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TEACHING ESL SCIENCE COMMUNICATION IN MULTIDISCIPLINARY MULTILEVEL CLASSROOM SETTINGS

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Abstract*. The transformation of modern science from monodisciplinary to multidisciplinary leads to cardinal changes in the methods of teaching English L2 science communication, which is a challenge for non-anglophone researchers who need to share research outcomes in English within and beyond their research-specific community. The paper describes a case study in which the main objective is to understand how immersion of English L2 speaking researchers into a multidisciplinary multilevel classroom setting affect the development of science communication skills needed to reach broader audiences through innovative dissemination channels, making research findings clearly intelligible to both specialists and non-specialists alike. The paper defines the potential of educational reconstruction of multidisciplinary science communication context that involves interaction of researchers with varying English proficiency levels, professional expertise, and research area. Our data demonstrate that metacognitive teaching strategies can assist early-stage researchers to develop their ability to integrate fully into the larger global science community and reap the benefits of science communication.*

Key words*: science communication, early-stage researchers, multidisciplinary multilevel classrooms*

1. INTRODUCTION

Today, the way science is done is fundamentally different from what it was in the previous centuries. It is no longer monodisciplinary as research studies increasingly draw on knowledge and expertise outside of one main discipline. The understanding of the present world can no longer be accomplished in the framework of monodisciplinary research. Modern science is embedded in economic activities, cultural orientations, and political environments that shape and legitimate scientific development as external drivers. Besides, to the role of an individual researcher has been added the power of organized research teams, which bring together individuals from multiple disciplines. Research networks, alliances, or international research consortia have evolved to strengthen ties within the international scholarly community.

Present studies state the importance of establishing connections between science and society, and researches and science communicators look for ways to help people not only

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comprehend science but also care about science-related issues using different techniques and tools, e.g., storytelling (Sheremet and Deviatko 2022), applying reflective practice within networks in order to deepen understanding of the lay audience's interests (Roedema et al. 2022), or focusing on culture and meaning, which opens up new ways of analyzing empirical material.

Furthermore, present-day digitally networked technologies are rapidly changing the way the results of academic research are communicated within communities and with the wider public (Baum and Coen 2019). Scientific information is now being collected, treated, and disseminated on a massive scale. Science communication is no longer a one-way presentation of facts but a two-way dialogue that depends on interpersonal skills (Appleby and Hiller 2012, Barrie 2012) of interlocutors who are forced to be able to work in their specific discipline while making connections with other disciplines in order to disseminate scientific findings, provide feedback on a concrete research project, interpret and repackage scientific information (Ford and Teare 2006) for a target audience with various levels of comprehension of the discipline (Appleby and Hillier 2012, Maxwell and Angehrn 2010) and for the non-research audiences.

Many now view an increasingly greater number of scholarly journals that request that authors write in a way that appeals to and engages a broader audience. Further, we list some excerpts of international peer-reviewed journals' aims and scope in support of this fact. For example:

"Physics Reports keeps the active physicist up-to-date on developments in a wide range of topics by publishing timely reviews [...]. These reviews are specialist in nature but contain enough introductory material to make the main points intelligible to a non-specialist. The reader will not only be able to distinguish important developments and trends in physics but will also find a sufficient number of references to the original literature" (SJR - Journal Search, n.d.-a).

"Current Opinion in Cell Biology serves as an invaluable source of information for researchers, lecturers, teachers, professionals, policy makers and students […]" (SJR - Journal Search, n.d.-b).

"*[Computer Physics Communication* requires that] (t)he introduction to each paper should be directed to a general audience and the author(s) must clearly articulate the novelty and significance of the paper and how it will advance the solution of an important physics application. Papers which, in the opinion of a Principal Editor, fail to do this will not be sent for review […]*"* (Guide for Authors - Computer Physics Communications - ISSN 0010-4655, n.d.).

Communicating science, multidisciplinary science in particular, with the broad range of audiences that make up 'the outside world' is a challenge of its own. It is very different from what scientific communication used to be several decades ago when scientists had to present their research findings to a select group of researchers and experts specializing in a specific subject area through print-based peer-reviewed publications or in-person science events. Indeed, science communication was used to communicate new scientific knowledge mostly through academic journal articles, technical reports, and presentations at conferences and grant applications to an audience of researchers, scientists, and technical experts. By contrast, present-day science communication deals with communicating research for a broad range of audiences that forms the general public, informing, educating, and raising awareness of science-related topics through innovative dissemination channels and formats. Table 1 highlights and compares "previous" and "current" trends in science communication that we considered when designing a course on science communication for STEAM professionals.

Table 1 Comparison of the Key Features of ‘Previous’ and Current Science Communication Trends

Features	Science Communication Trends	
	Previous	Current
Scope of scientific area	Monodisciplinary	Multidisciplinary
Scope and nature of audiences	A select group of researchers and experts specializing in specific subject areas	Professional academic social networks Non-research audiences: funding, industrial, legal organizations, religious organizations, politicians, policymakers, academic teachers, students General public (individuals outside of academic and research circles)
Model of Science	Deficit model	Dialogue model
Communication	A top-down information transmission mode (“The communicator is assumed to be authentic and honest in their presentation, while the receiver is a passive partner absorbing the information”. (Stine 2021, 9)	A bottom-up information transmission mode where multiple people shape the conversation (van der Sanden and Meijman 2008)
Dissemination	Print-based / in-person	Digital / virtual
Output	Scientific journals and the journals of the learned societies, scientific books, popular almanacs and calendars, monographs, personal letters between scientists, conferences, workshops, seminars	Open access science, preprints Teleconferences

Inspired by a variety of novel ways of communicating research findings, observations, and views to interact with different audiences, many L2 speaking researchers neglect sharpening their science communication skills or do not know how to overcome their shyness interacting with their potential audiences in English. As a result, they lack appropriate training and knowledge for effective science communication. Indeed, some research proves that “those lacking language proficiencies tend to feel frustrated, experience a sense of professional loss, and have difficulty maintaining dignity” (Hwang 2013, 9). As Charles (2007) points out, professionals could question their disciplinary expertise in relation to their perceived linguistic proficiency comparable to English L1 speakers in their profession (Huttner-Koros and Perera 2016). However, all scientists, regardless of their language, have to interact with multilingual and multicultural researchers with a range of associated knowledge skills and attitudes and different levels of English language proficiency.

Although previous studies have explored different methods for developing science communication skills, e.g., writing skills (Li and Flowerdew 2020, Fernandez et al. 2017, Burgess and Cargill 2013), oral communication skills (San-Valero et al. 2019, Ponzio et al. 2018, Purnomo and Fauziah 2018), and reading skills (Nigro 2022, Kim et al. 2021) in a learning environment, no study to date has examined strategies for science communication training in a multidisciplinary multilevel environment, and very little is known about the effectiveness of the immersion of English L2 speaking researchers into 'real-world' science communication context in a classroom setting to foster their intrinsic motivation to collaborate with other learners at the intersection of diverse scientific disciplines regardless of the level of English-level language competence.

2. OBJECTIVE

The overall objective of our case study is to understand how multidisciplinary multilevel classroom setting can help early-stage researchers (ESRs) hone their science communication skills to share their research findings to diverse audiences outside the discipline. Through qualitative research methods, this study will address the following questions:

RQ1: How does immersion into multidisciplinary science context affect the learners' motivation to communicate their research findings to a target audience with various levels of comprehension of the discipline and non-specialists through traditional and innovative dissemination channels?

RQ2: Do learners with different levels of language competence effectively communicate with one another?

RQ3: What teaching strategies can accommodate different disciplines and language levels in one class and cater to learners' needs in a less toilsome and time-consuming way?

To answer these research questions, we opted for a case study approach to problematize and add details to the theory and practice of teaching science communication in a multidisciplinary multilevel environment and to contribute to better understanding of ESRs' vision of the most important and salient aspects of science communication.

In an effort to address the objective, we set the context for our case study by outlining the basic components of the course on science communication for STEAM professionals, i.e., purpose, content, strategy, and assessment.

3. MATERIALS AND METHODS

For two years (2020-2022), we taught an eight-month course on science communication for faculty members, researchers, and students across all academic disciplines and fields that are taught and researched at our university. The course consisted of a four-month phase (first semester) in which the main focus was made on coping with English level heterogeneity of interlocutors involved in communication about science-related themes. During this phase, we discussed language-related barriers that could hinder effective communication, e.g., inappropriate use of jargon, abstract language, non-verbal behavior, and unnecessary complexity that could distract audience members. We used training (structured exercises emphasizing mutual listening and talking) developed with regard to the diversity of participants' English proficiency levels to stimulate interpersonal interaction based on solving a certain problem that involves the activation of four language skills allowing participants to develop language proficiency in the context of "natural" conversations.

The possibility of introducing blogging in a learning framework has proved to result in improvements the students' outcomes in terms of the European Framework of Reference for Languages by the researchers (Montalban 2022). Thus, the remaining four months of the course were devoted to the acquisition of science communication skills (both written and oral) using real-world innovative dissemination channels that go beyond traditional ones, e.g., social networking sites for scientists and researchers, science-related podcasts, pages and Facebook profiles, Academia.edu, LinkedIn, Twitter, Research ID, Mendeley Research Network, IEEE Collabratec, Research Gate, science talks on TV or radio, institutional websites, personal websites.

We assumed that students could construct their knowledge in collaboration with more capable individuals and those whose English level was high would take it upon themselves to explain grammar concepts or act as a kind of assistant for students who were less competent in English, which is always helpful on a practical level and also boosts the more advanced students' confidence in their understanding of English. We also assumed that higher-level students would monitor lower-level students, and lower-level students could monitor higher-level students, helping the latter become aware of fossilized errors they make.

Given the conceptual vision of our course, we relied on the belief that science communication skills should be taught through language-mediated cognitive activities, including peer-to-peer interaction as an opportunity for collaborative scholarly dialogue, sharing and networking as a tool for communicating research findings outside the sciences to policy makers, taxpayers, and general public, and discussing and debating as a strategy to influence the trustworthiness of researchers and the credibility of information.

Modeling real-world science communication context is impossible without identifying all limitations and regulations according to which students are supposed to act so that they feel confident to operate in typical professional scenarios. In fact, classroom learning can be only partly relevant to satisfying learners' current academic and professional communication needs since a researcher-teacher-peer relationship, which it can provide, is quasi-professional. It might not be considered satisfactory enough as there are no 'receivers' involved (e.g., experts, specializing in specific subject areas) who serve as 'gatekeepers' to research findings and, later, readers who make up the academic community.

However, in some cases, early-stage researchers become science communication leaders in their academic communities, and subsequently mentor their more senior colleagues. With this fact in mind, when developing our course, we utilized a collaborative learning approach in order to integrate both budding researchers who have little experience in science but have inquisitive mind and reveal a strong intention to embrace innovative dissemination practices in their research and "veterans" of science who may have high-profile results published in high-ranking journals but do not know how to tell compelling stories about their research.

Table 2 outlines four basic components – purpose, content, strategy, and assessment – that laid the foundation of the course on science communication for STEAM professionals.

Table 2 Teaching Model of Multidisciplinary Multi-level Course on Science Communication

Purpose		Content	
ESL Domain	▪ Development of an ability to cope with English level heterogeneity of interlocutors involved in communication about science-related topics	Quasi-professional	▪ Training materials (structured exercises emphasizing mutual listening and talking) developed with regard to the diversity of participants' English proficiency levels to stimulate interpersonal interaction based on solving a certain problem that involves the activation of verbal communication skills
SciComm Domain	▪ Acquisition of science communication skills (both written and oral) using innovative dissemination channels that go beyond traditional ones, e.g., academic publishing	Real-world	▪ Social media: blogs, social networking sites for scientists and researchers, science-related podcasts, science-related pages and Facebook profiles, Academia.edu, LinkedIn, Twitter, Research ID, Mendeley Research Network, Kudos, IEEE Collabratec, Research Gate, science talks on TV or radio, institutional websites, personal websites
Strategy		Assessment	
Multi-level teaching (Roberts 2007, Treko 2013)	▪ Teaching to the middle then assigning leveled activities allowing participants' involvement in reaching one definite aim ▪ Teaching around science-related themes to increase participants' motivation and foster their curiosity to learn from for peers with different scientific interests ▪ Integrating the four language skills in each class allowing participants to develop their language skills in the context of 'natural' conversations ▪ Peer teaching to increase the understanding of the course content and establish an environment where peers can learn in small groups and learn how to work as a team	Internal	▪ Self-assessment of personal development and improved performance ▪ Reflection on previous valued experiences in search of significant discoveries or insights about oneself, one's behaviors, one's values, or knowledge gained

Meta-cognitive	▪ Modeling real-world science communication situations where conversational language, shared stories, and relationship building can take place ▪ Integrating meta-cognitive activities, e.g., peer-peer interaction and collaboration at the intersection of diverse scientific disciplines, discussing, and debating ▪ Storytelling ▪ Encouraging participants to create new science communication resources via social networking sites, Twitter posts, Instagram stories, science-related pages and Facebook profiles, etc. ▪ Encouraging participants to initiate discussions via social media with members of the scientific community near and far ▪ Encouraging participants to ‘learn by doing’ ▪ Allowing students freedom – i.e. agency, autonomy and environments to foster self-efficacy – to develop skills that match real-world activity, provide scope for participants to discover and create what is most relevant to them (Walker 2022)	External	▪ Feedback from the peers and the target audience, i.e., the ‘receivers’ of the research outcomes (academic community)

The course content is divided into two equally significant domains depending on the purpose, i.e., ESL Domain and SciComm Domain. Firstly, quasi-professional content (ESL Domain) in which students approach science communication process collaborating with classmates (peer-to-peer learning) and the course instructor or ‘language mediator’ whose function was limited to selecting and analyzing best examples of science communication (model texts) in definite scientific fields. Peer-to-peer learning allows working through new concepts and language material with other peers, teaching and being taught by one another, broadening their perspectives and fostering meaningful connections. The course instructor also discusses texts organization according to particular rhetorical purposes revealing key stylistic and rhetorical features and identified recurrent patterns so that participants could gain mastery of these patterned features through their usage in various contexts. Secondly, real-world content (SciComm Domain) based on using social media in which students learn how to collaborate with each other at the intersection of diverse scientific disciplines, how to use science storytelling techniques effectively, how to create new science communication resources via social networking sites, Twitter posts, Instagram stories, science-related pages and Facebook profiles, etc. and how to share their observations and contribute to the collective construction of knowledge by discussing, supporting, or challenging ideas in interdisciplinary contexts. The selection of the course materials stems from the process of analyzing students’ needs and course objectives (Spirovska 2020). Thus, to ensure success of the course, the instructor needs to ensure a significant degree of diversity in terms of science communication attitudes and practices to facilitate students’ receiving valuable feedback provided by their classmates.

3.1. Participants

The participants of the study volunteered to take a course on science communication for STEAM professionals, aimed at developing science communication skills needed to reach broader audiences through innovative dissemination channels, making research findings clearly intelligible to both specialists and non-specialists alike.

All participants signed an informed consent form and were informed that they could withdraw from the course at any point, which helped them overcome the challenge of downplaying any problems or making an attempt to present themselves in a favorable light. The participants were well aware of the purposes of the case study, i.e., to define the potential of educational reconstruction of real-world science communication in a classroom setting and to identify effective teaching strategies that can accommodate different disciplines and language levels in one class.

Prior to the start of the course, a short background survey was emailed to a total of 136 people. Those invited to complete the survey received three follow-up reminders. The survey questions focused on preliminary factors that might affect science communication experiences, including: area of expertise, level of English proficiency, and academic degree. The survey was conducted through SurveyMonkey platform. A total of 108 complete responses were received. Twenty-eight respondents did not finish the survey, and for this reason were excluded from the data analysis. The final number of respondents was n=108 (79% response rate).

Certain limitations concerned the gender of the participants and their age since we considered them irrelevant for our study. The data collected are displayed in Fig. 1.

3.2. Semi-Structured Interview

In order to substantiate the background survey findings, we conducted face-to-face semi-structured interviews with 108 participants to understand in compelling enough detail and in sufficient depth their research experiences, awareness of essential issues around science communication, the audiences that they work with and their approaches to social technologies, skills and training, motivation and reasons for selecting the course, and expected course benefits for academic career in the future.

The interviews were conducted separately with each of the interviewee in the form of a conversation about their needs and expectations. The interviewees were first asked to give an account of their scientific experiences. Next, they were requested to identify the obstacles they encountered in science communication. The interviews proceeded with questions about reasons for choosing the course and participants’ vision of its benefits. The semi-structured format was not about strictly asking and answering questions but about the interviewee sharing stories from their own experiences of scientific interaction. Table 3 summarizes the interview questions and the coding scheme used for our analysis.

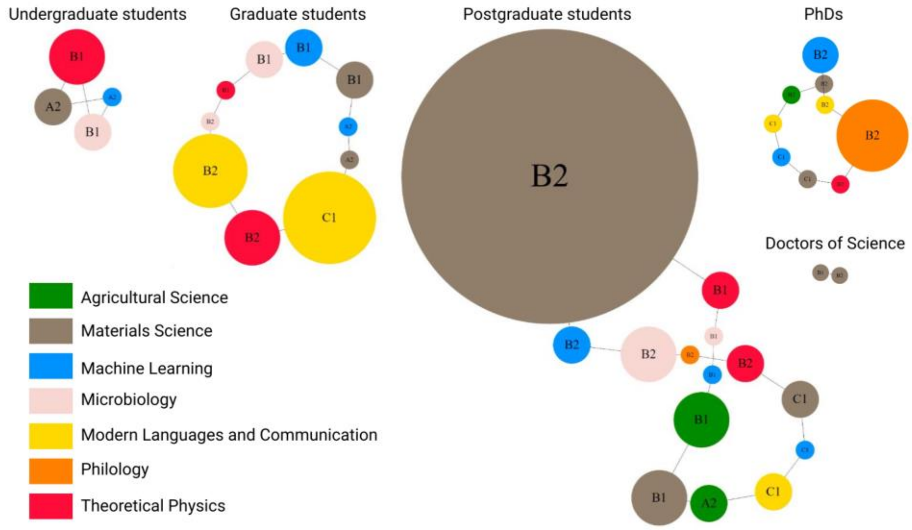

Fig. 1 Distribution of the Enrollees by their Area of Expertise, Level of English Proficiency, and Academic Degree

(a) Undergraduate students: Theoretical Physics (n=3), Materials Sciences (n=2), Microbiology (n=2), Machine Learning (n=1); Level of English proficiency: A2 (n=2), B1 (n=2), B2 (n=3), C1 (n=1); (b) Graduate students: Modern Languages and Communication (n=21), Theoretical Physics (n=16), Microbiology (n=3), Machine Learning (n=3), Materials Science (n=3); Level of English proficiency: A2 (n=2), B1 (n=5), B2 (n=8), C1 (n=5); (c) Postgraduate students: Materials Science (n=22), Agricultural Science (n=5), Microbiology (n=4), Theoretical Physics (n=4), Machine Learning (n = 4), Philology (n=1); Level of English proficiency: A2 (n=2), B1 (n=10), B2 (n=24), C1 (n=6); (d) PhDs: Philology (n=2), Machine Learning (n=2), Materials Science (n=2), Modern Languages and Communication (n=2), Agricultural Science (n=1), Theoretical Physics (n=1); Level of English proficiency: B2 (n=5), C1 (n=4); (e) Doctors of Science: Materials Science (n=2); Level of English proficiency: B1 (n=1), B2 (n=1).

Table 3 Summary of the Interview Questions and the Coding Scheme Used in the Analysis

Description	Category	Coding
Research experience	None	1
	1-5 years	2
	6-10 years	3
	More than 10 years	4
Publications	None	1
	1-5	2
	6-10	3
	More than 10	4
Types of publication(s) in (indexing) databases "In which indexing database can your publication be found?"	Russian journal in the Russian Science Citation Index (RSCI)	1
	Russian journal in the database of the Higher Attestation Commission (VAK) of the Russian Federation	2
	Russian journal in Scopus	3
	International journal in Scopus	4
	Russian journal in Web of Science Core Collection	5

	International journal in Web of Science	6
	Abstract/Conference proceedings in the Web of Science journals	7
	University journal	8
	None	9
Science communication channels “What science communication channels do you use, if any, to broadly share your expertise and research?”	Journal articles in a peer-reviewed journal	1
	SCOPUS Indexed Book Chapters	2
	Conference proceedings	3
	Lectures, workshops	4
	Social Media	5
	Science talks on TV or Radio	6
	Institutional website	7
	Summaries on a personal website, blog posts	8
	Informal chats with people at conferences	9
	Other	10
Science communication challenges/hurdles “What science communication challenges/hurdles have you faced in your academic career?”	Language considerations	1
	Communicating uncertainty	2
	Local science conventions	3
	Limited science communication opportunities	4
	Targeting broader audiences	5
	Lack of familiarity with science in general or with the scientific findings and issues related to a topic	6
	Psychological Barriers	7
	Attitude Barriers	8
	Perception Barriers	9
	Other	10
Reasons for selecting the course “Why have you decided to take this course?”	Professional development Self-imposed need to get published in high ranked journals Prerequisite for my doctoral studies Necessity to improve my research writing skills in English Seize an opportunity for collaborative research Desire to learn current trends in science communication Become a more mature researcher in my discipline Build interdisciplinary connections Socialize in scientific community Mandatory requirement for my academic position Terms of my effective contract	A tally of reasons declared by a participant
Expected course benefits “What benefits do you expect to reap after completing the course?”	Developed professional competencies in science communication in English Stronger skills in research writing Practical knowledge of international publications in peer-reviewed journals “Ready-for-submission” research paper Leadership in scientific community Increased KPI (key performance indicators)	A tally of benefits declared by a participant

An estimated frequency of participants reporting themes was recorded in this study according to the following ranking: ‘all’ (100%), ‘most’ (80–99%), ‘majority’ (60–79%), ‘more than half’ (51–59%), ‘half’ (50%), ‘less than half’ (30–49%), ‘some’ (11–29%), and ‘a few’ (1–10%) (Sandelowski 2009).

The interview revealed that most interviewees differ in the degree of research experience (2, 3, 4). Some of them had publications in highly ranked scientific journals (3, 6), whereas more than half proved to be inexperienced and their contribution to science was limited to conference proceedings (2) or publications in a local university journal (8). A few interviewees confessed being complete novice in the field of science (9). More than half interviewees reported predominantly communicating their research through such communication channels as peer-reviewed journal publications (1) and conferences (3). They also noted that the first audience for sharing their work was usually made up of their scientific advisors and heads of department (10). Only a few participants discussed their efforts to expand their communication of research findings to broader public audiences and share their accomplishments, ask questions, and get feedback on ideas from trusted and established scientists and researchers, using social media or professional platforms (5, 8, 9). Among the most frequent hurdles in communicating research ideas, the majority of interviewees recognized language considerations and lack of training for science communication readily available (1, 2), and more than half claimed that psychological barriers (7), attitude barriers (8), or perception barriers (9) negatively affected their science communication experience. Some interviewees acknowledged lack of familiarity with science in general or with the scientific findings and issues related to a topic (6). During the interviews, a number of themes emerged as being important reasons for taking a science communication course. One of such themes was the necessity to acquire language techniques to explain complex research ideas to a non-science audience. The majority of interviewees highlighted the importance of becoming a more mature researcher in their discipline able to get published in high ranked journals. More than half emphasized a necessity of building interdisciplinary connections and doing collaborative research. Less than half intended to improve their research writing skills in English, as it was required by the terms of their effective contract. A few interviewees had to choose to take the course because they wanted to learn current trends in science communication. Some of interviewees put requirements of an academic institution first. They were guided exclusively by formal motives, such as required professional development or the necessity to pass PhD qualifying exams in the English language, or increasing their KPI in order to have better salary terms.

If the interviewee spoke in generalities, prompts including specifying questions were asked. Prompts consisted of such questions as, for example: “Could you please specify what social media channels do you use to enhance your research impact?” In answer to this question some complained about the challenges of translating complex science to an easy to follow social media formats and creating accessible content which is not simplified but clear to a less specialist audience, some said that adjusting information to the audiences’ knowledge was problematic while others mentioned a lack of confidence that makes it difficult to communicated assertively. Another question asked was if the interviewee could remember a specific incident when a need for improving his/her science communication skills was critical. Almost all interviewees acknowledged the fact that such a need arose such a need arose whenever they found themselves in a situation requiring intensive communication. When asked “If you have an insight during your research or if you are taking photos of your experiment that you might use in your research talk or paper, do you tweet that insight or share your photos on social media?" almost all participants said that it had never even crossed their minds.

The most commonly reported theme while discussing interviewees' expectations from the course concerned the improvement of science communication. Some participants mentioned having a practical outcome as a paper ready for publication in English peer-reviewed journals and as a result obtaining a higher rank in an academic institution hierarchy.

The interviewees' perception of science communication proved to be so narrow that they seemed to be 'encapsulated' in their academic environment, limited to the only channel of interaction with their supervisor and department or lab staff. The most valuable outcome of science communication they mentioned was publication in high ranked journals. Obviously, they perceived themselves as passive contributors using no other ways for dissemination of their scientific findings and seeing no need for receiving feedback from wider public except for the narrow circle of people they were used to communicate (a scientific advisor, a reviewer or a journal editor). Being too local in their vision of science communication, the interviewees were good at presenting themselves as personalities in quite a few social media sources (e.g., science-related pages and Facebook profiles), but they had no idea of how to promote their research, share their findings through public channels with a broad scientific community. Thus, a challenge to overcome this disturbing situation enhanced attempts to create a course aimed at removing disconnection between researchers and their audiences.

Given the findings of our background survey and semi-structured interviews, the participants were divided into two cohorts based on heterogeneity and homogeneity of their area of expertise, level of English proficiency, and academic degree.

To populate Cohort 1, we selected 72 participants and randomly assigned them to six heterogeneous groups (G 1-6, experimental groups) with 12 participants in each group to ease the process of teaching (Appendix A). In all heterogeneous groups, we had a mixture of graduate students who have a good command of English and have had formal training in research writing but have little or no scientific data to share, doctoral candidates who have data to publish or speak about but are unfamiliar with how to share their research outcomes within and beyond their research-specific community, and establish STEAM professionals who have considerable experience in communicating about new research technologies and breakthroughs, but they only do it in their native language and within the context of the deficit model of communication, when "[they throw knowledge] into the world , with the hope it inspires a change' (Stine 2021, 12).

The participants came from different subject areas with diverse backgrounds and skills across both arts and science: Materials Science, Theoretical Physics, Philology, Agricultural Science, Microbiology, Machine Learning, Modern Languages and Communication. We were fortunate to have "hard" sciences participants who tend to rely heavily on the deficit model to communicate their knowledge and "soft" sciences participants who mostly rely on the dialogue model, as there is a deeper understanding of the human component (Stine 2021, 15)

Intentionally, they were not given an English placement test, as the objective was to create a learning environment that could most closely resemble real-world communicative situations, with interlocutors having different levels of the English language proficiency. Their level appeared to be quite heterogeneous, i.e., from A2 to C1, according to the Common European Framework of Reference for Languages (CEFR).

For Cohort 2, we arranged three almost homogeneous groups – Group 7 (G7 control group) – with the same subject area (Materials Science), level of English proficiency (B1-B2), and academic degree (postgraduate students); Group 8 (G8 control group) – with the same subject area (Modern Languages and Communication), level of English proficiency (B2-C1), and academic degree (graduate students) and Group 9 (G9 control group) – with the same subject area (Theoretical Physics), level of English proficiency (B1-B2), and academic degree (graduate students). The total number of participants in each group was 12. The level of English language proficiency ranged from B1 to C1, which was appropriate for the purposes of the course. The reason for choosing level B1 as appropriate for the course purposes can be justified by the fact that the minimum level for successful science communication is B2/C1 or a level no lower than B1 when speakers can understand the main points of clear standard input on familiar matters regularly encountered in their professional settings.

The selection of graduate and postgraduate students for Cohort 2 was based on two reasons: the significant number of graduate and postgraduate students who volunteered to participate in the case study and who specialized in Materials Science (n=22), Modern Languages and Communication (n=21) and Theoretical Physics (n=16), necessity of graduate students to participate in coauthoring and publishing an article to enter the Postgraduate Program and postgraduate students to meet the mandatory requirement to produce at least 2-3 publications before their PhD defence.

3.3. Class Observation

All the participants (assigned to either Cohort 1 or Cohort 2) were regularly observed during the course studies. Observation research was chosen since it provides an opportunity to monitor participants' performance in natural settings and is considered reliable being long-lasting and, thus, frequently used in combination with other methods. To monitor the performance, we measured several variables for each student and aggregated them by cohorts. Then we applied statistical methods to analyze how performance depends on the Cohort.

To compare performance in Cohort 1 (experimental groups) and Cohort 2 (control groups, we use two-sample Welch's t-tests with the null hypothesis that the samples have equal means (Welch 1947).

In our case study, live observation tools in the form of templates (Appendix B) were used as research instruments to judge students' performance. Frameworks of teaching effectiveness in both cohorts embraced observation categories characterized by organizational, social, and instructional processes (Eccles and Roeser 2010). Observational items that helped us capture general classroom dynamics were as follows: students' attendance, involvement (equitable participation in group work through students' contributions to classroom dialogue), attention, self-direction, and teamwork (active peer-mentoring).

Table 4 Observed Students' Performance via Surveys
(Average Teacher-assessed Scores Divided by 4)

Variable	Cohort 1 (experimental)	Cohort 2 (control)	Two-sample Welch's t-test p-value
Attendance	90%	74%	$1.4\cdot10^{-4}$
Involvement	95%	67%	$3\cdot10^{-8}$
Attention	97%	70%	$2\cdot10^{-8}$
Self-Direction	95%	77%	$5\cdot10^{-6}$
Teamwork	97%	74%	$3\cdot10^{-7}$

Course instructors registered the attendance data after each class (Variable 1). Engagement in classroom activities (participation in discussions (Variable 2), constant concentration on the given tasks (Variable 3), self-direction (Variable 4), active peer-mentoring (Variable 5) were scored by a teacher (1–4) based on evidence of almost no evidence (Score 1), limited evidence (Score 2), evidence with some weaknesses (Score 3), or consistent strong evidence (Score 4). During the observed lesson session, a template with basic descriptors of what happens (e.g., students provide ideas with reasoning, students pay attention) at regular time intervals (e.g., one description per lesson) was filled out by a course instructor.

Our correlation analysis obtained from the observation scores of both cohorts at the end of the course showed that participants in Cohort 1 (heterogeneous) had a more positive correlation with their attitude and awareness of science communication, which made us believe that there was a direct relationship between multilevel and multidisciplinary character of the group and students' feeling at ease with scholarly interaction (Table 4).

At the end of the course a retrospective qualitative questionnaire (Appendix C) was given to the course participants. The questionnaire was meant to reveal if self-assessments took the difference between a student's perception before and after a course into account. We chose to focus evaluation on these variables: V1 - perceived improvements in motivation, V2 - self-efficacy, V3 - self-confidence, V4 - science communication knowledge, and V5 - behavior resulting from science communication training (Rodgers et al., 2020). V1 represents the degree of persistence and the extent of effort to which a participant is committed to improving his/her science communication skills. V2 represents a participant's belief or conviction about being able to communicate research outcomes clearly and engagingly to diverse audiences using innovative dissemination channels. V3 presents an ability to maintain a clear and simple message about complex research, while also acknowledging scientific uncertainty. V4 represents a participant's knowledge of communication concepts, skills, and tactics for communicating with various audiences. V5 represents the ability to communicate succinctly and engagingly with nonscientist audiences.

The questionnaire, based on the Likert response scale (1 = strongly disagree; 5 = strongly agree), contained 20 items to explore the viable factors from classroom experiences and the participants' perception of the course and teaching strategy, interpersonal interaction, and feedback around science communication.

The thematic focus in the analysis of both cohorts' sets of qualitative data was participants' comments on their own broadly positive or neutral attitude and feeling comfortable with science communication in the English language after completion of the course. Both cohorts demonstrated different results concerning their perception of the course. Our findings from the datasets indicated strong associations between participants' engagement and aspects of the course they studied.

In general, the obtained results highlighted positive shifts in Motivation (Positive Attitude), Self-Efficacy, Self-Confidence, Science Communication Knowledge, and Behavior (Cooperative Learning) in Cohort 1 in comparison with Cohort 2 (Table 5).

Table 5 Observed Performance via Post-training Surveys
(Average Self-assessed Scores Divided by 5)

Variable	Cohort 1 (experimental)	Cohort 2 (control)	Two-sample Welch's t-test p-value
Motivation	94%	58%	$2.5*10^{-10}$
Self-Efficacy	93%	46%	$8*10^{-15}$
Self-Confidence	93%	53%	$7*10^{-13}$
Science communication knowledge	93%	63%	$5*10^{-11}$
Behavior	87%	52%	$2*10^{-12}$

We regarded a positive change in these measures as indicators of successful science communication training. Both cohorts' attitudes changed as measured by a questionnaire.

4. DISCUSSION AND CONCLUSION

Heterogeneous classrooms – multilevel, multilingual, multicultural, or multidisciplinary – are a fact of life in ESL programs around the world. The phenomenon of a multilevel and multidisciplinary class in teaching science communication reflects modern tendencies of science going global, breaking boundaries between scientific schools and communities. The things that make a multilevel class the most challenging are also often what make it the most vibrant as well (Hernandez 2012). Heterogeneity facilitates an opportunity for students to produce the best possible output for this ability. They can learn to listen to each other in a way that is cooperative and productive to the learning process, this is what Vygotsky points out with the idea of the zone of proximal development (Fritsche 2021, 22). The difference between the current level of cognitive development and the potential level of cognitive development (proximal development by Vygotsky 1978) may be reduced with the help of certain multilevel and metacognitive strategies: modeling real-life situations, learning through interaction with peers and communicating with lay audience broadening the scope of narrow scientific communities.

In this study, we investigated the effect of immersion into multidisciplinary science context on the English learners' motivation to communicate their research findings to a target audience with various levels of comprehension of the discipline and non-specialists through traditional and innovative dissemination channels (RQ1). Given the class observation of two cohorts of students (heterogeneous – Cohort 1 and homogeneous – Cohort 2), we assessed the education gains from two perspectives: a teacher-centered based on the degree of evidence and student-centered based on shifts in attitude. Findings from the datasets indicated strong associations between participants' engagement and the type of cohort. During class observation from the part of a teacher, the selected measurable variables: students' attendance, involvement, attention, self-direction, and teamwork proved to be higher in heterogeneous group than those of homogeneous group. The qualitative analysis of students' questionnaires demonstrated that motivation, behavior, self-efficacy, self-confidence and science communication knowledge in homogeneous and heterogeneous cohorts represented modest but discernible changes. For example, Cohort 2 tended to be neutral in participants' evaluation of the course in terms of science communication competence, whereas Cohort 1 was more positive. As the statistical analysis demonstrates, all variables in Cohort 1 are significantly higher on average than in Cohort 2 (p-value << 0.001).

Thus, in the course overview, we made an attempt to reveal how learners with different levels of language competence may effectively communicate with one another to exchange research ideas (RQ 2) and what teaching strategies can accommodate different disciplines and language levels in one class and cater to learners' needs in a less toilsome and time-consuming way (RQ 3). This research suggests that heterogeneous ability groups are more successful from a student perspective where students can benefit from innovative dissemination channels that go beyond traditional academic publishing: e.g., learning from their peers and get feedback from lay public. The two educational domains: quasi-professional content (peer-to-peer collaboration) and integration of social media contributed to reducing limitations, which occur when teaching English in multilevel and multidisciplinary classes.

For accommodating different languages and levels in a single classroom certain meta cognitive strategy should be used, such as science storytelling techniques, creating new science communication resources via social networking sites, Twitter posts, Instagram stories, science-related pages and Facebook profiles and designing selfie-style videos and/or podcasts. We hope that the proposed approach of bringing a liberal arts component into a science communication classroom will eventually lead to the development of complex methodology, capable of using heterogeneous character of students to the utmost advantage.

Despite the results obtained, more research is needed on partially heterogeneous groups to determine how they will acquire English science communication skills compared to the homogeneous in all respect, if, for example, their level of English is the same, but they have different specialties, or vice versa, or, if they have one specialty, but different levels of English. It could be our next objective in the future to achieve.

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

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APPENDICES

A Distribution of Participants in Heterogeneous (G1-6/Experimental) and Homogeneous (G7-9/Control) Groups

Group	Cohort	Members	Agricultural Science	Materials Science	Machine Learning	Microbiology	Modern Languages & Communication	Philology	Theoretical Physics	Total number of students
G1	Experimental	English Level	B1	A2/B1/B1	A2/C1	B1	B2/B2	C1	B1/B2	12
		Academic degree[1]	DC	U/Dc/DSc	U/PhD	U	G/G	PhD	U/DC	
G2		English level	B1	A2/B1/B2	A2/B1	B2/B2	B2	B2	B1/B2	12
		Academic degree	DC	G/DC/PG	G/G	DC/DC	PhD	DC	U/G	
G3		English level	B1	B1/B2	B1/C1	B1	B2/C1	C1	B1/B2	12
		Academic degree	DC	G/DC/DSc	DC/DC	U	G/PhD	PhD	G/DC	
G4		English level	A2	B2/B2/C1 /C1	B2	B2	B2/B2	C1/B2	B1	12
		Academic degree	DC	DC/DC/DC/ PhD	PhD	G	G/G	PhD/DC	DC	
G5		English level	A2	B2/C1/B2	B2/B2	B1/B1	B2/B2		B2/B1	12
		Academic degree	DC	DC/DC/PhD	DC/DC	G/G	G/G		G/DC	
G6		English level	B2	A2/B1/B2	B1	B1/B2	B2/B2	C1	B1/B2	12
		Academic degree	PhD	U/G/DC	G	DC/DC	G/G	PhD	U/PhD	
G7	Control	English level		B1/B2						12
		Academic degree		PG/PG						
G8		English level					B2/C1			12
		Academic degree					G/G			
G9		English level							B1/B1	12
		Academic degree							G/G	

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[1] U – Undergraduate; G – Graduate, PG – Postgraduate, PhD – Doctor of Philosophy, DSc – Doctor of Science

B. Observation Template

Cohort	Variable 1 Score (1-4)	Variable 2 Score (1-4)	Variable 3 Score (1-4)	Variable 4 Score (1-4)	Variable 5 Score (1-4)
	Attendance	Involvement (participation in discussions) a) Building on ideas b) Making reasoning explicit	Concentration on the given task (student pays attention)	Self-direction (student gets responsibility through freedom of choice)	Teamwork (active peer-mentoring)
St 1					
St 2					
St 3					
St 4					
St 5					
…					

C. Questionnaire

Please, rate how strongly you agree or disagree with each of the following statements by placing a check mark in the appropriate box:

	Defined Variable	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
	Perceived improvements in motivation					
1	As I gained experience with science communication strategies, my motivation has increased, and I have a much higher degree of autonomy to create new science communication resources via social networking sites, Twitter posts, Instagram stories, science-related pages, etc.	○	○	○	○	○
2	I see the value and utility of what I was learning during the course.	○	○	○	○	○
3	I feel more empowered, exposed, and connected to professional academic social networks.	○	○	○	○	○
4	I feel dedicated to finding innovative ways to enhance my science communication efficiency and overcome any communication barriers.	○	○	○	○	○
	Self-Efficacy					
5	I have developed an ability to demonstrate my research ideas and make them openly and easily understandable.	○	○	○	○	○
6	I can now use science communication tools and techniques in a way that appeals to and engages a broader audience into a two-way information sharing dialogue	○	○	○	○	○
7	I am capable to connect with diverse audiences through good storytelling.	○	○	○	○	○

	Self-Confidence					
8	I feel more prepared for discussing issues of science communication with other researchers whose level of English is higher/lower than mine.	○	○	○	○	○
9	I better understand my strengths and weakness in science communication and I am more prepared to share information through digital applications such as Facebook, Twitter, and Instagram.	○	○	○	○	○
10	I feel more confident to disseminate my scientific findings via social media platforms and interpret my research for a target audience with various levels of comprehension of the discipline.	○	○	○	○	○
11	I am capable of successfully pitching my scientific ideas to a broad range of audiences.	○	○	○	○	○
12	I perceive that the challenges of science communication are within my abilities, and I am capable of overcoming barriers that prevent effective communication.	○	○	○	○	○
13	After the course, I no longer feel frustrated that I might be lacking English language proficiency comparable to English L1 speakers to communicate assertively	○	○	○	○	○
	Science communication knowledge					
14	The course helped me fill gaps in knowledge about how to translate scientific findings to scientists beyond my immediate community and non-professional audiences.	○	○	○	○	○
15	I gained better understanding of science communication concepts, tools, techniques, and practices available to researchers.	○	○	○	○	○
16	I now have an idea how to communicate scientific outcomes simplifying and complicating normal scientific discourse.	○	○	○	○	○
	Behavior resulting from science communication training					
17	I can amend the communication to the level of knowledge of the target audience.	○	○	○	○	○
18	I no longer view my science communication activities as problematic or unnecessary.	○	○	○	○	○
19	After the training, I use more metaphors, analogies, or narrative techniques in explaining my research to a non-scientist audience.	○	○	○	○	○
20	After the training, I use less jargon, abstract language, and try to avoid complexity and non-verbal behavior that could distract audience members.	○	○	○	○	○