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Teaching roles and communication strategies in interactive web broadcasts for practical lab and field work at a distance

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Despite the widespread use of synchronous technologies in online and distance learning environments, it is still challenging for distance educators to use effective pedagogical strategies and ensure the best possible interaction for undergraduate students. Within science disciplines, teaching and learning are particularly challenging due to not being co-located with actual experimental equipment in laboratory or field settings. Compared to face-to-face practical work, socio-emotional challenges can exist in distance practical work. For instance, face-to-face settings make feedback, rapport and relationship-building more readily available whereas interaction and support may be hampered, delayed, or require frequent fostering in an online or distance learning environment. Several interactive learning environments can mitigate these challenges. For example, students and lecturers can converse in real-time using webcasting technologies as a way to observe practical work and enhance cognitive and affective engagement. Team-teaching and effective communication strategies can provide pedagogical and social synergy as well as increased student interaction and engagement. This study investigates the teaching roles and communication strategies teaching teams used in interactive web broadcasts across five undergraduate practical science and technology modules at a distance-learning university. Using a qualitative approach, the study used interaction analysis methods to analyse 14 web broadcast transcripts and text-chat logs. Focus groups, semi-structured interviews and questionnaire data from the teaching teams and students were conducted to gain a fuller picture of experiences using and engaging with web broadcasts. Results show that affective communication strategies predominated the web broadcasts although the most frequent was a cognitive strategy. The use of these strategies varied depending on the role that the teaching team occupied during the web broadcasts. Triangulation, which was applied to confirm the results from various methods, showed that the strategies used satisfied the interests and expectations of the students. The results are applicable to other distance and conventional campus-based institutions that offer courses in practical science and technology as well as those that deliver courses via synchronous delivery methods with a focus on student engagement and practical work.

KEYWORDS

team-teaching, pedagogical strategies, practical science, live streaming, webcasting, STEM, affective strategies, distance learning

1 Introduction

The role of teaching in online and distance education (DE) has received increased attention across several disciplines in recent years (Singh and Thurman, 2019). As a result of the 2020 global pandemic, forms of DE have been more widely adopted as technology continues to enable new modes of flexible learning (Bonk, 2020). However online and remote formats can often present unique pedagogical challenges that are absent from conventional face-to-face teaching (Moorhouse and Kohnke, 2022). The most significant of these is the requirement for collaborative team teaching that can enhance student engagement and community among distance learners and their educators (Gono and de Moraes, 2023). In view of this, it is important to provide teaching teams with the necessary training and resources to support successful implementation of distance learning (DL) courses at higher education institutions (HEIs).

Science-based disciplines often require interdisciplinary team approaches (Gao et al., 2020). DE universities have long coordinated and distributed roles among lecturers, tutors, technology specialists and subject matter experts (Mason, 2002; Badia et al., 2017; Black, 2018). Coordinated team approaches in course design and delivery allow for collective expertise while embracing diversity of approaches and opinions (Gono and de Moraes, 2023). Collaborative team approaches enable DE universities to operate at scale while addressing the academic and socioemotional needs of adult DE students (Daniel, 2019). However, offering distance students a practical experience that reflects real-world scientific tasks is challenging (King and Ritchie, 2012; Kennepohl, 2021). Several factors contribute to this, including the practical aspects of the laboratory or field (Kennepohl, 2021), technology-mediated tools to support practical work (Whalley et al., 2011) and pedagogical strategies that promote active engagement (Bolliger and Martin, 2018).

The integration of synchronous media facilitates interactive teaching and learning when face-to-face opportunities are not available or are limited. Extensive research have shown that synchronous media, such as live streaming and live chat tools, foster active learning, promote real-time discussions and encourage engagement (Martin et al., 2012; Lin and Gao, 2020; Moorhouse and Kohnke, 2022). This study contributes to the existing body of literature by providing novel insights into the types of teacher roles and strategies that emerge from live, interactive web broadcasts in practical science and technology modules.

2 Literature review

2.1 Course development in distance education

The notion of a team approach for course development is not a new phenomenon and has distinct roots in the pedagogical models of DE. Charles Wedemeyer argued that by dividing the teaching process into specialisations, multidisciplinary teams could integrate various communications technologies and teaching approaches (Black, 2018). This pluralistic approach was thought to be of higher quality than a single strategy (Black, 2018). Later, Otto Peters delineated the 'division of labour' as one characteristic to divide responsibilities or roles among university units specialising in a specific area such as course development (Diehl and Cano, 2018). As such a multidisciplinary team approach provides a wider range of disciplinary and instructional expertise.

The course team model used at The Open University, United Kingdom (OUUK) and other distance universities, such as Athabasca University in Canada, includes a multidisciplinary team approach where academics, educational technologist and media specialist contribute their pedagogical and technical knowledge and work together to build modules (Teaching and Research, 2017). A typical course team comprise of a course chairperson, who manages course development and central academics who conduct research, write the study materials and run in-person day schools. The course team is supported by associate lecturers who teach the study material, mark students' work and support students (Badia et al., 2017; Teaching and Research, 2017). Where practical skills are taught online, much of the teaching is similar to approaches found in conventional HEIs.

2.2 Teaching teams in higher education

Team teaching in higher education is often used as a pedagogic approach and covers a spectrum of practices from mentoring new teachers to planning and delivering learning materials (Minett-Smith and Davis, 2020). Varying terminology exists in the literature, such as collaborative teaching (Gono and de Moraes, 2023), team teaching (Minett-Smith and Davis, 2020) and co-teaching (Lock et al., 2016). However, there is consensus that it involves two or more teachers who share the planning, developing and presenting of course materials (Fuller and Bail, 2011; Morelock et al., 2017; Minett-Smith and Davis, 2020). Similar to earlier arguments for the multidisciplinary course team approach in distance education, Cruz and Geist (2019) and Lock et al. (2016) maintain that the equal investment between educators and the instructional dynamic that ensues is greater than can be achieved individually.

Various frameworks have emerged to facilitate the different models of team-teaching. White et al. (1998) proposed three models of team teaching: the interactive model where two or more teachers are present at the same time and have interactive dialogue; the rotational model, which requires each team member teach their area of expertise and the participant-observer model, whereby team members alternate taking the lead while the other observes and supports. The works of Cook and Friend (1995) and Friend et al. (2010) are widely cited and have been applied in higher education (e.g., Lock et al., 2016; Cruz and Geist, 2019). Friend et al. (2010) proposed six models for teaching dyads and teams:

1 One teach, one observe – One teacher leads while the other observes and assists students.
2 Station teaching – Teachers divide and present specific material to two groups.
3 Parallel teaching – Two teachers plan jointly but divide the class and deliver simultaneous instruction.
4 Alternative teaching – One teacher teaches a large group and the other provides additional support.
5 Teaming – Both teachers take turns to lead discussions, or one demonstrates a concept.
6 One teach, one assist – One teacher works with a smaller group while the other instructs (Friend et al., 2010, pp. 12–13).

2.3 Teaching teams in online and distance learning

Similar teaching approaches are used when the teaching mode combines in-person instruction with online interactive activities. Although terminology differ, comparable characteristics exists among some of the models (e.g., participant-observer vis-à-vis one teach, one observe). Collins et al. (1996) proposed multiple instructors and practicum supervisors working together and using a guest lecturer as a subject matter expert in undergraduate courses.

Team-teaching has been used to facilitate effective learning in undergraduate technology (Dennen et al., 2022; McKenzie et al., 2022); chemistry (Hester et al., 2022) and biology and environmental science courses (Kim Rezende et al., 2021). In their qualitative study of college-level co-teaching dyads, Morelock et al. (2017) reported that simultaneous methods that involved both partners participating in each class enhanced the learning opportunities for both students and instructors. The authors also found that the power and authority structures that co-teachers encountered influenced the ways they chose to frame the co-teaching dynamics. Lock et al. (2016) reported that instructors perceived the core of co-teaching to include elements such as "trust, respect, self-respect, mutuality and collaboration" (Lock et al., 2016, p. 27). Another study found that the integration of an instructional team had a significant positive impact on students' experiences when adapting a large (i.e., >500 students) introductory chemistry course to a live-remote course format (Hester et al., 2022). Together, these studies indicate that teaching teams are influenced by interpersonal and institutional interactions. The role of each team member becomes more salient in an online environment due to changes in communication online.

2.3.1 Team roles

Recent studies have examined teaching roles in online environments (Martin et al., 2019; Otts et al., 2021; Dennen et al., 2022). These studies suggest that instructors perform different roles to varying degrees in online settings. Team roles, defined by institutions, are specific tasks and competencies (Alvarez et al., 2009) and are categorised as pedagogical, social, technical, and managerial responsibilities (Berge, 1995). Pedagogical responsibilities involve assisting students' comprehension and reinforcing concepts. The social role involves fostering a friendly atmosphere and sense of community. The technical role responds to students and supports their technical issue, while the managerial role involves carrying out procedural tasks (Berge, 1995). Moderator strategies found in the literature include welcoming participants (Gunawardena, 1995; Palloff and Pratt, 2007) and not overloading students with much information (Berge, 1995; Scholl et al., 2006). Drawing on Berge's categorisations, Liu et al. (2019) found that instructors most strongly emphasised the pedagogical roles of facilitating the learning process to encourage students' understanding of key concepts. In addition, student feedback reported high satisfaction with the impact of their instructor's pedagogical guidance on their learning experiences.

In a mixed-methods study which set out to determine the characteristics of a practitioner-based approach to team-teaching for blended learning, Mckenzie et al. (2022) report on the use of live streaming, polls and live chat feeds among three team-teaching members. Findings show that the 'leader' role of the team member providing the main presentation was complex due to simultaneously interacting with the online activities and in-person audience. This resulted in a mixed role, one of content provider as well as online contributor. Studies indicate that the situational and context specific nature of teaching roles are factors in which teams are likely to differ based on the size of a class, the teaching approach and the technologies employed (Badia et al., 2017; Davis and Winter, 2019; Kim Rezende et al., 2021).

2.4 Communication in a distance learning environment

Teaching and learning are mediated through two primary technology-mediated systems: asynchronous (i.e., communication where the sender and receiver do not have to be online concurrently to interact) and synchronous (i.e., communication where the sender and receiver interact simultaneously). Asynchronous media include discussion forums, e-books and pre-recorded video. Synchronous media may incorporate live streaming, instant messaging and audience polling tools (Martin et al., 2012). Two-way communication facilitates the educational interactions between student-teacher, student–student and student-content (Moore, 1989). In investigating learner-instructor engagement in an online graduate course, Bolliger and Martin (2018) found that referring to students by name in discussion forums was the second highest strategy after emails, reminders and announcements.

Effective conversation and dialogue are needed in written materials and interactive environments to encourage students (Holmberg, 1960; Laurillard, 1993). Student engagement is achieved by "personal, friendly interaction between students and tutors and conversation-like presentations of subject matter" (Holmberg, 1986, p. 38). Studies have substantiated the benefits and challenges of asynchronous and synchronous communication on interpersonal interactions (de Lima et al., 2019; Douce, 2019; Moorhouse and Kohnke, 2022). Consequently, DE educators will often have to factor pedagogical, affective and cognitive strategies that support interaction and engagement.

2.5 Affective and cognitive engagement

The affective domain encompasses social, emotional, and feeling characteristics, while the cognitive domain involves remembering, understanding, and analysing (Anderson et al., 2001; Krathwohl, 2002). Ramma et al. (2018) argue that although the affective domain is acknowledged, scientific teaching and learning often prioritise cognitive engagement. Cognitive engagement plays a central role in developing critical thinking skills and aligning with scientific practice. Affective learning involves internalising positive feelings towards course material, the instructor, or the subject, and is "influential enough to provide directions for technology integration" (Ramma et al., 2018, p. 212).

The Community of Inquiry framework (Garrison et al., 1999) conceptualises online teaching practice and considers three instructional components: teaching presence, cognitive presence and social presence. Social presence is regarded as "the ability of participants in a community of inquiry to project themselves socially and emotionally, as "real" people through the medium of communication being used" (Garrison, 2016, p. 94). Rourke et al. (1999) validated a content analysis scheme for computer conferencing transcripts, identifying indictors of social presence through keywords and speech segments. The authors suggest that social presence and teacher immediacy indicate affective interaction (Rourke et al., 1999).

2.6 Immediacy behaviours and communication strategies

Distance learning often lacks the social context cues found in face-to-face interactions, posing a challenge. Research on psychological distance in the learning environment draws from Mehrabian's (1969) concept of immediacy, which refers to communication behaviours that enhance closeness and non-verbal interaction. Immediacy cues, such as using student names, encouraging engagement, humour, soliciting feedback, and sharing personal experiences, enhance the psychological connection between instructors and students (Conaway et al., 2005). Verbal immediacy and nonverbal immediacy, expressed through facial expressions, gestures, and eye contact, contribute to a more personal, engaging, and interactive learning environment (Conaway et al., 2005).

Lecturers can use specific cues to decrease the perceived distance between teachers and learners, impacting the learning environment and student outcomes (Ai and Giang, 2018). Kim and Thayne (2015) conducted a comparative study on online video-based instruction, implementing relation-building strategies such as a warm tone, colloquiums, encouragement, praise, and personal anecdotes. These strategies had a favourable impact on students' attitudes compared to a control group where these strategies were not used. Immediacy behaviours and interactive components have been shown to positively influence affective and cognitive learning (Conaway et al., 2005; Starr-Glass, 2020). Common strategies found in the literature are described in the following sub-sections, which can be conceptualised as autonomous but often overlap.

2.6.1 Student engagement and encouragement

Research show that engagement is a multidimensional phenomenon that incorporates students' behavioural, cognitive and emotional engagement (Reeve, 2013; Gono and de Moraes, 2023). The principle of encouragement and engagement often intersects with interaction and active learning (Prince et al., 2020). Bowden et al. (2021) found that student expectations and involvement influences their engagement. Through verbal cues, lecturers can encourage students to participate in a synchronous activity by giving timely feedback and creating a communication loop that enhances dialogue (Bonk and Khoo, 2014). Timely feedback is frequently cited as a key element to successful engagement (Jurs and Špehte, 2021).

2.6.2 Guiding students

The ability to guide students through the learning process is considered crucial. In earlier frameworks that investigated teacher-student verbal interactions, Flanders (1970) reported that guiding students through a series of interactions can influence students' critical thinking, engagement, and problem-solving skills. Through verbal behaviours, lecturers can set clear expectations for assignments and provide guidance on how to approach them by outlining key concepts that students need to focus on (Prince et al., 2020). For distance teachers, building pedagogical patterns of dialogue, supporting students as they work on complex tasks and guiding them through investigating and analysing problems is crucial (Laurillard, 2012).

2.6.3 Fostering a safe environment

The development of a psychologically safe learning environment continues to be of interest due to the ubiquitous nature of online learning (Catyanadika and Rajasekera, 2022). Students must be comfortable with their teachers, and peers (Bonk and Khoo, 2014) and have a sense of personal data security and psychological safety (Tatiana et al., 2022). Characteristics such as warmth, respect, choice, enthusiasm, and praise can foster feelings of safety and trust and mitigate apprehensions (Coppola et al., 2004; Bonk and Khoo, 2014). Scott et al. (2019) propose that preparatory virtual primers of fieldwork or videos of previous cohorts undertaking field activities might further help students better prepare and mitigate student anxieties. Tatiana et al. (2022) suggest that students' anxiety can occur due to the novelty of a virtual environment. Strategies include building trust, modelling affiliation and solidarity, offering guidance, and reinforcing regular patterns of behaviour and communication (Coppola et al., 2004).

2.6.4 Appreciation and praise

Showing appreciation and praise are mutually dependent communication acts, which serve to establish social bonds and can influence others' behaviour or attitudes (Rourke et al., 1999). Praise can be used to acknowledge and positively reinforce students' efforts and contributions (Flanders, 1961). Likewise, lecturers can use appreciation to create a positive learning environment by recognising and acknowledging the efforts and contributions of students (Swan, 2003). In their study on instructional interaction and teacher-student immediacy, Conaway et al. (2005) found that students do not automatically express appreciation, agreement or complement each other unless the instructor builds a learning community and transfers interactive roles to the students.

2.6.5 Using humour

The use of humour, along other social cues such as textual emoticons can help to create a sense of social presence. Rourke et al. (1999) suggest that humour can be used strategically to enhance communication, mitigate tensions that student may experience in the online environment and build a sense of camaraderie among participants. Humour has been described as an essential element for improving student interest and attention (Banas et al., 2011) and can be used in an online environment to gain students' attention, recall and give feedback (Erdoğdu and Çakıroğlu, 2021). Murillo and Tan (2022) report that humorous instructional video materials were found to be highly acceptable by mathematical expert evaluators. However, Bolkan et al. (2018) suggest that instructors be cautious and strategic in their implementation of humour.

2.6.6 Self-disclosure

Self-disclosure is the voluntary sharing of personal information to facilitate the development and maintenance of trustworthy relationships and is particularly salient in a DL environment where students might have minimal knowledge about their lecturer (Song et al., 2016). A lecturer's self-disclosure is "conscious and deliberate and may include statements on professional practice, personal history, and world views" (Rasmussen and Mishna, 2008, p. 192). Rourke et al.

(1999) suggest that expressing vulnerability is also a type of self-disclosure. In their study of 534 undergraduate students, Song et al. (2016) found that the influence of a lecturer's self-disclosure had a greater impact on teacher-student relationship satisfaction in online classes compared to face-to-face classes. Strategies include sharing personal information and expressing vulnerabilities (Rourke et al., 1999; Hayeon Song and Park, 2019).

2.6.7 Sense of belonging

Sense of belonging entails characteristics such as support, cooperation, and acceptance of others (Rovai, 2002). Consistent and positive interactions play a significant role in building online learning communities (Liu et al., 2010). Lecturers can foster this by creating a welcoming and inclusive learning environment through clear communication, supportive feedback and the promotion of social interaction (Bonk and Dennen, 2003). Affiliation to an institution can also foster a student's sense of belonging (Thomas, 2012). In their study of 216 undergraduate STEM majors, which investigated career beliefs, Belanger et al. (2020) found that students who read about a typical day in a chemical engineering lab and imagined themselves in the lab felt reduced feelings of exclusion and fostered a sense of belonging.

2.7 Summary

Team teaching approaches have been shown to be superior to individual teaching in both face-to-face and distance learning settings. In online environments, teachers assume various roles to varying degrees. To maintain cognitive and affective student engagement, communication strategies are crucial due to physical and psychological distance challenges. Nine strategies from the literature have been linked to affective and cognitive engagement. As synchronous media is increasingly being used in distance science and technology courses, this study examines team roles and communication strategies in such courses. The current study investigates the types of teaching roles and communication strategies used in web broadcasts at the OUUK and is guided by the research questions: *What strategies occur and are most effective in teaching roles during interactive web broadcasts? What are the perceptions of the teaching teams and students who participate in interactive web broadcasts?*

3 Research context

The OUUK employs a blended learning approach with resources for flexible study alongside tutorials and advisers. Students study online modules and undertake several learning activities. Students access their modules via a virtual learning environment, where they interact with their peers, lecturers and tutors. To reinforce learning, Tutor Marked Assignments (TMA's) and End of Module Assessments (EMA's) are used as formative and summative assessments. Practical skills are also supported through residential or lab schools on certain modules.

The OUUK's OpenSTEM Lab (OSL) is another resource utilised to deliver practical science online and allows students to use real, remote instrumentation, on-screen tools and observe live streaming of experiments and demonstrations through interactive web broadcasts. Web broadcasts take place during a module at OUUK levels 1–3 (equivalent to the Framework for Higher Education Qualifications levels 4–6) in the Science, Technology, Engineering and Mathematics (STEM) Faculty. The web broadcasts typically include presenters, moderators, and guest researchers, and are optional for students to attend live or watch the recording.

3.1 Interactive web broadcasting

Field and laboratory-based web broadcasts, known as fieldcasts and labcasts, are used in several STEM modules and deliver one-to-many live video broadcasting to accommodate potentially hundreds of students via their web browser with real-time text-chat and audience polling tools (widgets). Web-broadcasting here is distinct from many-to-many video conferencing tools such as Zoom, Microsoft Teams and Google Meet, which allow for two-way conversation. In web broadcasts, lecturers, tutors, topic specialists, and other experts can interact with students live during demonstrations, experiments, and field investigations. Stadium Live, an in-house platform, allows teaching teams to pre-plan live events. A technical production team mixes the live video stream using slides, video, and remote instruments, which is displayed alongside a set of pre-prepared widgets. Figure 1 illustrates the bi-directional communication, and Figure 2 shows examples of a map, word cloud, and two multiple-choice widget interfaces.

3.2 Modules

There were five modules involved in this study. Links to the modules can be found in the footnote except SXHL288- Practical science: biology and health which is now a retired module. Table 1 summarises the number of registered students on each module and the web broadcasts used in each module across the respective schools during the academic year 2019/2020.

Technologies in Practice (module code TM129[1]) is a level 1 computing and information technology module (equivalent to UK Framework for Higher Education – FHEQ level 4). It consists of practical activities around Robotics and AI, Networking and Operating Systems and starts twice a year in February and October. The labcasts feature demonstrations of a teaching robot and a Raspberry Pi network with a guest expert to discuss the practical applications of their research. The format includes question-and-answers, with the moderator compiling and posing the students' text-chat queries and the presenters responding. Widgets are used to assess prior knowledge on Raspberry PI usage and predict robot sensors.

Remote Experiments in Physics and Space (SXPS288[2]) is a practical science level 2 module (i.e., FHEQ level 5) for students pursuing physical sciences qualifications in a BSc in Physics or a Natural Science degree. Students practice observation and hypothesising through teamwork projects via the OpenSTEM Lab. Labcasts support projects through demonstrations of experimental

1 https://www.open.ac.uk/courses/modules/tm129
2 https://www.open.ac.uk/courses/modules/sxps288

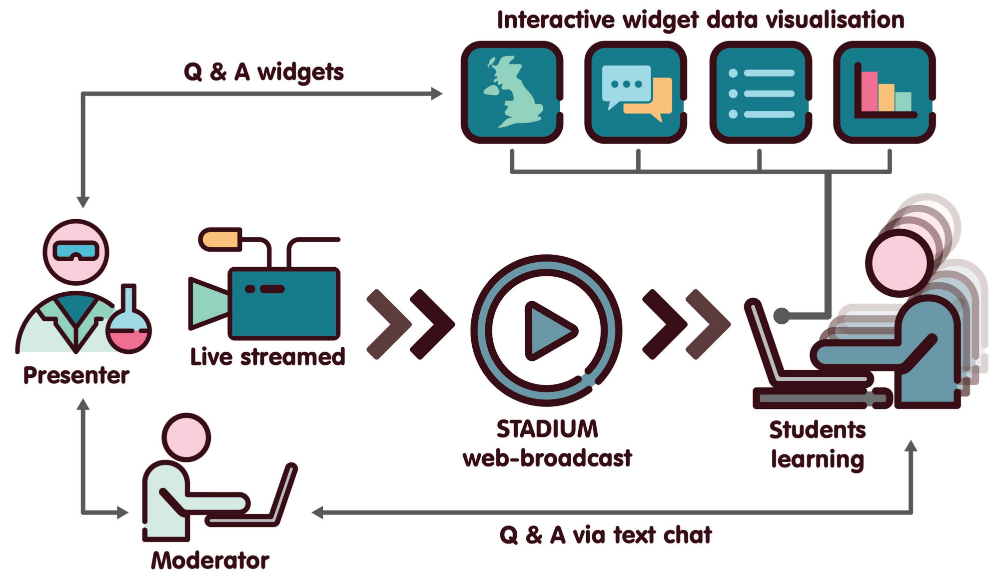

FIGURE 1
A screen image of the different widget interfaces.

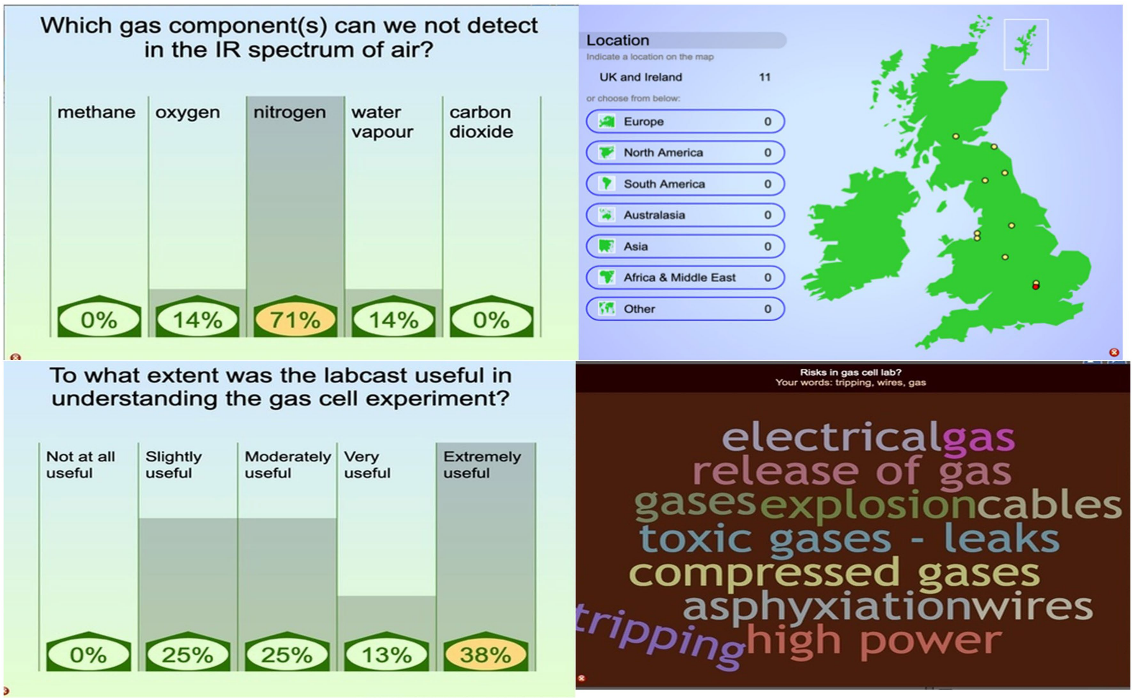

FIGURE 2
An illustration of the bi-directional communication flow in a Stadium Live Labcast.

equipment. A guest expert discusses planetary exploration. Widgets are used to hypothesise the direction of an electron and elicit responses.

Environmental Science (S206/SXF206[3]) is a level 2 module that leads to a BSc in Environment Science, an Open degree, or a Natural Sciences degree. Student cohorts choose between two tracks: an obligatory residential field course component or a virtual self-directed field course. The module covers water, air, earth life and cycles topics. Both cohort groups must attend or watch recordings of two fieldcast episodes and one labcast, which support scientific report-writing based on the presented field investigation. The teaching team describes environmental elements at a field site, and students use the widgets to choose a topic, vote on a hypothesis,

3 https://www.open.ac.uk/courses/modules/s206

TABLE 1 Web broadcasts used in module across schools.

School	Module	Registered students	Labcast title
Computing and communications	TM129 – Technologies in Practice	1,068 (2019)	TM129 Robotics demo
		993 (2020)	TM129 Networking demo
Physical sciences	SXPS288 – Remote experiments in physics and space	210	SXPS288 Intro to remote experiments
			SXPS288 Physics project
			SXPS288 Planetary science project
			SXPS288 Exploring Mars
Environment, earth and ecosystem sciences	S206/SXF206 – Environmental Science	364 (S206)	S206 Making observations and developing hypotheses
		225 (SXF206)	S206 Developing methods and data collection
			S206 Analysing data and making conclusions
Life, health and chemical sciences	SXHL288 – Practical science: biology and health	437	SXHL288 The human brain in action
			SXHL288 Cells and tissues close-up
	S315 – Chemistry: further concepts and applications	114	S315 Intro to experiment for TMA05

and choose a sample method. In the last episode, the team analyses the data.

Practical Science in Biology and Health (SXHL288) is a level 2 module for a Natural Sciences degree in Biology. It comprises three experimental investigations: attention and the brain, animal physiology, and drug metabolism. The OpenSTEM Lab facilitates practical activities. Labcasts include live demonstrations of electron microscopes and a computerised cognitive assessment programme. Widgets are used to predict gender performance and elicit free responses.

Chemistry: Further Ideas and Applications (S315[4]) is a level 3 (FHEQ 6) model for a BSc in Chemistry or Natural Sciences. The core topics are chemistry in the natural world and chemical reactivity. Three online chemical and drug interaction experiments are supported via OSL. The labcasts support the experiments by modelling mathematical equations and conducting live experiments of remote access to OSL titration equipment. The widgets are used to predict solvent ranges and select concentrations.

3.3 Web broadcast designs

The technical production team and teaching teams planned and scripted the web broadcasts. Depending on the discipline and objectives of each web broadcast, the widget types and teaching roles differed. Table 2 shows the web broadcast titles, purposes, widget types and number of teaching roles involved in each event.

4 Methodology

4.1 Study design

An exploratory qualitative design with an analytical framework based on immediacy and communication strategies was used to investigate the 14 web broadcasts and the perceptions of the teaching teams and students who participate in them. A deductive interaction analysis was used to examine typical communication strategies. Interaction analysis holds that knowledge and action are rooted in social and material ecologies and video-based researchers typically use predefined classifications systems (Jordan and Henderson, 1995). Table 3 shows the protocol used to code the web broadcasts and text-chat transcripts. The protocol draws on the immediacy behaviours and communication strategies discussed in Section 2.6 and which were found to be most representative in the literature.

4.2 Data collection and analysis

The study was designed in negotiation with academics from five modules who ran the web broadcasts listed in Table 1. These participants were purposively selected based on scheduled live broadcasts events. The research design was approved by the Human Research Ethics Committee of The Open University and the Student Research Project Panel. Several procedures were used to collect and analyse data: system data logs, interviews, focus groups and questionnaires.

Storyboards and scripts were collected from teaching teams for each web broadcast to facilitate observations and understand the running order, procedures, and processes. Observations were conducted during the live events and later by reviewing the recordings. Text-chat logs and video recordings were transcribed and coded using NVivo 12®. Content analysis was used to identify patterns and themes and provide a quantitative description. Video annotations and notes were cross-referenced and incorporated into question protocols for focus group discussions. System usage logs from the Stadium Live platform were downloaded and compiled into an Excel summary table. Calculations were performed to determine the number of users, chat posts and the percentage of interactive users.

Teaching team members and a guest expert participated in focus groups and semi-structured interviews via Adobe Connect or Microsoft Teams. Four focus groups ran with: three team members from TM129, three from SXPS288, four from S206 and three from S315. One SXHL288 team member and one SXPS288 external guest expert participated in an interview. Questions routes were designed

4 https://www.open.ac.uk/courses/modules/s315

TABLE 2 Purposes, types and number of widgets and ways teaching roles occurred in the web broadcasts across five modules.

Module	Web broadcast title	Web broadcast purpose(s)	Widget type (number)	Teaching roles				
				Lead presenter	Presenter & moderator	Presenter	Moderator	Co-presenter
TM129	TM129 robotics demo	To demonstrate an industrial robot and apply concepts taught in the block on the analysis of robot safety	Map (1) Continuum (4) Wordle (2)	1	1			
	TM129 networking demo-19	To demonstrate practical aspects of creating a small network using Raspberry Pi computers	Map (1) Multiple choice (4) Balance (1)	1	1	1		
	Block 2 robotics demo-20	As above (Block 1)	As above (Block 1)	1	1			
	Block 2 Networking 'homecast' demo-20	As above (Block 2)	As above (Block 2)	1	1	1		
SXPS288	An interactive introduction to remote experiments in physics and space	To introduce astronomy topic options for projects To discuss aspects of experimental technique and planning	Map (1) Multiple choice (1) Wordle (3)	1		1		
	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)	1		1		
	Planetary science project	To introduce the project and gas cell experiment	Map (1) Multiple choice (2) Wordle (2)	1		1	1	
	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)	1	1		1	
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)				1	3
	Fieldcast 2: developing methods and data collection	To design a sampling strategy and collect data	Balance (1) Multiple choice (2)				1	3
	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)				1	3
SXHL288	The human brain in action	To highlight important aspects of experimental design involving human participants for Topic 1	Map (1) Multiple choice (2) Balance (1) Wordle (1)				1	2
	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)					2

(Continued)

TABLE 2 (Continued)

Module	Web broadcast title	Web broadcast purpose(s)	Widget type (number)	Teaching roles				
				Lead presenter	Presenter & moderator	Presenter	Moderator	Co-presenter
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)		1	2		

TABLE 3 Interaction analysis protocol on communication strategies.

Informed by	Indicators	Definitions	Coding notes
Bonk and Khoo (2014); Coppola et al. (2004)	Psychological safety	Reassuring, in any form, about procedures within web broadcasts or related to overall aims within them.	Code for statements on voting, asking questions, content of presentation, interface or module materials. Example: *do not worry, no wrong answers.*
Rourke et al. (1999)	Use of humour	Teasing, cajoling, irony, sarcasm, joking.	Only code if a clear indication that humour is intended. May or may not use extra punctuation or emoticon in text-chat. Example: *our students are like X-men.*
Hayeon Song and Park (2019); Rourke et al. (1999)	Self-disclosure	Sharing personal information, relaying personal story, experience, comradeship, expressing vulnerability or feelings.	Code for expression that informs audience about circumstance. Example: *apologies for my writing.*
Flanders (1961); Rourke et al. (1999); Swan (2003)	Appreciation	Complimenting or showing appreciation of student action, behaviour or contents of messages.	Code for statements around appreciation including thanking participants. Example: *thanks for joining.*
Bonk and Khoo (2014); Jurs and Špehte (2021)	Encourages participation	Encouraging students to participate and interact with interface by asking questions or voting with widgets.	Code for statements that gender encouragement. Example: *please ask questions, tell us where you are today.*
Bonk and Khoo (2014); Flanders (1961)	Praise	Praising student action as it relates to questions, widget responses or project work connected to web broadcasts	Code for reactions to questions posed, widget responses, group, or individual praise. Example: *Good, Excellent, well-done*
Bonk and Khoo (2014); Bowden et al. (2021); Martin et al. (2012)	Promote further engagement	Promoting further engagement via forum, promoting future Labcasts or other resources, availability of recordings/transcripts	Code for references to forum, Labcasts, module materials. Example: *see you on the forum*
Flanders (1961); Prince et al. (2020)	Guiding students' thoughts & research	Related to instruction, advice, recommendations to guide students through investigations, assessments, or relevant information outside of module	Code for descriptive words that convey instruction, imperative or modal phrases. Reference to prior or future learning outcomes. Example: *Plan a network and be methodical.*
Liu et al. (2010); Rovai (2002)	Sense of belonging	Related to statements around belonging: a sense of identification and connection. Involves the feeling that one fits in the group and has a place	Code for phrases that signify recognition of place, being part of the OU, inclusive language, addressing the group. Example: *We are being good experimentalist.*

to prompt discussion and elicit responses around strategies. Data was transcribed, pseudonymized and thematic analysis used to identify the meanings and interpretations that the educators gave to their experiences. Student questionnaires consisting of five-point Likert scale questions and free-text boxes were devised to capture categories such as usefulness and impact of web broadcasts on learning. Thematic analysis of the responses was conducted. Four students from the SXPS288 module and three from S206 opted-in for individual interviews to discuss their perceptions on the web broadcasts. All personal identifiers were pseudonymized. Table 4 shows the study's population response rates.

5 Results

5.1 Students' interactions during web broadcasts

Unique users refer to the number of unique user accounts who participated in the live events, whereas interactive users are those who engaged with one or more widgets or participated in the text-chat. Table 5 displays the duration of the web broadcasts, the number of unique users and interactive users, the number of chat users and chat posts and the percentage of interactive users.

TABLE 4 Response rates and demographics across the modules.

Module		Respondents' demographics				
Module code	Total students available	Total responses (response rate)	Females	Males	Mean age	SD age
TM129-19J	527	18 (3%)	3	15	37.11	13.75
TM129-20B	537	9 (2%)	4	5	39.00	13.56
SXPS288-19J	83	15 (18%)	2	13	45.27	14.03
SXHL288-19J	116	9 (8%)	7	2	41.78	10.74
S206-19J	305	29 (10%)	14	15	39.72	14.73
S315-19J	47	3 (6%)	0	3	33.33	12.66

TABLE 5 Number and proportion of live viewers participating in text-chat or responding to widgets across the web broadcasts.

Module	Web broadcast title	Duration (mins)	Unique users	Interactive users	Chat users	Chat posts	Interactive users (%)
TM129 technologies in practice	TM129 Robotics demo 2019	60	117	104	77	302	89
	TM129 Networking demo 2019	65	63	45	44	192	71
	TM129 Robotics demo 2020	60	104	97	66	226	93
	TM129 Networking demo 2020	75	60	55	40	129	92
SXPS288 remote experiments in physics and space	SXPS288 Intro to remote experiments	45	59	59	45	92	100
	SXPS288 Physics project	45	50	49	27	43	98
	SXPS288 Planetary science project	45	37	34	20	125	92
	SXPS288 Exploring Mars	90	66	59	43	184	89
S206 environmental sciences	S206 Making observations and developing hypotheses	40	130	120	79	246	92
	S206 Developing methods and data collection	30	113	110	69	199	97
	S206 Analysing data and making conclusions	45	111	99	69	230	89
SXHL288 practical science: health and biology	SXHL288 The human brain in action	65	108	96	65	297	89
	SXHL288 Cells and tissues close-up	65	41	36	25	53	87
S315 chemistry: further concepts and applications	S315 Intro to experiment for TMA05	70	33	30	21	46	91

5.2 Communication strategies across web broadcasts

During the live events, the teaching teams displayed various communication strategies and behaviours aimed at facilitating student engagement. Table 6 outlines the distribution of strategies, as outlined in Section 2.6, that emerged from team members in separate roles across the 14 web broadcasts.

5.3 Types of communication strategies

The following subsections present the qualitative results of the communication strategies across the transcripts, staff focus group and interview data, and student questionnaires and interviews. The data presented is for the six most frequently observed strategies as identified in Table 6.

5.3.1 Guiding students' thoughts or research

The data shows that guiding students' thoughts or research was the most common communication strategy used in the five modules. Teaching teams offered recommendations or directions to guide students' thought processes in experiments, demonstrations, and assessments and often provided information beyond the scope of the module.

During a TM129 Networking demo labcast, while modelling a Raspberry Pi schematic, TM129-MT2 recommends planning a network and students being methodical. Thereafter, TM129-MT1 mentions in the text-chat that paper diagramming and simulation construction were similar. The SXHL288 Human brain in action labcast ran a live cognitive assessment. SXHL288-MT2 enquires about the reason for seeing the screen but not the participants, to which SXHL288-MT3 replies, "There's a very good reason for that. Because we are using human participants, we had to put this study through ethical reviews. It is something that students are going to

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TABLE 6 The distribution of strategies across the presenters and moderators roles during each web broadcast.

Interactive web broadcast	Role	Staff identifier	Guiding students thoughts	Encourages participation	Praise	Humour	Promote further engagement	Appreciation	Psychological safety	Sense of belonging	Self-disclosure	Total
TM129 Robotics demo 2019	Lead presenter	TM129-MT2	1	2	0	0	0	1	0	0	1	**5**
	Presenter and moderator	TM129-MT1	8	4	1	5	1	1	1	2	0	**23**
TM129 Networking demo 2019	Lead presenter	TM129-MT2	1	3	4	1	1	1	2	1	2	**16**
	Presenter and moderator	TM129-MT1	13	7	4	1	4	2	0	0	2	**33**
	Presenter	TM129-GP1	2	0	0	1	1	0	0	0	0	**4**
TM129 Robotics demo 2020	Lead presenter	TM129-MT2	4	2	2	1	1	3	0	1	0	**14**
	Moderator	TM129-GM1	1	6	2	2	2	2	0	0	1	**16**
TM129 Networking demo 2020	Lead presenter	TM129-MT2	3	2	3	1	0	1	2	0	1	**13**
	Presenter and moderator	TM129-MT1	5	6	3	2	4	2	4	1	1	**28**
	Presenter	TM129-GP1	2	0	1	0	3	0	0	0	0	**6**
SXPS288 Intro to remote experiments	Lead presenter	SXPS288-MT1	0	2	9	0	3	9	1	1	0	**25**
	Presenter	SXPS288-MT5	2	2	0	0	1	0	0	1	1	**7**
SXPS288 Physics project	Lead presenter	SXPS288-MT1	6	2	5	0	2	7	1	1	0	**24**
	Presenter	SXPS288-MT5	2	1	0	0	0	2	0	0	0	**5**
SXPS288 Planetary science project	Lead presenter	SXPS288-MT3	1	5	4	2	1	1	1	2	3	**20**
	Presenter	SXPS288-MT2	6	0	1	0	0	1	4	1	1	**14**
	Moderator	SXPS288-MT1	13	2	1	1	2	9	4	9	2	**43**
SXPS288 Exploring Mars	Lead presenter	SXPS288-GP1	6	1	6	4	0	3	3	1	5	**29**
	Presenter and moderator	SXPS288-GM4	2	2	0	7	2	2	0	4	3	**22**
	Moderator	SXPS288-MT5	0	0	0	0	0	0	0	0	1	**1**
	Moderator	SXPS288-MT1	4	7	8	0	6	7	1	4	0	**37**
S206 Fieldcast 1: Making observations and developing hypotheses	Co-presenter	S206-MT1	0	4	3	2	1	2	2	1	0	**15**
	Co-presenter	S206-MT3	2	4	4	3	2	1	5	1	0	**22**
	Co-presenter	S206-MT4	0	1	1	1	0	0	0	0	1	**4**
	Moderator	S206-MT2	15	14	0	2	2	2	2	2	0	**39**

(Continued)

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TABLE 6 (Continued)

Interactive web broadcast	Role	Staff identifier	Guiding students thoughts	Encourages participation	Praise	Humour	Promote further engagement	Appreciation	Psychological safety	Sense of belonging	Self-disclosure	Total
S206 Fieldcast 2: Developing methods and data collection	Co-presenter	S206-MT1	4	2	4	2	2	2	2	2	3	**23**
	Co-presenter	S206-MT3	1	1	2	3	1	0	1	0	0	**9**
	Co-presenter	S206-MT4	2	0	2	0	0	0	0	0	0	**4**
	Moderator	S206-MT2	4	2	2	3	0	2	1	0	0	**14**
S206 Labcast 3: Analysing data and making conclusions	Co-presenter	S206-MT1	1	4	2	4	2	1	2	0	2	**18**
	Co-presenter	S206-MT3	6	1	4	3	1	0	3	1	1	**20**
	Co-presenter	S206-MT4	3	3	1	2	1	0	4	0	0	**14**
	Moderator	S206-MT2	11	5	2	3	2	0	0	0	0	**23**
SXHL288 The human brain in action	Co-presenter	SXHL288-MT2	12	4	5	9	6	3	7	6	3	**55**
	Co-presenter	SXHL288-MT3	15	0	4	8	2	1	2	5	0	**37**
	Moderator	SXHL288-GM1	9	3	2	3	11	2	5	0	2	**37**
SXHL288 Cells and tissues close-up	Co-presenter	SXHL188-MT2	16	1	0	1	3	1	5	0	0	**27**
	Co-presenter	SXHL288-MT1	5	3	2	1	2	1	1	0	1	**16**
S315 Intro to experiment for TMA05	Lead presenter and moderator	S315-MT4	4	7	1	2	6	1	1	2	1	**25**
	Presenter	S315-MT2	5	0	0	0	0	0	3	0	0	**8**
	Presenter	S315-MT1	0	0	1	1	0	0	0	1	0	**3**
Total			**197**	**115**	**96**	**81**	**78**	**73**	**70**	**50**	**38**	

learn more about as they work through their own investigation" (SXHL288-MT3).

In staff focus group and interview data, team members discussed various aspects of the web broadcast processes. A team member commented on their moderating strategies during the 'Technologies in Practice' labcasts:

> *"I tend to try and build on whatever the presenter has said, to try and get the students to either contextualize it around something that they are interested in or know about in their own situation. I then see what happens or pose additional questions. If a question has been posed that's worth keeping, I make a note and hold it back until the Q&A" (TM129-MT1).*

Students survey, text-chat and interview data, reveal similar areas that aligned with the strategy. For example, during a TM129 Robotics demo labcast, a student responds in the text-chat "@MT1 Indeed, I never actually considered all the possible applications for detecting stalling in that matter" (TM129-19J-S8). During the S206 fieldcast 2 episode, a student responds in the text-chat, "Ahhh… so [the presenter] is marking the random coordinate?" (S206-S8). In survey data, an S206 student commented, "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 team was great" (SXF206-S4).

5.3.2 Encouraging participation.

Teaching teams encouraged participation by urging students to vote, provided guidance on where to find the widgets and invited students to post questions.

The S206 team utilised this strategy the most as they gave students the opportunity to drive the field investigation. For instance, S206-MT1 mentioned, "There are several ways you can talk to us. One of those is through using a series of widgets that you can see at the bottom of the screen. Have a go at the first widget which is a map one and tell us where you are." Similarly, in the text-chat, S206-MT2 provided instructions on how to navigate the interface and encouraged students to vote at various stages.

In student interview data, one S206 participant mentioned, "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. I think it made it a bit more fun" (S206-S03). However, not all perceived the encouragement as beneficial. For instance, in survey data a respondent mentions, "I was well-placed to investigate independently. I did not enjoy merely observing the tutors" (S206-S29).

5.3.3 Praise

Praise was used as a strategy to express approval, admiration, or positive evaluation of an individual or the collective student body. Examples included praising questions posed in the text-chat and complimenting the audience-wide widget responses. For example, in the SXPS288 Physics project labcasts, a first-time presenter responding to the widget poll exclaimed, "Excellent! Lots of sensible answers in there and they keep coming in" (SXPS288-MT5). SXPS288-MT1 praised the process and progress of students' learning activities within the module. Responding to a widget poll, a presenter commented, "That's a really good one. Well done for whoever came up with that" (SXHL288-MT2).

5.3.4 Humour

The teams used humour as an immediacy cue to create rapport and reduce potential anxiety. Except for the SXPS288 Intro to remote experiments and SXPS288 Physics project, the strategy was demonstrated in all other web broadcasts. In some cases, where a presenter exhibited humour, it was emulated by their co-presenter. For example, SXHL288-MT2 mentions, "It's quite hard to visualize, but I think [MT1] has got something a little bit tastier than an adipocyte" to which, SXHL288-MT1 replies, "It's a banana. It's not there to keep us going if we get a bit peckish. It's not really an adipocyte, but it allows us to illustrate several things." In an S206 Fieldcast episode, a co-presenter remarks, "Well done to the person who thought it was Geoff Hurst in the 1966 world cup, maybe just sort of driven by nostalgia rather than science" (S206-MT3) in response to an audience-wide polling response. In staff focus group data, a team member commented:

> *"I mean there's a bit of mucking about in the field or in the lab and that's intentional to make it an engaging experience so that the students hopefully feel called in and it's not serious and deadly dull"* (S206-MT4).

Students were responsive to the humour strategy. When discussing motivation to attend the live fieldcasts, an S206 student mentioned:

> *"I think it's always good to 'put a face' isn't it? I think that helped. All three of them were very natural. They engaged with each other well so there's rapport between them. There was sometimes a bit too much laughter you might argue. I cannot remember who was laughing but I would not worry that's a minor point really. I mean you are seeing real research scientist. I think it helps. It's better than just chatting in a forum"* (S206-S10).

5.3.5 Promoting further engagement

Teaching teams promoted future web broadcasts, the recordings, specialist topic forums and other resources outside of the module.

Moderators informed students of when the replay link would be available. S206-MT2 mentions in the text-chat, "There will be information and the data available on the forum in about an hour after the labcast" (S206-MT2) and SXPS288-MT1 comments, "Student S1 - yes an excellent question for the forum." In the S315 Intro to experiment for TMA05, the lead presenter and moderator promotes a day school opportunity. In the TM129 Networking demo labcast, TM129-MT1 promotes the guest presenter's website.

During an interview, the SXPS288 guest presenter mentioned the importance of the recordings for reviewing information:

> *"But then having a live broadcast, I would think it's smart to record it so they can click and stop at their own pace because some of these things go super-fast. I cannot retain all the information I hear in a one-hour lecture. Going back and being able to re-watch it is probably valuable"* (SXPS288-GP1).

5.3.6 Appreciation

The data confirms that teaching teams used appreciation by acknowledging the efforts and contributions of students for attending the events and interacting with the interface by voting and posting questions. This was observed through salutations at the beginning and closing of the web broadcasts and sometimes overlapped with praise.

In the SXPS288 Planetary science project labcast, SXPS288-MT1 thanks students for their attendance and questions. For example, in the SXPS288 Physics project labcast he mentions, "Thank you very much for joining us this evening. We really do appreciate you spending the time to watch this labcast and thanks to those of you watching the recording as well" (SXPS288-MT1). He also shows appreciation for students' activities on the forum and their engagement with the study materials. SXPS288-MT3 thanks the audience for their enthusiasm and completion of experimental projects. An S315 team member mentioned:

> *"I think the students are generally quite positive towards them* [i.e., *labcasts*]. *They are relatively high-quality things. The students probably recognise the effort that's put into them. I think that's ultimately right. If people recognise that you really are trying, I think that's appreciated regardless"* (S315-MT2).

Similarly, in text-chat transcripts, students showed appreciation at the closing of the web broadcast. For instance, "Really clear and interesting. Many thanks both" (SXPS288-S17) and after the first episode of a S206 fieldcast a student commented "Appreciated, thanks. See you guys in a bit" (S206-S56).

5.4 Types of teaching roles

This section presents the description of the teaching roles and the results of how strategies emerged within the five roles. Tables 7–11 present the distribution of communication strategies and behaviours across lead presenters, presenter and moderators, presenters, moderators and co-presenters.

5.4.1 Lead presenter role

A lead presenter presents to camera and conducts most of the demonstrations or runs remote experiments. Lead presenters are responsible for polling the question-and-answer widgets and reviewing the responses. The data shows that when a team member has a role as a lead presenter, they establish social connection and foster the tone for social interaction. This was achieved primarily by way of personal introductions, welcoming, praising and thanking the remote audience, outlining the objectives of the web broadcasts and orientating students to the Stadium Live interface. Table 7 shows the number of occurrences a lead presenter used a communicative strategy during an event and the sum of the strategies across different web broadcasts.

The data show two modules' teams (e.g., TM129 and SXPS288) used a lead presenter. Two out of the four lead presenters are experienced in teaching via web broadcasts and have done so for several years. In TM129, over the course of four labcasts, the lead presenter (i.e., TM129-MT2) demonstrates several strategies. In the TM129 Robotics demo 2019 and TM129 Networking demo 2019 labcasts there were 5 and 16 strategies, respectively. In the 2020 labcasts which repeat in topic and content, there were 14 and 13 strategies, respectively. TM129-MT2 praises, guides students' thoughts and encourages participation the most. The least demonstrated strategies are promoting further engagement and fostering a sense of belonging. Except in the 'Robotics demo 2019', TM129-MT2 is consistent in the frequencies of strategies across the labcasts.

Whereas in the SXPS288, over the course of two labcasts, the lead presenter (i.e., SXPS288-MT1), displays a higher number of strategies. For example, in the 'Intro to remote experiments' labcast there are 25 and in the 'Physics project' labcast 24 strategies. SXPS288-MT1 shows appreciation, praises and guides students' thoughts the most. The least demonstrated strategy is self-disclosure and humour. When there was a new and less experienced lead presenter (e.g., SXPS288-MT3), the data showed they demonstrated at least one or more strategies in every category. SXPS288-MT3 encouraged participation and praised students' module progression and widget responses the most. However, he also used self-disclosure statements as a new member of staff to share motivations of working in science. A first-time, guest presenter (i.e., SXPS288-GP1) demonstrated the highest number of strategies in all categories except in promoting further engagement.

5.4.2 Presenter and moderator role

A presenter and moderator is a dual role carried out by a team member, who presents to camera often by opening the web broadcast and welcoming the audience. During an event, they pose questions to the lead presenter and moderate the text-chat box. The most frequently used strategy differs to lead presenters (see Table 8). Three teaching teams (i.e., TM129, SXPS288 and S315) used the presenter and moderator format in their labcasts. The lecturers in this role opened the labcasts by establishing social connection. During the planned demonstrations or experiments, the presenter and moderator facilitate the text-chat by answering and collating questions for a Q&A session towards the end of an event.

The data illustrates that in the 'TM129 Robotics demo 2019' and the 'TM129 Networking demo 2019 and 2020 labcasts, TM129-MT1 used a higher number of communicative strategies (e.g., 23, 33 and 28) than TM129-MT2 (e.g., 5, 16 and 13) respectively. Across the three events, the most frequent strategies demonstrated were guiding students' thoughts, encouraging participation, and promoting further engagement and the least used strategies were sense of belonging and self-disclosure.

A faculty member of the School of Physical Sciences was a guest moderator for the 'SXPS288 Exploring Mars' labcast. SXPS288-GM4 equally demonstrated a high number of strategies similar to SXPS288-MT1 (see Table 6). SXPS288-GM4 used humour, sense of belonging and self-disclosure the most as verbal exchanges during the Q&A session rather than in the text-chat. In the 'S315 Intro to the TM05 experiment' labcast, S315-MT4 displayed 25 strategies compared to two fellow presenters who showed 8 and 3, respectively. The most employed strategies were encouraging participation, promoting further engagement, and guiding students' thoughts. The least used strategy were appreciation, praise, psychological safety, and self-disclosure.

5.4.3 Presenter role

A presenter differs to that of the lead presenter in that they are often presenting in a team of 2–3 and may include an external speaker as a guest presenter. Those in presenter roles do not lead and will not open the web broadcast. However, based on the running order script, they may have dedicated roles of presenting slides, a demonstration or running an experiment. They might be responsible for polling widgets,

TABLE 7 The distribution of strategies across the lead presenter roles.

Interactive web broadcast	Identifier	Praise	Appreciation	Guiding students thoughts	Encourages participation	Self-disclosure	Psychological safety	Humour	Promote further engagement	Sense of belonging	Total
TM129 Robotics demo 2019	TM129-MT2	0	1	1	2	1	0	0	0	0	**5**
TM129 Networking demo 2019	TM129-MT2	4	1	1	3	2	2	1	1	1	**16**
TM129 Robotics demo 2020	TM129-MT2	2	3	4	2	0	0	1	1	1	**14**
TM129 Networking demo 2020	TM129-MT2	3	1	3	2	1	2	1	0	0	**13**
SXPS288 Intro to remote experiments	SXPS288-MT1	9	9	0	2	0	1	0	3	1	**25**
SXPS288 Physics project	SXPS288-MT1	5	7	6	2	0	1	0	2	1	**24**
SXPS288 Planetary science project	SXPS288-MT3	4	1	1	5	3	1	2	1	2	**20**
SXPS288 Exploring Mars	SXPS288-GP1	6	3	6	1	5	3	4	0	1	**29**
Total		**33**	**26**	**22**	**19**	**12**	**10**	**9**	**8**	**7**	

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TABLE 8 The distribution of strategies across the presenters and moderators' roles.

Interactive web broadcast	Staff identifier	Guiding students thoughts	Encourages participation	Humour	Promote further engagement	Praise	Sense of belonging	Appreciation	Self-disclosure	Psychological safety	Total
TM129 Robotics demo 2019	TM129-MT1	8	4	5	1	1	2	1	0	1	23
TM129 Networking demo 2019	TM129-MT1	13	7	1	4	4	0	2	2	0	33
TM129 Networking demo 2020	TM129-MT1	5	6	2	4	3	1	2	1	4	28
SXPS288 Exploring Mars	SXPS288-GM4	2	2	7	2	0	4	2	3	0	22
S315 Intro to experiment for TMA05	S315-MT4	4	7	2	6	1	2	1	1	1	25
Total		**32**	**26**	**17**	**17**	**9**	**9**	**8**	**7**	**6**	

but this mainly lies with the lead presenter or presenter and moderator. Like the presenter and moderators, presenters guide students' thoughts.

Data from Table 9 can be compared with the data in Table 7 which found that guiding students' thoughts is the most frequent employed strategy. Three modules team (i.e., TM129, SXPS288 and S315) used this type of role, which involves conducting demonstrations, discussing methodological processes and in some cases reviewing widget responses. The guest presenter (i.e., TM129-GP1) in the 'TM129 Networking demo in 2019 and 2020', slightly increased in 4 and 6 strategies, respectively. The most frequent strategy was guiding students' thoughts and promoting further engagement, during a presentation of his real-world research activities.

Presenters in SXPS288 conducted experiments and demonstrated apparatus and equipment alongside the lead presenter. SXPS288-MT5 demonstrated 7 and 5 strategies across two labcasts. The most frequent was guiding student thoughts throughout the demonstration and encouraging participation with the widgets. During the 'Planetary science project' labcast, SXPS288-MT2, who has more experience in labcasts, demonstrated a higher frequency of strategies (i.e., 14). Similarly, she guided students' thoughts more frequently but also used psychological safety to reassure students about conducting a new remote Gas Cell experiment.

5.4.4 Moderator role

A moderator is a person who actively facilitates the text-chat and can be from the teaching team or a guest moderator from within a school. Moderators may or may not present to camera depending on the format of the web broadcast.

Four of the teaching teams (i.e., TM129, SXPS288, S206 and SXHL288) used a dedicated moderator. They helped to establish social connection by welcoming and thanking the audience, orienting students to the interface, troubleshooting issues relating to the livestream, and reinforcing and answering students' questions. Moderators often asked questions posted by students to the lead presenter towards the end of an event as part of a Q&A slot. Table 10 shows that the two most used strategies were similar to the presenter and moderators (see Table 7).

When SXPS288-MT1 acted as a moderator in the 'SXPS288 Planetary science project' labcast and 'SXPS288 Exploring Mars' labcast, they demonstrated a higher number of strategies (i.e., 43 and 37 respectively) than when they were a lead presenter. The strategies they exemplified the most were guiding students' thoughts, appreciation, and fostering a sense of belonging. Across three fieldcasts episodes, S206-MT2 demonstrated the highest number of strategies in the first and final episodes (i.e., 39 and 23) respectively. His most frequent were guiding students' thoughts, encouraging participation and humour. The least demonstrated were self-disclosure and sense of belonging. In the 'SXHL288 Human brain in action' labcast, a guest moderator (i.e., SXHL288-GM1) exhibited 37 strategies in the event with promoting further engagement as the most frequent. As a topic specialist they signposted students to the resources and answered questions related to assessment.

5.4.5 Co-presenter role

A co-presenter presents within a team-teaching whereby two or three lecturers present various stages of a web broadcast. Like the lead presenter, presenter and moderator roles, they establish social

TABLE 9 The distribution of strategies across the presenter roles.

Interactive web broadcast	Staff identifier	Guiding students thoughts	Psychological safety	Promote further engagement	Praise	Encourages participation	Appreciation	Sense of belonging	Self-disclosure	Humour	Total
TM129 Networking demo 2019	TM129-GP1	2	0	1	0	0	0	0	0	1	**4**
TM129 Networking demo 2020	TM129-GP1	2	0	3	1	0	0	0	0	0	**6**
SXPS288 Intro to remote experiments	SXPS288-MT5	2	0	1	0	2	0	1	1	0	**7**
SXPS288 Physics project	SXPS288-MT5	2	0	0	0	1	2	0	0	0	**5**
SXPS288 Planetary science project	SXPS288-MT2	6	4	0	1	0	1	1	1	0	**14**
S315 Intro to experiment for TMA05	S315-MT2	5	3	0	0	0	0	0	0	0	**8**
S315 Intro to experiment for TMA05	S315-MT1	0	0	0	1	0	0	1	0	1	**3**
Total		**19**	**7**	**5**	**3**	**3**	**3**	**3**	**2**	**2**	

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TABLE 10 The distribution of strategies across the moderators' roles.

Interactive web broadcast	Staff identifier	Guiding students thoughts	Encourages participation	Promote further engagement	Appreciation	Praise	Sense of belonging	Humour	Psychological safety	Self-disclosure	Totals
TM129 Robotics demo 2020	TM129-GM1	1	6	2	2	2	0	2	0	1	**16**
SXPS288 Planetary science project	SXPS288-MT1	13	2	2	9	1	9	1	4	2	**43**
SXPS288 Exploring Mars	SXPS288-MT5	0	0	0	0	0	0	0	0	1	**1**
SXPS288 Exploring Mars	SXPS288-MT1	4	7	6	7	8	4	0	1	0	**37**
S206 Fieldcast 1: Making observations & developing hypotheses	S206-MT2	15	14	2	2	0	2	2	2	0	**39**
S206 Fieldcast 2: Developing methods and data collection	S206-MT2	4	2	0	2	2	0	3	1	0	**14**
S206 Labcast 3: Analysing data and making conclusions	S206-MT2	11	5	2	0	2	0	3	0	0	**23**
SXHL288 The human brain in action	SXHL288-GM1	9	3	11	2	2	0	3	5	2	**23**
Total		**57**	**39**	**25**	**24**	**17**	**15**	**14**	**13**	**6**	

TABLE 11 The distribution of strategies across the co-presenters' roles.

Interactive web broadcast	Staff identifier	Guiding students thoughts	Humour	Praise	Psychological safety	Encourages participation	Promote further engagement	Sense of belonging	Appreciation	Self-disclosure	Total
S206 Fieldcast 1: Making observations and developing hypotheses	S206-MT1	0	2	3	2	4	1	1	2	0	**15**
	S206-MT3	2	3	4	5	4	2	1	1	0	**22**
	S206-MT4	0	1	1	0	1	0	0	0	1	**4**
S206 Fieldcast 2: Developing methods and data collection	S206-MT1	4	2	4	2	2	2	2	2	3	**23**
	S206-MT3	1	3	2	1	1	1	0	0	0	**9**
	S206-MT4	2	0	2	0	0	0	0	0	0	**4**
S206 Labcast 3: Analysing data and making conclusions	S206-MT1	1	4	2	2	4	2	0	1	2	**18**
	S206-MT3	6	3	4	3	1	1	1	0	1	**20**
	S206-MT4	3	2	1	4	3	1	0	0	0	**14**
SXHL288 The human brain in action	SXHL288-MT2	12	9	5	7	4	6	6	3	3	**55**
	SXHL288-MT3	15	8	4	2	0	2	5	1	0	**37**
SXHL288 Cells and tissues close-up	SXHL188-MT2	16	1	0	5	1	3	0	1	0	**27**
	SXHL288-MT1	5	1	2	1	3	2	0	1	1	**16**
Total		**67**	**39**	**34**	**34**	**28**	**23**	**16**	**12**	**11**	

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connection with the audience, but do not moderate the text-chat box. The format consists of a more conversational style between the co-presenters as they set up and progress stages of the scientific process such as conducting experimental or field work, demonstrating, discussing methodological processes, hypothesising, and observing. The use of humour is the second most utilised strategy as shown in Table 11.

Two teaching teams (i.e., S206 and SXHL288) used a co-presenter format. In the fieldcasts episodes, S206-MT1 and S206-MT3 demonstrated a similar number of strategies (i.e., 18 and 20). The teaching team was more demonstrative in encouraging participation and guiding students' thoughts throughout the three episodes. Likewise, there was equal number of humour and praise used between all three co-presenters. Although the discipline, duration, and number of labcasts and presenters were different, the data shows that co-presenters in SXHL288 labcasts similarly guided students' thoughts and used humour more frequently. However, SXHL288 co-presenters produced more statements of sense of belonging (i.e., 11) in the first labcast compared to S206 co-presenters (i.e., 5) in three fieldcast episodes. The data shows that when there are peer co-presenters, they tend to demonstrate the same strategy at similar frequencies.

6 Discussion

This study examined teaching roles and communication strategies in interactive web broadcasts and the perceptions of the teaching teams and students who participate in them. The pre-planned teaching roles varied across the modules but aligned with previous approaches of teaming (Friend et al., 2010), participant-observer and interactive models White et al. (1998) and the guest lecturer model Collins et al., 1996. The findings show that roles were of a pedagogical, social and managerial nature as classified in previous research (Berge, 1995).

The results show that guiding students' thoughts and research most frequently occurred across the web broadcasts. This finding suggests that presenter and moderators, moderators and co-presenters prioritise aspects of cognitive engagement (Ramma et al., 2018) and corroborates findings from Liu et al. (2019) on facilitating students' understanding of key concepts. Student datasets in TM129 and S206 confirmed positive reactions to the strategy in supporting understanding.

Similar patterns of strategies were seen among moderators (i.e., in TM129, SXPS288, S206 and SXHL288) and those with a dual role of presenter and moderator (i.e., in TM129, SXPS288 and S315). Both types of roles were more prolific in guiding students' thoughts and encouraging participation although individual team members differed in their role and had different numbers of occurrences. For example, TM129-MT1 although a presenter and moderator, moderates the text-chat over a longer period and facilitates questions at the end, whereas S315-MT4, as a lead presenter and moderator, presents to camera, sets up several widgets while simultaneously questions and engages in verbal exchanges with the other presenters. This leaves less time to moderate the text-chat box. Likewise, SXPS288-GM4, as presenter and moderator, demonstrates most of the strategies during verbal exchanges with the guest presenter and less so in the text-chat. However, there were two additional moderators to provide timely responses and engage in other social discussion. These results suggest that cultivating students' engagement and providing guidance is more likely to occur when there is consistent active moderation during the live event. The findings further corroborate the notion that team roles are situational and context-dependent (Badia et al., 2017; Davis and Winter, 2019; McKenzie et al., 2022).

Where a web broadcast design included co-presenters, there seemed to be similar occurrences of strategies between team members. This might be due to the conversational format designed within those web broadcasts and typical turn-taking functions that occur. However, it is also plausible that co-presenters experience more constructive collaboration together. The use of humour had the second highest occurrence among co-presenter roles, confirming the association between humour, camaraderie, and student attention and retention (Rourke et al., 1999; Erdoğdu and Çakıroğlu, 2021). An Environmental Science team member and student raised the theme of humour and banter. However, the student's comment reflected the caution advised by Bolkan et al. (2018) when using humour. Another interesting finding is that when one co-presenter acts as an expert and ask questions during an experiment or demonstration while the other co-presenter acts as novice and answers, similar strategies are used.

Lead presenters differed slightly in their strategies across disciplines with some producing more affective behaviours such as appreciation and praise. Those new to labcasting tend to model the types of strategies from more experienced lead presenters within their discipline and demonstrate more consistent or higher number of strategies. This result may be explained by the influences of power dynamics co-teachers encounter as reported by Morelock et al. (2017). However, lead presenters can differ in the number of strategies when they switch roles. This was observed in SXPS288-MT1 whose strategies were twice as high in their moderator role.

A common strategy was to praise and show appreciation for students attending live events which are optional learning activities. These strategies are especially important for adult DL students who are often 'time-poor' due to work, study and other commitments. The teaching teams' acknowledgment, praise and appreciation focused on students' efforts of posing questions and their audience-wide widget responses.

There are several valuable results. The nine strategies in the extant literature were found to be present across web broadcasts. This is reassuring since the communication strategies and dialogic feedback loops that occurred are representative of effective teaching and learning, offering potential insights for training and supporting distance educators. Students corroborated the value of many of the strategies either in the text-chat or through surveys and interviews. Students respond positively to the web broadcasts and the evidence suggest that the vast majority who attended live did not passively watch but engaged and interacted with their lecturers and each other through cognitive and affective engagement that support the learning process.

7 Limitations

There are some limitations to this study that should be acknowledged. First, the research setting is a single DL university. However, The OUUK is not alone in its use of web broadcasting or live streaming and the literature indicates that team teaching approaches are being applied at other DL universities and online teaching contexts (Hester et al., 2022; McKenzie et al., 2022). Nonetheless, the OUUK's educational broadcasting experience, media production processes and professional development programmes are likely to increase the consistency of teaching styles adopted within the web broadcasts. The type and frequency of communication strategies employed were found to be distinct to the role (i.e., presenter, moderator) regardless of the subject discipline. Therefore, further studies at other institutions would be needed to verify if these findings could be generalised beyond The OUUK.

Data collections methods varied by module but included consistent core questions in student questionnaires, the four staff focus groups (i.e., TM129, SXPS288, S206, S315) and two sets of student interviews (i.e., SXPS288 and S206). There was also a consistent approach to the analysis of system data logs and observations of the web broadcasts. This allowed comparison and triangulation across the data sets to draw conclusions and recommendations. It should be noted that two web broadcasts (i.e., TM129 'Networking demo 2020' and SXPS288 'Exploring Mars') occurred during the Covid-19 pandemic, which could have impacted the attendance and research participation of some students and staff.

8 Recommendations

The following are some suggested recommendations, based on the study's findings, for researchers and academics who use synchronous media technologies (e.g., livestream, polls, live text-chat) on commercial platforms such as YouTube, Facebook Live, Zoom or Microsoft Teams:

1. Pre-plan a team teaching model or designate team roles.
2. Introduce yourself and encourage student introductions.
3. Encourage interaction with the interface's tools early on and throughout the session.
4. Show appreciation for student participation, interaction and engagement.
5. Offer praise or positive evaluation to questions or comments.
6. Use self-disclosure and appropriate humour to humanise the presenter.
7. Give students choice on tools use (e.g., camera on/off) and offer eassurance.

9 Conclusion

Interactive web broadcasts are effective in mitigating challenges that distance students studying STEM disciplines might face. The ability of lecturers and other experts to connect with their students on a personal level is enhanced by providing students opportunities to participate in real-world scientific experiments, technological practices, and field investigations in real-time. A team teaching approach is useful for the planning and delivery of web broadcasting. The variety of roles allow for collective expertise and diversity in strategies. Both the similarities and variations of communication strategies and behaviours are beneficial to supporting undergraduate students on STEM modules. This study contributes to a better understanding of the types of roles that can be designated among staff and effective strategies for comparable technology-mediated systems. It also confirms the value of structuring roles and appointing a moderator to oversee questions and maintain a friendly atmosphere and of co-presenters to share expertise and provide multiple perspectives on practical lab or field work. A team-teaching approach can better support students and enhance their learning experiences.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the Human Research Ethics Committee of the Open University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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