioned the aspect of *scalability* as being an essential purpose for using web broadcasts. For example, PROD-1 commented that the concept of the Stadium Live and Labcasts was intended to engage with multiple presentations for an entire cohort. There was also a reflection on earlier practical science modules, some of which typically had thousands of students on them:

> We would potentially be targeting many students to come along. And I think some early ones, we did have a couple of hundred. So again, it's partially about technology and different solutions. Obviously, in the context of labs, we very much were focusing on the ability to stream good quality video that could highlight material (PROD-1).

There was discussion on functionality and the differentiation between learning environments such as Adobe Connect, a video conferencing platform, and web broadcasts. PROD-1 mentioned that Labcasts were "designed as a flexible tool that could be used in different ways (…) and would facilitate different styles of teaching compared to more tutorial-based ones (…) we could also deliberately target academics, ALs or guest presenters" (PROD-1).

Another theme to emerge was discussion around *affordances.* In the context of this property code, affordances refer to the actions acted upon by the properties of specific tools. The affordances need to be perceived and performed by the user related to concepts of technology and community support (Hammond, 2017). When reflecting on communication as being technologically mediated and the assumption that such mediation may support interaction, one technical production team member stated:

> One crucial design decision on Stadium Live was that we also wanted to ensure two-way interaction between the students: leaning forward into the event rather than passively watching it. That is why, to some degree, we considered the chat and the widgets very important. So, it was a very intentional design (PROD-1).

4.3.4 Intended aims and students' expectations

This section examines whether the pedagogical and socio-emotional intended aims for employing IWBs satisfied students' expectations or requirements. The first sub-section presents the qualitative data collected during the live events and towards the end of the module in student surveys and at the end of the module in interviews. The following sub-section present the quantitative data from student surveys.

4.3.4.1 Qualitative findings

Table 4.7 shows the distribution of similar coded themes from student data sets across the modules. The table shows themes found in the text-chat that was operative during the live event; the themes found in the open-ended comments of the student questionnaire; and the themes identified from student interview data. The circle symbol represents evidence of a theme, and a dash symbol represents silence on that theme (i.e., a theme was not identified among a module cohort).

Table 4.7: Similar themes of purposes identified from student data sets across the modules.

Themes	Modules					
	TM129-19J cohort	TM129-20B cohort	S206 cohort	SXPS288 cohort	SXHL288 cohort	S315 cohort
Text-chat						
student engagement	●	●	●	●	●	-
Student questionnaire						
student engagement	●	●	●	●	-	-
real-world context	-	-	-	-	-	-
authenticity	-	-	●	●	-	-
sense of community and belonging	-	-	●	-	-	-
Student interview						
student engagement	-	-	●	●	-	-
real-world context	-	-	●	●	-	-
authenticity	-	-	●	●	-	-
sense of community and belonging	-	-	●	●	-	-

The data in Table 4.7 show that the module teams' purposes (identified in Table 4.6) were also identified by four module cohorts (i.e., TM129, S206, SXPS288 and SXHL288).

Except for S315, students used textual chat and emoticons to generate affective responses that indicated student engagement. Examples of comments in the text-chat included: "Episode 2. Pretty good series so far, might recommend" (S206-S56); "Thank you, really helpful Labcast … made things more understandable!!" (SXHL288-S40); "Oooo, that is incredibly interesting :D" (SXPS288-S44); "OK, it's heavy going doing these two modules. I'm doing S294 too. Are you doing other modules?" (SXHL288-S40); "@ [student name] I need to look into that. I've not come across the richness/diversity section yet" (S206-S37) and "Thank you :) Was a good demonstration! Very interesting" (TM129-20B-S24).

In the open-ended survey questions, 15 students responded in S206; 9 students responded for SXPS288; 8 students for SXHL288; 13 students for TM129 (2019) and 5 students for TM129 (2020). The different types of Labcast groups can be in Section 4.2.2 on page 86 above. For example, TM129-S02-LNR refers to a student who watched the live but did not watch the recording. The comments varied, with some being outside the scope of the IWBs. A respondent in TM129-19J commented, "I felt the Labcasts to be very useful and engaging" (TM129-S02-LNR). Both S206/SXF206 and SXPS288 students indicated similar themes to the module teams. For example, one student from Environmental Sciences commented, "the Fieldcasts were an excellent way to get an idea of practical environment science fieldwork whilst bringing together the student community on an interesting and engaging common project. I found it very useful and most enjoyable" (SXF206-S05-LAR), indicating a *student engagement* and *a sense of community* was met. Another reported, "enjoyed the three I did. Good presenters and made it seem that I was taking part, would welcome this format in the future" (S206-S17-LAR). A student from the School of Physical Sciences alluded to the concept of *authenticity* as he commented:

> I particularly liked the human angle in the interview for the Mars project Labcast. Since being human is the only thing we all have in common for sure. I think it is important to see the human aspects of those that make science, not only the technical stuff. For example, to see the passion for the topic, not only the topic itself (SXPS288-S14-RNL).

A respondent from S206 also alluded to *authenticity* in their comment, "it was a good chance to see how the work was conducted and the equipment used. Seeing the

thought process behind the experiment from start to finish from the module team was great" (SXF206-S04-LAR).

In interview data, an SXPS288 student commented on being exposed to *real-world contexts* by means of experts in the field. For example, he remarked:

> I guess the thing I liked about the Mars surface one at the end was [SXPS288-GP01's] enthusiasm. I think the thing about the Labcast for me was they give you a different perspective from just working through the material. She talked about design of instruments for space missions in a way that brought to life what otherwise might have been quite a dull last project (SXPS288-S09-LNR).

Another SXPS288 student indicated a sense of *authenticity,* "when they showed you the equipment, one thing that clicked for me was the scale of the kit. It gave me a sense of, oh right! That's how small the thing is because it has gone to space - you just don't get that from pictures" (SXPS288-S05-LNR). A S206 student mentioned what he got from the Fieldcast, indicating *student engagement* and a sense of *authenticity*:

> I think what I got from the Fieldcast was really overall an enthusiasm to do the TMA. Because you'd be involved in the experience, the data was perhaps more meaningful in a way. I mean you see how it was collected, you'd seen the numbers and you got something from that, because you were involved it was like yeah, I'm gonna do this (SXF206-S10-LAR).

However, there were some mixed views. For example, one TM129-20B student commented that although they felt the two Labcasts were very interesting and informative, there was an assumption made that a person knew a lot about the module material. As such they would have preferred if presenters went into more depth (TM129-20B-S02-LNR). Another student commented that they enjoyed the Labcasts, but the large number of people present and the speed of which the chat box moved made asking questions difficult (TM129-S17-LAR). For one S206 student, the Fieldcasts did not meet expectations. When asked to leave an open comment of what they liked or disliked about the live events they commented, "the live Fieldcasts did not replace actual field work. It was restrictive with things it covered (…) should stop Fieldcasts and make field schools the way forward" (S206-S08).

Online questionnaires were distributed towards the end of the modules. Table 4.8 shows the response rates across the study's population. The S315 cohort returned 3 responses, and no student attended the live Labcast, so their responses are not shown in this section.

Table 4.8: Response rates and demographics across the modules.

Module		Respondents												
	Total available	Total (response rate)	Females	Males	Mean age	SD age	LAR	LNR	RNL	Neither	White	Asian	Other	No Disclosure
TM129-19J	527	18 (3%)	3	15	37.11	13.75	7	2	0	9	17	1	0	0
TM129-20B	537	9 (2%)	4	5	39.00	13.56	0	2	3	4	6	0	3	0
SXPS288-19J	83	15 (18%)	2	13	45.27	14.03	5	4	6	0	14	0	0	1
SXHL288-19J	116	9 (8%)	7	2	41.78	10.74	6	1	2	0	6	2	0	1
S206-19J	305	29 (10%)	14	15	39.72	14.73	19	0	10	0	28	0	0	1
S315-19J	47	3 (6%)	0	3	33.33	12.66	0	0	3	0	3	0	0	0

The summed results in Figures 4.4 – 4.7 show the distributions of responses on questions related to usefulness of the Labcasts and Fieldcasts. The five-point Likert scale ranked from degrees of usefulness (i.e., not at all useful to extremely useful).

In TM129-19J, 18 respondents completed the survey. Half (i.e., nine) of the respondents attended one or more Labcasts, and half did not attend a live event or watch the recordings. Figure 4.4 shows that the majority of students six (of nine) reported that the Labcasts were very to extremely useful in providing the opportunity to listen to their lecturers; five (of nine) reported that they were very useful to extremely useful in creating a feeling of being in the lab; five (of nine) reported that Labcasts were moderately useful in reducing isolation; eight (of nine) felt that the Labcasts were very to extremely useful in making the study material more personable and seven (of nine) reported that Labcasts were very to extremely useful in providing the opportunity to discover how concepts are practised in real-world situations.

Q4. How useful did you find the opportunity that the live Labcasts provided for the following:

Item	Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
4.1. Meeting your lecturers and other members of the module team at the start of the module	1		4	3	1
4.2. Listening to explanations and discussions between presenters	1		2	3	3
4.3. Feeling like you are 'really there' in the laboratory	1	1	2	4	1
4.4. Reducing isolation during your study on the module			5	3	1
4.5. Making the study material more personable	1	1		6	1
4.6. Discovering how technological concepts are practised in real-world situations	1	1	2	2	3

Figure 4.4: Responses from TM129-19J cohort on the usefulness of live Labcasts (n=18).

In TM129-20B, nine completed the survey with the same six items. Out of the two that attended live, one respondent reported 'very useful' for items 4.1 – 4.5. The other reported 'not at useful to slightly useful' for items 4.1 – 4.5. Both reported that the Labcasts were extremely useful for discovering how technological concepts were practiced in real-time situations.

In SXPS288, 15 respondents completed the survey. Figure 4.5 shows that the majority seven (of nine) reported the Labcasts were very to extremely useful in providing the opportunity to meet their lecturers and the module team at the start of the module and to listen to them explanations and discussion between presenters; five (of nine) reported that Labcasts were very to extremely useful in reducing isolation during the module; six (of nine) reported that the Labcasts were very to extremely useful in making the study material more personable and seven (of nine) felt they were very to extremely useful in discovering how scientific concepts are practiced in the real-world.

Q4. How useful did you find the opportunity that the live Labcasts provided for the following:

	Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
4.1. Meeting your lecturers and other members of the module team at the start of the module			2	4	3
4.2. Listening to explanations and discussions between presenters			2	2	5
4.3. Feeling like you are 'really there' in the laboratory		1	4	1	3
4.4. Reducing isolation during your study on the module		2	2	2	3
4.5. Making the study material more personable		1	2	2	4
4.6. Discovering how scientific concepts are practised in real-world situations			2	1	6

Figure 4.5: Responses from SXPS288 cohort on the usefulness of live Labcasts (n=15).

In S206/SXF206, 29 respondents completed the survey. 15 respondents were from the SXF206 track and 14 from S206. The data in Figure 4.6 shows that the overwhelming majority reported positively on the Fieldcasts. In particular, 13 (of 19) and 18 (of 19) reported that Fieldcasts were very to extremely useful in providing the opportunity to meet lecturers and module team members and to listen to presenters' explanations and discussions; 13 (of 19) felt that the Fieldcasts were very to extremely useful in creating a feeling of 'being there' in the field; 15 (of 19) reported they were very to extremely useful in reducing isolation; 15 (of 19) reported they were very to extremely useful in making the study material more personable and 17 (of 19) found the Fieldcasts very to extremely useful in discovering how environmental science is practiced in real-world situations.

Q4. How useful did you find the opportunity that the live Fieldcasts provided for the following:

	Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
4.1. Meeting your lecturers and other members of the module team during module	1	1	4	7	6
4.2. Listening to explanations and discussions between the presenters	1			6	12
4.3. Feeling like you are 'really there' in the field	1	1	4	8	5
4.4. Reducing isolation during your study on the module	2		2	6	9
4.5. Making the study material more personable	1	2	1	5	10
4.6. Discovering how environmental science is practised in real-world situations	1	1		6	11

Figure 4.6: Responses from S206/SXF206 cohorts on the usefulness of live Fieldcasts (n=29).

In SXHL288, nine respondents completed the survey. The data in Figure 4.7 shows mixed attitudes on the usefulness of the Labcasts. For instance, three (of nine) reported that the Labcasts were not at all to slightly useful in meeting their lecturers and listening to explanations and discussions; four (of nine) felt they were not at all useful to slightly useful in creating a feeling of 'being there' in the lab; four (of nine) did not deem the Labcasts useful or only slightly useful in reducing isolation on the module and three (of nine) felt they were moderately useful in discovering how concepts were practised in the real-world.

Q4. How useful did you find the opportunity that the live Labcasts provided for the following:

Legend: ■ Not at all useful ■ Slightly useful ■ Moderately useful ■ Very useful ■ Extremely useful

Item	Values
4.1. Meeting your lecturers and other members of the module team at the start of the module	1, 2, 2, 2
4.2. Listening to explanations and discussions between presenters	1, 2, 2, 1, 1
4.3. Feeling like you are 'really there' in the laboratory	2, 2, 3
4.4. Reducing isolation during your study on the module	3, 1, 2, 1
4.5. Making the study material more personable	2, 1, 3, 1
4.6. Discovering how scientific concepts are practised in real-world situations	2, 3, 1, 1

Figure 4.7: Responses from SXHL288 cohorts on the usefulness of live Labcasts (n=9).

4.3.5 Section summary

The data show that five broad themes emerged from the analysis of the module team: (1) *facilitating student engagement*, (2) *planning strategic points*, (3) *introducing real-world contexts*, (4) demonstrating *authenticity* and (5) fostering *a sense of community*. The reasons for using IWBs were influenced by different pedagogical issues. ALs from S206 and SXPS288 also perceived the Labcasts to facilitate student engagement. ALs from SXPS288 shared similar sentiments of observing authentic practice in a working laboratory. Both SXPS288 and S206 ALs perceived the purposes of IWBs was to foster a sense of community through using the interactive tools. In the case of one SXPS288 AL, they reported that the Labcasts made them feel part of the student community by observing how students interact in real-time. For an S206 AL, the idea of community was considered outside of Labcasts and there was reflection on how it emerged in tutorials. Similarly, the technical production team also perceived the broadcasts as a way to plan and support *strategic points* and foster a *sense of community*. One production team member in particular commented on *scalability* and the *affordances* as being important consideration in using IWBs.

The themes of *facilitating student engagement*, *authenticity, real-world contexts* and *sense of community* occurred throughout the qualitative student dataset, as Table 4.7 shows. These results suggest that the intended module teams' purposes were met positively from students in TM129, S206, SXHL288 and SXPS288 cohorts.

Data, therefore, shows a convergence of the findings as the summary of themes identified in the research has an agreement between participant groups across the data sets. Students reported that the IWBs were 'helpful', 'useful', 'engaging', 'enjoyable' and 'interesting' showing that students were overall engaged. They also mentioned themes of *sense of community*, *authentic practice* and *real-world contexts* in their reflections on IWBs during interviews. There were however mixed views with some students reporting difficulties with asking questions, assumed knowledge and dissatisfaction with Fieldcasts in replace of field work.

Given the critical factors of disengagement and isolation that can occur in a DL environment, the findings show that students responded well to the IWBs. For example, the quantitative data show that the majority of TM129-19J students (55% – 89%) who attended one or more live events reported positively on the opportunities that the Labcasts provided to listen to lecturers' explanations and discussions; feel a sense of presence in the lab; make the study material more personable and to discover how concepts are practised in a real-world context. Similarly, positive attitudes were reported on the same question items in SXPS288 (55% - 78%) and S206/SXF206 (68%-95%) cohorts. Most mixed and negative attitudes were reported in SXHL288 (33%-44%).

4.4 Implementation of IWBs

This section discusses the pedagogical strategies that the presenters and moderators used during IWBs and presents the data for the question: *What strategies do the presenters and moderators apply to interact and engage with students?* The section then discusses the types of student interaction that occurs during the IWBs and presents the data for the question: *How are students using the widgets to interact with the presenters?* Lastly, the section presents the data to the question: W*hat is the nature of students' discourse in interactive web broadcasts, and is it representative of knowledge building?*

Depending on the discipline and purposes of the Labcast, planned activities differed. Table 4.9 shows the broadcast types, number and types of widgets, types of resources used and whether question-and-answers were facilitated via a moderator, by the presenter or via forums across the IWBs. The Asterix symbol in the Widget type column represents where a Feedback widget question, devised by the researcher, was

used. The Feedback widgets were either in a Wordle or Multiple-choice format. Module teams have access to seven widget types which they can devise their own questions around.

Table 4.9: Learning aims, number of widgets, types of resources and ways questions were facilitated across IWBs and modules.

Module	Labcast title	Labcast purpose(s)	Widget types (number)	Integrated resources	Q&A format		
					Moderat	Presente	Forum
TM129	Block 1 Robotics demonstration (2019)	To demonstrate an industrial robot and apply concepts taught in the block on the analysis of robot safety	Map (1), Continuum (4), *Wordle (2)	Live feed to software program	✓	✓	✗
	Block 2 Networking demonstration (2019)	To demonstrate practical aspects of creating a small network using Raspberry Pi computers	Map (1), Multiple choice (4), Balance (1)	Live feed to software A3 paper	✓	✓	✗
	Block 1 Robotics demonstration (2020)	As above (Block 1)	As above (Block 1), *Wordle	As above (Block 1)	✓	✓	✗
	Block 2 Networking 'homecast' demonstration (2020)	As above (Block 2)	Map (1), Multiple choice (4) Balance (1), *Wordle (1)	Live feed to software program A3 paper PPT slides	✓	✓	✗
SXPS288	An interactive introduction to remote experiments in physics and space	To introduce astronomy topic options for student projects To discuss aspects of experimental technique and planning	Map (1), Multiple choice (1), *Wordle (3)	PPT slides Live feed to remote instrument Whiteboard	✗	✗	✓

	Session	Aims	Question types	Resources			
	Physics project	To review the results of the astronomy project To investigate how electrons interact with magnetic fields	Map (1), *Wordle (3), Multiple choice (2)	Whiteboard Live feed to remote experiment	✘	✘	✔
	Planetary science project	To introduce the project and gas cell experiment	Map (1), Multiple choice (2), *Wordle (2)	Still images Whiteboard Pre-recorded video clip PPT slides Live feed to remote experiment	✔	✘	✔
	Exploring Mars	To introduce the design of instruments for space missions from a NASA mission specialist	Map (1), *Multiple choice (4), Continuum (1), *Wordle (1)	PPT slides	✔	✔	✔
S206/SXF206	Fieldcast 1: Making observations and developing hypotheses	To introduce the field site, discuss characteristics to investigate and develop some hypothesis to investigate	Map (1), Wordle (1), Multiple choice (3)	Still images Pre-recorded video clip Field equipment Whiteboard	✔	✔	✘
	Fieldcast 2: Developing methods and data collection	To design a sampling strategy and collect data	Balance (1), Multiple choice (2)	PPT slides Field equipment Whiteboard	✔	✔	✘
	Labcast 3: Analysing data and making conclusions	To select the appropriate statistical test and graph, interpret results and discuss significance	Map (1), Multiple choice (2), Balance (1), Continuum (3), Wordle (1)	Pre-recorded video clip Still images Excel spreadsheet Plant samples	✔	✔	✘

SXHL288	The human brain in action	To highlight important aspects of experimental design and investigations involving human participants for Topic 1	Map (1), Multiple choice (2), Balance, (1) Wordle (1)	PPT slides Pre-recorded video clip Live feed to cognitive assessment test Still images Data log sheet	✓	✗	✓
	Cells and tissues close-up	To examine cells using a live microscopy and consider how to use cell counting to quantitate physiological change	Map (1), Multiple choice (4), Balance (1)	Still images Live feed to virtual/light microscope	✗	✗	✓
S315	Introduction to the experiment for TMA05	To introduce the investigation and give a background to the chromatography technique	Map (1), *Multiple choice (4), Balance (1)	Whiteboard PPT slides Pre-recorded video clip Live feed to remote experiment	✓	✓	✓

4.4.1 Interaction with students

Stages of the event is a unit of meaning and referred to one of the planned forms of interaction represented in the IWBs. The stages are time-specific and represent the number of interactional moves and talk during a stage. Presenters set up several main stages to facilitate the Labcast and Fieldcast aims.

Table 4.10 shows the range of coded references for and across each stage. The IWBs column represents the Labcasts and Fieldcasts in the order presented in Table 4.9 and is grouped by discipline and level. The numbers represent the occurrences that presenters, moderators (if applicable) or the technical production team said or did something to advance the stage. The theme *establish social connection* referred to phrases that helped set up and foster the tone or climate for social interaction by way of personal introductions, welcoming and thanking the remote audience, outlining the

objectives of the Labcast and orientating the students to the Stadium Live interface. The phrases that related to the module structure, future topics or how the Labcasts related to a TMA were coded under *module related*. The theme *question and answer* were categorised when presenters invited ad-hoc questions from the audience or when a specific time was allocated for live questions-and-answers. The themes *conduct experiment or field work, demonstration, discuss methodological processes, hypothesize* and *observation* stages are all forms of teaching reflecting the scientific process.

Table 4.10: Distribution of occurences of the main stages of IWBs across modules.

Web broadcasts	Establish social connection	Conduct experimental or field work	Demonstration	Discuss methodological processes	Hypothesize	Module related	Observations	Question & Answer
LC-TM129-19J-1	6	0	51	0	0	0	0	41
LC-TM129-19J-2	8	0	47	0	0	1	0	53
LC-TM129-20B-1	13	0	24	0	0	0	0	30
LC-TM129-20B-2	9	0	35	0	0	2	0	30
LC-SXPS288-19J-1	7	7	26	1	5	9	2	0
LC-SXPS288-19J-2	9	12	17	8	8	6	0	0
LC-SXPS288-19J-3	23	0	61	0	0	30	0	0
LC-SXPS288-19J-4	12	0	18	0	0	0	0	39
FC-S206-19J-1	19	0	0	8	20	1	36	0
FC-S206-19J-2	7	10	0	32	0	1	12	1
LC-S206-19J-3	11	0	8	36	32	14	5	2
LC-SXHL288-19J-1	27	38	0	102	32	23	0	0
LC-SXHL288-19J-2	13	0	11	20	25	15	0	0
LC-S315-19J-3	13	5	30	0	6	11	0	3

The data shows that all module teams *established social connections* during the live events. Both LC-SXPS288-19J-3 and LC-SXHL288-19J-1 show the highest numbers in social connection. For example, SXHL288-MT2 opens the Labcast in the following way:

> Hello and welcome to the SXHL288 Labcast tonight. My name's [SXHL288-MT2]. I am the chair of this year's presentation and also a topic specialist on topic two, so you're going to be coming across me in the forums a bit later. We're going to look at the human brain in action tonight and we'll be running a live experiment. We've also got (moderator name) in the chat box to guide you through and answer any of your questions. She's also your topic specialist.

In addition to SXHL288-MT2 presenting to camera, the moderator also welcomes the students in the text-chat box. Non-participant field and video observation data show that presenters outlined the Labcast aims either verbally (to camera) or through displaying on a whiteboard or slide. No measurable learning outcomes of the IWBs were provided. The data show that there is variation within the two LC-SXHL288

Labcasts with half the occurrences of social connection in LC-SXHL288-19J-2 than in LC-SXHL288-19J-1. There is also variation across the four LC-SXPS288 Labcasts with LC-SXPS288-19J-3 having the highest number of occurrences. LC-SXPS288-19J-3 was a new Labcast to support the new planetary science experimental investigation (see Section 3.3.4 for context) and involved a new presenter. All presenters encouraged students to participate by using the map widget to tell them where they were and to ask questions. The ways to interact were often reinforced by a moderator in the text-chat and support was given by a technical production team member if students were having difficulties in starting the live stream or navigating the interface.

During TM129 (19J and 20B) Labcasts, the teams primarily interacted with students during the demonstration and question-and-answer stages. In addition, the data show similar frequencies of interaction in the demonstration stages during both Labcasts and presentation years (i.e., 2019 and 2020). The S206 Fieldcasts and Labcast occurrences reflected the planned stages of inquiry for the three episodes: making observations and developing hypotheses; developing methods and beginning data collection; and analysis and interpretation. LC-SXHL288-19J-1 however show the highest number of talk at the *Discuss methodological processes* stage. LC-SXPS288-19J-4 included a question-and-answer stage due to the designed format (i.e., a talk by a NASA expert) unlike the previous three SXPS288 Labcasts.

The data show that all of the module teams presented a *module related* stage in at least one IWB. They connected experiments, investigations and demonstrations to a module's block, linked prior knowledge and made connections for the students. For example, during presenting to camera, SXPS288-MT2 mentions:

> You might have had a go at downloading and plotting a few Spectra from the NIST database during your skills week, so some of these might look familiar to you, but don't worry if they don't because you will learn all about it in the module material (SXPS288-MT2).

A presenter (SXHL288-MT2) in LC-SXHL2881-19J-1 made explicit how the three Labcasts fitted into the module and which Labcast was supporting which topic. In LC-S315-19J, the presenter (S315-MT4) links prior knowledge to an upcoming assessment:

You should hopefully enjoy the investigation. Actually, you will see when you look at the TMA that it's actually bringing together a lot of different aspects that you have met through the module. And [S315-MT2] was already talking about the cycle and the enzyme so it's really bringing together lots of things that you've met in the module.

IWBs linked to assessments (e.g., LC-SXPS288-1 to 3 (45 occurrences); FC-S206-1 to 3 (16 occurrences), SXHL288-1 and 2 (38 occurrences) and S315-1 (11 occurrences) referred to module-related information more than LC-TM129-19J-1 and 2 (1 occurrence); LC-TM129-20B-1 and 2 (2 occurrences) and LC-SXPS288-4 (0 occurrence), which were not linked to assessment. The data show variations in LC-SXPS288-3 (30 occurrences). This could be due to the fact that the Labcast was new, resulting in more TMA discussion. Similarly, in FC-S206-3 (14 occurrences), the Labcast aim was to report and analyse the data, which resulted in a lot of discussion about how to write the TMA. Despite the fact that both Labcasts in SXHL288 focused on supporting experimental investigations, it is probable that the presenters in LC-SXHL288-1 spoke more at this stage because it was the cohort's first Labcast.

Based on the content, purpose and activities within the Labcasts, module teams used a variety of widgets to interact with students and facilitate feedback. The widgets facilitate interaction with the audience. Seven widget types are available for teams to pre-configure in advance. The map widget was used to locate the audience. Open-ended and multiple-choice widgets were used to gauge knowledge, test comprehension, predict an outcome, choose a hypothesis and elicit free responses.

Table 4.11 shows the number of coded references across a widget cycle per Labcast and represents presenters' talk and moderators' chat. For this sub-section, a moderator in this context is an active moderator who operates the chat. It does not include a lead presenter that contributed at the beginning (e.g., saying hello) or answered a question at the end of the broadcast. The node *Poll question* referred to phrases used to set up and ask a question using the widget. Terms related to displaying an instant histogram or word cloud showing the audience-wide distribution of responses were coded as *Review*. The node *Evaluate is* used when a presenter (or moderator) followed up with general observations, judged or calculated the importance or value of something, offered a related rhetorical question or other

statements necessary for closure. The node *Revisit poll* referred to phrases where a presenter revisited the responses due to a misunderstanding or offered further explanation.

The data show that there is variation in how module teams use the widgets in each web broadcast and that the number of widgets is not equal to the same number of times the widget is reviewed, evaluated or revisited. For example, in LC-TM129-19J-2, four questions are polled to the audience and reviewed four times (out of six pre-configured widgets). A similar pattern is found in TM129-20B-2. The feedback widget was omitted in LC-TM129-19J-2. The moderator's pattern of interaction with the widgets is similar in frequencies across the module's Labcasts. In LC-SXPS288-19J-3 the widgets are reviewed twice (i.e., 10 occurrences) as much in relation to the five polled widgets. This indicates that there was much more discussion around the histograms and explanations around the results.

Table 4.11: Widget cycle across IWBs.

Web broadcasts (no. of widgets)	Widget cycle			
	Poll questions	Review	Evaluate	Revisit poll
LC-TM129-19J-1 (7)				
1 presenter	7	6	9	0
1 moderator	2	0	2	0
LC-TM129-19J-2 (6)				
2 presenters	4	4	2	0
1 moderator	2	0	0	0
LC-TM129-20B-1 (7)				
1 presenter	6	7	6	0
1 moderator	3	0	0	0
LC-TM129-20B-2 (7)				
2 presenters	5	5	2	0
1 moderator	2	0	2	0
LC-SXPS288-19J-1 (5)				
2 presenters	5	6	2	0
LC-SXPS288-19J-2 (6)				
2 presenters	8	6	5	0
LC-SXPS288-19J-3 (5)				
2 presenters	5	10	1	0
1 moderator	1	0	0	0
LC-SXPS288-19J-4 (7)				
2 presenters	8	4	4	0
1 moderator	4	2	0	0
FC-S206-19J-1 (5)				
3 presenters	7	27	2	0
1 moderator	6	5	0	0
FC-S206-19J-2 (3)				
3 presenters	5	6	9	0
1 moderator	3	0	1	0
LC-S206-19J-3 (8)				
3 presenters	8	8	8	3
1 moderator	4	0	0	0
LC-SXHL288-19J-1 (5)				
2 presenters	8	25	16	4
1 moderator	2	0	0	0
LC-SXHL288-19J-2 (6)				
2 presenters	12	10	2	0
LC-S315-19J-3 (6)				
3 presenters	8	11	5	0
1 moderator	1	0	0	0

The data show that all presenters used the first three stages of the widget cycle. Presenters polled questions in a variety of ways and often more than once. For example, in LC-TM129J-19J-1, seven widgets were used. The lead presenter polled the questions seven times, and on two occasions, the moderator reinforced the widget question by reformulating and typing the question in the text-chat. For example, the lead presenter TM129-MT2 stated, "so we do have a widget. Tell us how humanoid you think this robot is". As the presenter continues the talk and demonstration, the moderator TM129-MT1 writes in the text-chat, "so what do we think about how humanoid Baxter is" and "what do you think would make Baxter look more human?" Twenty students respond in the text-chat adding comments such as, "it has arms" (TM129-S55) and "has the shape of a torso and a makeshift head" (TM129-S17), and 94 users interact with the widget by selecting a position on a linear scale from 0 meaning 'not at all' to 10 meaning 'fully humanoid'. The presenter later reviews the widget showing the distribution-wide responses and reacts to the feedback: "So how humanoid are people judging it overall? Oh, quite low in number where people think not at all humanoid" (TM129-MT2). He further evaluates the widget responses by following up with general observations, for instance: "You know, I find that a bit surprising. Generally, this is quite humanoid in that it has two arms. I've got two arms. The arms have a very similar sort of geometry to mine. It can carry out the same sorts of movements that I can" (TM129-MT2). Likewise, the moderator offers evaluative remarks during the cycle by confirming the value of students' responses, for example: "leg is interesting – I believe there are versions of Baxter that are more mobile" and "voice is a good point – I don't think Baxter has a voice output by default but could be an interesting addition" (TM129-MT1). A similar process of the moderator reinforcing widget questions in the text-chat was demonstrated in S206 Fieldcasts.

Both FC-S206-19J-1 and LC-SXHL288-19J-1 IWBs had the highest numbers of *reviews*. In the case of S206, reviewing the widgets in FC-S206-19J (episodes 1 and 2) were strategically planned to demonstrate the students' decision making, the pragmatic options available in the field and the democratic verdict of how the investigation would proceed. In LC-SXHL2881-19J-2, presenters used a multiple-choice widget (e.g., *How many nuclei is in the 6 grid squares*?) as an active learning opportunity by doing a live counting experience to reinforce a principle. Presenters encouraged students to count the magnified cells on screen, make a note of the number and then to enter the

value into the widget. The presenters counted alongside before reviewing the distributed responses and offering further feedback. In setting up the last two multiple-choice widgets (e.g., *How many nuclei on the left image?* and *how many nuclei on the right image*?), the presenters instructed students to count the image on the left if the student's birthday was in the first 6 months of the year, and to enter the data into the widget related to the left-hand image and similar for those born between the last 6 months into the widget for the right-hand image.

In LC-SXPS288-19J-4, which involved a first-time guest presenter, the Labcast had a higher number of polled questions and reviews from the moderator. Both S206 and SXHL288 presenters revisited a poll. During the hypotheses stages in LC-S206-19J-3 and LC-SXHL288-19J-1, the presenters chose to revisit a widget after the responses were revealed. An example of the exchange between S206 presenters is presented below:

> Ok, what have you voted for? Do you support or reject the null hypothesis? So, the balance is 52 reject the null hypothesis, 30 accept the null. And the answer is to reject the null, accept the null (S206-MT4).

> OK, that puts us in an awkward position, doesn't it? We've confused you, or you've confused yourselves (S206-MT3).

> Well, maybe we should go back to the table and have a look and step through it to make it clear (S206-MT1).

> So, you can probably change your answer. Go ahead and change your answer or keep the original answer if you want. If you wish to change your answer in the light of that extra information and guidance, go ahead and do it. Alright, and we'll catch up again (…) Oh, look at that, yeah, very good. So, we're going to accept the null hypothesis; we're not rejecting it. And maybe there's something that illuminates what the Simpsons index is doing here (S206-MT3).

When asked to reflect on the LC-S206-19J-3 Labcast, two Environmental sciences student interviewees reported the following:

> The explanation, where we got the answer wrong, was explained. It helped definitely (S206-S13).

The one I went back to most was the third one, which looked at the results. I reviewed quite a bit about the diversity index, which was the thing we were measuring. I reviewed a lot of the discussion around that. In fact, I remember this now. When the results first came up, people were asked to vote what they thought the results had told them, and they found the majority got it wrong. I'm not being boastful; I didn't get it wrong. I got it right (S206-S10).

Similarly, in LC-SXHL288-19J-1, the presenters revisited the poll to clarify the scientific formulation of a question:

Before we move on to the results, could we bring up widget three again, where we talked about the sex and the RVP? So, we've got our split here. We ask people to predict who would perform better. We've talked about variables and how we have to be a little tighter about defining it better. But this is still quite a loose question (...) we have to formulise it into something called a hypothesis and again 288 students if you haven't gotten to it yet, you'll be seeing that material very soon in the investigation (SXHL288-MT2).

In the focus group discussions, both S315 and TM129 module teams perceived the use of the widgets as being important to gauge students' understanding. S315-MT3 mentioned that the idea was to get students to think and answer questions while making participation 'relaxing' and not feeling punished if they got the answer wrong. A TM129 presenter remarked on his strategy for responding to feedback through the widgets:

Sometimes you get obvious answers and sometimes you get something a bit surprising, and I think it's really nice to reflect that back to students. If I have to think about what they've said and maybe disagree with what they're suggesting, I think there's value that comes out of that, because obviously you learn things when there's a bit of tension. So, I think they're really quite useful for that. It kind of surfaces stuff; it gives you something to discuss and it gives you some way of engaging with the student, which is really difficult in general. In a way they're a bit noddy, but it's an opportunity to make more of a loop with the students (TM129-MT2).

As a first-time presenter, SXPS288-GP1 mentioned that the widgets, if used properly, could help with engagement and knowledge checking. In reflecting on her experience with using the widgets and her strategy she stated:

> I was thinking through the widgets that I put in. A lot of them were not knowledge checks, actually, there were more engagement checks. For example, the picture with the caption is this Mars or is this Earth? Even if they got the wrong answer, the point was they were supposed to get the wrong answer. It was confusing because they look so similar. And so, I kind of always know and I think I've done that quiz enough before that I know it's about a 50/50 split, so I predicted how that would go (SXPS288-GP1).

4.4.2 Engagement with students

In addition to setting up interaction through several planned stages and using the synchronous tools, presenters and moderators also demonstrated various communicative strategies and behaviours to foster engagement. This section outlines (1) the types of affective strategies that emerged from the web broadcast and text-chat datasets and (2) the patterns of web broadcast interaction based on an adapted Flanders Interaction Analysis Categories (FIAC) protocol (c.f., Table 3.3, Section 3.8.1, Chapter 3). Table 4.12 shows the coded references identified for presenters and moderators' strategies that were affective (c.f., Appendix K for NVivo codebook).

Table 4.12: Coded references of presenter and moderators' affective strategies.

Staff	Appreciation	Encourages particpation	Humour	Promote further engagement	Psychological safety	Self-disclosure	Sense of belonging
TM129-MT1	5	17	8	9	5	3	2
TM129-MT2	5	1	3	1	4	4	1
SXPS288-MT1	25	13	1	13	6	3	14
SXPS288-MT2	1	0	0	0	4	1	1
SXPS288-MT3	1	5	0	1	1	3	2
SXPS288-MT5	2	3	0	1	0	0	1
SXPS288-GP1	1	1	0	0	2	4	0
S206-MT1	4	5	0	4	3	2	3
S206-MT2	3	6	4	3	1	0	1
S206-MT3	1	0	4	3	4	0	2
S206-MT4	6	0	2	1	3	0	0
SXHL288-MT1	1	3	1	2	1	1	0
SXHL288-MT2	3	3	9	8	9	0	4
S315-MT1	0	0	1	0	0	0	1
S315-MT2	0	0	0	0	0	0	0
S315-MT4	1	6	2	3	0	0	2
PROD-1	0	1	0	6	1	0	0
PROD-2	0	0	0	2	0	0	0
PROD-3	0	0	0	1	0	0	0

The data show that most staff used affective communicative strategies and behaviours. During the Labcasts, SXPS288-MT1 demonstrated the most strategies, followed by TM129-MT1 and SXHL288-MT2. In addition to the verbal strategies, observation notes show that all presenters and moderators who presented to camera, displayed non-verbal immediacy behaviours such as smiles, eye contact and gestures.

The data shows that *appreciation* was demonstrated in at least one IWB in each module by the presenters and moderators (14 out of 19). Examples included thanking attendees for "joining", "tuning in on a weekday evening", "listening", and "voting". The strategy was used among the five module teams. Module team members encouraged *participation* to engage with the interface (12 out of 19). Presenters and moderators demonstrated this by instructing students on where to find the widgets, encouraging use of the map widget and posting questions in the text-chat. This was evident across all module teams and one person from the technical production team. Ten individuals across the five modules used *humour* as an immediacy cue. Examples included, "LOL is the limit of linearity, that's not laughing out loud" (S315-MT1) and "it means that our students are exceptional human beings that are probably X men" (SXHL288-MT2).

All module teams p*romoted further engagement* (15 out of 19). Presenters and moderators across the five module teams demonstrated this strategy by encouraging students to ask questions on the forums, promoting upcoming Labcasts or encouraging students to utilise other learning resources. The technical production team demonstrated this strategy mostly when Labcasts were not moderated, by informing students of when the replay would be available or advising students to post questions on a forum. Except for S315, team members from the other four modules offered statements of *psychological safety* (16 out of 19). For example, TM129-MT1 stated in the text-chat, "If you are finding the chat window a bit too active, do focus on what [TM129-MT2] is saying and dip back in as and when it's appropriate". Others offered reassurance around the anonymous nature of voting with the widgets, unfamiliar content that students may not have covered in the module material, asking for help on the forums and reassurance on conducting experiments.

Eight individuals made *self-disclosure* statements. This was found more frequently in TM129, SXPS288, but only by one presenter in S206 and SXHL288. Team members

relayed personal stories, disclosed a personal preference or showed camaraderie with the audience. For example, after reviewing a hypothesis widget, S206-MT1 mentioned, "I think that's great when things turn out to be different from what you expected. I think my best thesis chapter was the result that was exactly the opposite of my prediction. So, to accept a null hypothesis or to find the opposite result can be incredibly exciting and interesting".

Finally, twelve individuals made statements related to *sense of belonging.* The strategy was used most frequently in TM129, SXPS288 and S206 but only by one presenter in SXHL288 and S315. *Sense of belonging* was demonstrated by reviewing the map widget and welcoming students from various locations. Examples included "Hi all – good to see you. Make yourselves at home" (SXPS288-MT1) and "several in Europe, a couple in Asia and then beautifully scattered across the UK" (S206-MT3) in response to the map widget. Presenters also used inclusive language by using plural pronouns. For instance, while modelling equations direct to camera, SXPS288-MT1 remarks, "We've got 20 centimetres and being good experimentalist, of course, we want to know how accurately we're measuring everything". The example below illustrates *sense of belonging* between SXPS288-MT1 as a moderator and students in the text-chat during the Planetary Science Project Labcast:

> Is the hissing I can hear gas being released or another piece of equipment? (SXPS288-S44).

> There are pumps running. Good to have the noises of a real working lab (SXPS288-MT1).

> I almost feel like a real scientist listening to it... (SXPS288-S15).

> You guys are! (SXPS288-MT1).

> The effort that has gone into these remote experiments is amazing and, given the time it takes to set up and test, you do us, students, proud:) (SXPS288-S1).

> Yes, very impressive (SXPS288-S15).

> Thank you - we've all been working really hard this year to put this experiment together for you. @S1 – no expense is too much for you guys! You will be the first ones to use this experiment (SXPS288-MT1).

To identify the levels and types of participation demonstrated by presenters, moderators and students, an adapted FIAC protocol was used. In web broadcast teaching, lecturers are expected to provide much of the didactic conversation while integrating presentation and students' responses. The designed interactivity component means that students are expected to not only watch the IWB but respond, initiate their topics, ask thoughtful questions and respond to other students as learning is thought to be a social and collaborative activity among and within a group. If this premise is correct, students will be engaged and respond to many of the conversational pieces Flanders identifies in the original "Instructor" category.

In applying the framework, the study looked at TM129 'Technologies in practice' as a particular set of cases. TM129 is the only module in the study that has two presentations years (i.e., 2019 and 2020). Since the Labcast repeat in topic and presenters, a comparison is made of the interactions in both TM129-19J (episodes 1 and 2) and TM129-20B (episodes 1 and 2). Table 4.13 shows the patterns of interaction across rows of the observed Labcasts. The first column shows the IWBs, the number of chat users and the stakeholders involved, namely presenter, moderator and students. The presenter is categorised as one entity even if there were two lead presenters as initiation and responses among presenters can only be emitted one at a time. Response includes four categories: *accept feelings, praise, accept ideas,* and *ask questions*. Initiation refers to three types: *giving directions, guiding students' thoughts, and criticising or justifying authority*. The adapted framework assumes that the original category 'lecturing' or, in this case, presenting, where a lecturer gives facts or opinions about content or procedures, is the dominant characteristic of Labcasts. Therefore, that category was omitted. Where it was not clear what or to whom students or moderators were referring, comments were not coded. Comments in the text-chat and presentation transcriptions were only coded where there was a logical flow of conversation related to a stage, where individuals used emoticons such as the '@' sign or a clear Initiation-Response-Feedback (IRF) pattern was identified.

Table 4.13: Responses and initiation of presenters, moderators and students across TM129 (2019/2020) IWBs.

Labcasts (chat users)	RESPONSE				INITIATION		
	Accepts feelings	Praises	Accepts ideas	Ask questions	Give directions	Guide students' thoughts	Criticises, justifies authority
LC-TM129-19J-1 (77)							
1 Presenter	0	0	12	10	0	1	2
1 Moderator	0	1	34	2	2	8	0
Student-response	0	0	18	20	2	3	0
Student-initiation	0	0	21	0	0	1	0
Student-talk- responsive	0	0	3	0	0	0	0
Student-talk-initiative	0	0	0	0	0	0	0
LC-TM129-19J-2 (44)							
2 Presenters	3	5	4	4	0	4	0
1 Moderator	0	1	24	6	2	13	0
Student-response	0	0	14	16	0	7	0
Student-initiation	0	0	8	0	0	0	0
Student-talk- responsive	0	0	0	0	0	0	0
Student-talk-initiative	0	0	0	0	0	0	0
LC-TM129-20B-1 (66)							
1 Presenter	1	2	5	7	1	4	1
1 Moderator	0	2	13	3	3	1	1
Student-response	0	1	9	10	1	1	1
Student-initiation	0	0	1	0	0	0	0
Student-talk- responsive	0	0	3	0	0	0	0
Student-talk-initiative	0	0	0	0	0	0	0
LC-TM129-20B-2 (40)							
2 Presenters	2	6	3	6	0	10	0
1 Moderator	1	2	10	0	0	0	0
Student-response	0	0	6	0	0	0	0
Student-initiation	0	0	2	0	0	0	0
Student-talk- responsive	0	0	1	0	0	0	0
Student-talk-initiative	0	0	0	0	0	0	0

The data shows that the presenters and moderators initiated and responded to students across the IWBs. Three items stand out for presenters' interaction: *asking questions, accepting ideas and guiding students' thoughts or research*. In all four Labcasts, moderators accepted or used students' ideas by answering questions, acknowledging the students' ideas or clarifying an idea. Students engaged in the IWBs by responding to the presenter or moderator in what they saw and heard by commenting and initiating questions and offering answers.

In the demonstration stage of LC-TM129-19J-1, the presenter asked 10 questions; seven were question-and-answer widgets, and three were rhetorical type questions,

which were interrogative in form but emphasised information rather than requesting it, for instance, "So why seven degrees of freedom?". Rhetorical questions were considered interactional scaffolding to support a demonstration and were therefore coded as *ask questions* due to the often-unstructured nature of synchronous text-chat. The data show that students responded almost twice as much (n=20) to questions, including rhetorical questions. For instance, a student replies in the text-chat, "would there be any advantage to having more than 6 or 7 degrees of freedom in an arm? (TM129-S65). Questions, responses and comments of students were coded (n=18). The moderator accepted ideas almost twice as much (n=34) by acknowledging students' comments, questions, or building on an idea. For instance, "@Student S15 – interesting question. It is heavily used as a teaching robot as it has a range of sensors and actuators" (TM129-MT1). The moderator also reformulated the questions in the Q&A stage of the Labcast by synthesising similar question types and posing them to the presenter, thereby accepting ideas. The presenter (TM129-MT2) *accepted ideas* (n=12) and answered student questions by conceptualising them in his own words. Students also initiated talk and built on the ideas and comments of others. The excerpt below shows an example with the categories in parentheses:

> TM129-S49: Imagine a driverless car hitting a pedestrian (student-initiation).
>
> TM129-S61: part of one of the laws is not to allow a human to come to harm through inaction (student-initiation).
>
> TM129-S35: doubt it could care (student-talk-responsive).
>
> TM129-MT1: @student S35 – or have the concept of "human" or "harm" … hence the limited compliance (accepts ideas).

The data shows a slightly different pattern in LC-TM129-20B-1. The presenter asked questions (n=7), Six of which were widgets and one rhetorical, and the moderator asked three questions. The moderator is a staff member from the School of Computing and Communications. The moderator did not reformulate the widget question, instead asking: Cooking? What do you think? Anything else you can program it to do? (TM129-GM1). Students respond and initiate fewer questions and comments, although they behave similarly to the 19J cohort in explicitly responding to other students (n=3). In contrast to the 19J presentation, the moderator mainly accepts ideas by confirming

what students see. For instance, TM129-S49 asks, "Yea, what are those blinking lights? Reminds me of my router", to which the moderator (TM129-GM1) accepts the idea and replies, "blinking lights – good spot. [TM129-MT2] will demo that a bit later" (TM129-GM1) and in another case "well spotted [TM129-MT2] will talk about that near the end of the session. See if you could work out what they are indicating" (TM129-GM1). The moderator demonstrates some instances of applying the idea and taking the next step in logical analysis. For example, a student asks, "are those lights indicative of which part of Baxter is moving?" (TM129-S24). To which the moderator (TM129-GM1) replies, "Yes, directions of things nearby. It's not [the presenter's] speech but his location". Students respond to *ask questions* (n=10) and use the text-chat to answer the widget questions.

4.4.3 Students' interaction with the widgets

This sub-section presents the types of student interactions that occurred. Table 4.14 shows the duration of the IWBs, unique users, interactive users, number of chat users, number of chat posts and the percentage of interactive users across the IWBs in the 2019/2020 academic year. Unique users refer to the number of connected computers or people that were in the live event and interactive users are the number of people who interacted with one or more widgets or responded in the text-chat.

Table 4.14: Number and proportion of live viewers participating in text-chat or responding to widgets across the IWBs.

Module	Date (event)	Labcast title	Duration (mins)	Unique users	Interactive users	Chat users	Chat posts	Interactive users (%)
TM129	29/10/2019	Block 1 Robotics demonstration (LC-TM129-19J-1)	60	117	104	77	302	89
	21/01/2020	Block 2 Networking demonstration (LC-TM129-19J-2)	65	63	45	44	192	71
	18/02/2020	Block 1 Robotics demonstration (LC-TM129-20B-1)	60	104	97	66	226	93

	Date	Title						
	12/05/2020	Block 2 Networking 'homecast' demonstration (LC-TM129-20B-2)	75	60	55	40	129	92
SXPS288	15/10/2019	An interactive introduction to remote experiments in physics and space (LC-SXPS288-19J-1)	45	59	59	45	92	100
	14/01/2020	Physics project (LC-TM129-19J-2)	45	50	49	27	43	98
	03/03/2020	Planetary science project (LC-TM129-19J-3)	45	37	34	20	125	92
	21/04/2020	Exploring Mars (LC-TM129-19J-4)	90	66	59	43	184	89
S206/SXF206	22/02/2020	Fieldcast 1: Making observations and developing hypotheses (FC-S206-19J-1)	40	130	120	79	246	92
	22/02/2020	Fieldcast 2: Developing methods and data collection (FC-S206-19J-2)	30	113	110	69	199	97
	27/02/2020	Labcast 3: Analysing data and making conclusions (LC-S206-19J-3)	45	111	99	69	230	89

SXHL288	24/10/2019	The human brain in action (LC-SXHL288-19J-1)	65	108	96	65	297	89
	10/12/2019	Cells and tissues close-up (LC-SXHL288-19J-2)	65	41	36	25	53	87
S315	04/03/2020	Introduction to the experiment for TMA05 (LC-S315-19J-3)	70	33	30	21	46	91

The data indicates high levels of participation in the IWBs. Between 71% and 93% of TM129 attendees responded via one or more widgets or participated in the text-chat. In SXPS288 Labcasts it was between (89% - 100%); S206 (89% -97%); SXHL288 (87% - 89%) and S315 (91%). The data suggests that the students interacted with the presenter and one another using the Stadium Live interface. The next sub sections present the findings of the connected users and their interactions with the widgets in each of the modules' IWBs.

4.4.3.1   TM129-19J - 'Technologies in practice' Labcasts

Figure 4.8 shows the number of connected users during the LC-TM129-19J-1 Labcast. It started at 7pm and was scheduled to run for one hour. There were 84 connected users by 7:01pm and connected users (n=110) peaked by 7:21 pm. The data shows attendees came in on time and stayed throughout.

Figure 4.8: Number of connected users for the duration of the LC-TM129-19J-1 Labcast.

Table 4.15 shows that users interacted with 7 widgets during the Labcast. The Map widget was used by 62% of connected users with 71 users choosing the UK as their viewing location and 12 selecting Other EU. The data shows fluctuations in interactivity; the lowest at 20% and the highest at 80%. The Wordle widgets have the fewest interactions (23% and 38%). This could be because users have to input three words or phrases to be counted.

Table 4.15: Interactions with the widgets in LC-TM129-19J-1.

Question	Widget	Responses (% of 117 unique users)
Where are you watching from?	Map	73 (62%)
How humanoid is Baxter?	Continuum	94 (80%)
How many motors are needed to control one arm?	Continuum	72 (62%)
Enter 3 words to list Baxter sensors?	Wordle	23 (20%)
How autonomous is Baxter?	Continuum	79 (68%)
Does Baxter obey Asimov laws?	Continuum	82 (70%)
Tell us 3 things you will take away from the Labcast?	Wordle	38 (32%)

In the second Labcast (TM129-19J-2), Figure 4.9 shows that students come in on time with 44 connected users by 7pm. Connected users (n=63) peaked at twenty minutes into the Labcast, and attendees stayed throughout.

Figure 4.9: Number of connected users for the duration of the LC-TM129-19J-2 Labcast.

Table 4.16 shows that users interacted with 6 widgets during the Labcast. 78% of users interacted with the Map widget with 44 users choosing the UK as their viewing location and 5 choosing another EU country. The data shows a fluctuation in interactivity with the least interaction with the last Multiple-choice widget (21%).

Table 4.16: Interactions with the widgets in LC-TM129-19J-2.

Question	Widget	Responses (% of 63 unique users)
Where are you watching from?	Map	49 (78%)
What experience do you have with Raspberry Pi?	Multiple choice	51 (81%)
Is a Pi router good or bad?	Balance style	41 (65%)
Which tool would you use to test communication?	Multiple choice	45 (71%)
Which tool would you use to log in remotely?	Multiple choice	44 (70%)
What IP address will Pi get? 192.168…?	Multiple choice	13 (21%)

4.4.3.2   TM129-20B – 'Technologies in practice' Labcasts

Figure 4.10Figure 4.10 shows the connected users for the duration of the Labcast. 54 connected users were in the event by 7pm and stayed throughout the duration. There were 82 users by 7:05pm and a peak of 100 by 7:20pm.
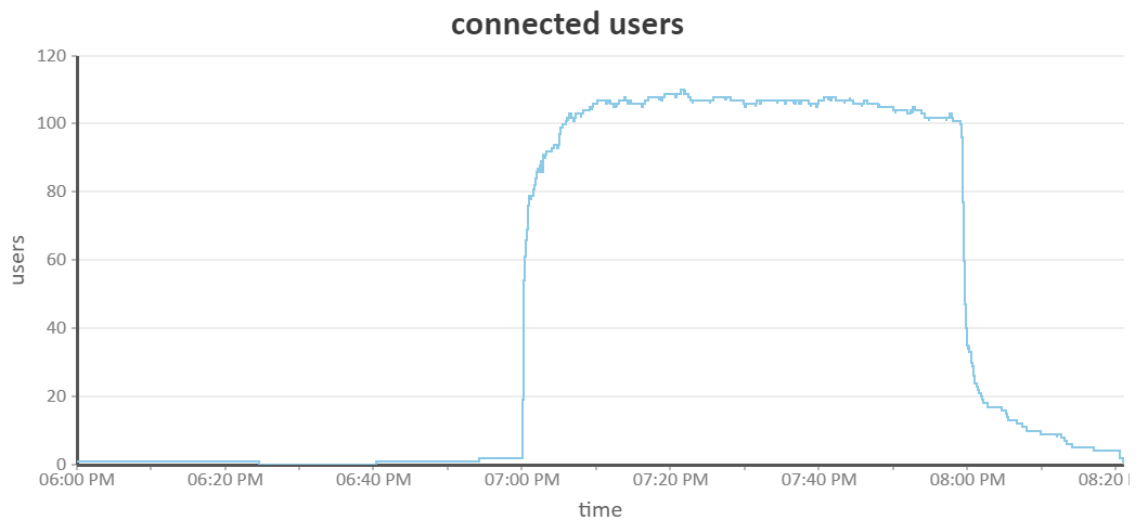
Figure 4.10: Number of connected users for the duration of the LC-TM129-20B-1 Labcast.

Table 4.17 shows users interacted with 6 widgets during the Labcast.75% of users interacted with the Map widget with 70 users choosing the UK as their location and 8 choosing another EU country. The data shows a fluctuation with an increase on the second Continuum widget (80%) and then a decrease (76%). The Wordle widgets have the least responses (39 and 14).

Table 4.17: Interactions with the widgets in LC-TM129-20B-1.

Question	Widget	Responses (% of 104 unique users)
Where are you watching from?	Map	78 (75%)
How humanoid is Baxter?	Continuum	83 (80%)
How many motors are needed to control one arm?	Continuum	76 (73%)
Enter 3 words to list Baxter sensors?	Wordle	39 (38%)
How autonomous is Baxter?	Continuum	79 (76%)
Does Baxter obey Asimov laws?	Continuum	73 (70%)
Tell us 3 things you will take away from the Labcast?	Wordle	14 (13%)

Figure 4.11 shows the connected users for the duration of the LC-TM129-20B-2 Labcast. The event started at 7pm and 38 connected users were in the event on time. The connected users (n=57) peaked at 7:17pm and users started to slowly drop off by 8pm although the Labcast ran over and continued for another 15 minutes.
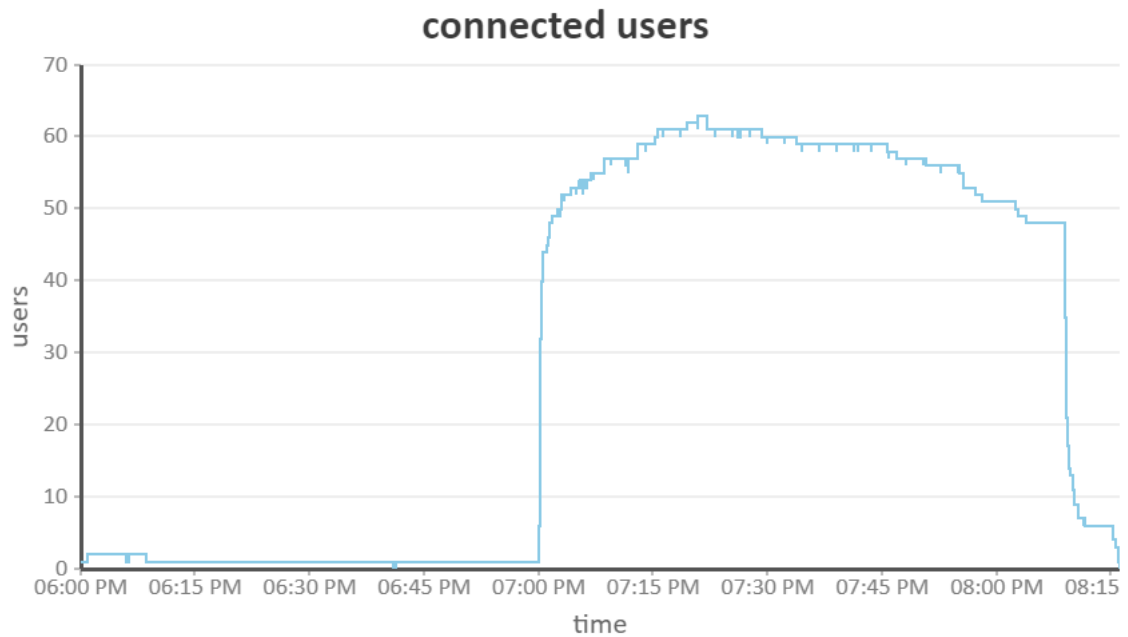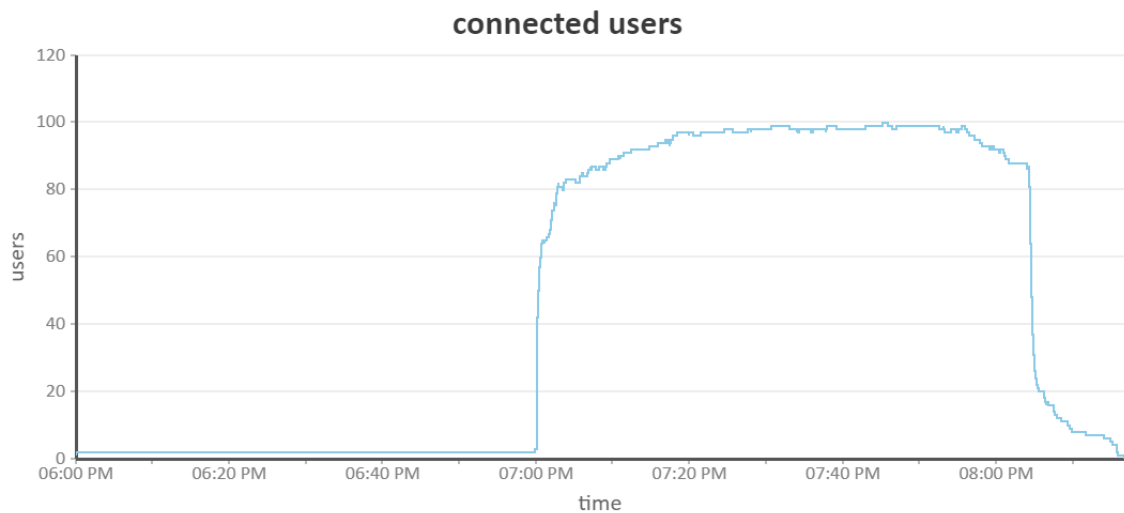
Figure 4.11: Number of connected users for the duration of the LC-TM129-20B-2 Labcast.

Table 4.18 shows that the users interacted with the 7 widgets during the Labcast. 75% of users interacted with the Map widget; 40 were viewing from the UK, 4 Other EU and 1 in Africa and Middle East. The data shows a similar fluctuation and proportion of interactivity with LC-TM129-19J-1 with the difference being an additional feedback widget (7%).

Table 4.18: Interactions with the widgets in LC-TM129-20B-2.

Question	Widget	Responses (% of 60 unique users)
Where are you watching from?	Map	45 (75%)
What experience do you have with Raspberry Pi?	Multiple choice	49 (82%)
Is a Pi router good or bad?	Balance style	38 (63%)
Which tool would you use to test communication?	Multiple choice	44 (73%)
Which tool would you use to log in remotely?	Multiple choice	45 (75%)
What IP address will Pi get? 192.168…?	Multiple choice	18 (30%)
Tell us three things that you will take away from the Labcast?	Wordle	4 (7%)

4.4.3.3   S206-19J – 'Environmental Sciences' Fieldcasts

Figure 4.12 shows the number of connected users during the FC-S206-19J-1 Fieldcast. The Fieldcast was scheduled to run for 30 minutes. Episode 1 started at 12 noon on a Saturday and there were 100 connected users at 12 noon. Connected users (n=122)

peaked at 12:18pm. The data shows attendees came in on time and stayed throughout. There was a drop in connections at 12:32pm although 60 users were still connected at 12:38pm which indicates students stayed to watch the extra 5-minute pre-recorded clip (i.e., of the site in Spring) at the end of the live stream.

Figure 4.12: Number of connected users for the duration of the S206-19J-1 Fieldcast.

Table 4.19 shows that users interacted with 5 widgets during the Fieldcast. The Map widget was used by 82% of connected users with 95 watching from the UK, 8 from other EU, 1 North America, 1 South America, and 2 from Asia. The data shows an increase of interaction as the episode progresses.

Table 4.19: Interactions with the widgets in FC-S206-19J-1.

Question	Widget	Responses (% of 130 unique users)
Where are you?	Map	107 (82%)
What environmental factors vary across the site?	Wordle	100 (77%)
Which topic would you like to study?	Multiple choice	104 (80%)
Would you like to test for a relationship or difference?	Multiple choice	109 (84%)
Which hypothesis would you like to test?	Multiple choice	114 (88%)

Figure 4.13 shows the number of connected users during the second episode of FC-S206-19J-2 Fieldcast which started at 1:30pm. 7 users started to come in by 1:

24pm.There were 98 connected users at 1:30pm and connections (n=115) peaked at 1:41pm. Attendees stayed throughout the 30-minute episode.

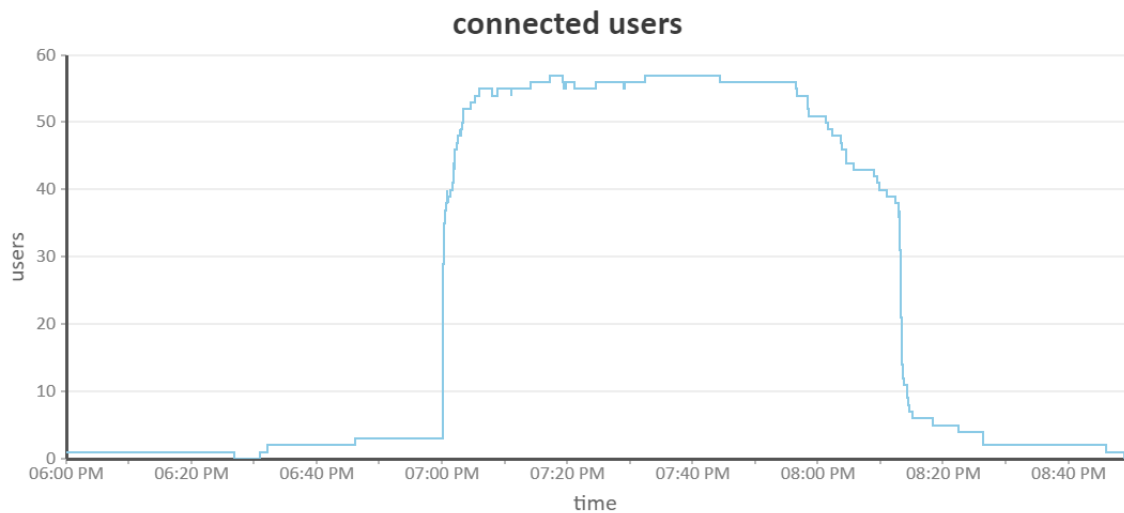*Figure 4.13: Number of connected users for the duration of the FC-S206-19J-2 Fieldcast.*

Table 4.20 shows that users interacted with the 3 widgets during the Fieldcast. There was no Map widget, instead a two-option Balance style widget was used to poll whether attendees were new (i.e., to episode 2) or returning participants (i.e., from episode 1). The data shows steady engagement with the widgets.

Table 4.20: Interactions with the widgets in FC-S206-19J-2.

Question	Widget	Responses (% of 113 unique users)
Are you new or returning?	Balance style	104 (92%)
Which do you think is the best sampling strategy to suit the question and location?	Multiple choice	105 (93%)
How many replicates would you like to be collected?	Multiple choice	105 (93%)

Episode 3 of the LC-S206-19J-3 took place on a weekday evening. Figure 4.14Figure 4.14 shows the connected numbers of connected during the event. There were 86 connected users at 6:30pm. Connected users (n=100) peaked at 6:36pm and users stayed throughout the duration of the Labcast.
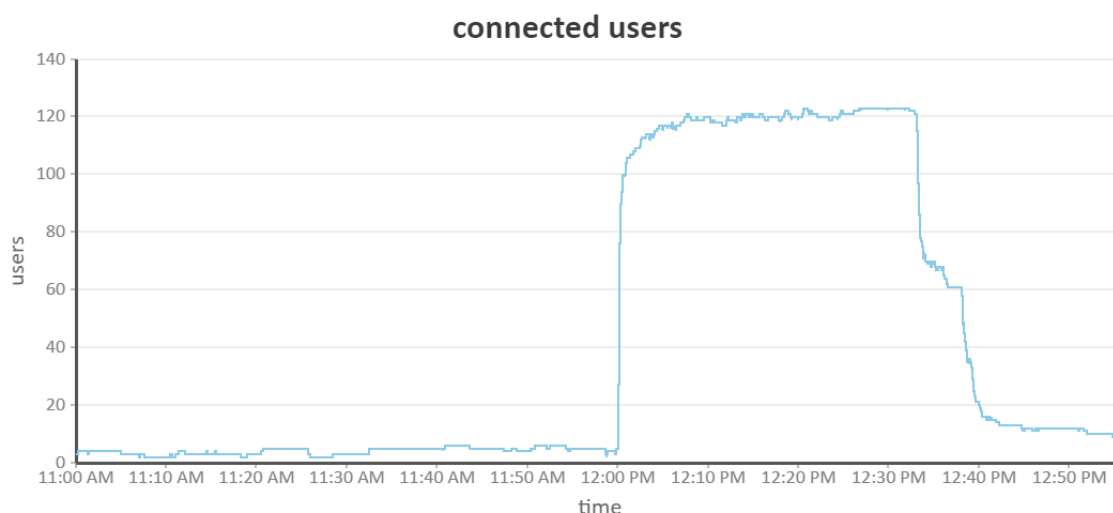
Figure 4.14: Number of connected users for the duration of the LC-S206-3 Labcast.

The data in Table 4.21 shows users interacted with 8 widgets during the Labcast. The Map widget was interacted with by 79% of connected users with 83 users selecting the UK as their viewing location, 4 in other EU and 1 in Australasia. The highest number of responses is the Multiple-choice widget 92 (83%) after which responses decrease by shows steady engagement as the Labcast progresses.

Table 4.21: Interactions with the widgets in LC-S206-19J-3.

Question	Widget	Responses (% of 111 unique users)
Where are you watching from?	Map	88 (79%)
Which is a suitable null hypothesis?	Multiple choice	92 (83%)
What type of graph and statistical test is most appropriate?	Multiple choice	87 (78%)
Do the data support accepting or rejecting the null hypothesis?	Balance style	85 (77%)
Enter three words that describes how you felt about the Fieldcast?	Wordle	68 (61%)
How helpful did you find the Fieldcast series?	Continuum	87 (78%)
How enjoyable did you find the Fieldcast series?	Continuum	85 (77%)
How involved did you feel in making decisions?	Continuum	84 (76%)

4.4.3.4 SXPS288-19J - 'Remote experiments in physics and space' Labcasts

Figure 4.15 shows the connected users for the duration of the Labcast. The LC-SXPS288-19J-1 Labcast started at 7:30pm and there were 51 connected users at the start of the event. Connected users (n=60) peaked at 7:48pm and students stayed.
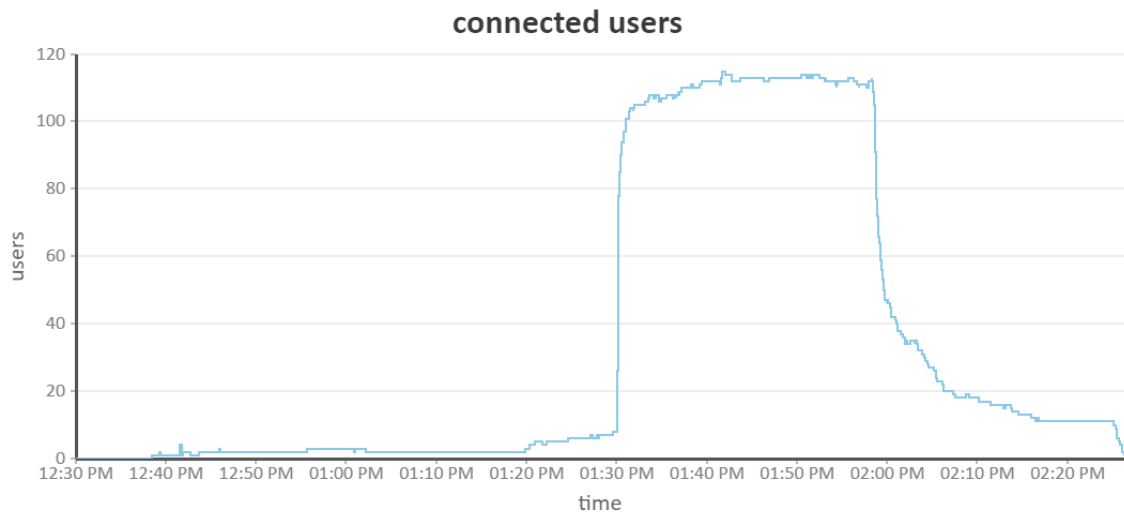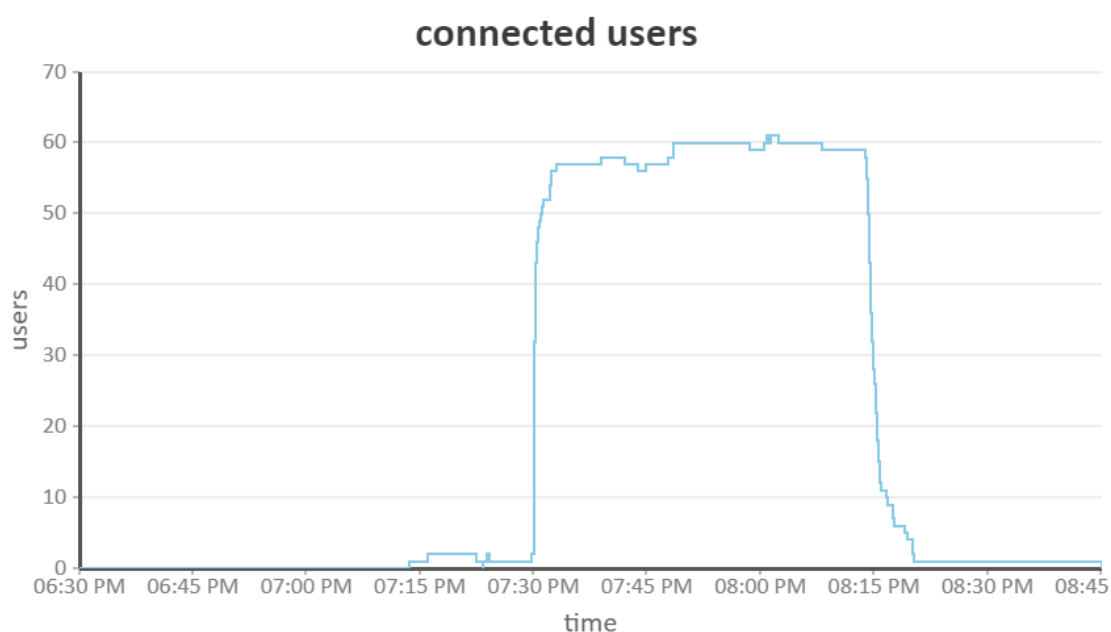

Figure 4.15: Number of connected users for the duration of the SXPS288-19J-1 Labcast.

Table 4.22Table 4.22 shows that users interacted with 5 widgets during the Labcast. 95% of users interacted with the Map widget with 48 users choosing the UK as their location and 8 choosing another EU country. As the Labcast progresses, the amount of interaction fluctuates with decreases in responses.

Table 4.22: Interactions with the widgets in LC-SXPS288-19J-1.

Question	Widget	Responses (% of 59 unique users)
Where are you?	Map	56 (95%)
Reasons for doing an experiment	Multiple choice	41 (69%)
Factors for a good experimental design	Wordle	21 (36%)
What skills does an experimenter need?	Wordle	32 (54%)
What three things will you take away from this Labcast?	Wordle	25 (42%)

Figure 4.16 shows the connected users for the duration of the LC-SXPS288-19J-2 Labcast. There were 41 connected users at 7:30pm. Connected users (n=52) peaked at 7:46pm and users stayed throughout the duration of the Labcast.
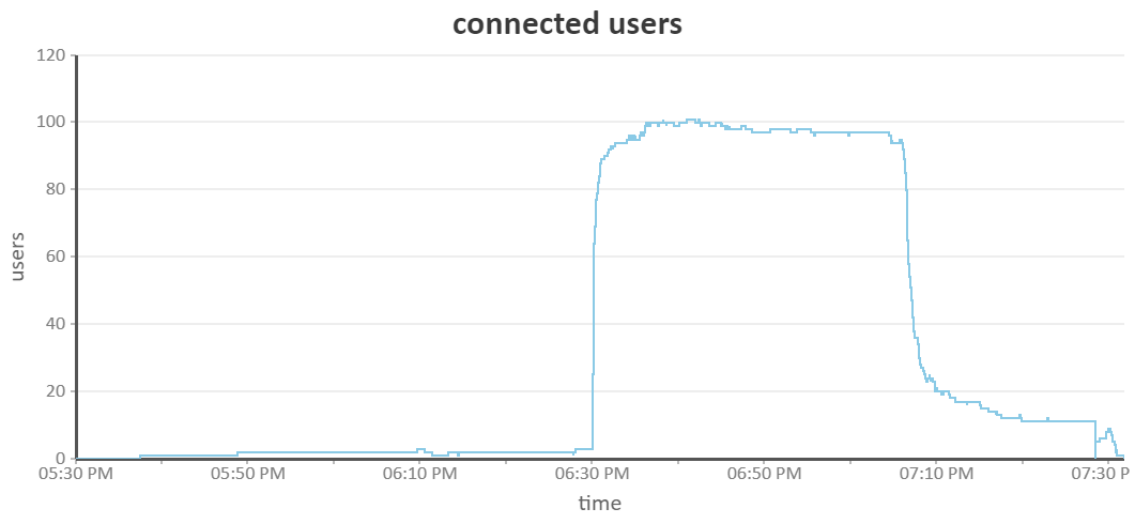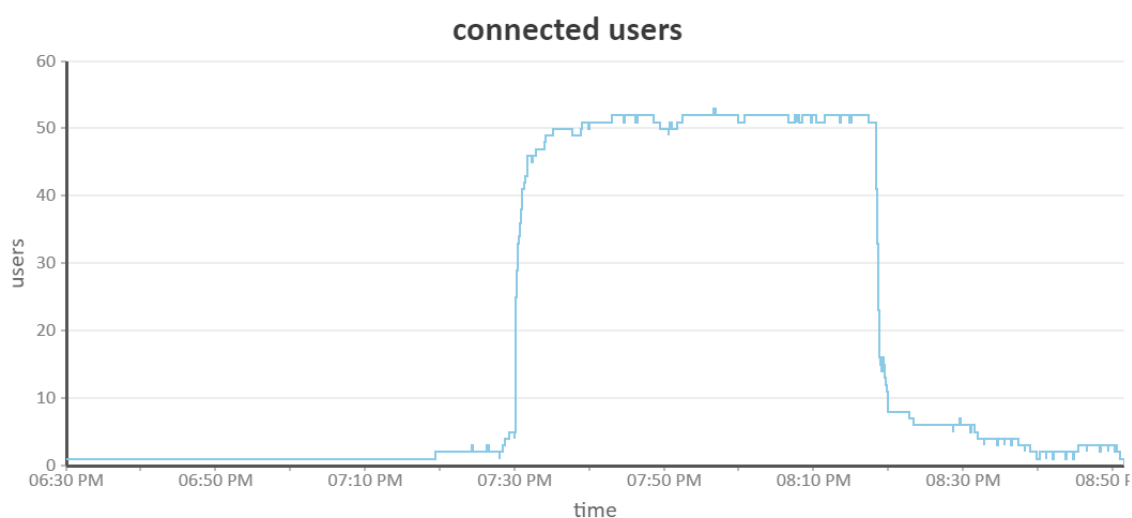

Figure 4.16: Number of connected users for the duration of the SXPS288-19J-2 Labcast.

The data in Table 4.23 shows students interacted with the 6 widgets. 90% of 50 unique users interacted with the Map widget with 40 attendees watching from the UK and 5 from another EU country. There are fluctuations in the responses especially with the Wordle widgets. The last two widgets are feedback widgets (see Section 3.7.2, p.71). The data shows a higher response rate (66%) with the Multiple-choice widget than with the Wordle widget (28%).

Table 4.23: Interactions with the widgets in LC-SXPS288-19J-2.

Question	Widget	Responses (% of 50 unique users)
Where are you?	Map	45 (90%)
What properties of electron can we investigate?	Wordle	19 (38%)
What will happen to the electron? It will…	Multiple choice	29 (58%)
Causes of errors in experiments?	Wordle	16 (32%)
To what extent do you feel that you gained better understanding of the physics of the Compton effect?	Multiple choice	33 (66%)
What 3 things will you take away from this Labcast?	Wordle	14 (28%)

Figure 4.17 shows the connected users for the duration of the LC-SXPS288-3 Labcast. There were 30 connected users in the event by 7:30pm. There was a peak of 42 users at 8:15pm and connected users started to leave by 8:16pm.

Figure 4.17: Number of connected users for the duration of the LC-SXPS288-3 Labcast.

The data in Table 4.24Table 4.24 shows students interacted with the 5 widgets. 84% of users interacted with the Map widget with 29 from the UK, 1 from Australasia and 1 from Asia. After the map widget there is a decrease in user interactions.

Table 4.24: Interactions with the widgets in LC-SXPS288-19J-3.

Question	Widget	Responses (% of 37 unique users)
Where are you?	Map	31 (84%)
What is the most abundant gas in the Martian atmosphere?	Multiple choice	26 (70%)
What are the key hazards and safety considerations in the gas cell lab?	Wordle	13 (35%)
The Labcast helped me understand what I will need to do in the gas cell experiment	Multiple choice	20 (51%)
What 3 things were most helpful about the Labcast?	Wordle	12 (32%)

Figure 4.18 shows the connected users for the duration of the LC-SXPS288-19J-4. The Labcast started at 7:30pm and was advertised to last for 45 minutes with time for questions afterwards. There were 55 connected users in the event at 7:30pm. The connected users (n=62) peaked at 7:41pm. The Labcast overran by 45 minutes and over 50% of users (n=32) stayed connected until 9pm, when it ended.

Figure 4.18: Number of connected users for the duration of the LC-SXPS2881-19J-4 Labcast.

The data in Table 4.25Table 4.25 shows that the students interacted with the 7 widgets throughout the Labcast. 62% of the users interacted with the Map widget with 38 users from the UK, 2 from Other EU and 1 from Asia. With the exception of the third multiple choice widget (n=39), users' engagement was stable.

Table 4.25: Interactions with the widgets in LC-SXPS288-19J-4.

Question	Widget	Responses (% of 66 unique users)
Where are you watching from?	Map	41 (62%)
Which photo was taken on Mars?	Multiple choice	44 (67%)
In this photo, which was taken on Mars	Multiple choice	39 (59%)
MOMA uses a pulsed UV laser with energy to analyse chemicals. What happens to the molecules on the surface?	Multiple choice	44 (67%)
How likely is it that scientist will find signs-of-life molecules in Mars sample?	Continuum	44 (67%)
What 3 things will you take away from this Labcast?	Wordle	27 (41%)
How much has the Labcast improved your understanding of the subject?	Multiple choice	40 (61%)

4.4.3.5 SXHL288 – Practical science: biology and health

Figure 4.19 shows the connected users for the duration of the Labcast. The SXHL288-19J-1 Labcast started at 7pm and there were 67 connected users at the start of the event. Connected users (n=93) peaked at 7:13pm and students stayed throughout the duration.
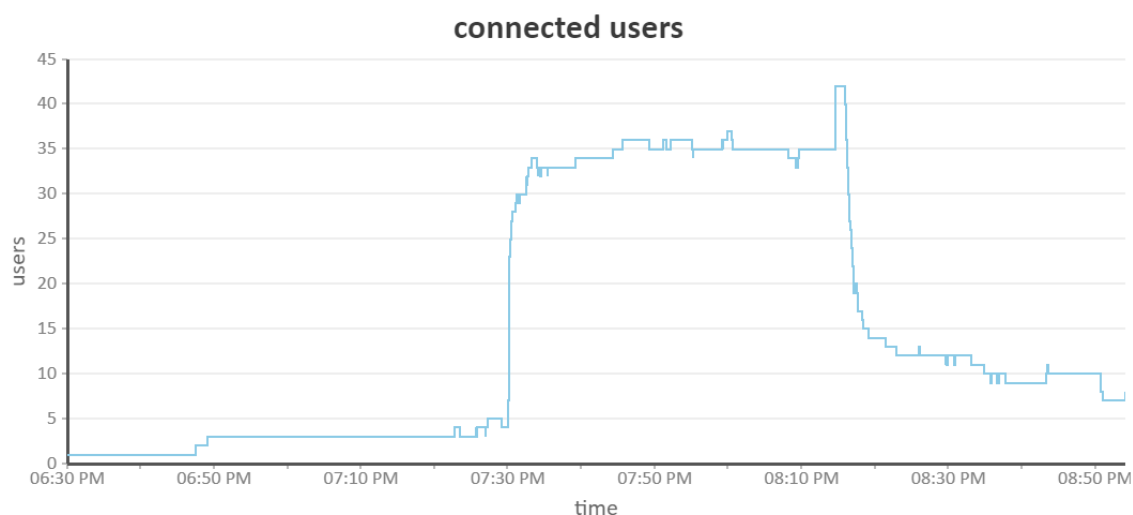

Figure 4.19: Number of connected users for the duration of the SXHL288-19J-1 Labcast.

Table 4.26 shows that the students interacted with the 5 widgets during the Labcast. 69% of users engaged with the Map widget; 58 people from the UK, 13 from Other EU, 1 from North America and 3 from Africa and the Middle East. There are some variations in the user interactions with the widgets.

Table 4.26: Interactions with the widgets in LC-SXHL288-19J-1.

Question	Widget	Responses (% of 108 unique users)
Where are you watching from?	Map	75 (69%)
What courses are you studying?	Multiple choice	73 (68%)
Which sex is better?	Balance style	86 (80%)
What other factors might alter RVP performance?	Wordle	63 (58%)
Is participant (A) male or female?	Multiple choice	77 (71%)

Figure 4.20Figure 4.20 shows the connected users for the duration of the Labcast. In LC-SXHL288-19J-2, there were 22 connected users at the start of the event. Connected users (n=35) peaked at 7:22pm and students stayed throughout the duration.
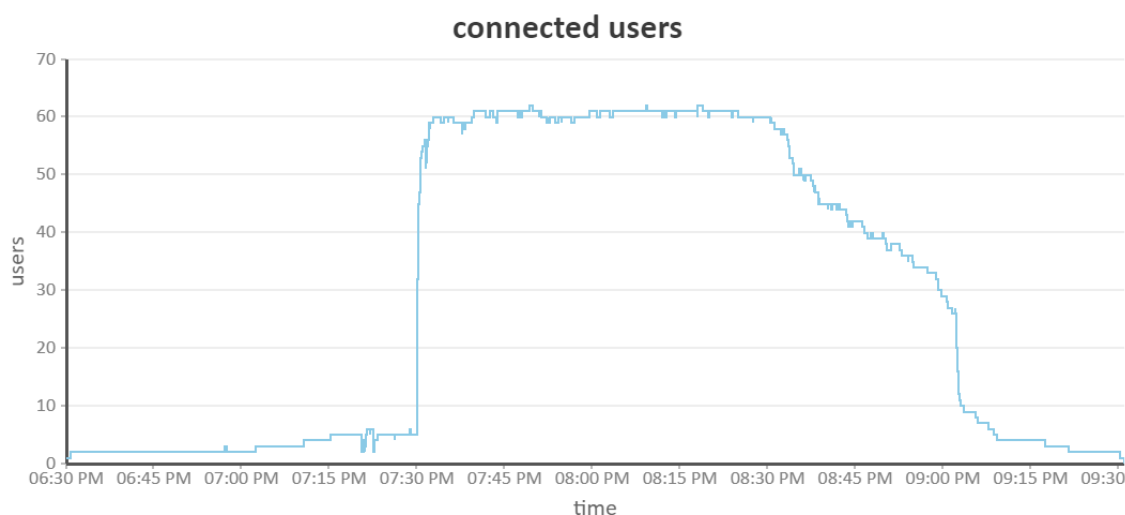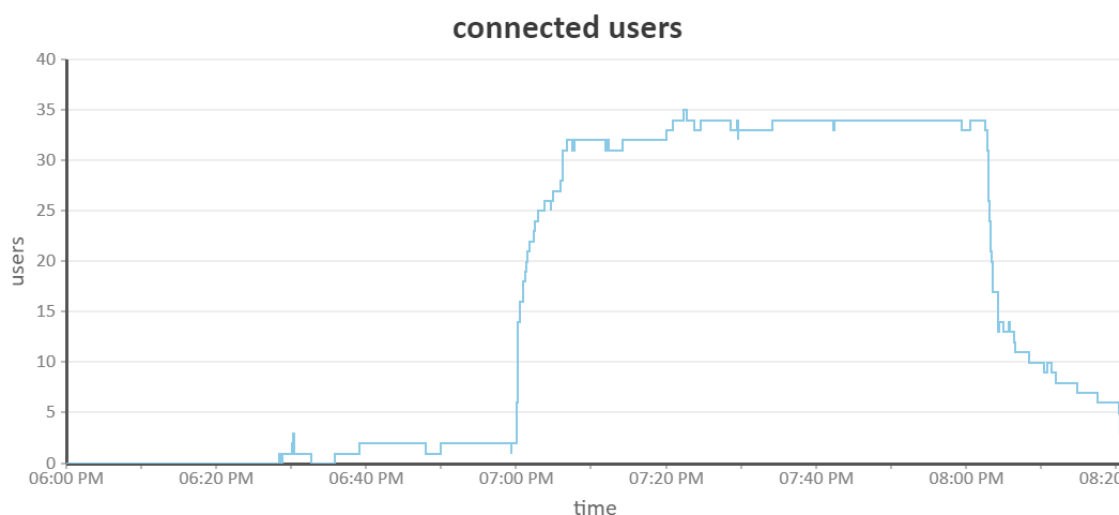

Figure 4.20: Number of connected users for the duration of the SXHL288-19J-2 Labcast.

Table 4.27 shows that students interacted with the 6 widgets. As the Labcast progresses, the number of responses decreases and increases. The last two Multiple choice questions (46% and 39% respectively) were questions on hypotheses and the presenters strategically used the widgets. The audience was asked to input data into the 'How many nuclei on the left image?' widget (46%) based on whether their birthday was in the first six months of the year and the 'How many nuclei on the right image?' widget (39%) for birthdays in the last six months of the year.

Table 4.27: Interactions with the widgets in LC-SXHL288-19J-2.

Question	Widget	Responses (% of 41 unique users)
Where are you watching from?	Map	28 (68%)
What is the tissue?	Multiple choice	25 (61%)
How many nuclei in the 6 grid squares?	Multiple choice	25 (61%)
If increased, depot size is due to increase cell volume, cell nuclei in the grid will…	Balance	31 (76%)
How many nuclei on the left image?	Multiple choice	19 (46%)
How many nuclei on the right image?	Multiple choice	16 (39%)

4.4.3.6 S315- Chemistry: further concepts and applications

Figure 4.21Figure 4.21 shows the connected users for the duration of the Labcast in LC-S315-19J-3. The Labcast started at 7:30pm and there were 24 connected users by 7:31pm. Connected users (n=30) peaked at 8pm and students stayed connected during the event.
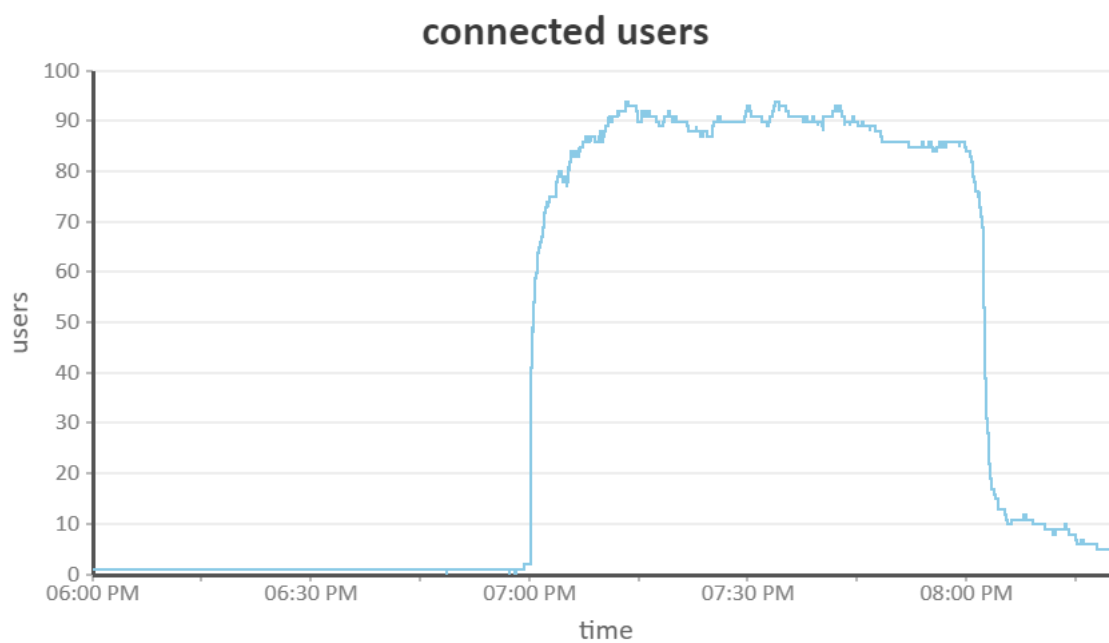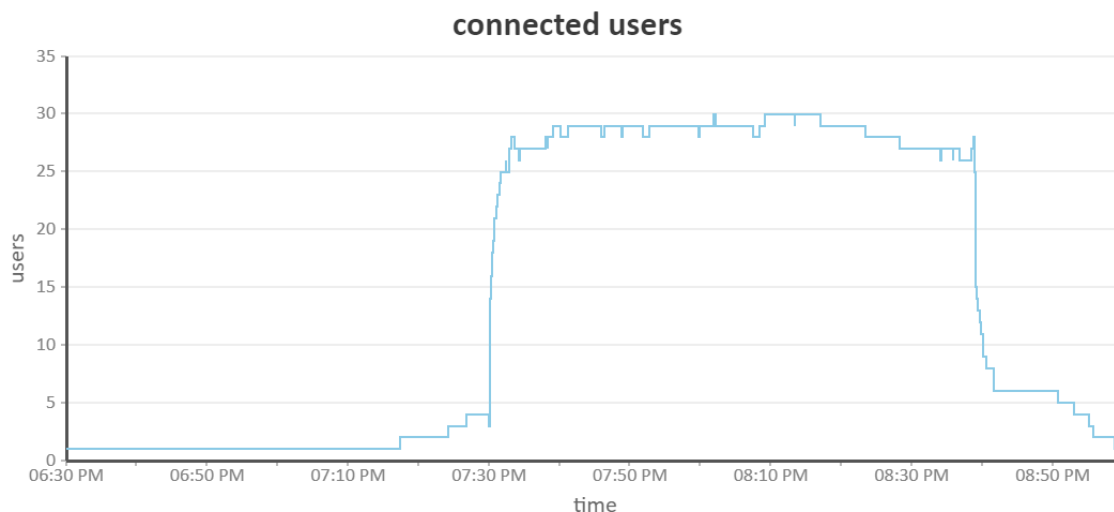

Figure 4.21: Number of connected users for the duration of the LC-S315-3 Labcast.

The data in Table 4.28 shows that the students interacted with the 6 widgets during the Labcast. 76% of users interacted with the Map widget with 22 people from the UK, 2 from other EU, and 1 from Other. After the map widget, there are fluctuations with responses.

Table 4.28: Interactions with the widgets in LC-S315-19J-3.

Question	Widget	Responses (% of 33 unique users)
Where are you watching from?	Map	25 (76%)
Which interactions are important in drug-protein binding?	Multiple choice	17 (52%)
Which line (A or B) corresponds to the metabolism of MDZ in the presence of an inhibitor?	Multiple choice	23 (70%)
Which solvent will speed up?	Balance	21 (64%)
Select the standard you would like to run	Multiple choice	22 (67%)
The Labcast helped me understand what I need to do in TMA05	Multiple choice	18 (55%)

Turning to qualitative data, students from SXPS288, S206 and SXHL288 described their experiences with widgets in various ways. Students commented on being impressed with the widgets, the quality and visual experience, and the anonymous nature of voting. For example, an S206 participant commented:

> It was very good actually and a lot of it is probably the quality of the widgets and how you could graphically see the results. There was one, I can't remember exactly what it was about now. It was earlier on, and I think people were asked to write… I think the idea was... you basically said what you interested in, and the results started coming in and it was a big balloon if you like with the key words appearing bigger. That was a really powerful way to see what everyone who was contributing was thinking really. I'd never seen that kind of widget before. I 'd never seen anything like that, and I thought wow, this is really neat. It was interactive so you are seeing in it in real-time and it was really clear what people was thinking of because the big words were there (S206-S10).

Others had mixed opinions about the use and purpose of the widgets as this SXPS288 student mentioned:

> If you ask students for their feedback, the three-word maps, I think that's fine because you paused, and you let them do that. Although I do think that did feel perfunctory. It did feel a bit throwaway, so I don't feel that activity was properly embedded. What I felt was it was just a bit disposable. We all did it and then somebody just said, thanks for that and then we moved on. I thought, if you're going to use it as a tool, then there has to be a reason for doing it. And it always missed the reason for doing it (SXPS288-S05).

> I would have preferred if questions asked with the widgets were more difficult and therefore my opinion on their use would more positive. As a concept, the widgets were good, their execution could have been improved (SXHL288-S09).

4.4.4   Types of discourse patterns in the text-chat

The data show that most students interacted with the synchronous tools by engaging with the widgets and the text-chat. This study aimed to examine the discourse patterns in the IWBs and presents the findings for the question: *How does participating in interactive web broadcasts contribute to knowledge-building*

discourses? The conceptual framework is discussed in Chapter 2, Section 2.5.4 and the inter-coder reliability in Chapter 3, Section 3.8.6.

Table 4.29 highlights the events that have the most coded occurrences of each classification type. The *Seek-fact* (i.e., questions seeking factual information) column refers to questions or statements where a student wants to know a 'Wh question' (e.g. what, who, when and how many) and which can be answered providing factual information. The *Seek-und* (i.e., questions seeking understanding) column refers to questions that need an explanation, cause-and-effect language or reasons. The *Exp-fact* column (i.e., explanations representing factual information) means any explanation when facts is provided without common causes or reasons. The *Exp-explan* (i.e., explanations representing explanatory information) is when explanations contain reasons, cause-and-effect relations or hypothesis. *Bridge-knwl* (i.e., bridging knowledge) refers to statements that link resources, materials or web links to others to enrich community knowledge and *Socio-aff* (socio affective) refers to phrases that express social and emotional discourse.

Table 4.29: Discourse classifications used in IWBs adapted from (Lipponen, 2000).

Web broadcasts	Fact oriented		Explanation oriented		Social oriented	
	Seek-fact	Seek-und	Exp-fact	Exp-explan	Bridge-knwl	Socio-aff
LC-TM129-19J-1	24	3	21	1	0	66
LC-TM129-19J-2	7	3	9	8	0	41
LC-TM129-20B-1	10	2	2	1	0	55
LC-TM129-20B-2	3	1	3	1	5	30
LC-SXPS288-19J-1	1	1	2	0	0	47
LC-SXPS288-19J-2	6	2	3	5	0	23
LC-SXPS288-19J-3	5	2	8	1	1	42
LC-SXPS288-19J-4	2	2	2	4	4	60
FC-S206-19J-1	2	2	11	3	0	64
FC-S206-19J-2	12	8	20	6	2	105
LC-S206-19J-3	13	5	13	5	0	63
LC-SXHL288-19J-1	8	3	10	3	0	82
LC-SXHL288-19J-2	3	2	3	1	0	27
LC-S315-19J-3	1	1	0	0	0	24
Totals occurrences	97	37	107	39	12	729

The data show that three main types of discourse were found in IWBs: Fact oriented, Explanation oriented and Social oriented discourses (c.f., Appendix K for codebook). The most significant occurrence of discourse across all IWBs was *socio affective* (n=729) which included phrases of salutations, self-disclosure, humour and talk around

family or community. *Factual explanations* were (n=107) and *questions seeking factual information* (n=97).

The FC-S206-19J-2 Fieldcast had the most socio affective coded references. Students returned to episode 2 after a lunch break. The data shows that students were more enthusiastic in social engagement than in episode 1. Examples included, "heloooo from blizzardly North Berwick" (S206-S35) and "rain has started again in South Wales" (S206-S26). There was more humour and banter exchanged. For instance, "Has that quadrant been nicked from the football pitch" (S206-S56) and "we'll be on Netflix soon" (S206-S1). Students also used self-disclosure phrases such as " I'm knackered and my brain isn't working" (S206-S69) in response to the richness/diversity discussions during the observation stage.

The data also shows the moderator predominately engaged in *explanation representing factual information* by giving explanations without necessary cause-effect or reasoning such as "it is between about 1.5 and 2m" (S206-MT2) in response to a student's question on how tall the shrubby layer was (S206-S37). Students also engaged in the *explanations representing factual information* discourse with each other. For example, in response to a student's misunderstanding on sampling techniques, S206-S86 commented, "No, we're restricted random sampling at each of the two sites". Another remarked, "15 max for Mann Whitney, I think. My tutor said 19 preferable" (S206-S69).

Similarly, the text-chat in LC-SXHL288-19J-1 had a high number of socio-affective discourse, which was mainly self-disclosure around students' experience doing a Rapid Visual Processing (RVP) test. For instance, SXHL288-S17 commented that RVP was harder than what they had thought it would be, which consequently started a thread of 10 responses that were affective in nature. Among the chat, students stated, "I didn't get one right lol!" (SXHL288-S17); "It was very hard" (SXHL288-S6) and "I found it confusing the first time I did it" (SXHL288-S5). As the text chat had an active moderator, this generated more explanations.

The data indicates that LC-TM129-19J-1 had more students *seeking factual information* (n=24) and the moderator offered more *explanations representing facts* (n=21) but without reasons. However, there is some variation in the other TM129 Labcasts. LC-TM129-20B-1 was moderated by a lecturer outside of the module team, which may

account for the lower number of explanation-oriented discourse. Similarly, FC-S206-19J-2 and 3 had higher occurrences of students *seeking factual information* (FC-S206-2 n=12; FC-S206-3 n=13) and *seeking understanding* (FC-S206-2 n=8 and FC-S206-3 n=5). Both TM129 and S206 moderators had more activity in these areas (TM129 n=21 and S206 n=20, respectively) compared to the other IWBs. Both IWBs were moderated by module team members who were very active in the text-chat and contributed to this pattern.

TM129, S206 and SXPS288 cohorts engaged in *bridging knowledge* discourse. In TM129-20B-2, the moderator shared the link of the guest presenter's research and other links such as ping.mit.edu. One student recommended an app stating, "apps like Termius for Android can connect via SSH and Telnet. I use it @home for my sat boxes" (TM129-S88). At the end of the LC-SXPS288-19J-4 Labcast, a student comments, "Don't forget to get out at 9pm if you are in the UK, look up to see the 40 Starlink satellites go overhead in a train, one every 30s or so!" (SXPS288-S17) to which a student replies "@StudentS17 I saw 42 go over on Sunday night. Will post a photo on the Open Studio later" (SXPS288-S27). In the FC-S206-19J-2, a student (S206-S37) shares a Google map link for the site location. Elsewhere in the chat another student replies "@Student37, Field Studies Council have waterproof field sheets" (S206-S26).

4.4.5 Students' feedback and recommendations

The qualitative data show that students assigned varying judgments about the merits, worth or significance of IWBs as an intervention. Several students reported mixed attitudes on how the synchronous tools were used. For example, an Environmental Sciences student mentioned, "people use the chat boxes to chat socially, which is nice on the one hand, but I was there to do the Fieldcast (…) it runs quite fast, so it's quite difficult to distinguish what's banter and what's actually talking about the subject" (S206-S13). In interview data, a Physical Sciences student was critical on the approach of tool use:

> I think there is a general tendency to feel that you have to use all the available functionality because it is the true sense of interactivity. If you can get students to listen, watch, tick boxes, and vote in polls to comment. And I think maybe we just lost the sense of communication and its use as a tool (SXPS288- S07).

In an open-ended survey question of what students liked or disliked about the Labcasts, one respondent made comparisons of the types of learning behaviours in an online environment and in a physical laboratory:

> In general, loved the Labcasts. It is particularly difficult, whether in the real lab or online, to do two things at once. Trying to "listen-and-learn" as well as engage with the chat box is particularly difficult. Your attention and ability to respond and learn at the same time is diminished. In the real lab you would never be asked to listen to the instructions from the lab-tech and also respond to your messenger on your phone (SXPS288-S05).

In survey data, students on SXHL288 were more critical of the Labcasts due to their experiences with the module. For example, one respondent who watched one or more live events reported, "the Labcast hadn't been useful to me" (SXHL288-S04). She also stated, "I disliked this entire module. Trying to do practical science online was always designed to fail (…) information is just all over the place that an inordinate amount of time is wasted just trying to find the relevant bits" (SXHL288-S04). Another Health and Biology student respondent commented, "to be honest there is so much information in SXHL, for me the Labcasts were just one more bit of information. I'm not knocking it but there's so much with tutorials, the module material itself, the forum activities, and the virtual labs it can get overwhelming" (SXHL288-S08). Others reported being confused about where to find the links for Labcasts on the module website (TM129-20B-S06). However, others had positive attitudes. For example, one respondent commented:

> A few weeks after the Fieldcast, I was fortunate to be able to attend the only field school to run for this module. I found the Fieldcast served as good preparation for the vegetation and soils element of the field school, preparing me for the "real" field work (SXF206-S11).

A student commented on the opportunity to be involved. For instance, one S206 student mentioned:

> I found them really fun, actually. I thought it was good to watch something live. The widgets were good. I think it was more about the interaction. I think that was what was appealing about it. It was like live TV, I suppose, but I liked the

fact that you could get involved in it. I think that made it a bit more fun. You get more out of it when you're asked to be involved in something. It helps you later on if you've been involved in the discussion. It's alright watching it back, but you've not had a say about what they've done. I think it's a good approach (S206-S03).

Students who engaged with the recordings also had mixed views especially around accessing the text-chat. For example, in an open-ended question on what students liked or disliked about the recordings, a student mentioned that they could not go back to see any of the chat discussions which they wanted to review because "good information was provided in the chat which you could have only seen if you attended on the day" (SXF206-S04). Another respondent commented, "I wasn't able to see the comments box in the recording and therefore could not understand some of the references made by the tutors in the Labcast" (SXHL288-S09).

For others having access to the recordings were important. For instance, one respondent commented, "the recordings were a great help, enabling me to go back and look at the investigation again when writing my report" (SXF206-S05). TM129-19J-S15 mentioned they liked the ability to watch the recording as it was not always possible to attend the Labcasts. Another student commented on the benefit of both options of the Labcasts:

> Being able to rewind parts is great but I think you lose that connectivity feeling, so having access to both options is ideal as some students learn at different speeds and I know being able to go over certain things is a great way of strengthening my knowledge (TM129-19J-S17).

Students also offered recommendations on how the IWBs could be adapted. Several themes emerged from the data, such as *having bespoke Labcasts* to help students address gaps in math skills; allowing *pre-Labcast questions* to canvas questions in advance and encourage students to think about the topic (SXPS288-S14). SXPS288-S14 and SXHL288-S02 mentioned *better advertising* of Labcasts. A TM129 student commented, "I think it could be an excellent resource if more focus was placed on it" (TM129-19J-S16).

For example, SXPS288-M-S05 mentioned how Labcasts in the 'Remote experiments in physics and space' module could be organised better by signalling different aspects of the module blocks:

> I think if the Labcasts all run to a well-known structure, and maybe they do, but perhaps it just needs to be signalled more clearly. So, this is the introduction where [SXPS288-MT01] will talk about the block and show you some stuff on the board. Here are two lab people. They will show you the kit working in the lab. Here is a pre-recorded example of some of the things that can go wrong. And here is me telling you about all the things that I've just told you about and how to get help and support when you're actually doing it. I think if they had a routine structure that when you join one, you know, what happens and maybe right at the start, there is just a pre-recorded one that is about keeping a lab book and walking around the lab and how you write up a lab paper and how that relates to how people write up journal papers. And that itself has the structure in it. So, when you go to the next one, you're pre-prepared for what's going to happen (SXPS288-S05).

Others had more eclectic recommendations around how the recordings could be used: For example, S206-S03 commented, "Just thinking like on Netflix, you've got the thumbnails at the bottom so that when you fast forward, you can start at each theme. That would be useful. Otherwise, you do end up scrolling through, and you realise that you missed it and have to go back". A Physical Sciences student who only watched the recordings mentioned, "They have been recorded, so there are a few hours of footage. I think they could be used to select the right footage. So, in a brief video of only one minute with some cool music to advertise, you can show this footage as an introduction to the module" (SXPS288-S14).

4.4.6 Section summary

Overall, the mixed data show that module teams implemented several activities to interact and engage with students during a live event. All module teams established social connections with students by using verbal (and non-verbal) cues to welcome, orient and engage with them. Presenters also used the widgets to facilitate engagement. The data shows students (and others who may have attended such as ALs) connected on time and stayed for the duration of the IWBs in most cases. There

were two incidences of Labcasts overrunning its advertised time: LC-TM129-20B-2 and LC-SXPS288-19J-4. The data show that users started to disconnect in TM129 but stayed in SXPS288.

Where a Labcast had an active moderator, widgets questions were often reinforced in the text-chat area. In eliciting students' feedback on what they gained or to what extent the Labcast helped in understanding, feedback widgets were used by the presenters towards the end of the Labcasts. However, some presenters failed to review the widgets with the audience. The module and technical production teams engaged in various affective strategies, and encouraging participation was the most frequent strategy. The data shows that if a Labcast is not actively moderated, this can impact how the students engage with the text-chat.

Students across the IWBs demonstrated high levels of participation by responding via one or more widgets or participating in the text-chat. Lastly, students engaged in three different discourse patterns to assert themselves socially and engage in meaningful chat utterances. They sought factual information, understanding and either offered or received explanations.

4.5 Impact of IWBs

This section presents the impacts of the IWBs on stakeholders and presents the findings for the questions: *How do interactive web broadcasts support students' learning, and what motivates students to engage (or not engage) with the interactive web broadcasts?* In *what ways does participation in interactive web broadcasts contribute to students' sense of community*?

4.5.1 Students' learning

Table 4.4, Section 4.2.2, p.86 shows the number of students across the module cohorts invited to the study and the response rates across the study population. The respondents' demographics have been discussed in Section 4.3.4.2. The module chairs agreed on open and close dates of the surveys. Slightly different questions items were devised due to the differences in Labcast and Fieldcast aims and in consideration of the interests of the module chair. The results summed for the surveys in Figure 4.24 - Figure 4.25 show the distributions of responses on questions related to learning. The five-point Likert scale ranked from degrees of agreement. The data show that the

majority of students across the modules perceived IWBs as a means to support their learning.

The results in Figure 4.22, summed for TM129-19J and TM12-20B, show the comparative distributions of responses on similar questions. In TM129-19J, 18 respondents completed the survey. Half (n=9) of the respondents attended one or more Labcasts, and half did not participate in a live or watch the replays. Figure 4.22Figure 4.22: Responses from TM129-19J (top) and TM129-20B (bottom) cohorts on the impact of Labcasts on learning (N=18 and N=9). shows that five (of nine) agreed that the Labcasts supported their understanding of the Linux practical activities and six (of nine) felt they helped to reinforce technological language and principles. Eight (of nine) agreed or strongly agreed that the Labcasts were pitched at the right level for understanding and seven (of nine) agreed it helped broaden their knowledge and interests of technologies outside the course.

In TM129-20B, nine respondents completed the survey. Two students attended the live, three watched the replays only, and four did not attend the live or watch the recordings. Both respondents were on polar opposites of the spectrum. They disagreed to strongly disagreed that the Labcasts had helped to reinforce language and principles, but both agreed that Labcasts helped broaden their interests.

Q5. To what extent do you agree that the labcasts supported your learning?

5.1. The labcasts have supported my understanding of the Linux practical activities	1 (Disagree) 1 (Agree)
5.2. The labcasts have supported my understanding of the installation of an operating system	1 (Strongly disagree) 1 (Disagree)
5.3. The labcasts have helped to reinforce technological language and principles	1 (Disagree) 1 (Agree)
5.4. The labcasts are pitched at the right level for me to understand	2 (Neither disagree nor agree)
5.5. The labcasts have helped me to broaden my interest and knowledge of technologies outside the course	2 (Agree)

Legend: ■ Strongly disagree ■ Disagree ■ Neither disagree nor agree ■ Agree ■ Strongly agree

Figure 4.22: Responses from TM129-19J (top) and TM129-20B (bottom) cohorts on the impact of Labcasts on learning (N=18 and N=9).

Figure 4.23 shows SXPS288 respondents who engaged with the Labcasts. Nine attended one or more live Labcasts, and six did not. The data show that the majority seven (of nine) strongly agreed that the Labcasts supported understanding of the remote experiments. The majority seven (of nine) agreed that the Labcasts helped to work with others in Physics and Astronomy and eight (of nine) agree that it supported their understanding of the TMAs; seven (of nine) disagreed that the Labcasts were not pitched at the right level. Similarly, those who only watched the recordings (n=6) agreed to strongly agree that the recordings supported their understanding of the experiments and the TMA. However, the majority four (of six) reported a neutral position on whether they helped them to work with others.

In question item 19.1 and 19.2, respondents were asked how useful the Labcasts were in understanding the new planetary science project and gas cell experiment. (13/15) students reported that LC-SXPS288-19J-3 was very to extremely useful in supporting their understanding of the planetary science project and (2/15) found it was moderately useful. (9/15) reported it was extremely useful in understanding the gas cell experiment, and five reported it was very useful.

Q5. To what extent do you agree that the labcasts supported your learning?

No. respondents who attended live or watched recordings

Statement	Values
The live labcasts supported my understanding of the remote experiments	1, 1, 7
helped me to work with others to explore physics and astronomy	1, 1, 3, 4
are not pitched at the right level for me to understand	6, 1, 1, 1
supported my understanding of specific skills and knowledge that helped me in my TMAs	1, 5, 3
The recordings supported my understanding of the remote experiments	3, 3
helped me to work with others to explore physics and astronomy	4, 1, 1
are not pitched at the right level for me to understand	5, 1
supported my understanding of specific skills and knowledge that help me in my TMAs	5, 1

Legend:
- Strongly disagree
- Disagree
- Neither disagree nor agree
- Agree
- Strongly agree

Figure 4.23: Responses from SXPS288-19J cohort on the impact of Labcasts on learning (N=15).

Figure 4.24 shows the distribution of responses from S206/SXF206 participants. 19 respondents attended the live and watched the recordings, and 10 watched the recording only. 15 respondents were from the SXF206 track and 14 from S206. The question items reflected the learning outcomes of TMA04. The data show that the majority of respondents (23/29) agreed or strongly agreed that the Fieldcasts helped support their understanding of field investigations' terms, classifications systems and units of measurements; (24/29) agreed or strongly agreed they helped to understand concepts and principles of environmental science and (18/29) strongly agreed that Fieldcasts helped understanding of the methods of acquiring, interpreting and analysing scientific data and information.

Q19. To what extent do you agree that the fieldcasts supported your learning?

No. respondents who attended live or watched recordings

Legend:
- Strongly disagree
- Disagree
- Neither disagree nor agree
- Agree
- Strongly agree

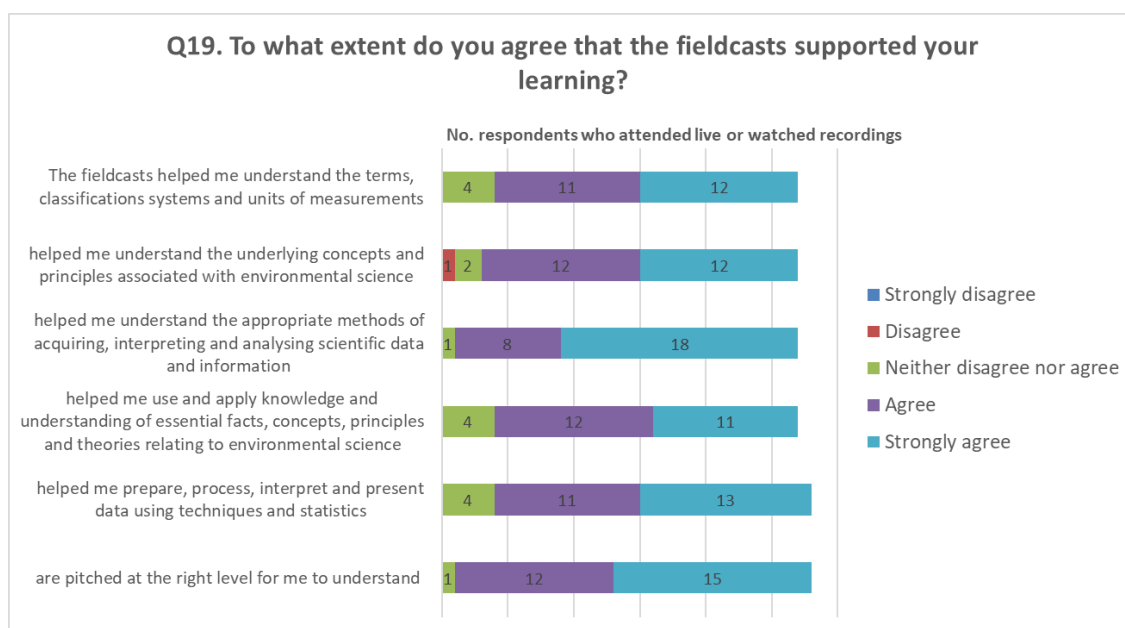| Statement	Neither disagree nor agree	Agree	Strongly agree
The fieldcasts helped me understand the terms, classifications systems and units of measurements	4	11	12
helped me understand the underlying concepts and principles associated with environmental science	1, 2	12	12
helped me understand the appropriate methods of acquiring, interpreting and analysing scientific data and information	1	8	18
helped me use and apply knowledge and understanding of essential facts, concepts, principles and theories relating to environmental science	4	12	11
helped me prepare, process, interpret and present data using techniques and statistics	4	11	13
are pitched at the right level for me to understand	1	12	15

Figure 4.24: Responses from S206/SXF206-19J cohort on the impact of Fieldcasts on learning (N=29).

Figure 4.25Figure 4.25 shows the responses from SXHL288 participants. Seven students attended the live Labcasts, one watched the recording, and one didn't engage with either the live events or the recordings. Generally, respondents reported mixed attitudes of agreement that the Labcast supported understanding of the investigations and the TMAs. The majority six (of nine) agreed that the Labcast was pitched at the right level. In question item 20, respondents were asked how useful the Labcasts were in understanding module topics, seven (of nine) reported that the Labcast was moderately or very useful in understanding the experimental design and computerised cognitive assessments (e.g., topics one and two of Cell Biology).
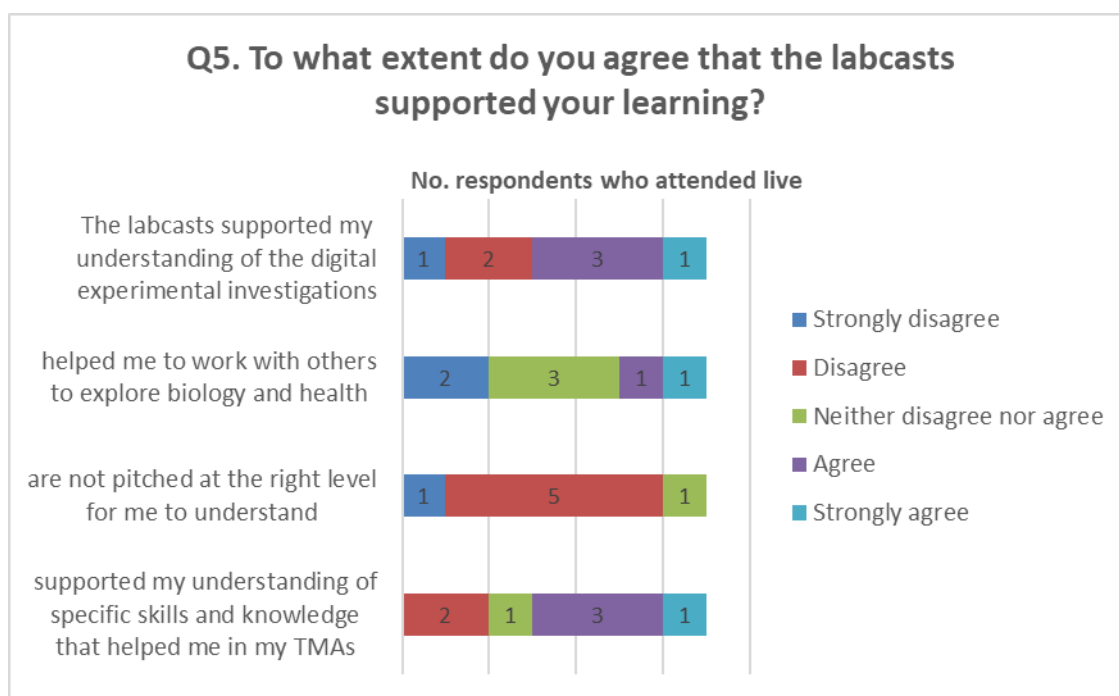
Figure 4.25: Responses from SXHL288-19J cohort on the impact of Labcasts on learning.

In S315-19J, three male respondents completed the survey and watched the replay only. All three agreed that the Labcast supported their understanding of the experimental investigation. Two agreed that the Labcast supported their understanding of TM05, and one strongly disagreed. The majority (2/3) reported that the introduction to the TMA05 Labcast was extremely useful in understanding construction and using calibration curves (e.g., a topic in drug-drug interactions).

Feedback was also collected real-time through feedback widgets during TM129 (2019/2020), SXPS288 and S315 Labcasts. The rationale is discussed in Chapter 3, Section 3.7, sub-section 3.7.1 and the proportion of users that interacted with the feedback widgets can be found in Table 4.15 - Table 4.28 (in Section 4.4.34.4.3).

Figure 4.26 - Figure 4.28 show the distribution of responses on a final widget polled in LC-SXP288-19J-3, SXPS288-19J-4 and LC-S315-19J-3, respectively. The five-point Likert scales ranked degrees of quantity and agreement. In Figure 4.26, the majority (20/37) agreed or strongly agreed that the Labcast aided their understanding of they what they needed to do for the remote Gas Cell. In Figure 4.27Figure 4.27, the data show that the majority of students (31/40) felt that the Labcast substantially improved their understanding of the subject matter. Figure 4.28Figure 4.28 shows the majority of students (18/33) agreed that the Labcast helped their understanding of TMA05.

The labcast helped me understand what I will need to do in the gas cell experiment

Figure 4.26: Responses from a feedback widget in LC-SXPS288-3 'Planetary science project' Labcast.

How much has the labcast improved your understanding of the subject?
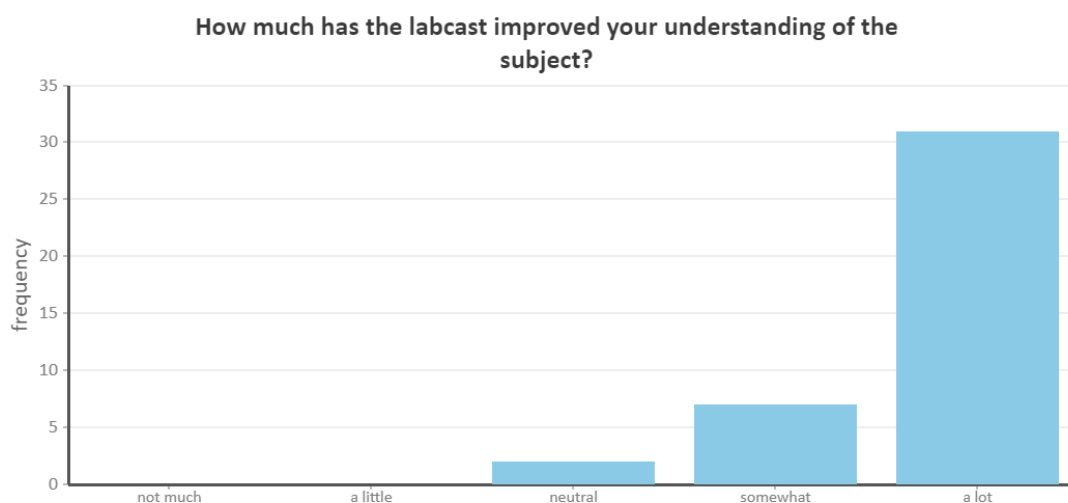
Figure 4.27: Responses from a feedback widget in LC-SXPS288-4 'Exploring Mars' Labcast.

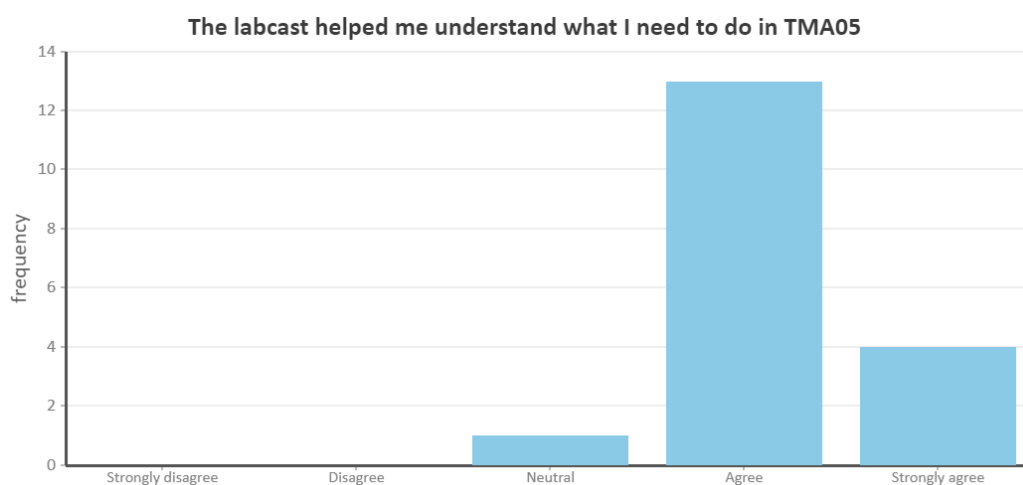**The labcast helped me understand what I need to do in TMA05**

Figure 4.28: Responses from a feedback widget in LC-S315-3 'Intro to experiment'.

Similarly, interactive users engaged with a Wordle feedback widget in TM129 and SXPS288. The widget provides a visual representation of the words in a text and displays the most frequent words in a large font. The question polled was: *Tell us three things you will take away from today's Labcast?* Students were asked to enter three words or phrases. Figure 4.29Figure 4.29 shows the responses for LC-TM129-19J-1 and LC-SXPS288-19J-1.
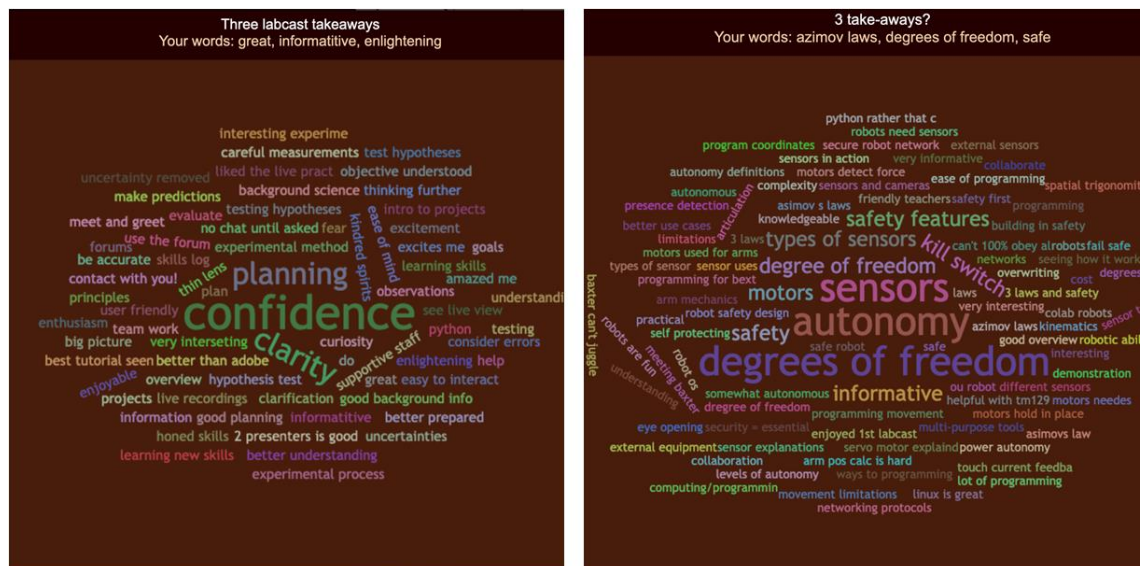

Figure 4.29: Wordle responses from an SXPS288 Labcast (left); Wordle responses from a TM129 Labcast (right).

In the SXP288 Labcast, 25 users interacted with the widget. Results revealed several affective factors such as "confidence", "clarity", "confidence", "ease of mind", and "kindred spirits". Similarly, affective factors such as interesting", "enjoyable" and "friendly teachers" were demonstrated in the TM129 Labcast where 38 users used the widget. Cognitive themes were found in TM129 such as learning about "sensors", "autonomy" and "degrees of freedom".

4.5.2   Students' motivation for engagement

Students reported several factors that motivated them to engage with the IWBs during interviews. S206/SXF206 students reported influencing the field investigation as a reason for attending the live Fieldcasts. For example, one SXF206 student mentioned that she was encouraged to attend as "we were told they were going to make it interactive" (SXF206-S13) and another participant mentioned being able to impact the course as seen in this comment:

We heard before that you get to steer where it was going, so I really wanted to do that. Because like in the other assignments, you're just given a scenario or whatever, and you just have to work on it. But with Fieldcasts, you can be yeah, I want that; I think we should do this and then we all vote (S206-S03).

Both S206 and SXPS288 students mentioned that timing and availability were crucial factors. For example, SXPS288-S07 mentioned that he found time to watch the Labcast because he knew in advance it was short. He further added: "they were run to time They said, they'd run for 45 minutes, and they did, and I thought that they [Labcasts] were very efficient use of my time" (SXPS288-S07). For SXF206-S13 not having to work on a Saturday made it easier for her to attend the Fieldcasts.

In contrast, SXPS288-S09 mentioned "the opportunity to listen to the practising scientist" as a reason. SXPS288-S05 and SXPS288-S07 mentioned understanding the TMAs as motivational factors. "Getting my head around the theory of a complex experiment" (SXPS288-S05) was reported as a reason for attending the Physics project Labcast. For S206-S13, having to write a scientific report for the first time motivated her to attend. One student emphasised the importance of the Labcast for understanding:

The reason I went is that it opened up how to learn. It helped me understand the educational process because in my TMA, even if I didn't know what was going into my experiment, they had kind of done the TMA during the Labcasts and the tutorials. I could pool parts of that to help me understand. So that's why I went. I don't know how you would have done it had you not. The fact that it was optional is really interesting because Aberdeen University wouldn't have passed me had I not attended the labs. In fact, registration was taken at labs. So that's interesting that it's optional. Did I even know it was optional? I guess yes. I could not have turned up, but I'd be terrified not to (SXPS288-S05).

Survey data from TM129-19J students showed several factors that prevented engagement in the Labcasts. 18 students completed the online questionnaire; nine of those surveyed reported that they neither watched the lives nor recordings. In response to question 17, *what were the reasons you did not watch the live or recordings*, the respondent selected as many categories as applied. Figure 4.30Figure

4.30 shows the responses and frequency. The most frequent reason was not knowing about the Labcasts, followed by a preference to study independently and lack of time.
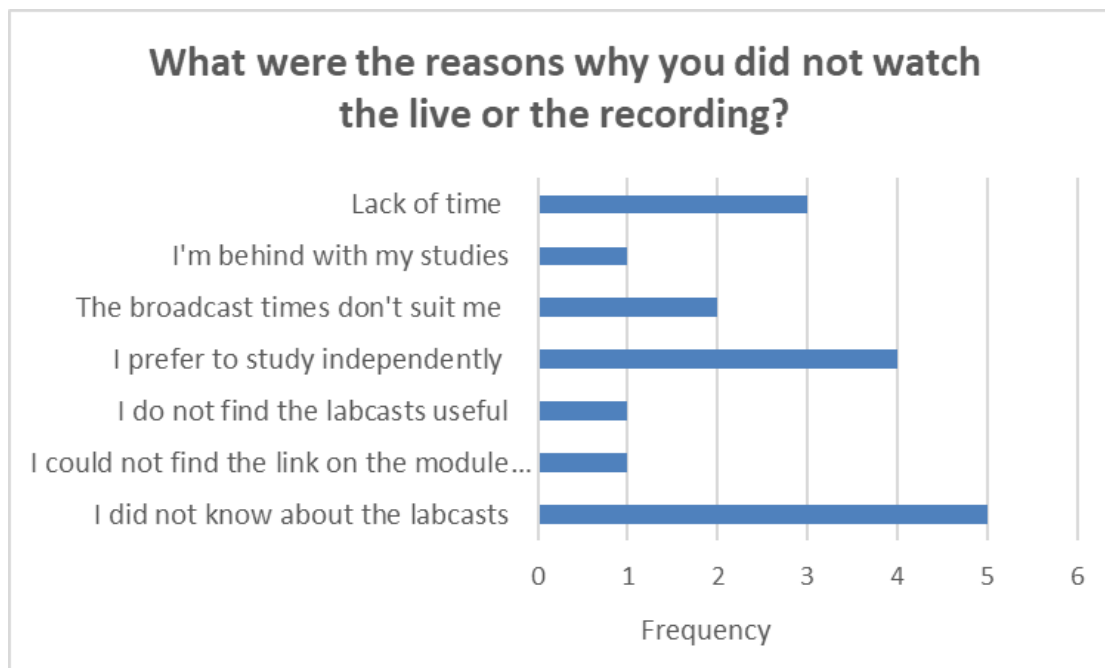

Figure 4.30: Responses on reasons for non-engagement with Labcasts in a subset of TM129-19J students (n=9).

In question item 18, respondents were asked to describe what would make it easier for them to engage with the live Labcasts or recordings. The comments revealed mixed attitudes around the learning experience and time factors due to work and family commitments. For example, one respondent reported that "the module material was not good, so I didn't see the benefit of putting in the extra time to take part" (TM129-19J-S09). Another mentioned feeling belittled by a lack of knowledge in a previous TM111 module resulting in not wanting to try any group activities and preferring to email their tutor if they had a problem or were struggling (TM129-19J-S01). One student (TM129-19J-S05) commented that they did not recall receiving any communications regarding Labcasts and suggested more prominence on the module's website and email reminders. Another (TM129-19J-S16) suggested placing the recordings on the OU Anywhere app.

4.5.3   Students' sense of community

This section presents the findings on students' SoC. The results draw on survey and survey data which includes a five-point Likert scale ranked from degrees of agreement (i.e., strongly disagree to strongly agree); a 20-item classroom community scale and

interview data. The application of how the 20-item scale was used in this study is discussed in Chapter 3, Section 3.24.

The summed results in Figure 4.31 show the distributions of responses on a question related to SoC at the IWB level. Respondents were asked to indicate their level of agreement. In SXHL288-19J, seven (of nine) attended the live Labcast. The data show mixed attitudes on the degrees to which the Labcast made them feel part of the STEM learning community with three disagreeing to strongly disagreeing and three agreeing to strongly agreeing. In S206/SXF206-19J, 19 (of 29) attended the live Fieldcasts and the majority agree to strongly agree that they facilitated SoC. In SXPS288—19J, nine (of 15) attended the live Labcasts, the majority agree to strongly agree that Labcasts made them feel part of the STEM learning community. In TM129-20B, only two attended the live events, one respondent strongly disagreed and one agreed. Finally, in TM129-19J, nine attended the live Labcasts and the majority agreed to strongly agree that the Labcast made them feel part of the STEM learning community. The data shows the majority reported positive attitudes in S206/SXF206 and SXPS288 and thus show commonality as IWBs are strongly linked to assessments.
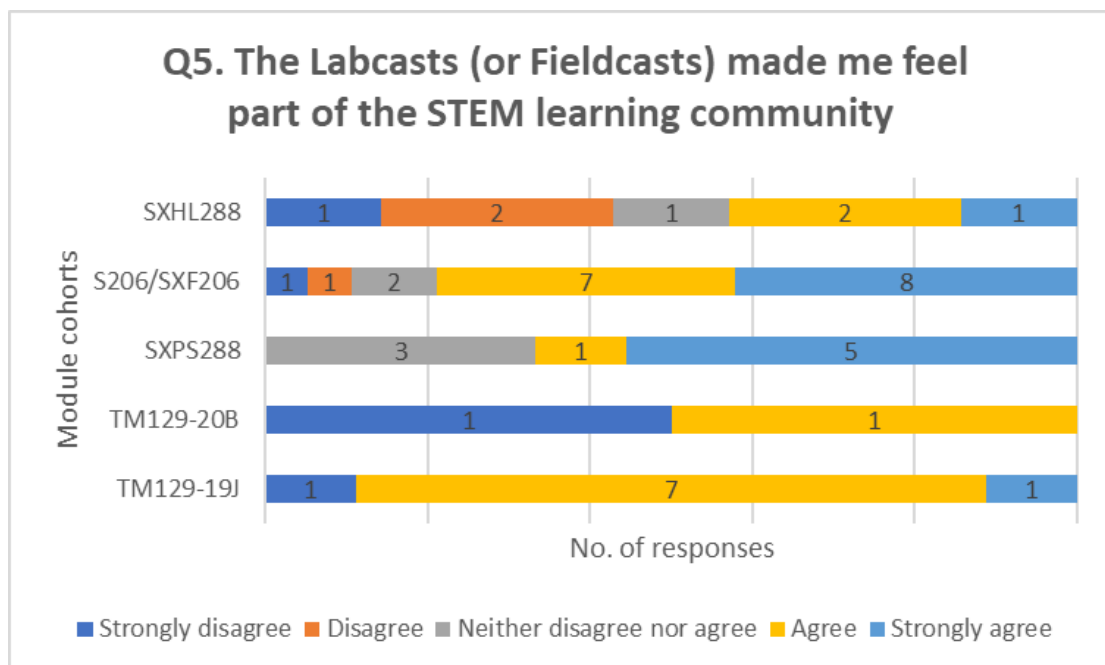

Figure 4.31: Responses from SXHL288, S206, SXPS288 and TM129 (2019/2020) on the influence of IWBs on SoC.

At the end of the questionnaire, students were asked to self-assess their perceptions of a SoC in their module. The measurement of community at the module level was to understand if students felt a sense of belonging, trust and cohesion and to what extent students shared similar learning values and goals. Table 4.30 shows the classroom community-scale across the five modules.

Table 4.30: Classroom community scale across the modules adapted from (Rovai, 2002b).

Module	Connectedness (Max 40)	Learning community (Max 40)	Overall community (Max 80)
Remote experiments in physics and space (SXPS288)	28.3 (SD = 6.0)	32.9 (SD=6.1)	61.2 (SD = 11.5)
Environmental sciences (S206/SXF206)	22.9 (SD = 6.1)	29.8 (SD =5.5)	52.7 (SD =10.9)
Chemistry: further concepts and applications (S315)	22 (SD =14.2)	29.63 (SD =9.5)	51.3 (SD =23.6)
Technologies in practice (TM129-20B)	20.8 (SD= 4.1)	26.2 (SD =5.2)	47 (SD = 8.3)
Technologies in practice (TM129-19J)	20.9 (SD= 6.0)	24.4 (SD = 7.5)	45.4 (SD =11.8)
Practical science: biology and health (SXHL288)	18.7 (SD=5.9)	24.8 (SD =8.5)	43.4 (SD =14.0)

The data show that the highest overall community scores was in SXPS288 (61.2/80). Students on the module reported more feelings of learning and interacting with each other (32.9/40) than feelings of connectedness (28.3/40). The lowest community score was in SXHL88 (43.4/80). Furthermore, the data shows that there is a similar range of scores in SXPS288, S206/SXF206 and S315 and an overall SoC is perceived as being stronger in those modules. A predictive factor is that modules that include group work or opportunities for face-to-face activities are likely to feel a stronger SoC in their modules.

This study used the seven students who participated in the interviews to explore various aspects of a SoC as reported by them. The proposal is that students who report a high overall score on the CCS would also report a higher level of agreement that

IWBs made them feel part of the STEM learning community. Positive statements would also be reflected in their qualitative date.

4.5.3.1 S206-S03 perceptions of SoC

In survey data, S206-S03 reported her connectedness score from the CCS as (24/40) and learning as (32/40). Her overall community score on perceptions of SoC on the module was (56/80). On the question items pertaining to Fieldcasts, she reported on item 4.4 that they were extremely useful in reducing isolation during the module. She also reported on item 5.5 that she strongly agreed that the Fieldcast made her feel part of the STEM learning community. In interview data she further expanded her perspectives of community, "I think the community is totally dependent on your modules. Last year, I didn't feel like I particularly belonged to a module, but this year with the WhatsApp group for S206, it was really good"(S206-S03). Regarding a SoC as it relates to the Fieldcasts she mentioned:

> When people are given opportunities like that, they tend to be more open, and it's always nice. It's a shame with those types of things. It's not video as well because students have been working from home. I've noticed people are putting their cameras on a bit more because it's nice to put a face to a name. I guess opportunities like that give people a voice but not a face. I know video takes so much bandwidth, but yeah, it's good to feel a part of a community (S206-S03).

4.5.3.2 SXF206-S13 perceptions of SoC

SXF206-S13 reported (21/40) on the connectedness sub-scale and (30/40) on learning. Her overall community score was (51/80). On survey item 4.4 she selected that Fieldcasts were 'very useful' for reducing isolation and 'agreed' that they made her feel part of STEM community. In interview data, when asked about whether she felt a SoC within the module and the Fieldcasts she revealed:

> On this module, I felt it [SoC] much less than my previous one and I think partly because there was so much interaction. I didn't have the time to process it and partly there wasn't the obligation to work together. Perhaps there was more people on this module, I'm just guessing (SXF206-S13).

It [the Fieldcasts] definitely helped to feel like you knew the module leaders better. Because they were people rather than a static photo, but if you want to use community to mean the other students, no, I wouldn't have said it did that. Well, not for me anyway (SXF206-S13).

4.5.3.3 SXF206-S10 perceptions of SoC

The respondent reported (28/40) on the connectedness sub-scale and (26/40) on the learning scale. His overall community score was (64). In the survey data, he also reported that Labcasts were 'extremely useful' for reducing isolation during the module and 'strongly agreed' that Labcasts helped to make him feel part of the STEM learning community. On reflecting on community within the module, he mentioned:

I know there's the forum which provides a means for students to interact, but they can be a bit clunky, I think. I'm not a regular poster or participant in the forums. When I do observe them, they tend to be the same small group pf people; probably quite a small percentage is very active on it and the rest just dip in occasionally. I sort of dip in occasionally so that doesn't do it. I guess part of the same thing is the face-to-face communication for me… maybe because of my age as well it's a much more important thing in terms of developing a sense of community than just online.

With regards to the Fieldcasts and whether they supported a SoC, he added:

I think it did because you are drawn in. You know that other people are watching, and you're all watching at the same time. So, you know there's an event that's happening, and there were lots of people watching. I think, on average, there was about 100. So, you knew that was going on, which creates an event if you like in the sense of a community; we're all doing that together and then you're all voting. Whereas when you're going through your module materials, most of the time, you're doing that in your own time whenever suits you. What other people are doing at the same time is irrelevant. In that sense, you don't feel as connected. The event of all doing something simultaneously, I think, does help create that (SXF206-S10).

4.5.3.4   SXPS288-S05 perceptions of SoC

In survey data, SXPS288-S05 reported (30/40) on the connectedness scale and (32/40) on the learning scale. The overall community scale was (62/80). He reported that Labcasts were 'moderate' in reducing isolation during the module and selected 'neither disagree nor agree' that Labcasts made him feel part of the STEM community. On reflection of SoC at the module level, he stated:

> There are two elements of this. There's my sense of community with the tutors and staff of the OU, and then there's my sense of community with my fellow students. With the tutors and the staff, yes. I felt community very much, perhaps due to the people who chose to communicate. MT01 [module team member] has a great way of responding on the forum. He is a great communicator. It's pretty rare to find that in science someone who can communicate to the common person and figure out some physics problems. It's a rare blend. I felt that the staff, lab people and MT01 were pouring their heart and soul into the course, which was great. With the students, yes. Ironically, a bit of a shame that that [SoC] came right at the very end when we did the group work. And once that group ended, the course ended. So, you knew you were never probably going to talk to these people again (SXPS288-S05).

4.5.3.5   SXPS288-S07 perceptions of SoC

SXPS288-S07 reported (33/40) on the connectedness sub-scale and (38/40) on the learning scale. His overall community score was (71/80). On the question items pertaining to Labcasts, he reported that they were 'very useful' in reducing isolation during the module. He also reported on item 5.5 that he 'strongly agreed' that the Labcast made him feel part of the STEM learning community. When asked whether he felt a SoC on the module and with Labcasts, he mentioned:

> Yes, I do. I think it's more than just a few tutors sitting around in their homes all over the country. And in a way this module has helped more with that in any other probably. In particular, MT01 [module team member] has been really available and really helpful in the forum in helping people with their problems. MT01 always answers in a positive way, as much as he can to help. I think he does that fantastically well, and he comes across as the sort of person who's in

charge of this module, seeing it all through. We had very good Python support from another gentleman. And we've had various specialists help out on experiment. But I would also say I've had very, very good tutors who foster a sort of warm learning environment and you build up a bit of a relationship with them over the modules, so the tutors are linked too (SXPS288-S07).

Almost everything you do at the OU is with one person tutoring or lecturing. With Labcasts, you're seeing two interacting in a way and respecting each other and enjoying themselves and smiling and things. It makes it much more fun and livelier and feels more like a community (SXPS288-S07).

4.5.3.6   SXPS288-S09 perceptions of SoC

In survey data, SXPS288-S09 reported (31/40) on the connectedness scale and (37/40) on the learning scale. The overall community scale was (68/80). He reported that Labcasts were 'extremely useful' in reducing isolation during the module and selected 'strongly agree' that Labcasts made him feel part of the STEM community. In interview data, he mentioned:

> I think there's a sense of community amongst the students. So, there were three experiments, where you worked with other people. On the first one, there was a little group, I think it was four of us who worked together on the star cluster, the Pirate experiment and that went well. And then the Gas Cell one was just with one other individual. He and I were both a bit busy. So, we came to it a bit late, but it worked well when we got to it. And then we did the one together as a group of what was actually the whole tutor group in the end. And there were 12 of us and we split ourselves into two little groups of six and went off and did some stuff and then came back together as a group of 12 to review it and write up the final report. And there was a sense of community in each of those (SXPS288-S09).

> I think the Labcast strengthened it [i.e., SoC] a bit. It's hard to do a remote science course where you don't get your hands on any equipment, especially once you get beyond the basic things you can do in a kitchen at home. So, I think seeing [module team members] and the NASA scientist does create a

sense of belonging to a group of people who are doing research science. And that's good (SXPS288-S09).

4.5.3.7 SXPS288-S14 perceptions of SoC

In survey data, SXPS288-S14 reported (31/40) on the connectedness scale and (34/40) on the learning scale. His overall community scale was (65/80) As he only watched the recordings, the routing pathway of the survey did not include question item 4.4 (on isolation). He reported that he 'agreed' that Labcasts made him feel part of the STEM community. In interview data he mentioned:

> Let's say I feel more like part of the module but not that much of the full university itself. Due to the nature of the university, I guess most of the students have sacrifices like me working full-time. We struggle to find time to study let alone to find time to be more involved with the university itself as a community. So, for example, I only visit the forums related to what I'm doing now. However, if I go somewhere and I saw a person with an Open University bag or sometimes I go to Waterstones and sometimes I see someone else with an Open University book, then I feel that connection (SXPS288-S14).

> I think it [i.e., Labcasts] helps, but not by itself. I think it contributes. For example, where you are watching from. They have the map. It's only about 20 seconds to do that and comment. This gives a sense of the wider community, I think. I was in Edinburgh during our group work, and another person was in Wales. Another one was in Germany and another near London. Knowing that you are connected to other people from different places, I like that. So, when they mentioned the widget where are you from now, I think that helps (SXPS288-S14).

A commonality between both cohorts was that they experienced SoC at the institutional level to varying degrees. Although several compared their prior traditional or campus-based university experience, all interviewees mentioned The OU positively. For example, S206-S13 mentioned, "On my LinkedIn account and Facebook, I've written that I'm a student at the OU, so I suppose that's part of my identity". SXPS288-S05 commented that the Labcasts helped build a sense of belonging whereby they

could identify with the role of "astronomer" or an "astrophysics scientist" (SXPS288-S05).

4.5.4   Staff professional teaching practices

An emergent theme from the staff focus group discussions was the impact of IWBs on professional teaching practices. The property 'professional teaching practices' refer to comments on these effects and related interpersonal relationships among module team members, tutors and other staff. The data revealed three dimensions or sub-themes: *a sense of involvement, collegiality and collaboration*, and *reflective practice.* Table 4.31 Table 4.31 below summarises the coded themes identified from the data.

Table 4.31: Number of coded references on staff teaching practices.

Themes	Sub-themes	Focus groups and interview							
		TM129	SXPS288	SXPS288 ALs	S206	S206 ALs	SXHL288	S315	PROD
Professional teaching practices	Sense of involvement	2	2	1	1	4	2	1	__
	Collegiality and collaboration	4	6	__	9	3	2	5	3
	Reflective practice	__	4	__	2	4	__	7	2

Several module team participants described aspects around a *sense of involvement* and shared various motivations for becoming involved with IWBs. There were comments on being "fortunate to be involved in the production module team" (SXPS288-MT2) and "doing the most fun bits" (S206-MT1). For some module team members, who had a longer length of service at the OU, there were similar positive comments on early involvement in the development of the teaching lab (S315-MT1), the OpenSTEM Lab Science grant (TM129-MT2) or shadowing those who presented the initial Labcasts (SXPS288-MT1). For one academic, it was an opportunity to get involved after a career break and return to the OU as stated, "I was absolutely thrilled when I came back that it was going so well, and then I was kindly invited to join the team again, so I did a bit of chat boxing and then presenting" (S206-MT4). For SXHL288-MT1, his involvement in Labcast sprang from being a lead and having years of

practical work in core biology and health science modules and designing online tools and interactive screen experiments. For TM129-GP1, there was an opportunity for professional development and cross-university collaboration across faculties as he mentions: "It was interesting for me to get involved, to get some practical experience of online teaching use of educational technology in a higher education setting" (TM129-GP1). However, for a new module team member getting involved in Labcasts produced some challenges:

> I guess the challenge for me was coming into a course that I hadn't been involved in from the start. This experiment was still being built, and content was still being created. I wasn't involved in creating any of that, so I was getting up to speed with that to present in some coherent way; that was the biggest kind of challenge for me (SXPS288-MT3).

Tutors also described aspects around a *sense of involvement*. A commonly held view of S206 tutors was the willingness to participate more in module production, Fieldcasts and residential schools. One tutor stated, "to be honest; more ALs can be involved in the production et cetera" (S206-AL3) and another commented, "it would be great to be more involved with the development of modules and materials" (S206-AL4). One AL mentioned:

> I mean, I'm on a three-hour drive, but if it was planned and they're looking for people to help out, it would be neat to be involved—the same for the residential courses. I've never chased it up, but I've always known how much fun residential courses are. But you know, from the early days when we did the precursor module, the general rule was the central academics picked them up because that was a week of fun (S206-AL1).

However, one AL was more doubtful around involvement in the Fieldcasts and its related activities due to being dispersed and feeling a lack of opportunity:

> To be honest, I doubt it because it's done centrally. And of course, we are all very dispersed, so opportunities to get involved in stuff is sort of ad hoc, isn't it [S206-AL1]? And of course, I don't hear about things, but there isn't a huge amount, and I certainly never have come across opportunities to be involved in

something like this before. Although I happen to keep my eyes open (S206-AL2).

The highest coded theme among the module teams was *collegiality and collaboration*, which refers to the nurturing and facilitation of relationships between colleagues, solving problems and sharing ideas (Haresnape et al., 2020). It also relates to discussions about teaching practice, organising, designing, evaluating and preparing materials together (Rahman, 2019). Two S206 module team members (S206-MT3 and S206-MT1) commented on developing a shared understanding of design and structure, sharing ideas and problem-solving. They attributed the success of Fieldcasts to their team members and the technical production team:

> I think a major part of the success of this from the start has been the fact that [MT1] ramped it up and is very organised and identified that what we needed was a clear structure and to be kind of well-organised and rehearse (…) I think my colleagues' insistence was we did need to rehearse, and we needed to have a kind of clear structure; that was critical (S206-MT3).

> In terms of overcoming things, I suppose what worked very well is just talking about everything. I think there were sometimes where we went, oh, this order isn't quite working because if we say this, then this won't feel very natural, or we get stuck on this. or we'd say, oh, it'd be nice if, if this came up on the screen and the technical team were just so fantastic at making anything, we asked for happen. They come back the next time and say, yes, we can do that. We've worked out how to manage that. So, any problems just sort of got talked about and solved as a group (S206-MT1).

A common opinion among module teams was recognising their colleagues' skills and attributes. One S206 team member mentioned "we're lucky on S206 to have a group of very experienced tutors" (S206-MT3). Another (S206-MT1) commented on working together with co-presenters and the technical production team. An SXPS288 team member referred to his colleagues as "lively and engaging presenters" (SXPS288-MT1), while another commented on a new academic who co-presented the planetary science project Labcast for the first time:

I think in this particular one, it wasn't so difficult for me as it was for him. He did a great job coming in straight into the deep end, picking up all that information, and presenting it. He did really well (SXPS288-MT2).

Like the module teams, *collegiality and collaboration* also emerged from the ALs perspectives. S206 tutors commented on the module team's effort in presenting the Fieldcasts and supporting the learning materials via the forums, which in turn helped the ALs in their understanding of supporting their tutorial groups:

There's a specific Fieldcast forum, and usually the academic, [S206-MT03] is very actively involved in that. So, you don't really need anyone else because he's very much there and helping the students. I always observe it because it's good to see what questions are being posed and what advice is given (S206-AL2).

Generally, the module team does give them a pretty good steer in the Fieldcasts, you know, cause they're [i.e., students] given a bit of guidance. If we happen to be doing a tutor group tutorial or anything, we will explain to the students what's expected. I think there's pretty good guidance (…). To be honest, on the whole, the module team has done a pretty good job with the Fieldcasts (S206-AL3).

The sub-theme *collegiality and collaboration* also emerged from the data regarding the technical production team. One participant commented on the sharing of ideas around camera work (PROD-2). Two members of the technical production team commented on other staff members' skills and attributes. One participant pointed out a particular module team, "the Fieldcasts are run by a lively group of academics who work very nicely as a team" (PROD-2). Another mentioned presenters' who were adept at using a type of communicative strategy:

I think [SXHL288-MT1] is very good at playing both roles, and I think [SXHL288-MT2] has also picked this up. Possibly through me saying it or maybe [PROD-2] reemphasising it. They are both swapping from the layperson to the expert and vice versa (PROD-1).

Modules teams also engaged in *reflective practice* and discussed the impact that the IWBs may (or may not) have had on student learning and assessment. For example,

S206 team members discussed the assessments associated with Fieldcasts. S206-MT2 commented that there was no substantial evidence that the Fieldcasts improved student performance on the TMA06. Another team member commented on the year's challenges (i.e., Covid-19 related), resulting in S206 and SXF206 students having different experiences (S206-MT3), the team member concluded that he felt the impact of Fieldcasts were "inconclusive at best" (S206-MT3).

However, the data show that some team members disagreed and held different opinions on the impact of Labcasts and how it supported student learning. For example, an interesting discussion evolved between the S315 module team:

> We want to underline some fundamentals in their preparation for doing each of these experiments and the TMAs associated with it (S315-MT3).

> I'd argue I'm not sure how effective the Labcasts are for that (S315-MT2).

> That was my question. Are students picking up on these essential concepts? (S315-MT1).

> In hydration, we address PKA and pH (S315-MT3).

> We all have different opinions, but I always wondered. Because a lot is going on in a Labcast, I think the explanations are sometimes less good (S315-MT1).

> I think it's many things. I think everyone's saying slightly different things, but I believe they are all true. They are, as [MT3] says, you know, to explain key ideas, the sense of community, all the rest of it, meet the academics. They are to gently introduce them to the big experiments. They are also flagstones (S315-MT2).

> I have a difference of opinion because some colleagues want to give lots and lots of equations, and while I think some equations written on the board are good, I guess you overload students with too many equations. That sort of thing can be done through other media, websites, documents or papers. Whereas showing the visual experiment is paramount, in my opinion, for the Labcast (S315-MT1).

Module team members (SXPS288-MT1 and SXPS288-MT2) discussed several methods to organise Labcasts, and better use them. There were differences of opinion on

question-and-answer points during the broadcasts and discussion on how presenters in other modules (i.e., level 1, discovery-based Labcasts) operated the text-chat box. One module team member welcomed the opportunity that the focus group provided for personal reflection:

> Thank you for this discussion because it was really interesting as well. I haven't thought about it much since the Labcast was done, and now, to have the opportunity to reflect on it was really nice (SXPS288-MT2).

Similarly, ALs on the S206 module engaged in *reflective practice* and discussed the impact that the Fieldcasts had on student understanding and the TMA04 assessment. Although one AL group (i.e., S206-AL3 and S206-AL4) felt that there was often confusion with 'voice' and how students wrote the actual scientific report, the other AL group (i.e., S206-AL1 and S206-AL2) did not see evidence of this in their marking of the TMAs. One tutor stated, "we can take back to the module team, making sure that guidance is clear about voice, et cetera. That's probably useful for them to know" (S206-AL3).

The technical production team also engaged in *reflective practice* and commented on the impact that the IWBs have on students' participation. For example, PROD-1 mentioned that a potential disadvantage of live Labcasts was the requirement for students to attend a fixed time. In contrast, the recordings were seen to bridge the gap and encourage people to make time to attend live if they considered it more beneficial. Another technical production team member remarked on the aspect of participating in Labcasts as a skill:

> I think participating in these events is a skill. It's not necessarily a specific Labcast skill; it's a learning skill. It's a community in the complete sense of involvement in the community. And I think at level two and level three, students find that much easier because obviously, they feel more part of the community. They'd been with the OU a lot longer. They identify as OU students. Level one is a bit shaky, so it takes a bit longer. It's about feeling confident in your learning (PROD-2).

4.5.5 Staff feedback and recommendations

Staff members directly or indirectly involved with IWBs reported their perceptions of them and their impact on the teaching and learning process. Module team members expressed difficulties in managing multiple tasks during presenting. For instance, SXPS288-MT2 mentioned the problem of interacting with the widgets and the text-chat box while presenting. S206-MT2 commented on the challenges of the time delay in the text-chat, which had caused some problems when interacting in real-time with the lead presenters. Although the module teams agreed that IWBs "had value" (S315-MT3), "were fun" (S206-MT1), and "helped to connect with students" (SXHL288-MT1), one module team mentioned the process of Labcasts being on occasions "time-consuming and a bit stressful" (SXPS288-MT2). An S206 participant described his perceptions around the recordings of Fieldcasts and how students relate to recordings to facilitate retention, understanding and application of learning, for example:

> I've got a bit of a bee in my bonnet, and it's about recorded stuff and kind of ad hoc delivery of things. So, this is my theory, which is entirely untested. If you were stood in the field with a group of students in front of you, just chatting away and doing what we do in the Fieldcasts. Because the words are gone as you've said them, then students can hang on to every word. And so, your words are kind of filtered onto their page if they're taking notes at all or their memory. Your average student has less confidence in their record or memory of what has been said. So, if something seems odd or doesn't conform with their expectation or understanding, they're more likely to query it or investigate further.

> My theory is that with the availability of recordings, this kind of goes for lectures and any type of delivery; the student has a kind of document that they can treat as gospel to go back to. And academics haven't adapted the nature of their delivery to account for the fact that I think human nature reverts to treating the word of an authority figure as gospel. I think that makes for a challenge if we're doing complete live, unplanned stuff as we do here. We see it a little bit with some forum's comments. Occasional comments about 'Oh, but you said this in the Fieldcasts. Maybe people are accepting of that, but I think the inclination is to assume that what you say is gospel (S206-MT03).

For first-time presenters in SXPS288, participants mentioned the nuances of presenting to a remote audience without visual cues (SXPS288-GP1 and SXPS288-MT3). However, both SXPS288-GP1 and SXPS288-MT3 mentioned the support of the technical production team in assisting them in dealing with those perceived challenges.

Module team members offered recommendations on how the IWBs could be adapted for future use. SXPS288-MT1 mentioned that the tools could be defined or improved from the students' point of view in how they interact with the widget. SXPS288-MT2 mentioned replacing some widgets with more specific questions to a problem so that students "felt like their voices are being heard". S315 and SXPS288 team members both discussed more AL involvement. For example, SXPS288-MT1 commented on the rationale for encouraging ALs to become more involved to take on the role of fielding questions and feeding them to the presenters. Whereas for S315-MT2, the recommendations seemed to be more on raising awareness:

> I wonder how well we promoted with the tutors, though. I would wonder as a tutor what the hell these things [i.e., Labcasts] were. I just wonder whether tutors are buying in. I just wonder whether that's something worth considering? I don't know; it feels like a little bit of an Island somehow. So maybe we should try and get the tutors onboard more. When you do the tutor's induction to the module, maybe show little clips from the Labcasts (S315-MT2).

In reflecting on future Labcasts, SXHL288-MT1 mentioned a new module (i.e., S290 'Investigating human health and disease') he was involved in and some of the challenges in incorporating Labcast material into a tightly produced module that would run for several years. As a result, he expressed his enthusiasm on extending Labcasts beyond the module, as he mentioned:

> What I'm very keen on doing is actually pushing some of the discussion and trying to build the community outside. I want the discussions to happen on Twitter and Instagram, and I'm not sure about Facebook yet, but I keep saying to PROD-2, we should be able to stream in Facebook, please let's do it. So, I'm keen on trying to push us slightly in that direction. Partly, just to generate a bit of an interest. I think actually at the moment, we don't tend to make our Labcasts available to non-module material, or non-module students. In theory,

we should be able to edit those three together into a kind of for lack of better words, like a show reel, and then PROD-1 just put it on the science site and actually try to generate some interest. I don't think we use them effectively.

4.5.6   Section summary

The data show that the majority of students across the modules perceived IWBs as a means to support their learning. Feedback widgets show that students in TM129, SXPS288 and S315 took away positive cognitive and affective factors and felt that the Labcasts had improved their understanding of particular TMAs or subject matter.

Students held various motivational factors for engaging (or not) with IWBs. Availability, the opportunity to interact, and understanding the TMAs were the main reasons among those who attended live events. However, survey data revealed not knowing about the Labcasts, a preference to study independently, and lack of time as reasons for not engaging with live events or the recordings.

Overall, most students across the five modules who surveyed agreed to strongly agree that the IWBs made them feel part of the STEM learning community. Students perceived a SoC in their modules, with most cohorts reporting fewer feelings of learning but more feelings of connectedness. Student interview data revealed various degrees of SoC and SoB at the institutional, module and IWB levels.

Staff members discussed various impacts and benefits of IWBs on professional teaching practices. Most module team members and tutor groups, involved in this study, reported aspects related to a sense of involvement, collegiality, collaboration, and reflective practice. The themes related to module production, working with colleagues, the opportunity to personally reflect on practice and the impact of IWBs on students' learning and assessment.

4.6   Chapter summary

This chapter presented the findings of focus groups, semi-structured interviews, system usage data logs, text-chat and IWBs transcripts as well as survey data conducted with staff and students involved in IWBs across the STEM faculty at The Open University. The chapter organised the findings around the macro themes of Planning, Implementation and Impact to present the findings of the six research questions outlined in Chapter 2, Section 2.1, p.10.

Before discussing the specifics of these findings in light of the literature and the research aims (discussed in Section 1.3, p.4), the following will provide an overview of how the findings connect to the research questions.

RQ1 starts with the module teams' *purposes* for using IWBs. The findings from the focus group data show that module teams used various purposes and aims that were of a pedagogical, socio-emotional, and technological nature. A shared rationale across module teams was using IWBs to facilitate student engagement. Tutors from the SXPS288 and S206 modules also perceived that the IWBs facilitated student engagement. The findings suggest intended purposes of the module team were met positively or perceived by students who attended live events or watched the recordings as similar themes were found in qualitative and quantitive student data (see Sections 4.3.4.1 and 4.3.4.2 4.3.4).

RQ2 focuses on the *strategies* the presenters and moderators apply to interact and engage with students. The findings show that module teams implemented various activities to interact and engage with students. They set up planned forms of interactions or stages to facilitate the IWBs aims. The most frequently found stage that was conducted in all IWBs was establishing social connection. The findings show that module teams also used the widgets in a variety of ways and when a moderator was involved, the widgets questions were often reinforced. The data also found that module teams' communicative strategies and behaviours exhibited were mainly affective and they initiated and responded to students by asking questions, accepting and building on ideas and guiding students' thoughts or research.

RQ3 focuses on how students are using the widgets to *interact* with the presenters. The data show a high level of participation in the IWBs overall. Findings show those that attend IWBs interact with the widgets. The Map widget is interacted with at the beginning. The Wordle widget is often the least interacted with and most IWBs have fluctuations in the number of responses across the widgets. Interview data show mixed attitudes on the widgets; namely, their quality and design, purposes and execution.

RQ4 looked at whether participating in IWBs contribute to *knowledge-building* discourses. The findings show that the most significant discourse in IWBs is social talk. Where there are active moderators, discourse that is representative of problem

solving and knowledge building is more likely to occur. Although the vast majority of text-chat is socially oriented, the findings show that students are willing to engage in the aspects of engaging in knowledge sharing, problem-solving and general cooperation between students characterised by support and helpfulness.

RQ5 focuses on how IWBs support *students' learning*, and the *motivations* of students to engage (or not engage) with the IWBs. The findings, from survey and interview data show that the majority of students across the modules perceive IWBs as a means to support their learning. Students are motivated by factors such as timing and duration of IWBs and students' availability, the chance to interact in real-time and understanding the TMAs. On the contrary, factors that prevent participation and engagement are not being aware of Labcasts, preferring to study alone and a lack of time.

RQ6 focuses on the ways participating in IWBs contribute to students' *sense of community*. The findings from survey data show that most students across the five modules perceived that the IWBs made them feel part of the STEM learning community. The results from the CCS show a variation of SoC within the module. Most students report fewer feeling of learning and more feelings of connectedness. Out of a maximum of 80, no module scored less than 40. Findings also show students experienced SoC at the institutional, module and IWBs levels.

Finally, an emergent finding was that using IWBs had varying impacts on staff members professional teaching practices. Participants reported aspects related to their teaching and interpersonal relationships. Emergent themes included a sense of involvement, collegiality, collaboration, and reflective practice on students' learning and assessment.

Chapter 5 discusses the findings and the results in light of the literature. It will close by answering the overarching question: **How do interactive web broadcasts develop distance learning students' engagement with practical lab and fieldwork?**

5   Discussion

In this chapter the key findings from the preceding chapter are discussed in relation to the research aims, questions and literature. The chapter is organised around the six research questions outlined in Chapter 2, Section 2.1.

5.1   Module teams' purposes for using IWBs

The first question in this study sought to identify the *purposes* of the module teams in using IWBs. As pointed out in the literature, there is no singular purpose of practical work in the sciences (see Section 2.5). MacDonald (2008) suggests that a course's learning objectives and students' needs influence the academic purpose of an intervention. Module teams used IWBs as part of a blended learning approach, which was situated within a module and aligned with its learning outcomes and objectives.

While the focus group data yielded five prominent themes related to why the module teams used IWBs (see Chapter 4, Section 4.3), the discussion focuses on four findings that are particularly pertinent: facilitating student engagement, introducing real-world contexts, demonstrating a sense of authenticity, and fostering a sense of community.

5.1.1   Facilitating student engagement

A commonly held view of the five module teams was to *facilitate student engagement*. This finding is consistent with studies that have noted the importance of student engagement and the opportunities of fostering it using synchronous channels of communication (Karal, 2011; Maimaiti et al., 2021; Martin et al., 2012). IWBs were regarded by the module teams as a way to foster favourable emotions in students such as enthusing, motivating, encouraging and exciting students in practical work (see Section 4.3.1, pg.91). As discussed in the literature, fostering emotional as well as cognitive qualities can be influenced by an intervention or a type of setting (see Section 2.5.1).

In TM129, the module team used the Robotics and Networking Labcasts to pique students' curiosity in the module's blocks and signpost them in the direction of possible future trajectories (see Section 4.3.1). The team demonstrated concepts using a teaching robot and computers and incorporated a guest expert, which further extended understanding of the module's concepts. In the cases of S206, SXPS288 and S315, the IWBs were used to engage students in research activities that would support

their independent learning and practical experimental projects. For those module teams, it was important for students to understand the goals and aims of their investigations and experiments. An SXPS288 student who attended a live Labcast alluded to this objective. In his account of why he attended Labcasts, he mentioned wanting to understand the learning process as it related to the experiment and assessment (see Section 4.5.2 pg.157).

One of the purposes, according to an SXHL288 team member, was to create a semblance of social presence and immediacy, which could be a viable alternative to previous face-to-face approaches such as residential schools and wet laboratories (see Section 4.3.1, p.91). The team member's intention echoes much of the research of those who advocate social presence and immediacy (see Section 2.5.2, p.31). A technology-mediated system, such as IWBs, and its affordances of instant messaging and widgets, in addition to its high-definition audio/video transmission, can help to create that 'viable alternative'. However, the media is also accompanied by presenters who can enhance presence and immediacy through their own personality and communicative strategies.

 The ALs also revealed that the IWBs had the potential to foster engagement and involvement, maintain interest and support retention at a specific point in the module (see Section 4.3.1 pg. 79). The tutors were also proactive in encouraging their students to attend IWBs. These findings suggest that module teams intended multifaceted aspects of engagement and align with Christenson et al. (2012) and Reeve's (2013) behavioural, emotional and cognitive characteristics of student engagement (see Chapter 2, Section 2.5.1 above). The purposes also concur with Mawn's (2016) 3E model in which fostering student engagement is one of the three objectives for an online science laboratory.

Laurillard (2012) suggests that in the design of teaching activities, aims are designed to appeal to students' likely interests and expectations, so students' encounter the environments and conditions whereby they are motivated and equipped to learn. Across the data sets, the module teams' purposes of *facilitating student engagement* were also indicated by four (i.e., TM129, S206, SXP288, SXHL288) of the student cohorts (see Section 4.3.4, Table 4.7, p.100). This was evident in the real-time text-chats. Students engaged in behavioural or social engagement through communication

with fellow students, presenters, and moderators. Across modules, students echoed similar affective responses that of excitement, interest, enjoyment, and engagement (see Section 4.3.4, p.100). Similarly, in questionnaire data, students commented on the IWBs as useful, interesting, and engaging. Students demonstrated aspects of cognitive engagement through aspects of knowledge sharing and constructing understanding together in asking and answering questions in the majority of IWBs across modules (see Section 4.4.4 p.143).

However, as discussed in the Literature review chapter, the extent to which student needs were met is likely to be variable as sense of engagement is a dynamic and fluid construct (see Section 2.5.1). Qualitative data from student surveys show that engagement can indeed be in-flux. For example, one TM129 student remarked that although they found the Labcasts valuable and engaging, the large number of attendees and fast nature of synchronous text-chat meant it was difficult to ask questions (see Section 4.3.4, p.88). The student's comment does not imply that he disengaged, rather as Kahu et al. (2015) mention, different emotions have different linkages to engagement. As a result, at least one aspect of engagement might have been compromised as he struggled to ask his question. In addition, Laurillard (2012) points out that the necessity for quick reactions and fast typing, which is common in synchronous situations, can inhibit careful thought and reflection. Although the IWBs are designed to be large-scale events, not all students will value the large volume of people in an online environment. Another possible explanation is that the student's perspective might have been influenced by the different dynamics and smaller tutorial numbers that students become accustomed to as reported in Campbell et al.(2019).

Unlike the ALs, the module teams do not usually have opportunities to engage with their cohorts. The commentary from staff indicate that they used IWBS to establish rapport with the students by employing friendly, conversation-like presentations. Triangulation with quantitative data show that the majority of students reported positively on the opportunities that the IWBs provided for meeting their lecturers and other members of the module team.

5.1.2 Introducing real-world contexts

The second commonly held purpose was using IWBs to *introduce real-world contexts*. As mentioned in the literature review, one of the most difficult aspects of DL practical science teaching is being able to assign meaningful activities that are relevant to real-world situations (see Section 2.4.3). A purpose of the Labcast, according to an S315 team member, was to present students with meaningful and authentic experiences of remote experiments, which would help them prepare for the experiments and prevent them from trivialising the experiment as a 'video game' (see Section 4.3.1, p.91).

Both TM129 and SXPS288 module teams invited guest experts to present their contemporary research. This aim not only contextualised module concepts, but it is likely that it helped students to develop an awareness of the nature and challenges of research in the real-world. Both teams incorporated a live question-and-answer stage which allowed students to ask questions of the researchers. For TM129, including a guest speaker to discuss how technologies were used in a real-world context helped to construct meaningful experiences in what might otherwise be considered 'dry' material (see Section 4.3.1). The format of the Labcast was designed to incorporate a discussion on how Raspberry PIs were used to connect people and solve local community challenges in rural community settings; hence, bridging theoretical concepts with applied practice as a way to engage and motivate students.

The SXPS288 module team invited a NASA expert to present the 'Exploring Mars' Labcast. The format of the Labcast was designed to allow a presentation of two researchers: an OU academic, who co-presented and moderated, and her contact from NASA who was the main presenter. The presentation was based on the guest's background and trajectory into science and her research on the ExoMars Rover mission. The aim, according to the module team chair, was to provide students with a 'fantastic opportunity' to listen to a NASA expert and experience a practical example of remote cooperation and collaboration among scientists, while also connecting module themes of teamwork and working at a distance (see Section 4.2.1).

The use of guest experts by both TM129 and SXPS288 module teams are activities that, according to Bonk and Dennen (2003), enhance student interaction and community building. Although a guest expert could be used in an asynchronous discussion context, the synchronous text-chat can provide authenticity and a more reactive, targeted

approach to problem solving and answering questions. In addition, exposing students to real-world contexts through guest experts might help create a sense of belonging to a group of people who are doing research science (see Section 4.5.3.6, p.165) and therefore is likely to resonate with part-time, adult DL students who may aspire to work in their associated fields. On the Mars Labcast, students from SXPS288 were very enthused, complementary and spoke passionately about being exposed to *real-world contexts*. SXPS288-S09 mentioned the NASA expert's "enthusiasm" as well as the overall conversation "brought to life what otherwise might have been quite a dull last project". Furthermore, the feedback widget polled at the end of the Labcast show that the majority of students (31 out of 40) felt that the Labcast significantly improved their grasp of the subject 'Exploring Mars'. This suggests that IWBs can help to introduce students to scientific communities of practice and motivate students by observation; a strategy deemed important in influencing or developing positive attitudes to students' disciplines.

Findings from students' survey data across the five module cohorts (e.g., TM129-19J and TM129-20B, SXHL288, S206 and SXPS288) show that the majority of students reported favourably and found that the IWBs were very useful to extremely useful in providing the opportunity to 'discover how scientific (and technological) concepts are practiced in real-world situations.

5.1.3 Demonstrating a sense of authenticity

Authentic experiences are considered important for realistic and engaging DL (Sauter et al., 2013). A *sense of authenticity* was mentioned as a purpose by S206, TM129 and SXPS288 module teams. The terms authenticity and real-context are often used interchangeably in descriptions of laboratories (cf., King & Ritchie, 2012). The term and its application in coding transcripts is discussed in the Methodology chapter (see Section 3.8.5 p. 79). Two members of the S206 team commented on authenticity in relation to personality and adaptability (see Section 4.3.2 p.95). For one academic, having a personality in Fieldcasts seemed salient Another team member felt that the intent was to reproduce an authentic field experience by demonstrating the unpredictability of field investigations and showing the teaching team making mistakes and being challenged (see Section 4.2.2). Whereas SXPS288 and TM129 module teams seem to position *authenticity* as the practice and handling of equipment and

apparatus. For an SXPS288 team member the intent was to create the visual experience of observing optical experiments in a working laboratory (see Section 4.2.2). For TM129, demonstrating networking and equipment in a home context, which could be believable and relatable to students to replicate, was relevant (see Section 4.2.2).

Qualitative data from student surveys and interviews show that S206 and SXPS288 students experienced *a sense of authenticity* (see Section 4.3.4, Table 4.7, p.100). For example, an SXF206 student alluded to personality in seeing the module team as real people rather than a static photo (see Section 4.5.3 p.123). A surprising finding was that an SXPS288 student also picked up on personality as *authenticity* as he commented on the human aspect of observing scientists (see Section 4.2.4, p.88) Another student pointed to visually seeing the apparatus and noting the 'scale of the kit' when referring to the Gas Cell experiment in the Planetary Science Project Labcast (see Section 4.3.4, p.100). What seems common in these students' commentary is the illustration of scientific practice; whether that is seeing what a scientist looks like or observing apparatus and equipment in a way that is more enhanced than other media.

The findings in the preceding sections indicate that the module teams' set of individual and shared purposes for using IWBs were influenced not only by individual module's aims and learning outcomes, but also by students' likely interests and expectations. The module teams' purposes are consistent with those stated in the literature (see Section 2.5, p.25). It is likely that the purposes facilitated the acquisition of scientific and technological concepts (Hofstein and Lunetta, 2004); influenced positive attitudes towards subject matter and introduced students to the scientific communities of practice (Scanlon et al., 2002).

5.1.4 Fostering a sense of community

The importance of learning community is well established in the literature (see Section 2.5.3, on page 35). Modules teams from SXP288 and S315 held the view that *a sense of community* was a purpose of IWBs (see Section 4.3.2, p.95). This finding further supports the ample evidence to suggest that establishing a SoC helps foster engagement and impacts learning (see Section 2.5.3). Both teams mentioned that IWBs gave students the opportunity to meet the module team, other academics, and researchers. The IWBs provided an opportunity to come together in real-time, talk

together and benefit from the immediacy cues that a synchronous broadcast event could provide (see Section 4.3.2). The IWBs were seen as an opportunity to directly communicate with students and shift the perception of an isolated DL process to a more interactive, humanised experience (see Section 4.3.2).

The findings show that the ALs also perceived IWBs as a means to foster SoC. For an S206 AL, the use of the widgets, where students collectively drove the decision-making process enhanced student connectedness and SoC within the Fieldcasts (see Section 4.3.2). An SXPS288 AL perceived the text-chat as a means for student community building, which she enjoyed observing and being a part of (see Section 4.3.2). It is probable therefore that IWBs can also support community building among ALs and the wider student cohort and that the IWB experience is distinct from the experience of community that may exist in tutorials.

The technical production team also agreed SoC was an intent of the IWBs. The team described them as a means to add a human dimension to module presentations, to foster a sense of presence of 'being there' and to stimulate dialogue between the module teams and students.

Despite the fact that only two module teams reported SoC pertaining to purposes, the data presented in Section 4.4.2 discusses how moderators and presenters used communicative strategies and behaviours to engage students, which also indicate SoC. The IWBs also build on the university's long-standing practice of using broadcast TV, video and synchronous media to mitigate isolation and promote online learning communities. It can therefore be inferred that the other teams that did not report SoC may believe it to be an inherent purpose. Based on the requirement for HEIs to foster a SoC and the OUUK's five-year strategy in which a commitment is made to strengthen SoC (see Section 1.1), it is possible that the module teams' used IWBs as a way to develop and further extend the learning community aspect within modules and that SoC gains could drive learning and the understanding of a subject.

With respect to students, the majority of the five student cohorts (except for S315) reported that they agreed or strongly agreed that the IWBs made them feel part of the STEM learning community (see Figure 4.31, p.160). S206 and SXPS288 cohorts viewed the IWBs as fostering a SoC. The Fieldcasts, according to one S206 student, supported practical environment science fieldwork while also bringing the student community

together (see Section 4.3.4 p.100). An SXF206 student mentioned the large audience, which gave a perceived SoC of many people watching and participating in an activity simultaneously (see Section 4.5.3, p.159). It is important to note however that SoC is subjective and may be crucial for some students to experience positive learning experiences but less so for others. However, at a school level across the STEM faculty, the goal should be that OU students gain an insight into the teaching support being developed through the use of IWBs and that the IWBs provide students an opportunity to understand the dynamics of community, help influence it and experience an online learning community at the highest level if they wish to do so. Having discussed purposes, this section now turns to themes that emerged from the data and considers the value and impact of IWBs on professional teaching practice.

5.1.5 Emergent finding: a sense of involvement

Module teams discussed their motivations for being involved with IWBs (see Section 4.5.4, p.167). All five module teams appeared to be equally enthused concerning involvement. The majority of module and technical production team members have between 4 – 7 years of Labcast experience (see Section 4.2.1, Table 4.3, p.83), with the majority in this category being involved from the early Labcast roll out.

The impact that IWBs can have on the wider staff cohort are of particular interest. A cautionary note that *impact* in this context is understood in the general sense of developing individual skills, knowledge and experience over time and does not consider measurement of satisfaction or change of behaviour of staff but rather staff reflections (De Rijdt et al., 2013). For instance, a *sense of involvement* was perceived by the guest presenter of TM129. For him, the Labcasts provided cross-university collaboration and professional development opportunities. The finding suggests that the IWBs can provide staff development opportunities which can help individuals improve their skills and gain practical teaching experience over time. This finding may have implications for IWBs scalability in its wider form in incorporating professional development opportunities for staff in other faculties However, Labcast participation and involvement may not be as straightforward for newer module team members. SXPS288-MT3, for example, described some of the challenges of being imported into a module with a new student project and experiment in which he was not initially involved in and having to present in a Labcast (see Section 4.5.4, p.167). However, the

data shows camaraderie and support from more experienced academics in the module team.

The ALs who taught on the modules also voiced their ambitions to become more involved. The findings show that although there was a readiness to participate more in Fieldcasts, module production and residential schools, S206 tutors shared a sense of pessimism. Another AL alluded to the dispersion of tutors and a lack of opportunity. The findings support Rienties et al. (2013) claim that DE tutors have fewer opportunities to participate in meaningful, practical activities and can often face difficulties of integrating into the broader academic environment (Beaton & Gilbert, 2012). However, the data from the ALs must be interpreted with caution because *sense of involvement* is likely to be subjective and there may be opportunities that ALs are not aware of within their schools or across the wider university. Furthermore, the culture of a module differs across modules and schools with the possibility that some ALs are more aware of IWBs than others as indicated by a S315-MT2 who felt that there should be more on raising awareness for ALs.

Teaching via IWBs can be a time-consuming and stressful activity as reported by SXPS288-MT2 (see Section 4.5.5, p.173). The design, production and rehearsals take several iterations and most IWBs broadcast in the evening. If the existing module teams are to attract more people (e.g., central academics, ALs, postgraduate students and early career researchers) to labcasting, module teams may need to consider how participating could support professional development criteria such as those outlined in the HEA Fellowship (Fellowship | *Advance HE*, 2020).

5.1.6 Emergent finding: a sense of collegiality and collaboration

Two members of the S206 module team discussed how they built a shared understanding of Fieldcast design and structure, as well as how they communicated ideas and solved problems. They credited their team members and the technical production team for its success (see Section 4.3.2). The findings show that there were changes to the conceptions of teaching Fieldcasts over time and the development of knowledge among the technical production team and module team. Sharing ideas and addressing problems as a group resulted in *a sense of collegiality and collaboration*. The "supportive tutors on the module" were also acknowledged by the module team,

and similarly S206 tutors were complimentary of the module team and the Fieldcast implementation.

Likewise, members of the SXPS288 module team reflected on the skills and personal characteristics of their colleagues who participated in IWBs. The new module team member's first Labcast presentation was praised by more experienced presenters. This finding supports Shah's argument that by bringing experienced and less experienced individuals together, collegial groups can help create a cooperative climate that fosters enthusiasm among colleagues and aids newcomers (Shah, 2012). Furthermore, the data suggests that IWBs can enhance good practices across schools where staff can collaborate in shared repertoires and resources.

5.1.7 Emergent finding: reflective practice on IWBs, student learning and assessment

Three module teams (i.e., S206, S315 and SXPS288) engaged in reflective practice and discussed the influence of the IWBs on student learning and assessment. The assessments connected with Fieldcasts, for example, were discussed by the S206 module team. There was no indication that the Fieldcasts benefitted student performance on the TMA06, according to one team member. Another team member felt that the Covid-19 pandemic resulted in distinct experiences for some S206 and SXF206 students, concluding that the impact of Fieldcasts was at best inconclusive. S206 ALs who marked the assessment reflected on student voice in report writing with one AL group reporting it as an issue and another group not. Further discussion revealed giving feedback to the module team to ensure "guidance about voice was clear" (see Section 4.5.5).

In reflecting on practice, researchers have proposed that stakeholders should assess specifically what progress has been accomplished and what insights have been gained that may be incorporated into practise to inform future development (Bjælde & Godsk, 2015; De Rijdt et al., 2013). The focus of S315's reflection was on the aim of the Labcasts and whether they were effectively preparing students to conduct experiments and support learning. Differences of opinions emerged as to the extent students were picking up key concepts and the best learning resource to achieve that. Members of the SXPS288 module team discussed the format of Labcasts, as well as the use of widgets and text-chat. An SXPS288 team member welcomed the opportunity to

discuss and reflect on teaching in Labcasts, indicating the suitability of a focus group methodology.

The technical production team also engaged in reflective practice and discussed issues related to student participation in the IWBs. According to one team member, level 2 and 3 students may find it easier to participate in the community aspect that IWBs can provide, however, level 1 students may take a little longer. There are similarities between the opinion expressed by the team member and those described by Swan (2003). The author reported that affective indicators and self-disclosure responses were found more among cohorts who had already formed interpersonal bonds and peaked by the third module and declined thereafter.

5.1.8 Section summary

The module teams' purposes for using IWBs are facilitating student engagement, planning strategic points, introducing real-world contexts, demonstrating a sense of authenticity and fostering a SoC. Taken together, these results from staff and students provide insights into the pedagogical purposes of using large-scale IWBs to support practical STEM modules. The findings from student data show that the purposes aligned with the majority of students interests and expectations. The findings also reveal that student engagement is unique to each individual and multifaceted. It is subject to change since it is socially constructed and reconstructed through their interactions with others and the learning environment (Bryson, 2014). Student engagement appears to be on a continuum, with some students expressing optimal engagement and others experiencing disengagement (Kahul et al., 2015).

Finally, the IWBs had a beneficial impact on staff collegiality and teamwork. In general, the findings indicate that IWBs can help staff improve their knowledge, skills and professional teaching practices. However, the findings are less favourable for ALs, particularly in terms of involvement.

5.2 Presenters and moderators' strategies to interact and engage

The second question investigated the *strategies* that presenters and moderators used. To unpack this question, 'interaction' and 'engagement' were treated as distinct attributes as explained earlier (Chapter 3, Section 3.8.2, p.76). The first two sub-

sections will discuss the *strategies used to interact*. These are followed by four subsections discussing the *strategies used to engage with students*.

The module teams (alongside the producer from the technical production team) set up planned forms of interaction, a number of pre-configured widgets and integrated resources to interact with the students (see Section 4.4, Table 4.9, p.108). The findings show that module teams implemented up to eight different forms of stages or interactions dependent on the Labcast or Fieldcast aims (see Section 4.4.1,Table 4.10, p.112). The stages were *establishing social connection, conducting experimental or field work, demonstrations, discussing methodological processes, hypothesis, module related, observations, and questions-and-answers.* The following sub-section describes one stage: *establishing social connections* which was seen evidenced in all IWBs and is germane to student engagement and its interrelated constructs.

5.2.1 Establishing social connection

As noted in Chapter 2, Section 2.3.1, p.14, Holmberg's empathy approach and conversational theory, which the OU has used as a dialogical model, begin with a focus on building personal, friendly interactions between students and lecturers with conversational-like presentations on subject matter (Holmberg, 1986). The five module teams *established social connection* as a way to foster the tone and climate for interaction. Presenters and moderators used a conversational and personable approach. They introduced themselves and their roles on the module, used phrases such as, "you're going to be coming across me in the forums a bit later" (see Section 4.4.1, p.111) to convey familarity, outlined the Labcast's aims and helped to orient the students to the Stadium Live interface (see Section 4.4.1, p.111).

Students are said to be socially engaged when they enjoy social interaction and build positive relationships with lecturers and tutors (Pittaway, 2012). The e*stablishing connection* stage seemed to function as an icebreaker to help students feel more at ease and encouraged asking questions in the text-chat and conversing with their peers. If students experienced trouble with starting the live stream or navigating the interface, a moderator or technical production team member often offered support. This stage also likely helped to establish expectations about what was coming up in the Labcast and allowed those attending Labcasts for the first time to adjust to a different form of teaching and delivery; that is from tutorials and the familiar Adobe Connect

platform to the Stadium Live platform. The findings show that the third SXPS88 Labcast and the first SXHL288 Labcast had the highest number of coded occurrences at this node. However, there was variation across them. In the case of SXPS288, the third Labcast was new and designed to support the new planetary science experimental investigation and student project. It also involved the new presenter, SXPS288-MT3. Both module's Labcasts had two lead presenters although the presenters in SXHL288 were more conversational in their presentation. Because this stage of interaction is social in nature, it's likely that presenters that are 'chattier' are prone to talk more at this stage.

The text-chat data across all IWBs show that students were responsive to the social connection stage as the majority of discourse was socio-affective (see Section 4.4.4, p.143). These phrases included a high number of salutations, humour and self-disclosure. However, it is important to note that this discourse type was developed throughout the live event and not just at the beginning.

5.2.2 Polling questions, reviewing and evaluating using widgets

As discussed in Section 2.6.1, p.44, audience polling devices can increase student participation and engagement. From a pedagogical perspective, the widgets are intended to drive dynamic interaction (Beatty et al., 2006) and support interactivity through a bi-directional loop of question-and-answer. As discussed in Chapter 2, the strategy of using online question approaches might decrease passive watching and listening by allowing students to simultaneously respond to questions (Hartwell, 2017).

This research adapted Beatty and colleagues question cycle model (2006) as discussed in Chapter 2, Section 2.6.1, p.44. The five module teams used a variety of seven widget types across the IWBs to interact with students. The findings show that all presenters used the widgets across three cycles: *polling the question, reviewing and evaluating* (see Section 4.4.1, Table 4.11, p.116). The data further show that moderators who facilitated the text-chat box throughout the broadcast often reinforced or reformulated the question to generate interaction in the chat. In the cases of LC-TM129-19J-1 and 20B-2, LC-SXPS288-19J-4, FC-S206-19J-1 and FC-S206-19J-2, moderators also engaged in *review* or *evaluation* cycles by offering comments around the distribution of responses displayed or following up with evaluative remarks.

In the S206 Fieldcasts, the presenters used the *review* stage of the widgets cycle strategically to demonstrate the students' decision-making and discuss the pragmatic options available in the field, based on the democratic vote of how the investigation would proceed. The findings suggest that the ways the widget cycles were implemented in the Fieldcasts helped foster interaction and engagement. For example, the data on widget interactivity in FC-S206-19J (episodes 1 and 2) showed a high and steady level of engagement (88% and 93% respectively, see Section 4.4.3, Table 4.19) Similarly, in a SXHL288 Labcast, the presenters used a multiple-choice widget with an active learning stage by encouraging students to count cells live and input their number in a widget, later discussing the distributions of responses. Widget interactivity in LC-SXHL288-19J-2 suggest a steady level of engagement (61% see Section 4.4.3, Table 4.26, p.140). Hartwell (2017) cautions using online questions ineffectively, overusing or asking redundant questions which could have a negative impact and frustrate students. With the exception of these two modules, other modules primarily used the widgets to poll questions and review the responses, which can create a feeling of the activity feeling perfunctory and not having value as pointed out by an SXPS288 student.

Only presenters in FC-S206-19J-3 and LC-SXHL288-19J-1 *revisit[ed] a poll.* This is of interest because by doing so, there is an opportunity for further reinforcement, feedback and engagement. The widget questions in the third S206 Labcast are more closed as opposed to the first two Fieldcasts, which are designed to be more open questions and allow the students to drive the field investigation. The findings show that the S206 presenters *revisited a poll* when students voted and chose the wrong hypothesis. On displaying the histogram, the presenters chose to go back a few steps to demonstrate the Simpson index (i.e., a calculation used to quantify the biodiversity of a habitat). The presenters gave the option for students to change their vote based on the additional information and guidance. Interview data from two S206 students indicated that students benefitted from the reinforcement. One student stated that the explanation was beneficial. Another student mentioned he reviewed that particular recording the most although he voted correctly at the time. He also participated in the forum discussions following the Labcast, where the module team chair provided additional support in understanding the diversity index issue. The findings confirm that Beatty et al's (2006) question cycle model can be adapted for an

IWB context and indicate that revisiting a question or allowing for a change in decision-making can help students to explore and extend their knowledge (Beatty et al., 2006). What seems to be less common from the way widgets are used across the modules is the presenter utilising widgets for a teachable moment whereby they can redirect or guide students' understanding (Kulkarni & Iwinski, 2016). This is not easily achieved in the IWBs environment and would require careful planning, timing, and coordination. However, the first step would be for module teams to decide whether widgets are solely engagement checks or knowledge checks.

Turning now to engagement, the following four sub-sections will discuss the *strategies used to engage with students*. In addition to setting up interaction in the planned stages and using the synchronous tools, the module team members demonstrated communicative strategies and behaviours to foster student engagement. The web broadcast and text-chat datasets produced seven themes of affective strategies (see Section 4.4.2, Table 4.12, p.120). The discussion focuses on the four findings that presenters and moderators employed the most.

5.2.3 Encouraging and promoting student participation

In synchronous broadcast environments, a lecturer's verbal immediacy behaviour is especially important for setting the tone and creating an atmosphere that encourages student participation (Hutchins, 2003). The findings show across the five teams, 12 (out of 19 individuals) *encouraged participation* with the interface, and 15 (out of 19) *promoted further engagement* with future IWBs, forums and other learning resources. This technique aligns with the module teams' shared purpose of facilitating student engagement (see Section 4.3.1, p.91). The data show that students interacted with the interface and responded to the presenter or moderator in what they saw or heard by commenting and initiating questions and offering answers.

5.2.4 Showing appreciation

A common attribute or strategy used by the five module teams was to show *appreciation* (14 out of 19). Presenters and moderators demonstrated this by recognising the students' efforts to attend on weekday evenings, for listening to the presentations and for voting (see Section 4.4.2, p.120). Expressing appreciation, an indication of social presence (Rourke et al., 2001), can facilitate social interaction and contributes to the tone and climate in the DL environment.

5.2.5 Fostering psychological safety

With the exception of S315, 16 (out of 19) staff engaged in *fostering psychological safety*. S206 presenters reassured students on the anonymity of interacting with the widgets. SXHL288 presenters reassured students on content that they may have not come across yet but would be covered in the Labcast. SXPS288 and SXHL288 presenters encouraged students to ask for help on the forums, engage with their topic specialists, and gave reassurance on conducting experiments. In the case of TM129, the moderator was very explicit at the start of the Labcast that if students found the text-chat too active, they should focus attention on the demonstration and use the chat box selectively. This finding indicates that the moderator was aware of the fast nature of real-time chat and what researchers have termed the cognitive overload that can sometimes occur in media-rich environments (Scholl et al., 2006). As mentioned earlier, a TM129 student remarked on this very issue in survey data. In addition, the term 'interactive' in the use of Labcast and Fieldcasts might prevent some students in participating or engaging if they think that they will be asked to speak or be 'put on the spot'. Research on OU tutorials show that students prefer to use text-chat to interact rather than ask questions via their microphones (Jones & Gallen, 2016). Therefore, to debunk potential misunderstandings of the Stadium Live and Adobe Connect platforms, module teams should consciously use this strategy to reassure students.

5.2.6 Fostering a sense of belonging

12 (out of 19) presenters and moderators across the five modules fostered *a sense of belonging*. This was more prolific in TM129, SXPS288 and S206 IWBs. Presenters and moderators demonstrated this after reviewing the map widget and welcoming students from their locations. An SXPS288 presenter used inclusive language, suggesting cooperation with others. For instance, "we are being good experimentalist" as he modelled equations on the white board. The findings also suggest the presenter adopted a conversational approach which fostered a sense of identity; from novice to experts (Lave, 1991) as demonstrated by the conversation between SXPS288-MT1 and several students (see Section 4.3.2). Across the data sets, student cohorts in S206 and SXPS288 reported that they perceived a *sense of belonging.*

Finally, the findings show that certain presenters demonstrated a higher number of communicative strategies than others. For example, across the seven categories,

SXPS288-MT1 had coded references (n=75); TM129-MT1 (n=49) and SXHL288-MT2 (n=36). However, it is important to note that the high number of coded references were likely impacted by the number of times individuals presented a Labcast, the Labcast design and the proportion of time a presenter was allocated to speak on a segment based on the running orders. However, the nature of an individual being 'more talkative' or more personable is also probable.

5.2.7   Initiating talk and responding to students

In applying the FIAC framework, the analysis focused on TM129 'Technologies in practice' as a particular set of cases that had two presentation years (i.e., 2019 and 2020). A common pattern of interaction found that presenters and moderators primarily engaged in interaction that was responsive. As discussed previously, if we accept that the 'presenting' component (of what was Flanders's initial 'lecturing') form the largest proportion of IWBs, we can assume that presenters and moderators initiated most of the interaction by making the first move, leading and introducing a topic. The findings show that presenters and moderators' interactive moves were to ask questions about the content or a procedure (via the widgets or text-chat), accept the ideas of a student by acknowledging the idea, clarifying, building or developing ideas by students, guiding student thoughts and research, praising student action and accepting feelings. The findings also show that there were less initiation moves of giving directions or criticism or justifying authority. Students responded to the questions either by answering the question posed by the presenter or engaging with the moderator in the text-chat. The findings show similar data in how students respond and initiate questions and comments in both 2019 and 2020. The differences seem to be in how they accept ideas and build on the ideas of others, which seems to generate more conversation and thereby more engagement.

5.2.8   Section summary

The module teams' strategies to interact with students included setting up eight planned forms of interaction as main stages depending on the IWBs purpose and aim. These stages were *establishing social connection, conducting experimental or field work, demonstrations, discussing methodological processes, hypothesis, module related, observations, and questions-and-answers.* The data show that establishing social connections was conducted in all of the IWBs.

Module teams used the widgets support interaction and engagement. Presenters *polled questions, reviewed and evaluated* student response. This was done by relaying the histogram and collective responses with coordinated media shots of the interface and by a moderator reinforcing the question and offering evaluative comments. The findings show that when an active moderator reinforces widget questions or evaluates an answer, it can generate more interaction in the text-chat. Revisiting a widget or allowing for a change in direction can help to further engage students, offer clarification and extend their knowledge. A specific timeframe, for example five minutes could be planned into the IWBs to allow for that spontaneity or planned activity.

Finally, module teams engaged in communicative strategies that were social and affective in nature by encouraging, creating a safe and reassuring learning environment and fostering a SoC. Patterns of interaction show that presenters and moderators had an indirect approach to influence participation or action. All Module teams engaged in various communicative strategies to build social connection and set up a psychologically safe environment for learning and social interaction. Presenters and moderators did this by way of personal introductions, orienting students to the Labcast and the interface and having a friendly demeanour.

5.3 Students' use of synchronous tools to interact with presenters and fellow students

The third and fourth research questions investigated the ways in which students used the widgets to interact with the presenters and how participating in the IWBs contribute to knowledge-building discourses.

5.3.1 Interactions with the widgets

The findings show that students were willing to interact with the interface and used the widgets and text-chat to interact with the presenters and each other. These findings align with prior research that show students interest and willingness to engage with audience polling systems (Morrell & Joyce, 2015). Findings show those that attend the live IWBs interacted with the widgets. The Map widget is interacted with at the beginning and students often write their locations in the text-chat simultaneously. The Wordle widget is often the least interacted with and most IWBs have fluctuations in the number of responses across the widgets. Although the data shows a high

number of interactive users, there were fluctuations in interactivity across particular Labcasts. For example, the TM129 (2019/2020) Labcasts showed fluctuations in the interactions per widget. The S206 Fieldcasts showed a steady engagement with widgets across episodes 1 and 2. However in the third Labcast, there is a slight fluctuation in interaction as the Labcast progresses. The first three Labcasts of SXPS288 show variation in interactions with the widgets. However, there was a more consistent pattern with the fourth Labcast, which was presented by the NASA guest speaker. The widget interactivity is also supported by the connected users log, which shows that over 50% of users stayed connected to listen to the talk although the event overran. In SXHL288, Labcasts had some variations in the user interactions with the widgets and in S315, the second and last multiple-choice widgets had the least interaction. In particular, the Wordle widgets across IWBs tend to be lower in number because the user is required to input 3 words or phrases to generate the word cloud. In addition, student interview data show mixed attitudes on the widgets.

The data show that students engaged in the text-chat across the IWBs to interact with the presenters, moderators and with other students. Where there was an active moderator, chat users produced a higher number of chat posts than those Labcasts that were not actively moderated. Interaction patterns show that students engaged in the IWBs by responding to the presenter or moderator in what they saw and heard by commenting and initiating questions and offering answers. In a TM129 Labcast, students responded to questions posed either by the presenter or the moderator. Students also initiated talk and built on the ideas of others. They engaged in responsive talk with one another. The findings indicate that students are responsive and react to ideas that have been expressed in IWBs. However, 'responsiveness' is likely to vary based on the student body and other motivational factors.

5.3.2   Types of discourses produced in text-chat

The predominate discourse that emerged from text-chat among the text-chat users was social-oriented talk. This finding did not support the previous research of Lipponen (2000) who found fact-oriented discourse as the main mode of discourse. In this study, students engaged in phrases of salutations, humour and banter, self-disclosure and sentiments of a sense of belonging. These findings suggest that students were engaged although Lipponen (2000) points out that social talk has little value unless it is positive

social talk that has functions such as facilitating group cohesion and motivation. Fact-oriented discourse was found in all broadcasts and explanation-oriented were found in all, except S315. In episode 2 of S206, the data show that students seemed more enthusiastic in social engagement than in episode 1. This could have been due to several variables such as participating in the first episode, familiarity and feeling more comfortable with the interface, the experience of meeting the module team or experiencing what an authentic field investigation looked like. The data show that students engaged in explanations representing factual information and were responsive to others by giving explanations that represented factual information to students and moderators. In TM129, S206 and SXS288 students engaged in bridging knowledge by sharing web and app links and other information to enrich community knowledge. The findings show that participating in IWBs can contribute to discourses that represent understanding and knowledge sharing. However, there is no data to support that students participated in knowledge building. Rather the data show that moderation in the text-chat can foster scaffolding strategies to enhance understanding. The extent to which discourses of understanding and sharing of knowledge were found in IWBS seem dependant on the content, number of students and personal traits of the chat users.

5.3.3   Section summary

Students across the five modules use the widgets to interact with the presenters by first coming to the live events on time and staying connected throughout, which indicates a level of engagement. Second students are responsive to presenter's and moderator's requests to use the widgets and engage with the map widget to select their location. Findings show connected users interacted with one or more widgets and with the text-chat to interact with the module team and with each other. Across the IWBs students predominately engaged in social chat of various kinds, indicating that the text-chat function primarily serves a social engagement purpose. However, there was evidence of knowledge building where students and moderators initiated questions, and answers and responded to the presentation.

5.4   Motivating factors of students to engage in IWBs and their capability to support learning

The first part of the question examined what the motivations of students were to engage (or not engage) with the IWBs. The second part of the question discusses how

the IWBs support students' learning. Learning is in the context of the module's learning and assessment outcomes. Students reported five factors that motivated them to engage with the IWBs: *being available and running to time; getting involved and influencing an investigation; and understanding the assessments and practical work.* The following sections describes the factors.

5.4.1 Being available and running to time

One of the most critical obstacles shown in past research to be a barrier for DL students is the aspect of time. Students are typically represented as being time-poor and have competing demands of study, work and family commitments (Kahu et al., 2014; Muilenburg & Berge, 2005). Both SXPS288 and S206 students mentioned time as a motivational factor. Knowing the Labcast was 'short' was crucial for an SXPS288 student and the scheduled Fieldcast time on a Saturday was convenient for an S206 student. The findings show that students are selective in when and how they assess time in order to engage in IWB activities. Except for the SXPS288 Exploring Mars Labcast, SXPS288 Labcasts ran for 45 minutes as advertised. Advertised timings seem to be noted by some students and is therefore important that module teams try their best to keep to those scheduled times.

5.4.2 Getting involved and influencing an investigation

The research literature show that social interaction is strongly related to online learning enjoyment and effectiveness of learning online (see Section 2.5.1). Students from S206/SXF206 reported the opportunity to be involved (see Section 4.3.5), to interact and being able to influence the field investigation (see Section 4.4.1, p.134) as motivational factors. Fuller (2006) argues that student perceptions of the value of fieldwork is enhanced whether by hands-on application of techniques or not. The opportunity to 'impact' and 'steer' the learning process of a field investigation indicates that students perceived the activity valuable. Their motivations also indicate a willingness to demonstrate autonomy in their learning (Hartnett, 2012). One student made a distinction between types of assessments. For her there was a difference between structure where a scenario was given and autonomy and having a voice on what could be contributed. The student-driven process of Fieldcasts seemed to offer something different from their usual module activities and online experiences and there is indication that this difference was a motivating factor. Others reported that

the Fieldcasts helped bring together the student community to learn practical environment science fieldwork. This finding concurs with Fuller (2006) who reported that meeting new people, working in a group, feedback and exchanging ideas were rated as valuable in a field trip amongst an undergraduate Geography cohort. The findings also show that a SoC was experienced at the Fieldcast level.

5.4.3   Understanding the assessments and practical work

As mentioned in Chapter 3, Section 3.3.1, SXPS288 projects are introduced by Labcasts and S206 Fieldcasts facilitate students to write a scientific report based on a field investigation. As discussed in the literature review, demonstrations that occur in a modelling environment and the 'how' and 'why' discussions between students and lecturers are beneficial (Pask, 1975). SXPS288 students reported the need to understand the TMA and the theories underpinning the experiments. One student mentioned that the Labcasts helped him to understand the educational process and pool together the knowledge needed to understand the experiments while another respondent mentioned the opportunity to listen to a practicing scientist as motivational factors. Students have access to interactive study materials, video and interactive assessments for each learning block and the support of project specialists and tutors. However, the findings suggest that the IWBs added an additional important learning component. Research shows that there is often anxiety around doing lab and field work (Boyle et al., 2007). The modelling of important mathematical equations and demonstration of experimental investigations in real-time might have been more salient for the students and enhanced their motivation to engage with the Labcasts and the module materials thereafter. The reference of 'listening to a practising scientist' points to the cognitive and affective emotions of presence and immediacy which IWBs can convey.

5.4.4   Unawareness of IWBs and preference to study alone

As it relates to non-engagement, half of the survey respondents from TM129-19J reported that they did not watch the live Labcasts or the recordings. The most frequent reason was students not being aware of the Labcasts, followed by a preference to study independently and a lack of time. Students reported that they were not aware of the TM129 Labcasts and made suggestions as to where they felt it could be more visible on the module website. Other comments revealed that the

motivation to engage was sometimes hindered by other study priorities, feeling overwhelmed with the amount of module content or previous negative learning experiences which impacted students' perceptions of attending activities in groups. The findings concur with research (Karal, 2011; Muilenburg & Berge, 2005) which have highlighted similar barriers to engagement in the DL environment. Student questionnaires were designed to capture students who did not watch the lives or recordings (i.e., group 4). However, no data was collected from the remaining four student cohorts (e.g., SXPS288, SXHL288, S315, S206) so it is not clear what other barriers existed for those cohorts. However, one of the easiest barriers to remove would be clearer signposting and advertising of IWBs on module websites. Students' comments in questionnaires and interviews showed that the IWB could be easily overlooked or not made attractive enough for students to attend. Positioning IWBs as a valuable resource to student learning, support in practical work and SoC should therefore be prioritised by module teams.

5.4.5 IWBs supporting learning

Students across the modules perceived IWBs as a means to support their learning. TM129 students perceived that the Labcast supported their understanding of the practical activities in Robotics and Networking and helped to reinforce language and principles. Live feedback through the Wordle widget showed that students took away affective benefits such as interest, enjoyment and meeting friendly teachers and cognitive benefits such as learning about the equipment and concepts taught in the module.

Likewise, the SXPS288 cohort that attended live and watched the recording reported that the Labcasts supported their understanding of the remote experiments and TMAs. In the new student project and Gas Cell experiment, students reported that the Labcast was useful in supporting their understanding. Live feedback with the widgets found that those that attended live strongly agreed that the Labcast helped to understand what they would need to do in the Gas Cell experiment and grasping concepts during the Exploring Mars Labcast. Attendees perceived that the Labcast had improved their understanding of the subject. Students also reported on affective benefits such as confidence, clarity and kindred spirits.

In S206/SXF206, students reported that the Fieldcasts helped support their understanding of field investigations' terms, concepts, method and processes. The findings indicate that Fieldcasts supported key learning outcomes of the TMA, which students wrote before participating in the online survey. Live feedback widgets devised by the module team showed that students found the Fieldcast series helpful, enjoyable and felt involved in the decision-making process. Students in SXHL288 reported mixed feelings as to the extent Labcasts supported understanding of the investigations and the TMAs. However, the majority felt it was pitched at the right level. In S315 a feedback widget showed that the attendees agreed that the Labcast helped to understand what they needed to do in TMA05.

While there were differences between the students (e.g., age, discipline, length of OU study) and other structural influences (e.g., time factors, accessibility), the general consensus indicates that IWBs support experimental and theoretical learning. In addition, the feedback widgets show there were cognitive and affective benefits which could affect motivation and engagement.

5.4.6   Section summary

Students across two modules reported five motivational factors that helped them to engage with the IWBs and one student cohort reported the factors that prevented engagement. A commonality between the three cohorts was 'time'. Students were either able to schedule time around their own activities and commitments or were not able to. Some preferred independent learning. Having an assessment component demonstrated in IWBs also was a motivational factor. However, those who did not engage also reported factors that are demonstrative of some of the challenges in DL. Overall, students across all five modules perceived that the IWBs supported learning and those that attended live reported cognitive and affective benefits.

5.5   Students' sense of community in IWBs

Students across the five modules reported their experiences of SoC. The data revealed that this was perceived at three levels: institution, module and the IWB.

5.5.1   Institutional level

A SoC as it related to the OU was mentioned by SXPS288 and S206 students. There was recognition of the different types of learning experiences that contribute to SoC, such

as previous face-to-face OU tutorials, and how that had not translated as well to an online environment. Students made comparisons of their campus-based university experiences and seem to align more with their past experiences in that setting. There was recognition that the OU had other community-related spaces, but time constraints was a barrier to participation.

5.5.2 Module level

A SoC was perceived in all five modules. Students in TM129, SXPS288, SXHL288 and S315 reported fewer feelings of learning and interacting with others. The results mean that the students generally did not share values and beliefs concerning the extent to which their educational goals and expectations were being satisfied. S206 students reported fewer feelings of connectedness meaning they generally did not feel cohesion, spirit, trust and independence. SXPS288 and S206 students who self-assessed as having a higher level of SoC, as determined by the CCS, reported a higher agreement that the IWBs made them feel part of a scientific learning community. However, there was also a perception that the extent to which community is felt is dependent on the module.

Distinctions were made between SoC among staff and students. One student commented that he felt SoC with the tutors and staff more so, as SoC with students was not felt until the end of the module during group work. This indicates that SoC is a construct that is not stable and is likely to change as students move from one module to a next or from activity to activity. A SoC was also attributed to the use of a third-party app such as WhatsApp. Previous research has found that students form their own independent social networking groups as an extension of their OU study (Foley & Marr, 2019). On the other hand, another SXF206 student did not experience a SoC at the module level. This lack was attributed to excessive interaction, the inability to process the plethora of information and the non-obligation to work with others.

5.5.3 Web broadcast level

The findings show that the majority of students across the modules perceived that the IWBs made them feel part of the STEM learning community. Interview data from SXF206/S206 students revealed that Fieldcasts facilitated feelings of community due to the opportunity it provided to know the module leaders better and because of the scale and synchronicity of people all watching and doing an activity simultaneously.

The Fieldcast also helped in personalisation that is meeting the people behind the module material. Physics Labcasts were also found to enhance a sense of belonging where students could identify with the role of 'astronomer' or an 'astrophysics scientist' indicating students taking on new learning and professional identities (Lave, 1991). This is of interest in light of Coll and Eames (2008) critique that students in university contexts tend do not acquire a sense of the culture of science or becoming a scientist.

The presenters' communicative strategies and immediacy behaviours helped to enhance SoC. The diversity of the student body means that some students will be cognizant of non-verbal behaviour, personalities and the human aspects that make up communication that are part of the IWB experience. It is important to note that strategies and immediacy cues and the extent to which they are performed is likely to be subjective and depend on the personalities of individuals and the roles (i.e., presenter or moderator) they play in each IWB. However, the careful curation and direction from the production team ensure that each IWB meets an "acceptable" presentation standard that is representative of live broadcasting. Finally, the map widget, which is used to set up the first stages of social interaction and engagement across the IWBs, also seems to play a significant role in displaying the wider community. The use of widgets for a collective voting experience were perceived as enhancing SoC.

It is possible that the different designs of IWBs take different approaches to developing a SoC. For example, in the Fieldcasts, there is the notion of students democratically driving the field investigation together as a wider group although students write the TMA as an individual activity later. This strategic plan is likely to influence SoC in a different way compared to a more didactic Biology or Physics Labcast that support assessments that are conducted in student groups. Student data from S206 and SXPS288 in particular indicate that students perceived SoC in two ways: (1) at the IWB level as a large-scale, synchronous activity in the field or (2) at the module level where students perceived SoC in the practical work (i.e., the experiments, team-work, the module team and materials).

5.5.4 Section summary

Participating in IWBs contribute to students SoC because of the varied opportunities it provides. The IWBs allow students to meet their lecturers and the module team and therefore humanise the learning experience and put personality behind the module materials. The power of synchronous activity, especially in S206, which is driven by student-led decision making contributes to SoC. In addition, the presenters themselves and their communicative strategies and being researchers in the field can make some students feel aligned to being a scientist. However, SoC and how participating in IWBs contribute to it cannot be divorced from the macro level of the OU or the ecology of the module. Students reported positive attitudes towards the OU as a distance university and different levels of connectedness and community within modules. Participating in IWBs could contribute to students' SoC in a number of ways namely, by feeling a sense of togetherness in large-scale synchronous activity, by fostering new and emerging identities and by humanising the learning experience.

5.6 Chapter summary

This chapter discussed the findings in the context of the research questions outlined in Chapter 2, Section 2.1, p.10 and the literature which aligned with or supported the findings in Chapter 4. The chapter organised the discussion around the six questions.

The discussion focused on the five pedagogical purposes that module teams used IWBs to support practical lab and fieldwork in STEM modules. The overarching purpose was to facilitate student engagement. The purposes aligned with those found in the literature and also appealed to students' interests and expectation such that similar themes were found in student data sets. The module teams' intentions were primarily affective and fostered emotional and cognitive student engagement. The purposes of using IWBs align with the objectives of teaching and learning practical science in an DL environment as well as those objectives that would be seen in conventional, campus-based settings. Moreover, IWBs can have a positive impact on the stakeholders who produce, present or participate in them in terms of fostering collegiality and collaboration and lecturers' professional development.

Presenters and moderators use a number of strategies that foster the affective space of social connection, encouragement, safety and belonging. Students' value IWBs for many reasons. It is interesting, engaging and informative and provides an authentic

context in a way that may not be experienced in the other online learning activities. IWBs that have assessment components are particularly valued. The findings add to our understanding of how large-scale live events can be used to create authentic teaching and learning experiences.

In answer to the main research question:

- **How do interactive web broadcasts foster distance learning students' engagement with practical lab and fieldwork?**

The use of IWBs foster DL students' engagement with practical lab and fieldwork by enabling lecturers, topic specialists and other experts to interact with the student body in real-time. The IWBs provide a well-designed and executed live production that demonstrates the complexities of practical work in the form of demonstrations, experimental investigations and field investigations. In general, two factors foster DL students' engagement: 1) the technology-mediated system itself and its interactive components 2) the people behind it who produce, present and moderate. A particular strength is the potential rich interactions where visual interaction focuses on data and visual artefacts alongside conversations.

A criticism of TEL innovations used in education is that they may be employed because people are excited to try something new rather than common-sense assumptions of what the technology can do (De Freitas & Neumann, 2009; Ng & Przybyłek, 2021). However, staff data indicate that module teams and the technical production team use pedagogic-driven planning and perceive IWBs as a complement to the module ecosystem in fostering engagement with practical sciences. It gives central academics the opportunity to extend their module materials in creative ways and influence a SoC within and across modules. The challenges of combining use of multiple media seem to be mitigated by the expertise of the technical production team and the module team members who write the materials and design the experiments. Both teams of practitioners work together to understand the interrelations of multiple media used synchronously for learning purposes and the models that can be used to support practice.

For students that attend the live events or watch the recordings, they perceived that IWBs supported their learning and they benefitted from understanding their

assignments as well as experiencing the broader notion of what it means to 'do science or technology' and what it looks like to be a scientist or a technologist. One of the added benefits is that in addition to pre-recorded video clips of laboratory settings and equipment, the IWBs give the students a real-time, personal, close-up seat in the actual laboratory or field and offers additional interactivity and connectedness that might not be experienced otherwise. There is no empirical evidence to show that students learned a specific component(s) of a subject as there was no measurable assessment or pre/post-test associated with IWBs. An assumption can be made that the students who regularly attend tutorials are more likely to be the ones that attend IWBs and report positive benefits. However, the challenge is encouraging students who do not participate in either mode and who may be susceptible to isolation, alienation and student withdrawal.

In closing, Chapter 6 discusses the contribution of this research and recommendations for practice. It also outlines the limitations of the research and directions for future work.

6 Conclusions and future work

The aim of this thesis was to investigate how large-scale, IWBs are used in five undergraduate practical science and technology modules at The Open University. The study investigated the purposes for using IWBs, as well as the strategies and types of interactions that staff and students used to engage and interact with one another. It also examined how the IWBs influenced students' learning, motivation and SoC. The final chapter of this thesis is divided into three sections. The first section will summarise the key findings, discuss the research study's contributions and outline some recommendations. The next section explores the study's limitations. The chapter concludes with some suggestions for future research.

6.1 Synthesizing the findings

The findings of this study are summarised below. The study clarifies the pedagogic aspects of using IWBs by evaluating the reasons for using them and the ways they benefit the stakeholders who use them, which had not been clearly articulated or studied in the OU context before.

The first key finding is that the overarching purpose for module teams use of IWBs is to foster student engagement to support students' engagement with practical lab and fieldwork. The pedagogical approaches of using IWBs to introduce real-world contexts and authenticity were equally important as well as establishing a connection to the module team and other staff. Presentations of real-world collaboration and research, and expert lecturers were highly regarded and well received. Module teams perceive student engagement as core for students to maintain interest and motivation.

Presenters and moderators demonstrated communicative strategies that encouraged participation, reassured students on learning activities and created a psychologically safe environment for learning and social interaction. The tutors in this study also perceived student engagement as paramount and contributed to promoting IWBs to their tutorial groups.

The module teams and the technical production team maximise the medium's potential for deeper student engagement. The implications are that these top-level purposes stimulate social interaction, assist students in applying theory to practice and engage them in a wider learning community. Communicative behaviours and

strategies that help bridge the 'distance' between presenters and their remote audience are intrinsically aligned with the greater module aim. As a result of this new insight, module teams should leverage and continue to find ways to include affective strategies into their presentations, in addition to imparting factual, conceptual and procedural knowledge. As the findings revealed, students responded favourably to various approaches so these planned communicative strategies should be conscious pedagogical decisions.

The second finding relates to the students. The majority of students who attend live events or watch the recordings perceive IWBs as supporting their learning and understanding of practical activities, remote experiments, field investigations or project work. Students in Environmental and Physical Sciences, in particular, value the synchronised activities provided by IWBs and are motivated to make time to attend.

Students perceive IWBs as a valuable learning resource. They are curious enough to attend live or watch the recording and see the IWBs as an opportunity to interact, learn about their assessments and understand aspects of practical work. The purposes described above appealed to students' interests and expectations. Similar themes that demonstrate engagement were found across the student data set. For students who attended live events, they demonstrated engagement by staying connected throughout the broadcast and interacting with the widgets and the text-chat. Across the IWBs, students predominately engaged in social chat, indicating that the text-chat primarily serves a social engagement function. Knowledge building discourse is most likely when an IWB is actively moderated. Students reported cognitive and affective aspects of learning during the IWBs. They also reported that IWBs supported their learning, mitigated isolation and made them feel part of the wider STEM community.

Affective features of presence and personalisation are also important and recognised by students. Students appreciated being able to meet their lecturers. Students experienced SoC at the institutional, module and IWB levels. Attending or watching the recordings of IWBs was found to enhance a sense of belonging and nurture an emergent professional identity associated with their discipline.

6.2 Contribution of the research study

The contribution of this research is a richer empirical understanding of the use of IWBs to support practical lab and fieldwork across STEM disciplines. This thesis adds to our understanding of the ways IWBs have been used and applied in a distance, HE context and offers insights into the value and benefits IWBs bring to the stakeholders engaged in them. Specifically, this thesis contributes to the state of the art as discussed in the following:

The first contribution to knowledge is that the use of IWBs has positive impacts on professional teaching practices. This research found that staff who assist in the creation and presentation of IWBs feel a sense of involvement, collegiality and collaboration. The findings show that IWBs can facilitate cross-university collaboration and professional development opportunities and enable module teams to try new approaches. This further adds to our understanding of peer support and professional development in a technology-mediated learning environment.

The second contribution is that module teams' strategies and approaches are primarily affective. The purposes and aims for using IWBs are to facilitate student engagement, foster a SoC, demonstrate authenticity and real-world contexts. Their strategic approaches aid in establishing the right tone and climate for social interaction and encouraging and promoting student participation during and after the IWB. These approaches stimulate social interaction and students respond positively.

The third contribution is that IWBs, and the ways in which they are used, mitigate feelings of isolation for DL students. As discussed in Chapter 2, (Section 2.4.1, p.18), isolation is one of the main barriers for distance learners. This study found that the majority of students that attended live events reported the IWBs as being useful in reducing isolation during their module. This further adds to our understanding of the use of effective design and pedagogical strategies that promote engagement and connectedness that help mitigate students' feelings of isolation.

6.2.1 Guidelines for planning and implementing IWBs

The following are proposed guidelines for effective strategies in an IWB environment, which are linked to the research findings. This sub-section is relevant for the technical production and module teams who design and present the IWBs.

1. Include an active moderator that is familiar with the subject matter. If this is not possible, consider ways of providing students with the opportunity to ask questions and raise issues that can then be addressed or discussed before or during the IWB.

2. Factor in a specific timeframe to revisit a poll or allow for a change in voting (as in SXHL288 and S206).

3. Advertise the IWBs. Provide a clear, brief description of what the IWB will cover on the students' module website. Consider doing this in the form of a short video.

4. Involve ALs in IWBs by inviting them to participate (e.g., moderate the text-chat box) early in the design process.

5. During the welcoming stage, include a slide or other textual format of the IWBs aims, as well as 2 – 3 measurable learning outcomes, to help students anticipate what they will gain from the experience.

6. At the end of each Labcast, use feedback widgets to evaluate students' engagement and understanding, and report the results to the audience (as in SXPS288).

6.2.2 Guidelines to foster engagement in IWBs

The following are some suggested guidelines for presenters and moderators in several effective strategies based on the research findings:

1. Assure students on using the synchronous tools that work best for them (e.g., as in TM129). Recognise that multitasking in a media-rich environment might be overwhelming for some students, resulting in disengagement.

2. Offer clarity early on the differences between the Adobe Connect and the Stadium Live platform so students are clear of the tools and the anonymous nature of voting.

3. Emphasise the interactive and personable nature of the IWBs by using phrases such as "you can talk to us through the text-chat" (as in SXHL288 and S206).

4. Use inclusive language and humour where appropriate and include some self-disclosure remarks (e.g., "when I did my degree…") to connect with the audience.

5. Use voting and polling tools to make important or interesting decisions to provide students with a voice or choice within the event (e.g., as in S206 and S315).

6. Bring in a guest expert to discuss issues in real-time with pre-set questions or spontaneous discussion.

6.3 Limitations

There are certain limitations to the study because the research context is unique to a single institution. Further research is required to determine whether the findings are relevant or transferable to institutions that use a comparable technology-mediated delivery system. The study was also impacted by some common issues that can often encroach on the practice of social research in education.

The questions were answered using a qualitative mixed methods design, and data collection was negotiated with module team chairs. Negotiating approval to attend rehearsals, access to students, the opening and closing of surveys, distributing questionnaires and reminders was via 'gatekeepers', namely the module team chairs, and curriculum managers. This proved to be unproblematic in the majority of cases, however there were situations where those tasks were executed late and therefore may have affected response rates.

While the focus groups and interviews provided rich data and provided a range of views across the cases, the absence of some participants did limit further conclusions that could be drawn. For example, only seven students across modules: S206 'Environmental sciences' and SXPS288 'Remote experiments in physics and space' agreed to participate in interviews. Negotiations were made with the 'Technologies in practice' module team who opted for collection of student questionnaire data rather than interviews. One module team participant, out of a potential five, was available for an interview in SXHL288 'Practical Science: biology and health'. Although the participant is well versed in labcasting within chemistry modules, the collective voice of the SXHL288 module team is absent. In addition, there were no AL voices except for in the S206 'Environmental Sciences' and SXPS288 'Remote Experiments in Physics and Space' modules.

Survey responses were particularly low in S315, SXHL288 and TM129-20B. Although, The OU typically has low return rates of questionnaires, the response rates limited the

findings in being able to obtain more satisfactory results for the research project and to make comparisons of presentations (e.g., between TM129 in 2019 and 2020). The Chemistry module S315 was the only level 3 module in the study. With no take-up in the S315 student focus group and only 3 out of 47 questionnaire responses received, there is an absence of the student voice, in particular the female voice. Obtaining the perspectives of students at this level who are nearing the end of their degree would have been insightful. The incorporation of feedback widgets, to collect real-time feedback towards the end of an IWB, was restricted to three (e.g., TM129, SXPS288, S315) out of the five modules. As such, the students' opinions on perceived learning gains in the moment was not captured, which could have provided additional triangulation of the findings across other student data sets.

Another limitation to consider is the characteristic difficulties that can be encountered in survey research (Bryam, 2016). The respondents and participants were self-selecting, so they may have been more driven to engage with the questionnaire and be more knowledgeable about the topics and issues of their module and IWBs. The questionnaire items were devised to be relevant to the students on different modules so that a comparison could be made. However, the questions might be viewed differently or be less relevance to certain groups of students which points to the problem of meaning and interpretation. An example is a question on whether IWBs helped to support working in groups, which would only be relevant to those that had compulsory group work as part of an assessment. The research was also constrained because of the number of times a reminder can be sent to students to complete a survey. This is a university and module policy and was therefore outside of the researcher's capacity to make multiple contact attempts. This was mitigated, where possible, by using other data sets such as the text-chat transcripts or feedback widgets, where available, to answer the questions.

Analysing video transcripts and text-chat datasets were particularly challenging. This is because it was difficult to compare the timestamps of the broadcasts and the timestamps of the text-chat due to variations in the buffering of the video. This made it difficult at times to know exactly when and what the students were commenting on in each action. One way of mitigating that issue was to look at broader patterns of interaction and engagement in the transcripts as opposed to minute detail. By looking

for patterns, this also facilitated looking across the video and text-chat transcripts so as to have a uniform analysis of the module cases.

Drilling down into detailed interaction is equally important. In addition, the FIAC protocol as a coding scheme to analyse interaction and talk was difficult to implement in an IWB context with multiple actors and actions. While it did produce some useful findings on the frequencies of those that respond and initiate, it does not account for the multiple interaction patterns in an IWB. Therefore, the FIAC should continue to be revised to fit each context appropriately.

Lastly, the Covid-19 pandemic had a significant impact on several module presentations. Labcasts in TM129 (2019), SXHL288 and S315 were cancelled due to the pandemic and field trips in SXF206 were cancelled. Staff focus groups that were originally intended to run in a face-to-face context were moved online. Student interviews were also conducted online during this time. It is difficult to determine whether unfavourable or low responses were caused by the impact of the pandemic on students' study and the cancellation of IWBs and field schools in those modules that cancelled or used pre-recordings.

Future work

IWBs supports the cognitive as well as the social aspects of learning. In building on the contributions made by this thesis, understanding further how stakeholders can benefit from using such an intervention would be key. For example, *how does participating in IWBs support new academics in their professional development of teaching the sciences at a distance?* This could extend the research community's knowledge on what is known of standard training protocols of new lecturers. A study on this particular group of people could further extend our knowledge of teaching practice with technology-mediated systems and useful pedagogic strategies.

Another area of interest is in understanding the student experience. This thesis has established that IWBs support students' learning and understanding of specific scientific concepts, processes and practices. A comparative study on *the extent to which IWBs impact students' marks from assignments as it relates to practical science (or other disciplines)* would be of interest, whereby one group could be treated with the intervention of an IWB and the other with another means of learning the same

material. This could be conducted on a non-assessed learning activity or as part of a research study.

Finally, this thesis has established that IWBs can mitigate isolation. Another side of the coin is the concept of retention so investigating *how IWBs support student retention* could be valuable as a means of relating students' sense of community and belonging directly to retention and progression.

6.4   Conclusion to this chapter

The research concludes that IWBs are effective in fostering DL students' engagement with practical lab and fieldwork. Real-time engagement in practical scientific experiments, technological practises and field investigations aids student understanding of theory, concepts and principles, while also allowing lecturers to become more personable and relatable to the study body. The module teams purposes for using IWBs and their communicative strategies to interact and engage with students underpin student engagement. Students find value in IWBs and engage with them. However, the IWBs could be better advertised to give more students the opportunity to engage with them. This research contributes to a better understanding of the processes of planning and implementing IWBs and the impacts of the IWBs on students' engagement, learning, SoC and staff members' professional teaching practices. As HEIs and other educational providers continue to shift to online delivery, this research has broader applicability outside of the OUUK modules and can contribute to understanding pedagogic-driven planning and use of a comparable, synchronous technology-mediated delivery system.

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Appendix A: Example of a research design proposal

The Role of Interactive Web Broadcasts to Develop Online Learning Communities in STEM: a multiple case study

SXHL288-19J Evaluation study

Venetia Brown

Project aims

The purpose of this research is to evaluate the different ways that the interactive broadcasts (i.e., labcasts and fieldcasts) have been used in modules across the STEM disciplines. The project will investigate the extent to which the interactive, fieldcasts influence students' sense of community, motivation and support learning. Findings will be used to develop a set of guidelines and recommendations to inform the use of interactive broadcasts in STEM. The study will investigate four research questions:

RQ1. What are the module teams' purposes for using interactive broadcasts?

RQ2. What strategies do the presenters, moderators and tutors participating in broadcasts apply to engage and interact with students, and how do these strategies contribute to the students' sense of community?

RQ3. In what ways are students using the widgets and text-chat features to interact with presenters and with each other, and how does participating in broadcasts affect their learning?

RQ4. What motivates students to participate and/or engage with the interactive broadcasts and what prevents students' participation and/or engagement with the interactive broadcasts?

Evaluation aims

The specific aims for this study will be to:

EA1. explore the experiences and perspectives of module team members on the purposes of labcasts

EA2. explore presenters' communicative and teaching strategies used in labcasts

EA3. observe the production and presentation process of labcasts

EA4. compare students' participation in labcasts with students' participation in fora (i.e., tutor group, topic and skills development forums)

EA5. observe student interactivity with the synchronous tools during the labcasts

EA6. survey students on their participation, sense of community and motivation to engage with the labcasts

Methodology

The project will use a mixed-method research approach to expand quantitative results with qualitative findings. A case study design will allow me to collect data through various methods and study multiple units within the case (i.e. the module); showing the differences and similarities among the other cases.

Methods

Observations

<u>Live events</u>

Direct observation of labcast production and presentation processes will be conducted on the 24th Oct, 10th Dec, and 19th Mar 2020. Observational notes and comments from the production team and the presenters will be collected to help form descriptions of the presenters' and moderator's communicative and teaching strategies.

<u>Stadium Live data logs</u>

Data logs will be extracted from the Stadium Live platform to analyse and summarise student interactivity (i.e., unique users in live event, interactive users, number of chat room posts etc.) with the widgets and text-chat. It would be of interest to conduct a content analysis on the text-chat[1] to identify ways students and moderators interact with each other and to identify social presence - a strong indicator of connectedness and sense of community. The platform and discussion data will be validated further through subsequent interview and questionnaire methods.

Secondary data

Subject to the curriculum manager's agreement, internal reports (e.g. SEaM, module VLE activity charts) will be collected to compare students' participation in labcasts and in forums. It would be useful to know who the students are attending tutorials, participating in forum discussions and attending labcasts. Data will be collected after the final labcast and will be validated further through subsequent interview and questionnaire methods.

Staff Focus Group

Depending on staff availability, face-to-face or online focus group interviews will be conducted with the presenters, moderators, production team members, associate lecturers and curriculum manager. Interviews would provide an opportunity to explore the experiences and perspectives of staff regarding the labcasts.

Examples of the type of questions might be: *What were the reasons for including labcasts in this presentation? How do you feel the labcasts support students' understanding of the assessment? How did you use the question-and-answer format in the SXHL288 labcasts? What strategies did you use to encourage student engagement with the widgets and chat?* Data will be collected after the labcasts in March 2020 and will help to understand if students are getting what the module team intended.

Student online questionnaire

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[1] Access to student data and analytics is generally covered by overarching OU regulations

An online questionnaire with a sample population will be used to collect information on students' perspectives regarding their participation, sense of community and motivation on the labcasts and other module learning activities.

The questionnaire will include closed and open-ended questions. Examples might be: *please indicate your level of agreement with the following statements: I found the labcasts helped my understanding of the online practical activities? I feel the labcasts helped my confidence in the collaborative activities? I feel connected to others in this module?* Questions will also be designed to understand student participation with the forums.

Sampling strategy will use a structured sample of the student cohorts across four groups to select: 1) students who were 'live users' and watched the recording; 2) students who were 'live users' but didn't watch the recording; 3) students who weren't 'live users' but watched the recording and 4) students who neither watched the live or the recording. Data collection will be collected in week 29, approximately 10th May 2020.

Student Focus Group

Approximately 15 students who volunteer will be asked to discuss their motivations and perspectives on the module and labcasts. I will run three groups with five students on the SXHL288 module. Questions will be explored through themes (e.g., studying the module, reasons for watching live events or recordings, attending the laboratory school and sense of community). Data will be collected during the residential school SS022 – laboratory skills for biology and health in June 2020.

Data collection matrix

Research questions	Evaluation Aims	SXHL288-19J Practical Science: biology and health				
		staff focus group	observations	Secondary data	student	student focus group
RQ1.	EA1	●				
RQ2.	EA2., EA3	●	●			
RQ3.	EA5., EA6		●		●	
RQ4.	EA4., EA6		●	●	●	●

Appendix B: Student participant information sheet

The Role of Interactive Web Broadcasts to Develop Online Learning Communities in STEM

Research study participant information sheet

1st Oct 2019 About me

I'm a second-year research student based in the Knowledge Media Institute (KMi) at the Open University. My background is in education, primarily English language teaching and adult literacy. I have taught in higher education institutions and have experience of supporting students through learning technologies.

I would like to invite you to take part in a research study that I am conducting as part of my research for a Doctorate of Philosophy (PhD). Before you decide whether to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. If you have any questions or concerns, please do get in touch with me at venetia.brown@open.ac.uk or my lead supervisor, Dr Trevor Collins at trevor.collins@open.ac.uk

What is the purpose of the study?

I'm researching the different ways that the OpenScience web broadcasts (i.e. labcasts and fieldcasts) are being used in STEM modules to support OU students. The web broadcasts allow lecturers to conduct live experiments and connect with students via live web streaming, instant messaging and polling widgets.

I would like to understand the factors influencing student engagement and to what extent the web broadcasts may (or may not) enhance students' sense of community and support their learning. I am interested in understanding what students find helpful about them, and what could be done to improve them. Even if you didn't attend any of the live broadcasts or watch the recordings, I am interested in hearing about your experiences on the module. I will be using a mixed-methods research approach to explore the motivations, online interactions and perspectives of students, module staff and tutors in the different STEM disciplines. By gathering feedback from OU students, my research will develop a better understanding of how the broadcasts are being used, what impact they are having, and what could be done to improve the use of labcasts and fieldcasts in future module presentations. You have been sent this information as your current module includes field or labcast-based learning activities.

The study is being conducted by myself, Venetia Brown and supervised by Dr Trevor Collins and Professor Nicholas Braithwaite. This research has been approved by the OU Human Research Ethics Committee (HREC).

What will I be asked to do if I agree to take part?

If you agree to take part, I will ask you to complete an online questionnaire. I am interested in hearing your views on this important subject, and this approach will help you to complete the survey conveniently and confidentially. The questionnaire will take no more than 20 minutes.

I will also ask some students to volunteer to take part in a short one-to-one online interview or a focus group discussion. Focus groups involve more than one student, and your opinions will be shared with others in the group. Interviews may be either 1) online via Adobe Connect or Skype and will include a small group of 4 -5 students on the module or 2) at a residential school that you attend as part of your learning activities on the module. The online interview or focus group will be a discussion on your perspectives on the web broadcasts and will be audio-recorded. I might quote some of your responses in my research, but I will not identify you in any publication or feedback to the module team.

My research will also involve observing the widgets and chatbox responses from the S206 fieldcasts events that are being broadcast in February 2020. I will extract this data from the Stadium Live platform. This will help me gather data and analyse the interactions among students and between the module team and students. Any personal information used from the chat dialogue will be fully anonymised, meaning your name will be replaced with a code. Anything that identifies you will not be used. The chatbox is only active in the live labcasts and is not part of the 'catch up' recordings.

It is up to you to decide whether to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you choose to take part, you are still free to withdraw at any time and without giving a reason. Choosing to either not take part or take part in the study will have no impact on your marks, assessments or future studies.

Your input will help to inform the STEM faculty's decision-making about the use of labcasts and fieldcasts in modules and to understand how effective labcasts and fieldcasts are and how they can best support student engagement and interaction.

How will the data I provide be used?

Any personal information you provide will be treated in the strictest confidence. All research data from surveys and observations will be managed following GDPR and the OU's requirements. The data will be stored on the OU's secure server, and all files will be encrypted. The data will be held for the duration of my doctoral studies and stored one year after the end of the research project (the latest date is July 2021). No personal identifying information will be used, and quotes will be anonymised and paraphrased where necessary.

Personal information will be collected through an online survey. JISC survey software complies with the UK/EU data protection regulations. Signed consent forms will be encrypted and stored on secure servers for the duration of the research project. Research findings may be disseminated through educational conferences and publications. All data will be anonymised, as mentioned above, to ensure confidentially.

Your right to withdraw from the study

You have the right to withdraw from the study at any time during your participation. You also have the right to ask for your data to be removed after your participation in the study by contacting the researcher at venetia.brown@open.ac.uk up until the time all data have been anonymised.

How do I agree to take part?

If you would like to participate, please tick the boxes to opt-in for the study on the Informed Consent form and email a copy to venetia.brown@open.ac.uk

Thank you for taking the time to read this leaflet and please remember to keep a copy of it should you decide to take part.

Best wishes,

Venetia Brown

PhD research student

Knowledge Media Institute

The Open University, UK

Appendix C: Invitation email to student cohorts

Subject: [module code] Interactive Labcasts: The Open University would value your feedback

Dear [STUDENT NAME],

Now that you have submitted your EMA for [module code], I am writing to ask if you would be willing to participate in a survey to enable us to understand how useful you found the interactive labcasts during this presentation. I would like to introduce you to Venetia Brown, who is working on a research project examining labcasts across the STEM curriculum.

Venetia is a second-year PhD research student at The Open University in Milton Keynes. For her research, she is studying the different ways that labcasts (i.e. the interactive broadcasts from the OU labs) are being used in STEM modules to support OU students. Venetia would be grateful if you could complete a short feedback questionnaire about your experiences of the three labcasts on [module code].

She is particularly interested in understanding factors influencing student engagement with the labcasts, what students find helpful about them, and what could be done to improve them. Even if you didn't attend any of the live labcasts or watch the labcast recordings, she is interested in hearing about your experiences on the module. By gathering feedback from OU students, this research will develop a better understanding of how the labcasts are being used, what impact they are having, and what could be done to improve the use of labcasts in future module presentations.

An information sheet that describes her research project is attached to this email. If you are willing to provide some feedback based on your experiences in [module code], please read through this information sheet and then click on the link below to access the online questionnaire. [questionnaire link]

I appreciate your engagement with this and hope that we can use the feedback you provide to develop the interactive student experience for future students.

Kind regards,

[module code] Module Team Chair

Appendix D: Consent form

Human Research Ethics Committee

Informed Consent for Research Project: The Role of Interactive Web Broadcasts to develop Online Learning Communities in STEM

Venetia Brown, PhD Research Student, Knowledge Media Institute, Faculty of STEM

Please tick the appropriate boxes   Yes   No

1. Taking part in the study	Yes	No
I have read and understood the study information dated 08/06/2020. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I have the right to ask for my data to be removed after my participation in the study by contacting the researcher at venetia.brown@open.ac.uk up until the time all data have been anonymised – this is expected no later than August 2020.	☐	☐
I understand that taking part in the study involves providing commentary on my opinions of the labcasts and lab-based activities on [module code].	☐	☐
I agree to participate in an audio-recorded interview. I understand that any personal information, such as names, collected through the discussions, will be anonymised.	☐	☐
	☐	☐

I agree to my text-chat responses, if I contributed during a live Labcast or Fieldcast to be anonymously analysed.	

2. Use of the information in the study

I understand that the information I provide will be used for the researcher's thesis and educational conferences and publications. I understand and agree that my data can be quoted in research outputs.

I understand that my data will be stored on the OU's secure server, and all files will be password protected. Data will be anonymised before and after transcription. Audio recording files will be securely deleted after transcription. The anonymised data will be held for the duration of the researcher's doctoral studies and stored one year after the research project- this is expected no later than July 2021.

4. Signature

Name of participant	Signature (electronic)	Date

Please email this form to venetia.brown@open.ac.uk. This research project has been reviewed by Dr Claire Hewson, and received a favourable opinion, from the OU Human Research Ethics Committee - HREC reference number: 3413. http://www.open.ac.uk/research/ethics/

Student Experiences of SXPS288-19J Labcasts

Student Experiences of labcasts

Thank you for answering the following questionnaire.

Purpose

Labcasts are interactive web broadcasts that have been used on SXPS288 to introduce students to the module, explore the scattering of X-rays from electrons, demonstrate the gas cell experiment as part of the Mars atmosphere investigation and present the design of instruments for space missions with a NASA mission specialist. These broadcasts are also available as recordings after the live events through the module website.

This questionnaire is part of a PhD research project which is exploring the role that labcasts can play in supporting students' learning and enhancing a sense of an online learning community. I would like to know how valuable the labcasts have been to you and find out your experiences of the live labcasts and labcasts recordings, and whether you did (or did not) find them useful to your learning. Your responses will help inform the STEM faculty's use of labcasts and how they can best support student engagement and learning.

Participation

Completing the questionnaire is entirely voluntary and your participation or nonparticipation will not be linked to, or impact upon your studies in any way. The questionnaire should take no longer than 20 minutes.

Consent

Completing the questionnaire confirms that you give consent for the researcher to use the data that you provide (i.e., your responses to the questionnaire) as specified in the following paragraph.

Data Protection

The data you provide (i.e., your responses to the questionnaire) will be processed and stored in accordance with The Open University's Student Privacy Policy. Raw data will be seen only by Open University staff. Aggregated anonymised data will be used for research and quality improvement purposes at The Open University and may be published in the researcher's PhD thesis, academic journals or in other educational contexts. You may withdraw your data at any time until the data is aggregated.

Accessibility

If you have a disability or an additional requirement that makes it difficult for you to complete the questionnaire online, please email the researcher at venetia.brown@open.ac.uk

If you have any questions relating to the questionnaire, please do not hesitate to contact me at venetia.brown@open.ac.uk

The questionnaire has been designed for use on a standard computer (desktop or laptop). Full accessibility on a handheld device (such as a smartphone or tablet computer) cannot be guaranteed.

Please make sure you complete all the survey in one go as your responses aren't recorded until you reach the end of the survey. Your original responses aren't saved if you close the browser window half-way through and you will need to start again.

Your contribution is very much appreciated.

Venetia Brown

Knowledge Media Institute

The Open University, UK

venetia.brown@open.ac.uk

Consent to take part in questionnaire

Please read the below consent statements. If you agree, select Yes to complete the survey.

- I voluntarily agree to participate in this research study.

- I understand that I can withdraw permission to use data from my questionnaire within two weeks after completing the survey, in which case the material will be deleted.

- I have had the purpose and nature of the study explained to me in writing and I have had the opportunity to ask questions about the study.

- I understand that participation involves answering questions about my experience of labcasts on SXPS288 at the Open University.

- I understand that the chat responses during the live labcasts via Stadium live will be anonymously analysed.

- I understand that any information I provide for this study will be treated confidentially.

- I understand that the questionnaire responses will be stored securely for the duration of the research project (up until July 2021) and kept confidential in accordance with GDPR regulations.

- I understand that I am free to contact the person involved in the research to seek further clarification and information.

1. I have read the consent statements and agree to participate in this survey. ⍰

Required

- ○ Yes
- ○ No

Your OU Computer Username (OUCU)

2. PleaseaddyourOUCUnumberbelow ⬚ *Required*

[   ]

Watching the live labcasts

3. Did you attend any of the live labcast events for SXPS288 (i.e., when they were being broadcast)? ⬚ *Required*

○ Yes

○ No

About the live labcasts

4. How useful did you find the opportunity that the live labcasts provide for the following: ⬚ *Required*

Please don't select more than 1 answer(s) per row.

Please select at least 10 answer(s).

	Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
Meeting your lecturers and other members of the module team at the start of the module	☐	☐	☐	☐	☐
Listening to explanations and discussions between presenters	☐	☐	☐	☐	☐

Feeling like you are 'really there' in the laboratory	☐	☐	☐	☐	☐
Reducing isolation during your study on the module	☐	☐	☐	☐	☐
Making the study material more personable	☐	☐	☐	☐	☐
Discovering how scientific concepts are practised in real-world situations	☐	☐	☐	☐	☐
Answering the presenter's questions using the widgets	☐	☐	☐	☐	☐
Asking questions in the chatbox	☐	☐	☐	☐	☐
Contributing to answering questions in the chatbox	☐	☐	☐	☐	☐
Contributing to social talk in the chatbox	☐	☐	☐	☐	☐

5.   If you have attended one or more labcasts live, please indicate your level of agreement with the following statements: ☐ *Required*

Please don't select more than 1 answer(s) per row.

Please select at least 5 answer(s).

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
The labcasts have supported my understanding of the remote experiments	☐	☐	☐	☐	☐
The labcasts have helped me to work with others to explore physics and astronomy	☐	☐	☐	☐	☐
The labcasts are not pitched at the right level for me to understand	☐	☐	☐	☐	☐
The labcasts have supported my understanding of specific skills and knowledge that helped me in my TMAs	☐	☐	☐	☐	☐
The labcasts made me feel part of a scientific learning community	☐	☐	☐	☐	☐

6. If you have attended one or more labcasts live and interacted with the widgets, please indicate your level of agreement with the following statements:

Please don't select more than 1 answer(s) per row.

Please select at least 6 answer(s).

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
I like using the widgets to answer the presenter's questions	☐	☐	☐	☐	☐
I like that the widget responses are anonymous	☐	☐	☐	☐	☐
I feel more engaged in the labcast when I use the widgets	☐	☐	☐	☐	☐
Using the widgets is a good way to test my knowledge	☐	☐	☐	☐	☐
I find the widgets a distraction	☐	☐	☐	☐	☐
There should be a wider variety of widget questions	☐	☐	☐	☐	☐

7.   If you have any other comments on what you liked or disliked about the live labcasts,

pleasetypetheminthespacebelow

8. Did you also watch the recording(s)?

○ Yes

○ No

About the labcast recordings

9.   If you have watched one or more of the labcast recordings, please indicate your level of agreement with the following statements: ⬚ *Required*

Please don't select more than 1 answer(s) per row.

Please select at least 3 answer(s).

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
I liked being able to watch the recording at a convenient time	☐	☐	☐	☐	☐
I found it useful to pause or replay parts of the recording	☐	☐	☐	☐	☐
I found it useful to revise for my TMAs	☐	☐	☐	☐	☐

10.   If you have any other comments on what you liked or disliked about the recordings,

pleasetypetheminthespacebelow

11.   Whatwouldmaketherecordingsmoreusefulforyou?

12.   Didyouwatchanyofthelabcastrecordings?

○ Yes

○ No

13.   How useful did you find the opportunity that the recordings provide for the following:⬚ *Required*

Please don't select more than 1 answer(s) per row.

Please select at least 4 answer(s).

	Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
Seeing your lecturers and other members of the module team during the module	☐	☐	☐	☐	☐
Listening to explanations and discussions between presenters	☐	☐	☐	☐	☐

Making the study material more personable	☐	☐	☐	☐	☐
Discovering how physics and astronomy is practised in real-world situations	☐	☐	☐	☐	☐

14. If you have watched one or more of the labcast recordings, please indicate your level of agreement with the following statements: ⃞ *Required*

Please don't select more than 1 answer(s) per row.

Please select at least 5 answer(s).

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
The labcasts have supported my understanding of the remote experiments	☐	☐	☐	☐	☐
The labcasts have helped me to work with others to explore physics and astronomy	☐	☐	☐	☐	☐
The labcasts are not pitched at the right level for me to understand	☐	☐	☐	☐	☐
The labcasts have supported my understanding of specific skills and knowledge that help me in my TMAs	☐	☐	☐	☐	☐
The labcasts made me feel part of a scientific learning community	☐	☐	☐	☐	☐

15. If you have any other comments on what you liked or disliked about the recordings,

pleasetypetheminthespacebelow

[   ]

About the labcast format

16. Overall, please rate how you feel about the labcasts on a scale from 1 to 5 where 5 is the highest. ⓘ *Required*

Please don't select more than 1 answer(s) per row.

Please select at least 7 answer(s).

	1	2	3	4	5
Being in real-time with students and the presenters	☐	☐	☐	☐	☐
Presenters creating an interest in the topic	☐	☐	☐	☐	☐
Ease of using the Stadium Live interface	☐	☐	☐	☐	☐
The live demonstrations	☐	☐	☐	☐	☐
Asking questions and getting answers	☐	☐	☐	☐	☐
Pace of delivery	☐	☐	☐	☐	☐
Length of time	☐	☐	☐	☐	☐

About the live labcasts and the recordings

17.   Please select the reasons why you **did not** watch the live labcasts (i.e., when they

werebeingbroadcast) Selectallthatapply

- [ ] Ididnotknowaboutthelabcasts
- [ ] Icouldnotfindthelinkonthemodulewebsite
- [ ] Idonotfindthelabcastsuseful
- [ ] Iprefertostudyindependently
- [ ] Lackoftime
- [ ] Thebroadcasttimesdon'tsuitme
- [ ] Mybroadbandspeedistooslow
- [ ] I'mbehindwithmystudies
- [ ] Technologyproblems
- [ ] Other(pleasespecify)

17a. IfyouselectedOther pleasegivefurtherdetailsinthespaceprovided

17b. Pleaseselectthereasonswhyyoudidnotwatchtherecordings Selectallthat apply

- [ ] Ididnotknowaboutthelabcastrecordings
- [ ] Icouldnotfindthelinkonthemodulewebsite
- [ ] Idonotfindthelabcastsuseful
- [ ] Iprefertostudyindependently
- [ ] Lackoftime
- [ ] Mybroadcastspeedistooslow
- [ ] I'mbehindwithmystudies

□

Technologyproblems

□

Other(pleasespecify)

17b. Ifyouselected Other, pleasegivefurtherdetailsinthespaceprovided

18. Please describe what would make it easier for you to engage with the live labcasts

orrecordings

About your understanding of the Planetary science: Mars atmosphere block

In week 20, you learned how to plan, calibrate and carry out your own remote experiments in the Gas Cell laboratory using infrared spectroscopy.

These questions are about the planetary science project, gas cell experiment and the associated labcast.

19. Overall, to what extent was the labcast useful in understanding of the following: ⍰

Required

Please don't select more than 1 answer(s) per row.

Please select at least 2 answer(s).

	Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
Planetary science project	☐	☐	☐	☐	☐
Gas cell experiment	☐	☐	☐	☐	☐

20. Please indicate your level of agreement with the following statements: ⍰

Required

Please don't select more than 1 answer(s) per row.

Please select at least 4 answer(s).

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
The labcast aided my understanding of what I needed	☐	☐	☐	☐	☐

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
to do in the experiment itself					
The project forums aided my understanding of what I needed to do in the experiment itself	☐	☐	☐	☐	☐
The Video 5.1 Introducing the Gas Cell clip on the module website did not aid my understanding of the infrared spectroscopy experiment.	☐	☐	☐	☐	☐
Support from my tutor was not helpful in completing this experiment	☐	☐	☐	☐	☐

21.   Please indicate which of the following, if any, added to the authenticity of the experiment. *Optional*

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

Please don't select more than 1 answer(s) per row.

Please select at least 4 answer(s).

Seeing the lecturers presenting in the Atmospheric Infrared Gas Cell Laboratory	☐	☐	☐	☐	☐
Hearing the valves of the gas cell experiment during the labcast	☐	☐	☐	☐	☐
Carrying out a remote operation of real apparatus	☐	☐	☐	☐	☐
Working with another student	☐	☐	☐	☐	☐

22. How important is it you that your experience mimics an authentic laboratory experience? Please rate on a scale where 1= Not at all important and 5 = Extremely important. *Optional*

Please don't select more than 1 answer(s) per row.

Please select at least 1 answer(s).

	1	2	3	4	5
Please select one	☐	☐	☐	☐	☐

About the SXPS288 module

The following questions ask about your feelings about the module. Read each statement carefully and select the box that comes closest to indicate how you feel. There are no correct or incorrect responses. Do not spend too much time on any one statement but give the response that seems to describe how you feel.

23. How do you feel about this module? Please indicate your level of agreement with the following statements: ☐ *Required*

Please don't select more than 1 answer(s) per row.

Please select at least 20 answer(s).

	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly agree
Students in this module care about each other	☐	☐	☐	☐	☐
I am encouraged to ask questions	☐	☐	☐	☐	☐
I feel connected to others in this module	☐	☐	☐	☐	☐
It is hard to get help when I have a question	☐	☐	☐	☐	☐
I do not feel a spirit of community	☐	☐	☐	☐	☐
I receive timely feedback	☐	☐	☐	☐	☐
Students on this module feel like a family	☐	☐	☐	☐	☐

I feel uneasy exposing gaps in my understanding	☐	☐	☐	☐	☐
I feel isolated in this module	☐	☐	☐	☐	☐

I feel reluctant to speak openly during tutorials	☐	☐	☐	☐	☐
I trust others in this module	☐	☐	☐	☐	☐
This module results in only modest learning	☐	☐	☐	☐	☐
I can rely on others on this module	☐	☐	☐	☐	☐
Other students do not help me learn	☐	☐	☐	☐	☐
Some students on this module depend on me	☐	☐	☐	☐	☐
I am given ample opportunities to learn	☐	☐	☐	☐	☐
I feel uncertain about others in this module	☐	☐	☐	☐	☐
My learning needs are not being met	☐	☐	☐	☐	☐
I feel confident that others will support me	☐	☐	☐	☐	☐

| This module does not promote a desire to learn | ☐ | ☐ | ☐ | ☐ | ☐ |

Helping us further with our research

I will be carrying out further research as a result of this survey and would like to interview a small number of students to hear more detail about their experiences with labcasts. If you would be prepared to support my research by attending a brief telephone interview, please select the option below and add your email address in the space. I hope to conduct these interviews in June 2020.

24. I am happy to be conducted to arrange a follow up telephone interview on my

experiencesofthelabcastsonSXPS288

○ Yes

○ No

25. Pleaseaddyouremailaddressifyouarehappytobecontacted

Thank you for your responses

Thank you for completing this questionnaire. Your responses are important to the university and will help inform the use of labcasts in future presentations of this module.

Appendix F: Student interview script

SXPS288 Remote experiments in physics and space – Labcast survey

Student interview script

Welcome

- Thanks for agreeing to this interview.

- My name is Venetia Brown. I am a PhD research student at The Open University in Milton Keynes.

- I conduct research into the ways fieldcasts and labcasts are used across STEM modules.

Introduction

- I'd like to talk to you about your experiences of the *labcasts* events that you attended/watched and any the remote experiments on the module this year.

Informed consent

- I am going to record this interview. I might quote some of your responses, but I won't identify you in any publications or feedback to the module teams.

- Are you happy for me to record the interview and begin? [confirm]

A. Your experience studying on the module

1. Can you tell me a bit about how long you've studied at the OU, and a little bit about your educational/professional background?

2. Can you briefly describe how it's been studying on the module? Elicit: Any challenging aspects e.g. subject knowledge/ studying via distance

3. How did you find the media (e.g pictures/HD video clips) on the module website?

B. Your labcast experience

1. Can you briefly describe your labcast experience?

2. Attending the live labcasts are optional, so what motivated you to attend them?

3. What did you learn about doing the physics of the Compton effect from the second labcast (Jan) and the 3rd labcast on the gas cell experiment in March?

4. [Prompt: Can you give me an example?]

5. How did the labcast aid your understanding of the experiment?

6. Did you feel involved in the experiment? In what ways?

7. Did you view the labcasts as a broadcast (i.e. to watch) or an opportunity to interact in real-time?

8. In what ways did the labcasts make you feel part of a learning community?

9. How does engaging with students and the teaching team in labcasts feel different to engaging with them in the online tutorials?

10. Did the labcast help to understand the structure of the module and how things were connected e.g. how project 1 related to project 2.

11. SXPS288 involves lots of mathematical equations. Did Alan do the math modelling on the white board help?

12. How did you feel about seeing the posters in labcast 2?

13. Did you use the labcast forum after?

14. You mentioned you watched the recordings, what specific things did you glean from the recordings [prompt: terminology, statistic/calculations, processes?]

C. The TMA and the labcast

1. Were there any specific things in the labcast that *helped your confidence* in writing up a TMA or Project?

    i. What do you think about this approach?

D. Your understanding of remote experiments

1. Do you feel as though you now have a good understanding of the process of scientific remote experiments?

    i. Prompt: Can you give me an example of something that improved your understanding?

E. Your understanding of a learning community

1. Do you feel a sense of belonging to the OU? [prompt why/why not]

2. How would you define an online learning community? [can you give me an example]

3. Do you feel labcasts help foster this sense of community?

4. In your opinion, what ways could the fieldcasts be made more attractive to students who typically do not watch the lives or the recordings?

F. Close

Thank you for answering my questions, I'll use the data from these interviews to develop a set of guidelines and recommendations to inform the use of fieldcasts in the module and across STEM

Do you have questions about the interview or the work that we've discussed?

Thanks for your time and good luck with your future studies and career.

Appendix G: Staff participant information sheet

The Role of Interactive Web Broadcasts to Develop Online Learning Communities in STEM

Research study participant information sheet

About me

I'm a third-year research student based in the Knowledge Media Institute (KMi) at the Open University. My PhD focuses on the role that interactive wen broadcasts play in enhancing students' sense of community. Engagement and learning within STEM modules.

I would like to invite you to take part in a research study that I am conducting as part of my study for a Doctorate of Philosophy (PhD). Before you decide whether to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. If you have any questions or concerns, please do get in touch with me at venetia.brown@open.ac.uk or my lead supervisor, Dr Trevor Collins at trevor.collins@open.ac.uk.

What is the purpose of the study?

I'm researching the role that the OpenScience web broadcasts (i.e. labcasts and fieldcasts) can play in developing distance learning students' sense of community within the STEM module cohorts. The web broadcasts allow lecturers to conduct live experiments and connect with students via live web streaming, instant messaging and question-and-answer widgets.

I would like to understand the ways in which you are using labcasts in [module code] and the strategies that are being used to interact and engage with the students during each labcast and how students many be responding. I intend to compare the effectiveness of the interactive broadcasting strategies adopted across several STEM modules in order to develop a set of guidelines or recommendations on the pedagogic and social features supported by these strategies. Using a mixed method research approach, the project will explore the motivations, online interactions and perspectives of module staff and students across the various STEM disciplines. You have been sent this information as you are part of the module staff involved in labcast-based learning activities.

The study is being conducted by myself, Venetia Brown and supervised by Dr Trevor Collins and Professor Nicholas Braithwaite. This research has been approved by the OU Human Research Ethics Committee (HREC).

What will I be asked to do if I agree to take part?

If you agree to take part, I will ask you to participate in an individual interview or a small face-to-face or online focus group. I am really interested in hearing your views on this important subject and this approach will help us to listen to the opinions of colleagues and respond to ideas and comments in the discussion. The discussion will involve more than one member of staff and your opinions will be shared with others in the group. The focus group will take no more than 1 hour. The focus groups will be conducted at a time and date that is convenient to you and will be moderated by myself. The discussion will be recorded for the purpose of note taking only. Notes will be shared with the participants after the discussion allowing participants to read and/or amend any personal comments made. Any personal information used from the discussion will be fully anonymised and anything that identifies you will not be used.

Before we start the discussion, I will ask your permission to record. I might quote some of your responses in my research, but I will not identify you in any publications or feedback to other module teams.

My research will also involve observation of live labcasts and fieldcasts and their recordings from the 18J, 19J and 20B presentations that were broadcast between Oct 2018 – Aug 2020. The observations will help me form initial descriptions of the presentations. Observational notes and comments from the production team and presenters will be collected to form descriptions of the planning and preparation phases such as the running order for the session, widget choice/design, objectives for the session and presenters' and moderator's communicative and teaching strategies.

System data logs will be extracted from the Stadium Live platform after each live event to analyse and summarise student interactivity (i.e. unique users in live event, interactive users, number of chat room posts, widget frequency etc.).Text-chat will be downloaded to conduct a thematic analysis to identify ways students and moderators interact with each other and to identify social presence - a strong indicator of connectedness and sense of community. The Stadium Live platform data will be validated further through subsequent focus group or individual interviews and student questionnaires.

It is up to you to decide whether to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time and without giving a reason.

Your input will help develop a better understanding of the effectiveness of labcasts. By participating in this research, the students will gain a further insight into the teaching support being developed through the OU's use of interactive broadcasts and will enable the module teams and developers to review and enhance the learning design and system.

How will the data I provide be used?

Any information you provide will be treated in the strictest confidence. All research data from focus group interviews will be managed in accordance with GDPR and the OU's

requirements. The data will be stored on the OU's secure server and all files will be encrypted. Audio recordings will be destroyed once fully transcribed. The anonymised data will be held for the duration of my doctoral studies and stored one year after the end of the research project (Jan 2021). No personal identifying information will be used, and quotes will be anonymised and paraphrased where necessary. Signed consent forms will be encrypted and stored on secure servers for the duration of the research project. Research findings may be disseminated through internal and external educational conferences and publications. All data will be anonymised as mentioned above to ensure confidentially.

Your right to withdraw from the study

You have the right to withdraw from the study at any time during your participation. You also have the right to ask for your data to be removed after your participation in the study by contacting the researcher at venetia.brown@open.ac.uk up until the time all data have been anonymised.

If you would like to participate, please tick the boxes to opt-in for the study on the Informed Consent form and email a copy to venetia.brown@open.ac.uk.

Thank you

Thank you for taking the time to read this leaflet and please remember to keep a copy of it should you decide to take part.

Best wishes,

Venetia Brown (PhD research student).

Appendix H: Staff focus group questioning route

Staff Focus Group: Questioning Route for [module code]

Welcome

- Set recording.

- Introduce self.

- Time involved.

- General purpose of the group.

- Overview of topic

Outline research objective and aims.

- Primary goal of today's discussion is to explore your experiences and perspectives on the labcasts/fieldcasts associated with the [module code].

- Research questions

    o What are the module teams' purposes for using interactive broadcasts?

    o What strategies do the presenters, moderators and tutors participating in broadcasts apply to engage and interact with students, and how do these strategies contribute to the students' (a) learning and (b) sense of community.

- Questions will be explored through five broad themes

    o Teaching/supporting students in the [STEM discipline], specifically [module code]

    o Labcasts/fieldcasts as situated in [module code]

    o Strategies used to engage and interact with students within labcasts/fieldcasts

    o Students' sense of learning community

    o Future labcasts/fieldcasts

- The results will be used to develop a set of guidelines and recommendations to inform the use of interactive broadcasts in STEM.

- Opportunity to add questions/further comments at the end.

Ground rules

- No right/wrong answers, only differing views.

- Talk to each other, one person speaking at a time.

- Recording the session for note-taking purposes.

Opening questions

- Can you introduce yourself; tell us how long you've worked at the OU and your role/experience in the [module code] labcasts? (Round Robin)

Middle

- Teaching/supporting students in the [STEM discipline]

- How many students started/finished the module? [Curriculum Mgr.]

- What were the factors that caused drop-out?

- What is the gender balance in cohort?

- What seemed to be the most challenging aspects for students? [All staff]

    o In terms of subject knowledge

    o In terms of studying via distance

    o In terms of student motivation

- What were the most challenging aspects for the associate lecturers?

- What were the most challenging aspects for labcast production?

- How were the module forums used in this presentation?

- Labcasts/fieldcasts as situated within the [module code]

    o What were the reasons for broadcasting the labcasts/fieldcasts at certain points in the module?

    o What do you feel were the most valuable aspects of the labcasts/fieldcasts for this cohort?

    o How did the different media in the VLE and labcast/fieldcasts elements complement each other?

    o In what ways do labcasts/fieldcasts help the confidence [elicit those who attend the residential schools, field-trips]?

- Strategies applied to engage and interact with students within labcasts/fieldcasts

    o Thinking back on your first experiences of presenting/moderating live, were there any social/emotional issues that you yourself encountered and if so how did you overcome them?

    o In the most recent 19J labcasts, could you describe the types of strategies or tactics you may have used to interact and engage students

    o Before the labcasts/fieldcasts, during and after labcasts/fieldcasts (elicit: widget, Q&A and chat strategies)

- Students and a sense of learning community

    o The OU has long had an ethos of building relationships and communities both through face-to-face and online spaces. We know that students studying at a distance can experience feelings of isolation, which can

cause disengagement and create barriers to learning. Creating a sense of community, where students feel connected to others can help mitigate those issues.

- o How would you define an online learning community?
- o In your opinion, to what extend does the OU as an institution help foster a sense of community among students and staff?
- o To what extend does teaching and learning outside labcasts on [module code] facilitate a sense of community?
  - From the perspective of the module team chair
  - From the perspective of the curriculum manager
  - From the perspective of the associate lecturer
- To what extend do live labcasts/fieldcasts facilitate a sense of community?
- Future labcasts
  - o If you could change one aspect of the way labcasts/fieldcasts were used, what would it be?
    - Widget design/flexibility
    - Type(s) of demonstrations/experiments
    - Stadium Live
    - Logistics
  - o In your opinion, what ways could the labcasts be made more attractive to students who typically do not watch the lives or the recordings?

End

- Summarise discussion (changes or additions)
- Final questions/comments anything missed?
- Next action: 1) to write up notes of the discussion and disseminate for participants to read, check and validate.
- Thanks and close.

Appendix I: AL focus group questioning route

Associate Lecturers' Focus Group: Questioning Route for [module code]

Welcome

- Set recording

- Introduce self

- Time involved

- General purpose of the group

Overview of topic

- Outline research objective and aims.

- Primary goal of today's discussion is to explore your experiences and perspectives on the fieldcasts.

- Research questions

  - What strategies do the presenters, moderators and tutors participating in broadcasts apply to engage and interact with students, and how do these strategies contribute to the students' (a) learning and (b) sense of community.

  - Questions will be explored through five broad themes

    - Tutoring students in [module discipline], specifically [module code]

    - Labcasts/fieldcasts as situated in [module code]

    - Strategies used to engage and interact with students in labcasts/ fieldcasts

    - ALs perspectives on how labcasts/fieldcasts support learning and assessment

    - Sense of community

  - The results will be used to develop a set of guidelines and recommendations to inform the use of interactive broadcasts in STEM.

  - Opportunity to add questions/further comments at the end.

Ground rules

- No right/wrong answers, only differing views.

- Talk to each other, one person speaking at a time.

- Recording the session for note-taking purposes.

Opening questions

1. Can you introduce yourself; tell us how long you've worked at the OU and what teaching experience you have had (i.e. internal/external to OU)? Round Robin

Middle

1. Tutoring students in environmental sciences

    A. In your opinion, what is the role of an AL?

    B. How has online tutorial provision influenced your teaching? [elicit challenges/benefits]

    C. How would you describe your teaching approach?

    D. What do you feel are your expectations of your student groups?

    E. What seemed to be the most challenging aspects for students?

        i. In terms of subject knowledge

        ii. In terms of studying via distance

        iii. In terms of student motivation

2. Labcasts/Fieldcasts as situated within [module code]

    A. Has your engagement or interest in labcasts/fieldcasts changed? [elicit examples]

    B. To what extent has labcasts/fieldcasts improved student engagement in

        i. Tutorials

        ii. Tutor-led field trips [if applicable]

        iii. Residential schools [if applicable]

3. Strategies applied to engage and interact with students within labcasts/fieldcasts

    A. In the most recent 19J labcasts, could you describe the types of strategies you may have used to interact and engage students (e.g. moderating the chat or in the forums)

4. ALs perspectives on how labcasts/fieldcasts on assessment

    A. How has labcasts/fieldcasts supported the understanding and development of students' learning or assessment

    B. What changes have you generally noticed with the TMAs or EMA?

        i. In terms of academic improvement

        ii. Motivation/confidence

5. Sense of learning community

    The OU has long had an ethos of building relationships and communities both through face-to-face and online spaces.

    A. In your opinion, what does community mean to you?

      B. To what extend does the OU as an institution help foster a sense of community?

      C. To what extend does tutorials facilitate a sense of community?

      D. To what extend do live labcasts facilitate a sense of community?

6. Summarise discussion (changes or additions)

Final questions/comments anything missed?

1. Next action: write up notes of the discussion and disseminate for participants to read, check and validate.

2. Thanks, and close.

Appendix J: Guest presenter interview script

Interview: Questioning Route for (NASA) participant

Welcome

- Set recording

- Introduce self

- Time involved

- General purpose of the interview

Overview of topic

- Outline research objective and aims.

- Primary goal of today's discussion is to further explore your experience and perspective of the Mars labcast

- Research questions

    o What are the module teams' purposes for using interactive broadcasts?

    o What strategies do the presenters and moderators participating in broadcasts apply to engage and interact with students and how do these strategies contribute to the students' (a) learning and)b) SoC

    o Questions will be explored through three broad themes

        ▪ Experiences of the Mars labcast

        ▪ Sense of learning community

        ▪ Future teaching of distance and online science

    o The results will be used to develop a set of guidelines and recommendations to inform the use of interactive broadcasts in STEM.

Middle

1. **Experiences of the Mars labcast**

    A. Have you done something similar before? [do you know of any institutions that use similar online formats to teach practical science?)

    B. What type of context would you usually do that type of presentation in? e.g. colleges, non-specialist, general public etc.

    C. You met with Kate and Ben during rehearsals/briefings

        i. How did you come up with assessment points (e.g. to ask questions during your presentation slides with Ben and Kate)

    D. How did you feel about the labcast?

E. How did you feel about the presentation being initially a one-way communication vs. two-way communication? [elicit ways it would be more responsive or interactive]

F. How did you feel about factoring in the 60 sec lag before feedbacking on widget responses?

G. There were lots of questions in the chat that Suzanne fielded, and you answered how did you feel about that section of the presentation?

H. What type of benefits might undergrad students studying physics and space benefit from in this type of live event?

I. The use of personal pictures of team but also at the end of yourself and family, why do you choose those?

2. Sense of learning community

The OU has long had an ethos of building relationships and communities both through face-to-face and online spaces.

A. In your opinion, how might these types of interactive broadcasts facilitate a sense of community between experts in the wider STEM community and students?

3. Future teaching of distance and online science (looking forward)

With the current situation, a few schools have adapted the live labcasts from the teaching-labs by using a combination of video conference calls (e.g. via Zoom), slides (mixing in content) or taken elements of previous labcast recordings that are broadcast live with live voice overs. This maintains the live feel to the event and having students engage with the widgets as normal.

▪ With that in mind, how do you see the teaching of practical science via distance or online?

End

▪ Final questions/comments anything missed?

▪ Thanks and close.

Appendix K: NVivo Codebook

The role of interactive, web broadcasting in STEM-Main study

Second iteration - main coding for types of strategies, interaction types, discourse types in labcasts and chatlogs. themes/categories for staff focus groups

Name	Description
Engagement	Overarching code of engagement SRQ1.1 - 1.3 fall under this parent node to capture purpose of use, communicative strategies.
Communicative Strategies	Based on FIAP interaction analysis for web broadcasts including own emerging codes relevant to context.
accepts feelings	Accepts and clarifies an attitude or the feeling tone of the students in a non-threatening manner.
accepts ideas	Accepts or uses ideas of students. NOT FOR WIDGETS Clarifying or building or developing ideas or suggestions by a student.
appreciation	Refers to phrases of thanking participants.
ask question	Code when presenters or moderators ask questions (widgets or interrogative) with intent students respond to. Includes rhetorical questions which students may answer.
criticises or justifies authority	Statements intended to change student behaviour from non-acceptable to acceptable pattern, stating why the presenter is doing what they are doing. Intended to produce compliance.

Name	Description
encourages participation	Statements and phrases which encourage student participation to engage with the interface by asking questions in chat or voting with widgets. My own emergent code.
giving directions	Directions, commands or orders to which a student is expected to comply.
guide students' thought	Giving directions Includes statements intended to guide a student's thought or research. Related to instruction, advice, recommendations to guide students through experiments, assessments or relevant information outside of module.
humour	Code for humour, sarcasm intended to invoke immediacy cue.
links to learning	Statements that reference/link back to prior or future learning or learning outcomes relevant to the module materials or labcast objectives. Linking knowledge back to prior studies.
praises	Praise student action or behaviour. Jokes that release tension as a RESPONSE to the widgets polls or something said in the chat - react to ideas which have already been expressed or to amplify ideas. Examples incl. exclamations such as Right, Good, OK.
promote further engagement	Promotes further engagement via forum if applicable or promotes future labcasts/recording/transcript availability or engagement with other resources.

Name	Description
psychological safety	Statements that offer reassurance in any form whether about the procedures within labcasts e.g. Voting, asking questions or the contents of the presentation or module materials.
reinforces	Statements that include or demonstrate types of reinforcement of instruction, learning outcomes or points made throughout presentation. Include presenters acting in novice roles, asking questions of the expert. Include directions or commands around use of the interface in broadcast or chat.
self-discourse	Refers to verbal immediacy cue. Could include relaying a personal story, experience or disclosure regarding commonalities.
sense of belonging	A sense of belonging and identification connection. Involves the feeling, belief, and expectation that one fits in the group and has a place there, a feeling of acceptance by the group, and a willingness to sacrifice for the group.
student-initiation	talk by students which they initiate own topic, asking thoughtful questions. Deals with independent judgement, higher mental processes and development of own explanations/theories only.
student-response	Student response to presenter or moderator. Students' response means to take action after an initiation. to counter, to amplify or react to ideas which have already been expressed, to conform or

Name	Description
	even to comply to the will expressed by others. Code for most expressions that indicate students are attending to what they are seeing or hearing.
student-talk-responsive	Student response to another student
student-talk-initiative	Talk by students which they initiate to another student
Types of discourse	Different types of discourse modes
bridging knowledge	Refers to statements made 'linking to web or other materials to enrich community knowledge
explanations-explanatory	Explanations of explanatory information contained postulations of cause-effect relations, common causes, reasons.
explanations-factual	Explanations that represent factual information when a list of facts provided without expressions of common causes cause-effect relations or reasons.
question-seeking-fact	Questions or statements seeking factual info - such as what, who, how many and when questions - can be answered providing factual information concerning for example identification, places, persons and times.
question-seeking-understanding	Questions such as why, what for and how come. Cannot be satisfactorily answered without

Name	Description
	constructing explanations containing postulations of common causes, cause-effect relation and reasons.
socio-affective	Refers to phrases that express social-affective and emotional aspects of interactions. Code for salutations (i.e. greeting, self-introduction, closure), self-disclosure (i.e. disclosing personal issues, prior experiences or vulnerabilities), humour (i.e. teasing, joking, sarcasm), sense of belonging or commitment to the group.
Labcast Units	Key unit of analysis within labcasts - stages of event and widget cycle
Stages of event	
conduct experimental or field work	Refers to procedure carried out to support, refute or validate a hypothesis in live experiment or field work stages
demonstrate	Refers to procedure carried out for the purposes of demonstrating scientific principles. Code for demonstrations on workbench, equipment, or graphical modelling on whiteboard or through PPT slides and video animations.
discuss methodological processes	Refers to discussion of various scientific methods such as study type, research questions, hypotheses, variables, defining the sample, collecting data, analysing data and drawing conclusions.

Name	Description
establish social connection	Refers to setting up the tone/climate for social interaction. Includes introducing presenters, orientation of the system (use of widgets) and outlining purpose of event. Includes words/phrases that foster tone/climate at the beginning and end of event.
hypothesize	Refers to stages in labcasts and fieldcast where hypothesis is a focus.
module related	Code for stage where focus is on module structure, how labcast relates to TMA etc.
observations	Refers to parts of running orders/storyboards that signify types of observation.
question & answer	Q&A stage where presenters have conversation style discussion or when presenters incorporate specific time for Q&A and invite questions from remote audience.
Widget cycle	Phrases of presenters set up questions, review polled answers, show demonstration, evaluate, feedback and/or reinforce
evaluate	Judge or calculate the quality, importance, amount or value. Follow up with general observations, add/or revise questions, offer a related question or whatever else is necessary for closure.

Name	Description
poll question	Poll/ask the widget question both in broadcasts and text-chat
review	Phrases that relate to when viewing and displaying of an instant histogram or word cloud showing the class-wide distributions of responses.
revisit poll	Phrases where a presenter may revisit a poll due to misunderstanding or to change direction.
Motivations and perspectives	
Attitudes	Magnitude/evaluation coding. Refers to words or phrases that assign judgements about the merits, worth or significance of labcasting as an intervention.
mixed	Refers to statements that have mixed or conflicting sentiment
negative	Refers to statements that are mostly negative in sentiment
neutral	Refers to statements that lacks any strong sentiment
positive	Refers to statements that are mostly positive in sentiment.
Pedagogical	Refers to teaching principles and strategies

Name	Description
adaptability	Refers to the presenter's adaptability to change, adjust and modify their practice in response to variability, novelty and uncertainty.
voice	Statements around voice in writing the TMA
encouraging retention	Strategies around retention
facilitating student engagement	Refers to statements of labcasts as demonstrating or facilitating student engagement. The intensity and emotional quality of a learner's involvement in a task or activity. Sustained behaviour involvement and overall positive affect or emotion in a task. Definition of Engagement: Having continuous interaction with an artifact or person.
facilitating student interaction	Definition Interaction: The ability to have an input on an artifact or with a person and receive an immediate output
introducing real-word contexts	Refers to purposes and intents around exposing students to real-contextualised environments and experts.
linking prior learning	Refers to statements around building upon prior knowledge and understanding.
modelling	Refers to modelling techniques and strategies around a demonstration of a concept or approach to learning

Name	Description
	whereby students observe; either cognitive or practical
forums	Statements around lab and fieldcast forums but can refer to other forums.
impact of Covid	statements that refer to impact of the pandemic on modules, residential schools or labcasts
residential or field schools	Includes fieldtrips. refers to any face-to-face approach that is part of a module.
promote tutorials	refers to a purpose related to tutorials
purpose - remedial	Refers to a purpose
strategic points	Refers to module team align purposes with teaching activities and appropriate assessment strategies providing timely activities
support conceptual threshold	Threshold concept is a 'conceptual gateway' into a subject. They open a door into a new way of thinking about something and therefore enhance the ability of learners to master their subjects.
supporting learning	Refers to statements around the design of learning methods that support learning or experiences of participant's learning preferences.
Professional practices	refers to how or to what extent labcasting impacts on professional/working practices and development

Name	Description
	among module team members, staff and ALs. Draws on peer support and situated learning theory.
collegiality and collaboration	refers to statements around the nurturing/facilitating relationships between colleagues. Interactions between other module team members, production team, ALs, experts and staff members from the wider OU community.
reflective practice	self -reflection on teaching skills and strategies and practice.
sense of involvement	Phrases on how involved people perceive themselves.
Recommendations	Statements of ideas and recommendations.
advertising	Relates to advertising.
AL involvement	Having more ALs involved.
authenticity	statements relating to practices or ideas relating to authenticity.
bespoke labcast	Having a discrete labcast
compulsory	Making thing compulsory
recordings	adaptions
scheduling timings	Statements around timing

Name	Description
student involvement	buddy scheme student involving other students
Socio-emotional	Refers to statements of social-emotional nature that may relate to beliefs (e.g. growth mindset), values and other rational attitudes (e.g. trust)
anxiety and apprehensions	statements around anxiety whether alleviating it or contributing to it
fomo	fear of missing out, A type of social anxiety stemming from the belief that others might be having fun.
authenticity	Refers to statements around authenticity in terms of what was intended and what was perceived.
autonomy	statements around student autonomy and ownership of their learning, both in terms of what they learn and how they learn it. Whether overall or as part of individual learning activities,
Community	Refers to a Soc (or psychological sense of community). Refers to the experience of community
connection	Phrases related to connectedness
institutional level	SoC at the institutional level
interaction	members participate with persistence, regular and over time.

Name		Description
	module level	Refers to statements around community at the module level.
	sense of belonging	Refers to statements around belonging: being similar to other people, sharing differences and accepting others belief systems, emotional sensitivity, more about the quality of interpersonal relationships. Nurtured trough constant, regular and positive interactions with other people in a social group. Might be evident at the intuitional, module or web broadcast levels
	third-party spaces	refers to statements around student use of social media platforms to collaborate and socialise with other students
	web broadcasts level	SoC at this level
confidence		Phrases on confidence
disengagement		Phrases of discontent and alienation
	commitments	statements around personal, family, study and work commitments
	unawareness	statements around students not knowing
identity		refers to statements around when participants self-disclose, voice their subjectivity or values

Name	Description
isolation	statements around isolation or remoteness.
live vs. f-2-f	statements around comparisons around face-to-face teaching/learning and technology-mediated environments
live vs. recordings	refers to statements around differences or similarities
live vs. tutorials	comparisons, differences or similarities
motivation	refers to statements around motivation or lack thereof.
online vs. f-2-f	statements that compare or contrast ODL and face-to-face interactions and learning,
Social Presence	Refers to statements around social presence theories: mediated special presence and social telepresence.
immediacy behaviours	Refers to the behavioural engagement, which refers to the behavioural interaction
sense of presence	Statements that refer to telepresence and social presence
sense of sound	Refers to statements around audio quality or sound channels as perceptions of social presence
Technological	Refers to the affordances
design aspects	comments relate to the design of labcasts

Name	Description
forum	refers to any post labcast forum
production	refers to statements around production team and/or production processes of labcasts
recordings	Statements related to recordings and the nature of how they be used.
scalability	Refers to statements around scale
timing aspects	Refers to statements around time - whether labcasts being time efficient or time constraints.
widgets	Attitudes and comments around them

Appendix L: Labcast running order

SXPA288 Astronomy Labcast 15 Oct 2019: Widgets and running order

We'd like to use the widgets in the following order:

1. MAP: Enter your location

2. Reasons for doing an experiment (multichoice->histogram) << Note title

   - Measurement

   - Investigation

   - Curiosity

   - To test a hypothesis

   - Exploration

3. Factors of a good experimental design ? (Wordle)

4. What skills does an experimenter need ? (Wordle)

Full running order with timings and shots below.

SXPA288 Labcast 15th October - Introducing SXPS288 and the Astronomy Project

19:30 - Introduction (+MAP WIDGET) • Welcome to the Open Science Lab and to SXPS288 • Please fill in Map Widget • Astronomy topic about to start • Introductions (Alan + Jo) • Please ask questions in chat • Review MAP WIDGET	Alan, Jo to camera

19:40 - Design of Experiments(+DESIGN WIDGET)
 	
• Astronomy project investigating structure of galaxy
 	
• Videos and stills in Powerpoint from laptop
 	
• Video: Milky Way over COAST - We are inside galaxy
    ○ https://drive.google.com/open?id=XXX
• Video: ARROW Slewing
    ○ Can use Radio telescope (As usd previously)
• Video: PIRATE Circumpolar - And optical telescope
    ○ https://drive.google.com/open?id=XXY
	Alan, Jo

• Whiteboard - structure • PowerPoint - M31 and - Source - detector - data - Same techniques for both • Review DESIGN WIDGET	
19:50 - Demo - lenses and images	Jo + Alan

20:00 - Experimental Skills and techniques (+SKILLS WIDGET)
 	
• Skills weeks develop skills applicable to all experiments
 	
    ○ Communication
 	
    ○ Design of experiments
 	
    ○ Programming
 	
    ○ Recording skills - learning log
 	
• Review SKILLS WIDGET
	Alan

20:05 Visit to experiments
 	
• ARROW Interface Live to experiment
 	
    ○ https://learn5.open.ac.uk/mod/url/view.php?id=X
 	
    ○ https://learn5.open.ac.uk/mod/htmlactivity/view.php?id=Y
 	
    ○ [Use IE]
 	
• Live to Tenerife
 	
    ○ https://abot-ui-ou.azurewebsites.net/#/XXX
	Alan,
	Jo

20:15 – Close • First thing now is planning your observing session • Make sure you have booked slot • Work in teams • Support from Project Specialists (ARROW and PIRATE forums) • Thank you for joining tonight • Recording will be available in 24 hours • Follow up: Post Labcast Discussion on forum • Best of luck with observing projects !	Alan, Jo