Current Research in Physiology 8 (2025) 100141

Contents lists available at ScienceDirect

Current Research in Physiology

journal homepage: www.sciencedirect.com/journal/current-research-in-physiology

Enhancing laboratory education through collaborative online international learning: A case study between USA and UK students

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ARTICLE INFO

Keywords:
International Learning[1]
Technology enhanced Learning[2]
Laboratory Education[3]
Collaborative online international Learning[4]
Pedagogy[5]
Student Experience[6]

ABSTRACT

Collaborative Online International Learning (COIL) has emerged in recent years as an effective and viable alternative to increase the international opportunities within taught curricula. Through recent innovations in online collaboration tools, and elevated demand for international opportunities, there has been a recent increase in the development of COIL opportunities globally across a range of health aligned disciplines. This style of learning has been described as positively contributing to the internationalisation of students and enhancement of their transferable skills. However, there have been no reported COIL opportunities described in the fields of laboratory medicine and biomedicine, likely due to the large practical elements associated with the subjects. This study therefore aims to develop a COIL opportunity that incorporates practical laboratory elements and evaluate the efficacy of this teaching and learning approach.

A laboratory-based COIL was developed and delivered across two days. Day one was composed of synchronous livestreamed laboratory demonstrations and practical activities, with day two focused on the completion of a time-dependent team-based task. The pedagogical impact of this laboratory-based COIL was evaluated through 1) pre and post surveys and 2) an overall survey utilising Likert scales.

The laboratory-based COIL was well received by students (n = 34) with the majority enjoying (94.1 %) and learnt a lot (94.1 %) by participating in the session. It also produced highly positive benefits to student confidence (97.1 %), teamworking (100 %), and communication (97.1 %). Pre (n = 46) and Post-analysis (n = 35) revealed significant enhancement of students international education knowledge, international medical practice knowledge, cultural intelligence, social initiative, emotional stability, and work-based flexibility ($P < 0.05$). Further analysis based on participants international institution revealed significant differences in responses between the two participating cohorts, namely questions relating to cultural intelligence and their confidence of working with cultures unfamiliar to themselves.

We are the first to report that implementation of laboratory-based COIL opportunities have significant potential in enhancing students' international, cultural and transferable competencies within laboratory and health education. These findings suggest that practical-based COILs are effective methods for preparing students to thrive in a globalized healthcare environment, making a strong case for its continued use and expansion in educational programmes.

1. Introduction

International learning has historically been delivered by physical exchange programmes between institutions from different countries to strengthen students cultural and academic experiences (Fabricius et al., 2017). However, these physical exchanges are often limited to relatively small cohorts of students and usually have a significant fiscal outlay for the student, potentially making these accessible to only the most

Abbreviations: **ANOVA**, Analysis of Variance; **COIL**, Collaborative Online International Learning; **UK**, United Kingdom; **UoS**, University of Salford; **USA**, United States of America; **WSU**, Wayne State University.

This article is part of a special issue entitled: Current Research in Physiology Education published in Current Research in Physiology.

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https://doi.org/10.1016/j.crphys.2025.100141
Received 28 August 2024; Received in revised form 16 January 2025; Accepted 31 January 2025
Available online 1 February 2025

socioeconomically advantaged students (Potter and Bragadóttir, 2019). In recent years through advances in videoconferencing and online collaboration tools, the idea of virtual global exchanges has shown significant promise to combat common limitations of physical exchanges and increase the equity of international opportunities (Rubin and Guth, 2023). Implementing a global virtual exchange, commonly referred to as Collaborative Online International Learning (COIL), provides significant opportunities for students to develop international and cultural competencies without leaving campus (Rubin and Guth, 2023; Villar--Onrubia and Rajpal, 2016).

The COIL model enables faculty and students to engage with peers worldwide using online platforms, enhancing discipline-specific knowledge and refining essential skills in communication (Vahed and Rodriguez, 2021). Assessing the impact of COIL on undergraduate students is crucial in understanding its role in enhancing international capital, student experience, and employability. By participating in culturally enriched and globally connected online learning environments, students can broaden their global perspectives, and develop adaptability, empathy, and global mindedness (Mestre-Segarra et al., 2022; Lewis and O'Dowd, 2016). This type of education enhances the student experience with competencies to thrive in an increasingly interconnected world (Hackett et al., 2023).

There are several examples of successful use of COIL in health and medical education, mostly as part of nursing curricula (De Castro et al., 2019; Niitsu et al., 2023; Hua et al., 2023; Hammonds and Newman, 2023; Jenssen et al., 2024; Davis et al., 2023), but also in medicine and public health (Wood et al., 2022; Collins et al., 2022; Case et al., 2022). COIL in health professions aims to prepare students for work in diverse and multicultural environments, especially in healthcare professions (De Castro et al., 2019). The collaborative learning experience in previous studies was generally employed from 2 to 3 weeks (Jenssen et al., 2024; Davis et al., 2023), to 5–6 weeks (De Castro et al., 2019; Hammonds and Newman, 2023; Wood et al., 2022; Collins et al., 2022). Student work during COIL experience focussed on differences in professional practice in different cultures (De Castro et al., 2019; Hua et al., 2023) or investigated a specific topic relevant to the course (Hammonds and Newman, 2023; Jenssen et al., 2024). Students could use information obtained from their counterparts in another country to complete individual assignments (De Castro et al., 2019), group presentations (Jenssen et al., 2024) or both (Hammonds and Newman, 2023).

The impact of COIL in health courses was evaluated by either comparing pre- and post-event responses or by evaluating the COIL experience after students had completed their engagement in COIL. De Castro et al. (2019) (De Castro et al., 2019) reported a positive change in perceived intercultural competency and communication skills, whereas Niitsu et al. (2023) (Niitsu et al., 2023) and Hua et al. (2023) (Hua et al., 2023) reported an increase in intercultural sensitivity score when pre and post tests were compared. Similarly, student reflections after their COIL experience suggested overall positive experience, increase in cultural awareness as well as increased perception that intercultural collaboration augments learning experience (Jenssen et al., 2024; Davis et al., 2023; Wood et al., 2022). The findings suggested that intercultural exchange had a positive effect on mutual respect, and increased awareness of intercultural issues (De Castro et al., 2019; Hua et al., 2023; Beelen et al., 2021).

Student discussions and completion of assignments within COIL's are mostly facilitated by combining online asynchronous activities with virtual meetings. Asynchronous discussions were held on virtual learning environment based discussion boards (De Castro et al., 2019), Padlet's (Niitsu et al., 2023; Hua et al., 2023; Davis et al., 2023) or Canvas' (Wood et al., 2022; Collins et al., 2022) whereas virtual group discussions or presentations were conducted utilising online collaboration tools such as Zoom (Niitsu et al., 2023; Hua et al., 2023; Jenssen et al., 2024; Davis et al., 2023). However, to our knowledge, COIL has not been used to explore the demonstration and streaming of practical diagnostic laboratory activities in physiology, biomedicine or laboratory medicine education.

To address this gap, this novel study sought to design a COIL workflow to investigate the feasibility of a laboratory-based COIL with an emphasis on evaluating soft skill enhancement focusing on teamwork, communication, and confidence in the international collaboration. Additionally, we sought to examine the impact of integrating international development into the curriculum and to assess students' awareness of and engagement in international medicinal and educational practices.

2. Material and methods

2.1. Study participants

Given their small sample size, this study recruited all current junior (second year) Medical Laboratory Science students at Wayne State University (WSU) to ensure a comprehensive analysis. A total of 18 students participated, consisting of 14 females and 4 males from the same level of study. The inclusion of all current students enhanced the study's relevance and applicability to the academic environment within WSU's Medical Laboratory Science program. The cohort from the University of Salford (UoS) was recruited as an extracurricular opportunity for students studying Biomedical Science, Human Biology and Infectious Diseases or Pharmaceutical Science. This extracurricular recruitment approach was selected to ensure parity between the cohort sizes. A total of 43 students were recruited, with 31 participating in the event. Of these participants, the cohort contained 25 females and 6 males. Participants from UoS were predominantly first year students (57 %) with the remainder being second (39 %) and third year (4 %) students.

2.2. Session design

During the two-day COIL event, students from Wayne State University (WSU) and the University of Salford (UoS) engaged in a detailed exchange of lab activities within their respective programs. The event was structured to enhance inter-university learning and provide a platform for sharing best practices. Students were not provided any advanced information about each other's university or degree programme before participating in the COIL event.

On day one, each program was allocated one and a half hours to sequentially present a section of their choosing within the Microbiology, Haematology, Immunology, Immunohematology, and urinalysis hands-on labs. Students and faculty utilized Microsoft Teams (Microsoft, USA) for live streaming to allow students to discuss and demonstrate their lab activities, at close hand, in real-time. These demonstrations involved students approaching the livestreaming camera and delivering "micro-teaching" sessions of key practical skills associated with professional practice as a Biomedical Scientist or a Medical Laboratory Scientist. This interactive format allowed participants to observe and gain insights into the practical aspects of each program's laboratory training.

On day two, the programs worked together for 4 h to create a poster for presentation. The session began with academic staff introductions and an introduction to COIL group work using the Zoom videoconferencing platform (Zoom Video Communications, Inc, USA). The goal of day two aimed to bring together individuals from different parts of the world to develop collaboration, idea exchange, and to create a meaningful poster. A digital research poster Microsoft PowerPoint (.ppt) (Microsoft, USA) template file was shared in the chat, and breakout rooms were assigned. Students from each institution were randomly assigned to breakout rooms at a ratio of 3:2 (UoS:WSU).

Groups introduced themselves, held unscaffolded discussions regarding their motivations for joining the program, and interesting personal facts. They engaged in brainstorming sessions to discuss ideas, themes, design elements, and content for their posters, which encouraged creativity and critical thinking. The groups also prepared for the presentation by discussing roles and individual contributions. Faculty

checked in to help as needed. Poster presentations occurred, with each group having 5–7 min to present their poster and reflect on their learning process. The presentation ideas presented by students included comparing and contrasting student life between countries, educational and accreditation operations, scientific practices, and financing of education. The day concluded with whole-cohort feedback and a post-event survey to gather overall student feedback. The created posters were then graded by WSU faculty as contributions to their final credit.

2.3. Survey design, delivery and analysis

Evaluation of the impact of international collaborative learning sessions was conducted via two approaches: **1)** a pre- and post-survey to allow for the evaluation of student's internationalisation and knowledge acquisition as a result of the completing the session, and **2)** an overall survey to evaluate students overall experience and their thoughts on if the session enhanced key transferable skills. All questions on both the pre/post survey and the overall survey were approved and checked for biases as a part of ethical approval processes at all participating institutions. All participants were provided with a participant information sheet before consenting to participate in the study.

The pre- and post-surveys (Supplementary Table 1) were delivered as separate surveys via Microsoft Forms (Microsoft, USA) immediately before the initiation of the event (to gather student baseline data) and upon completion of the session (to determine the impact of the event). Questions within the pre- and post-surveys were identically worded, and with questions focusing on students' cognitive and international awareness based on the factors described within the Multicultural Personality Questionnaire (Van der Zee et al., 2013). Questions on this survey were scored on a 10-point scale with a low of 0 and a high of 10. We received 46 responses for the pre-survey and 35 responses for the post-survey.

The overall survey (Supplementary Table 2) was also delivered using Microsoft Forms and was provided to all students who participated in the session following its completion. Survey questions (modified from (Hussain et al., 2023)) related to participant demographics and to six main analysis themes including student experience, learning, transferable skill development, employability, international practices and future curriculum embedding. Survey questions were either open answer for participant demographics or using a 5-point Likert scale for the themed questions. Scores of 1 or 2 were grouped as negative responses, 3 being a neutral response, and scores of 4 or 5 being classified as positive responses.

2.4. Statistical analysis

All statistical analysis was performed using GraphPad Prism version 9.5.1 (GraphPad Software, USA). The results of all student surveys are reported as mean ± standard deviation. Data normality was evaluated using the Shapiro-Wilk test or Kolmogorov-Smirnov test for normality dependent on the sample size evaluated. All two group comparisons were conducted using parametric unpaired t-tests, or non-parametric Mann-Whitney tests as described in the associated figure legends. All multi-group analyses were conducted using a one-way analysis of variance (ANOVA) with a Tukey post-hoc test. Statistical significance was determined at $P \leq 0.05$ for all statistical analyses.

2.5. Ethical approval

The studies involving human participants were reviewed and approved by the ethics committee at the University of Salford under the Ethics Application ID: 408. The study was additionally ethically approved by Wayne State University Institutional Review Board under the protocol number: IRB-24-02-6583. All questionnaires and analysis procedures were also approved by these ethics' committees. The participants provided their written informed consent to participate in each stage of the study and were allowed to withdraw at any time prior to publication.

3. Results

3.1. Surveys of student experience and capital development

Survey questions related to student experience and transferable skill development were highly positive with the majority of participants providing positive responses to these questions, as shown in Fig. 1. A total of 94.1 % of students completing the survey reported enjoying and learning through participation in the session. All participants agreed that the session supported the development of their teamworking skills. The majority of participants (97.1 %) stated that the session developed their communication skills and their confidence. Most students (85.3 %) also stated that the session helped them to develop employability skills which would benefit them upon graduation.

3.2. Surveys of international development and curriculum embedding

Evaluations of how the collaborative online international learning event impacted students' international development and participants opinions if international learning should be embedded into the taught curriculum in the future are shown on Fig. 2. Most participants (94.1 %) stated that the session helped them to understand international practices and enhanced their ability to work with professionals from other backgrounds (97.1 %). The majority of participants also stated that international learning would help them to get a job after graduation (81.8 %), with only 4.5% of participants providing a negative response. All respondents stated that they would like more internationally collaborative sessions in the future, with 94.1 % of students stating they would like collaborative international learning embedded into the future taught curriculum.

3.3. Does collaborative international learning enhance students perceived cognitive and international awareness?

To ascertain if participants' cognitive and international awareness were enhanced by the completion of collaborative international learning events, students participating in the session were provided with a pre- and post-survey to evaluate their perceived cognitive and international awareness. The results of these surveys are summarised in Fig. 3.

Overall, we found significant increases in numerous cognitive and international awareness parameters following the completion of the session. Students reported significant increases in their perceived knowledge of international educational practices (Pre: 5.4 ± 2.8 (n = 46), Post: 8.1 ± 2.1 (n = 35), $P = 0.0001$, Fig. 3A), international medicinal practice knowledge (Pre: 5.2 ± 2.7 (n = 46), Post: 8.0 ± 2.1 (n = 35), $P < 0.0001$, Fig. 3B), and their cultural intelligence (Pre: 6.4 ± 2.5 (n = 46), Post: 8.5 ± 1.4 (n = 35), $P < 0.0001$, Fig. 3C). It was also identified that students reported significant increases in their perceived social initiative (Pre: 7.7 ± 1.9 (n = 46), Post: 8.6 ± 1.7 (n = 35), $P = 0.0373$, Fig. 3H), emotional stability (Pre: 7.6 ± 2.0 (n = 46), Post: 8.4 ± 2.0 (n = 35), $P = 0.0221$, Fig. 3I), and work-based flexibility (Pre: 7.7 ± 1.8 (n = 46), Post: 8.9 ± 1.5 (n = 35), $P = 0.0047$, Fig. 3J).

However, it was found that collaborative international learning had no significant impact on students perceived enjoyment of working with people from other cultures (Pre: 9.2 ± 1.4 (n = 46), Post: 9.4 ± 1.0 (n = 35), $P = 0.8200$, Fig. 3D), confidence working with unfamiliar cultures (Pre: 7.6 ± 2.0 (n = 46), Post: 8.5 ± 1.7 (n = 35), $P = 0.0516$, Fig. 3E), their cultural empathy (Pre: 8.9 ± 1.4 (n = 46), Post: 9.4 ± 1.0 (n = 35), $P = 0.1906$, Fig. 3F), and their perceived open-mindedness (Pre: 9.3 ± 0.9 (n = 46), Post: 9.5 ± 1.0 (n = 35), $P = 0.9034$, Fig. 3G).

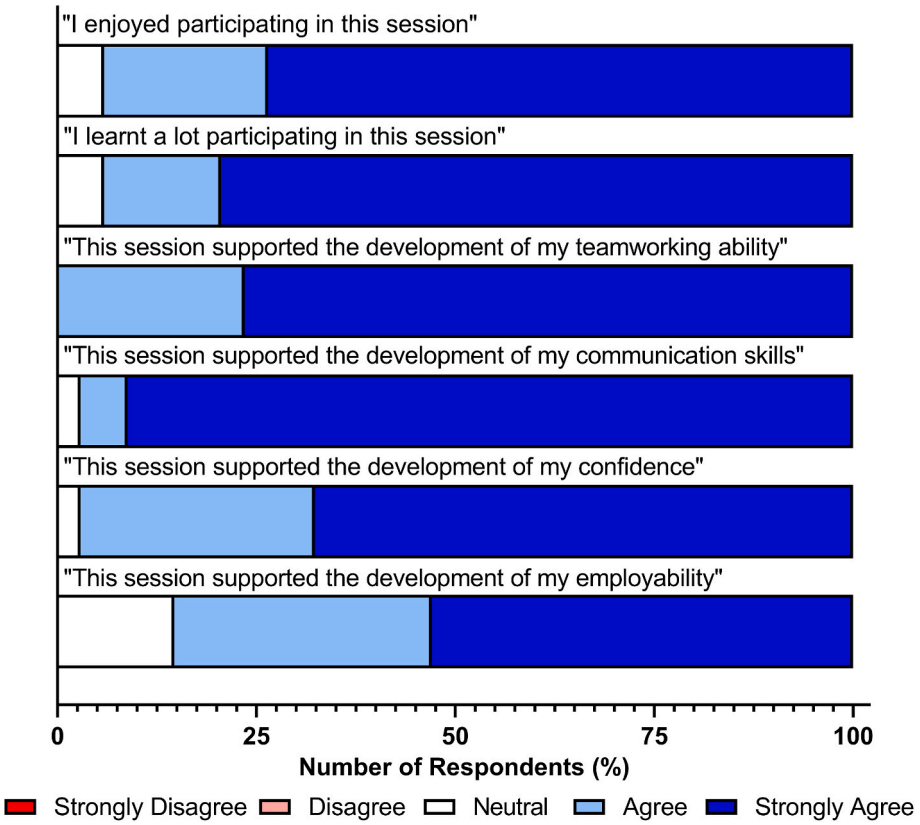

Fig. 1. Student participants experience and graduate capital development following engaging with Collaborative Online International Learning. *Shades of red indicate negative responses, white indicates neutral responses and shades of blue indicate positive responses. n = 34 for all questions.*

3.4. Does student experience, cultural, and international development differ between international cohorts?

To determine if student experience, cultural development and international development differed between the international cohorts who participated in the collaborative international learning event, student responses to both the overall feedback survey (Supplementary Table 2) and the pre and post-surveys (Supplementary Table 1) were stratified based on the participants international location of study.

Stratification of the overall survey based on the international cohort completing the survey (Fig. 4) revealed highly positive responses to all questions irrespective of geographical location, with no significant differences in question responses between the cohort from the United Kingdom and that of the United States of America when provided questions relating to overall experience (Fig. 4A), learning (Fig. 4B), transferable skill development (Figures C–E), employability (Fig. 4F) international practices (Fig. 4G–H) and future curriculum embedding (Fig. 4I–J).

When student responses to the pre- and post-survey were stratified based on the international location of study were conducted (Fig. 5), overall, we saw similar patterns of response between both international cohorts. When students from both the UK and USA were questioned relating to their knowledge of international education practices (Fig. 5A) it was found that despite both populations increasing their awareness of international practices only the responses of students studying in the UK were found to be significantly elevated following the completion of the collaborative international learning event (Pre: 5.0 ± 2.4 (n = 28), Post: 8.3 ± 1.5 (n = 19), $P = 0.0002$). Similar findings were observed when the cohorts were questioned on their knowledge of international medicinal practices, with only students studying in the UK revealing a significant increase following the event (Pre: 4.7 ± 2.0 (n = 28), Post: 7.9 ± 1.7 (n = 19), $P = 0.0002$, Fig. 5B).

When questioned on their perceived cultural intelligence, we observed that students studying in the USA scored themselves significantly higher before the completion of the collaborative international learning session than those studying in the UK (UK Pre: 5.7 ± 2.4 (n = 28), USA Pre: 7.8 ± 2.2 (n = 17), $P = 0.0059$, Fig. 5C), based on this, it was also observed that only students studying in the UK significantly increased their perceived cultural intelligence following the session (Pre: 5.7 ± 2.4 (n = 28), Post: 8.1 ± 1.6 (n = 19), $P = 0.0006$, Fig. 5C).

We also observed significant differences in student response scores between international cohorts when questioned on their confidence of working with cultures unfamiliar to themselves. We found that students studying in the USA scored themselves significantly higher than the students studying in the UK before the start of the session (UK Pre: 7.3 ± 2.0 (n = 28), USA Pre: 8.5 ± 1.5 (n = 17), $P = 0.0390$, Fig. 5E), with these differences remaining following the completion of the session (UK Post: 7.8 ± 1.9 (n = 19), USA Post: 9.1 ± 1.2 (n = 17), $P = 0.0271$, Fig. 5E). We observed no significant differences between all other questions in the pre and post survey when the cohort was stratified based on their international location of study.

4. Discussion

The internationalisation of education is a valuable aspect of learning and teaching within higher education which has been traditionally limited to international exchanges or placement programmes (Rubin, 2017). However, whilst effective at developing an individual's internationality, they can be financially prohibitive and limit this highly valuable professional development opportunity to a small number of individuals. Therefore, the ability to provide this in an accessible manner is vital for ensuring equity in the students who can complete international opportunities and increase the number of students who can gain international experience. One way of doing this is though

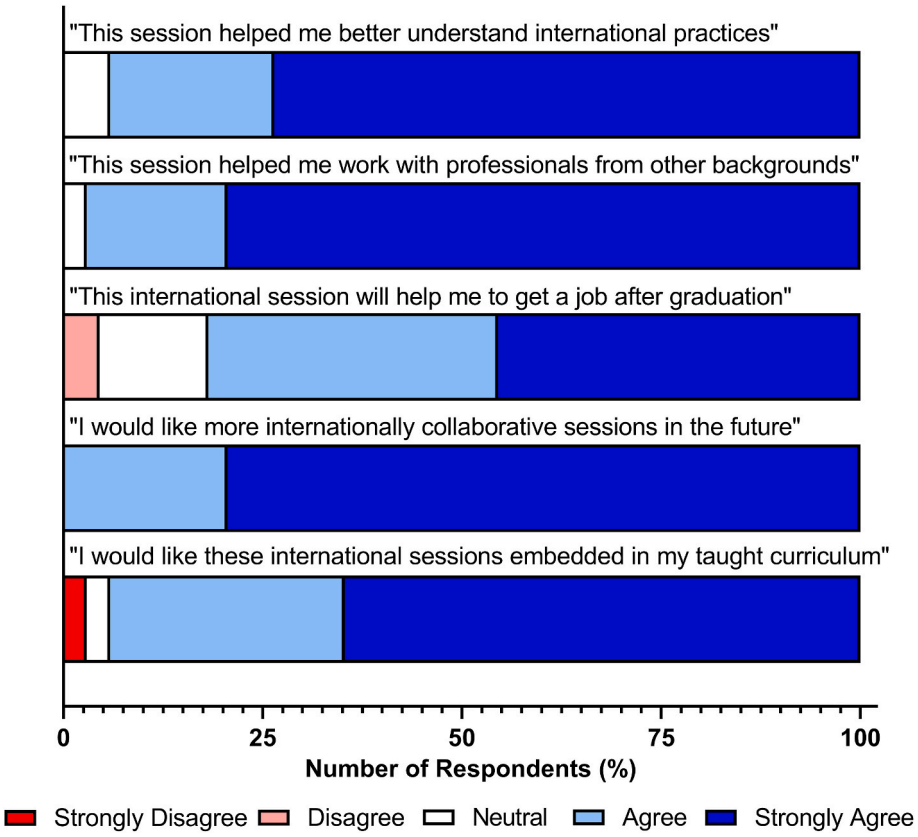

Fig. 2. Student participants' international development and opinions on further curriculum embedding following engaging with Collaborative Online International Learning. *Shades of red indicate negative responses, white indicates neutral responses and shades of blue indicate positive responses. n = 34 for all questions.*

Collaborative Online International Learning (Vahed and Rodriguez, 2021; Hackett et al., 2023; Munoz-Escalona et al., 2022) which offers the benefits of increasing the internationalisation of whole degree programmes and increasing the equity of international opportunities (Vahed, 2022). Despite their success, there have been no previous reports of these COIL opportunities incorporating in-person practical elements to showcase differences in international practice. Our study describes for the first time, how practical activities can be incorporated into COIL-based approaches, to allow for simultaneous practical skill development and international learning.

Our study showed that all participants had a positive experience during the completion of the COIL activity containing practical elements (Fig. 1). No participant reported negative student experience or graduate capital development. We also identified that the COIL had a positive impact on students' understanding of international practices and working with professionals from other backgrounds (Fig. 2). These positive benefits were further highlighted by the majority of students stating they would like more collaborative international sessions in the future and would like these incorporated into their taught curricula. We also found that students on both sides of the COIL, from both the UK and USA, found comparable experiences and development of key transferable skills (Fig. 4) showcasing the effectiveness of design of the COIL to meet the level and learning requirements of both participating cohorts by the contributing academic staff. This is therefore an important consideration when designing COIL opportunities to ensure all participating cohorts receive the benefits online international learning.

When we evaluated the development of student's cognitive and international awareness through the utilization of a pre and post-survey (Fig. 3) we identified significant increases in the development of the majority of these parameters. With these parameters being core learning objectives of COIL activities, the confirmation by students that their understanding and awareness of international and cultural aspects were significantly increased by this activity is highly positive and corroborates findings of other studies examining the impact of COIL's (Hackett et al., 2023; Munoz-Escalona et al., 2022; Naicker et al., 2022). In addition to this, the fact that these enhancements such as a better understanding of international practices can be observed through the completion of a single 2-day event showcases the fact that this knowledge and associated skills can be rapidly transferred to students through the combination of taught academic and peer-to-peer content, something which has taken weeks in previous studies to achieve similar outcomes (Niitsu et al., 2023; Hammonds and Newman, 2023; Case et al., 2022). The utilization of this approach to collaborative online international learning may increase the potential for higher educational institutions to offer COIL-based opportunities as a part of the curriculum. Despite some students not completing both the pre and post survey, the significant impact on internationalisation and cognitive awareness remains present to the same extent when single survey completers are removed from analysis.

The positive impact of COIL on student experience shown in this study agrees with the findings from surveys conducted in other COIL projects (Jenssen et al., 2024; Davis et al., 2023; Wood et al., 2022; Collins et al., 2022). Our collaborative learning experience encompassed two days of student interactions and was therefore markedly shorter as described previously, where concise COIL projects lasted 2–3 weeks (Jenssen et al., 2024; Davis et al., 2023), but a longer COIL exchange (5–6 weeks) was typically more common (De Castro et al., 2019; Wood et al., 2022; Collins et al., 2022; Naicker et al., 2022). Group work and preparation of poster assignments took place in breakout rooms in Zoom which created a safe environment for students to interact and develop relationships (Jenssen et al., 2024) before presenting their findings to a wider cohort of their peers.

Further analysis based on participants international institution (Fig. 5) revealed some significant differences in responses between the

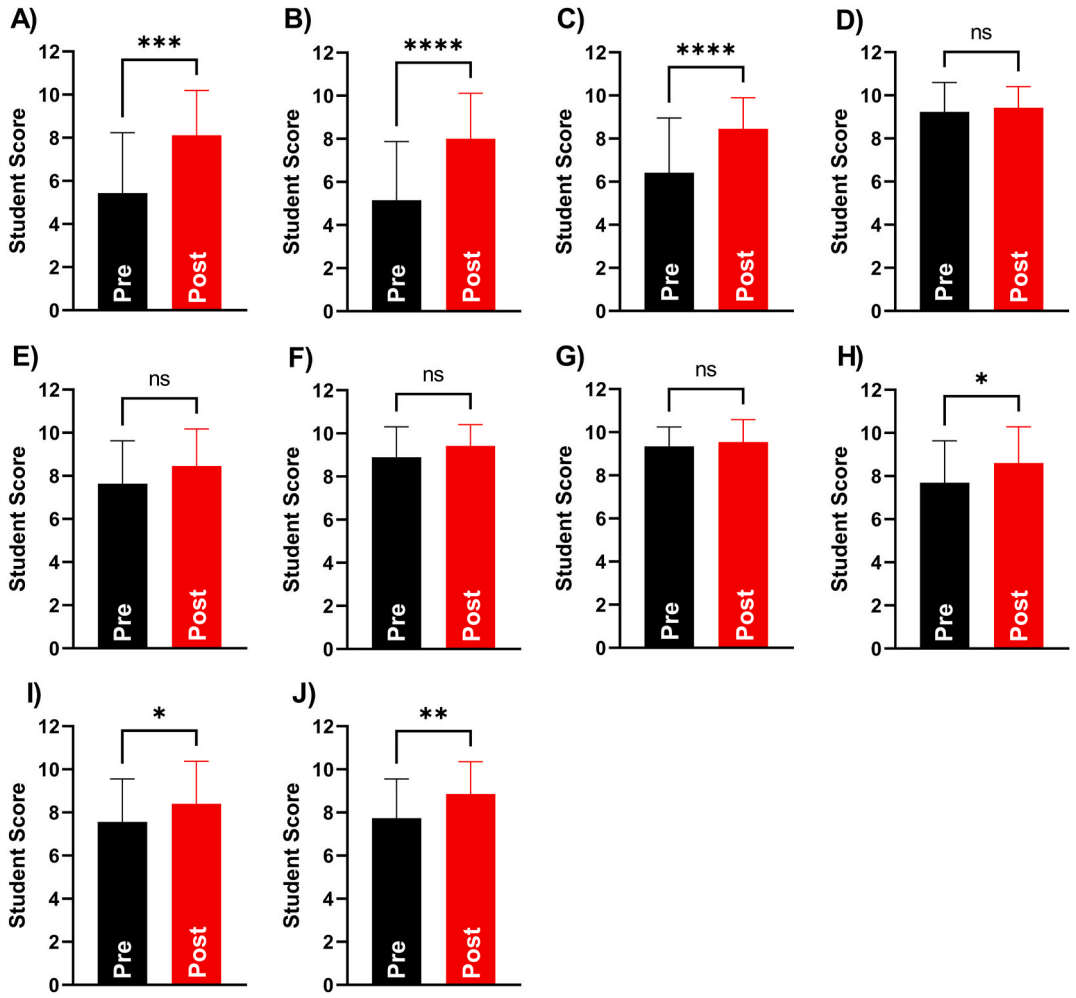

Fig. 3. Student participants cognitive and international awareness pre and post engaging with the Collaborative Online International Learning activities. Pre (Black) and Post (Red) impact of Collaborative Online International Learning on students **A)** International education knowledge, **B)** International medical practice knowledge, **C)** Cultural intelligence, **D)** Enjoyment of working with people of different cultures, **E)** Confidence of working with cultures unfamiliar to themselves, **F)** Cultural empathy, **G)** Open mindedness, **H)** Social initiative, **I)** Emotional stability, and **J)** Work-based flexibility. Student responses were self-scored on a scale of 0 (no knowledge/score) to 10 (maximal knowledge/score). n = 46 for the pre-survey and n = 35 for the post survey. Statistical significance was determined by paired student t-tests. * indicates $P < 0.05$, ** indicates $P < 0.01$, *** indicates $P < 0.001$, and **** indicates $P < 0.0001$.

two participating cohorts. We found that on average the cohort from the USA scored themselves higher in both the pre and post-survey compared to those participants from the UK. This was significantly different when questions related to cultural intelligence (Fig. 5C) and their confidence of working with cultures unfamiliar to themselves (Fig. 5E). This disparity in responses may be attributed to the cohort from the USA being more mature (based on their level of study) than that of the UK participants and therefore have more life experience than the UK cohort who were predominantly in their first year of undergraduate study.

This study faced some limitations that may have impacted the overall experience of participants. First, technical streaming issues posed a significant challenge during the international collaboration sessions. These issues occasionally disrupted communication between participants, potentially affecting the quality of idea exchange and visualisation of practical demonstrations, one of the key outcomes of this study. Although every effort was made to address these challenges promptly, the intermittent technical difficulties may have led to some participants being less engaged or having an incomplete understanding of the material being presented. Future COIL projects involving streaming of laboratory activities need to ensure powerful internet connection within the laboratory and identify redundancies in place in case of technical issues. This may also limit the effectiveness of this approach if COILs are established with global partners where the access to high-speed internet may pose a challenge or may be unavailable within their institutions, therefore, this potential infrastructure limitation should be considered and thoroughly tested before the initiation of a similar laboratory-based COIL project.

Second, there was an overlap in the poster ideas submitted by students, particularly in cases where similar topics were chosen for international collaboration. While the diversity of perspectives is a strength of such collaborations, the similarity of some poster topics may have reduced the variety of insights and innovations presented. To further strengthen the collaboration between students during the poster preparation and to avoid similarity of topics, laboratory tasks could be designed to be complementary in different institutions. This would allow students to explore the methods showcased in the laboratories in more depth and discuss the integration of their data in joint poster presentation, similar to collaborative information exchange described previously (Hammonds and Newman, 2023; Jenssen et al., 2024). Despite these limitations, our study provided valuable insights into the potential of international collaboration in laboratory and health professions education and highlighted areas for future improvement in virtual collaboration strategies.

The authors would also like to acknowledge that the students within the UK cohort engaged in COIL experience as an extracurricular activity, whereas COIL was a mandatory part of taught programme in the USA

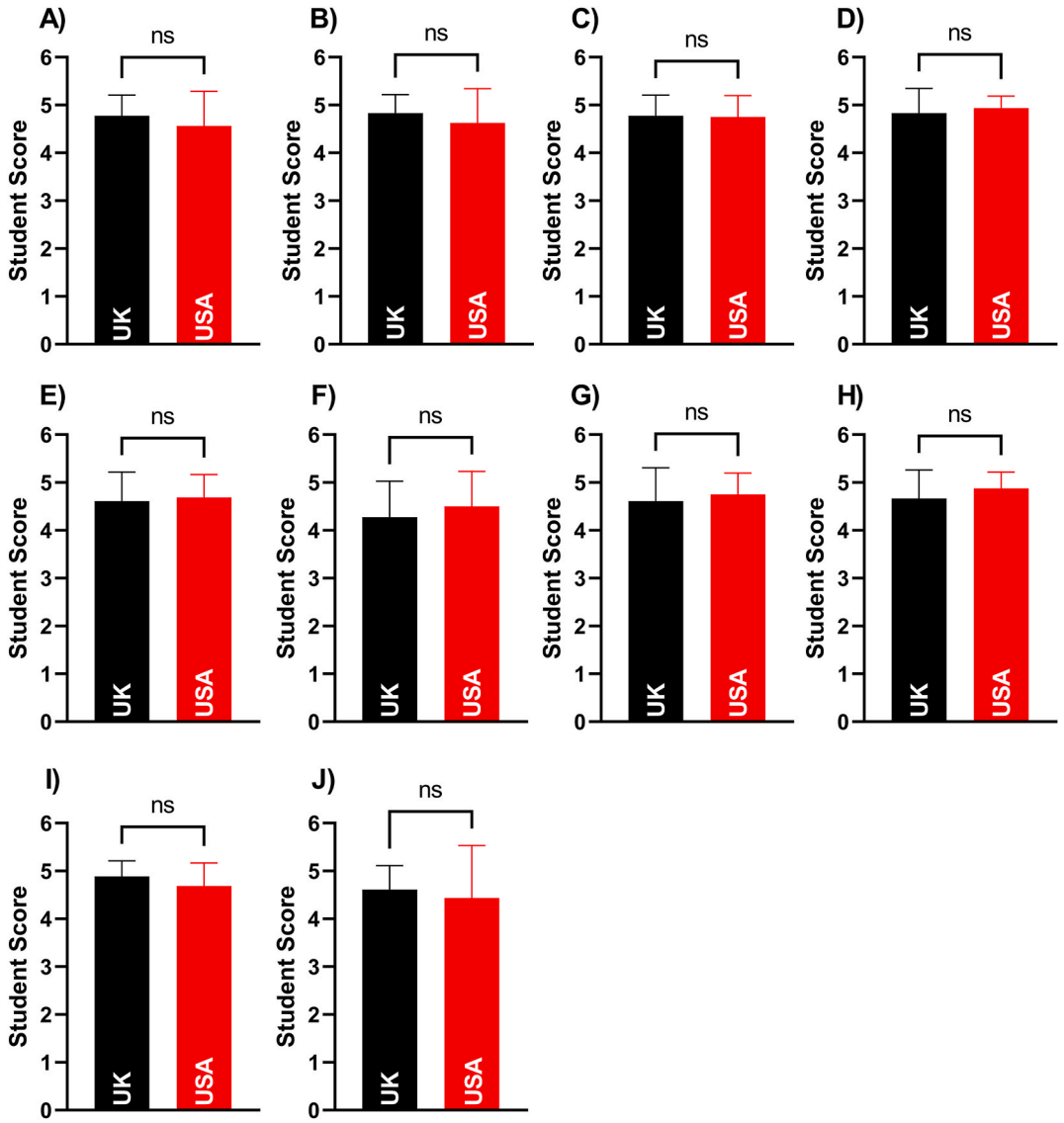

Fig. 4. Comparisons of each international cohorts' responses to the overall survey relating to student experience, learning, transferable skill development, international learning and curriculum embedding. *A) session enjoyment, B) session learning, C) team working development, D) communication skill development, E) confidence development, F) employability development, G) understanding of international practices, H) working with professionals from other backgrounds, I) want more international sessions in the future, J) want international session embedded into the taught curriculum. Student responses were self-scored on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Statistical significance was determined by unpaired student t-tests. n = 18 for the United Kingdom (UK) cohort and n = 16 for the United States of America (USA) cohort.*

institution, which may influence student responses. In the future it would be beneficial to fully embed COIL in the UK institutions curriculum, however, substantial disparities in cohort sizes between institutions may make this challenging. This could potentially be achieved as part of new teaching module development or through the development of multi-institutional partnership to create an equitable balance in cohort sizes. Collaboration on this project also opened new possibilities for in-person exchange of students and placement opportunities between the two participating institutions, further highlighting the wider benefits of establishing of establishing COIL programmes within higher education institutions.

5. Conclusion

The implementation of a laboratory-based Collaborative Online International Learning opportunity has demonstrated significant potential in enhancing students' international and cultural competencies, particularly within laboratory and health education. This study highlights the positive impacts of laboratory-based COILs on students' cognitive awareness, international understanding, and the development of essential soft skills such as communication, teamwork, and confidence. These findings suggest that practical-based COILs is an effective method for preparing students to thrive in a globalized healthcare environment, making a strong case for its continued use and expansion in educational programmes.

CRediT authorship contribution statement

Matthew Allan Jones: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Pika Miklavc:** Conceptualization, Methodology, Investigation, Resources, Writing – original draft, Writing – review & editing, Project administration. **MaryAnne Stewart:** Conceptualization, Methodology, Investigation, Resources, Writing – original draft, Writing – review & editing, Project administration.

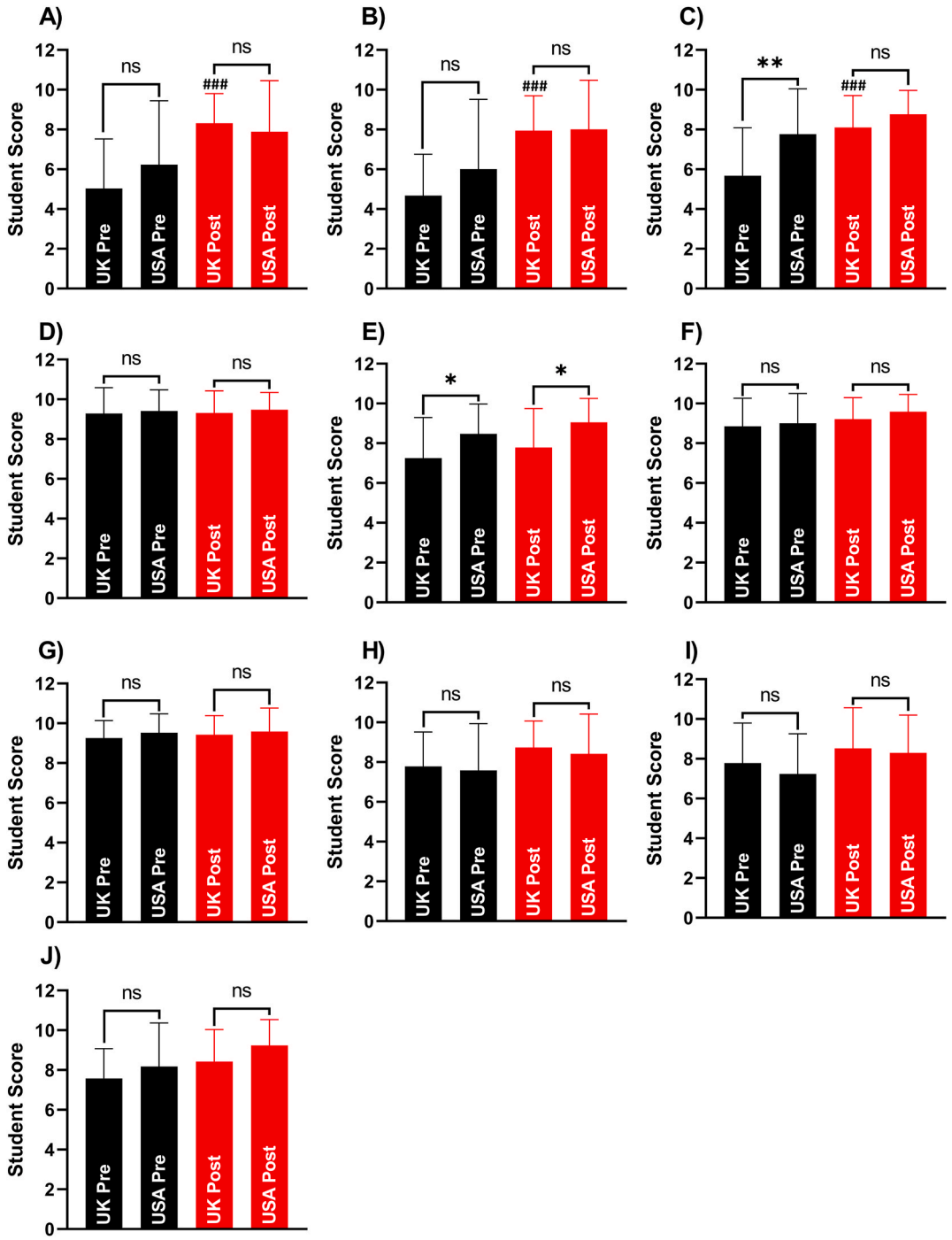

Fig. 5. Comparisons of each international cohorts' responses to the cognitive and international awareness pre- and post-survey. Pre (Black) and Post (Red) impact of Collaborative Online International Learning on students **A)** International education knowledge, **B)** International medical practice knowledge, **C)** Cultural intelligence, **D)** Enjoyment of working with people of different cultures, **E)** Confidence of working with cultures unfamiliar to themselves, **F)** Cultural empathy, **G)** Open mindedness, **H)** Social initiative, **I)** Emotional stability, and **J)** Work-based flexibility. Student responses were self-scored on a scale of 0 (no knowledge/score) to 10 (maximal knowledge/score). n = 28 for the UK Pre-survey, n = 19 for the UK Post-survey and n = 17 for both the USA Pre- and Post-surveys. Statistical significance was determined by a one-way ANOVA with a Tukey post-hoc test. Astrix's indicate significant difference from between international cohorts, hashes indicate significant differences between pre- and post-responses of the same international cohort. * indicates $P < 0.05$, and ** indicates $P < 0.01$, ### indicates $P < 0.001$.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank the Walter Bodmer teaching laboratory technical team at the University of Salford for their support with preparing for the practical session. We would also like to thank the Associate Dean – International Development within the School of Science, Engineering, and Environment at the University of Salford and the International Opportunities Teams at both the University of Salford and Wayne State University for supporting the establishment of this collaborative project.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crphys.2025.100141.

Data availability

Data will be made available on request to the corresponding author.

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