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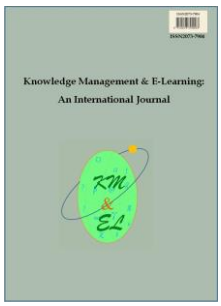

Knowledge Management & E-Learning: An International Journal (KM&EL)
ISSN 2073-7904

Recommended citation:
Chong, C. T., Zhang, H., Guo, L., Qiu, Y., Valera-Medina, A., & Ng, J. H. (2025). Effects of applying the BOPPPS-based collaborative online international learning model in a summer online course. *Knowledge Management & E-Learning, 17*(3), 497–518. https://doi.org/10.34105/j.kmel.2025.17.023

Knowledge Management & E-Learning, 17(3), 497–518

Effects of applying the BOPPPS-based collaborative online international learning model in a summer online course

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Abstract: The study investigated the effects of applying the BOPPPS-based collaborative online international learning (COIL) model, i.e., COIL-BOPPPS model, in a summer online course for international students. BOPPPS refers to six steps in lesson planning: Bridge, Objective, Pre-assessment, Participatory learning, Post-assessment, and Summary. The study assessed the model's impact

on students' perception of the online learning method, intrinsic and extrinsic motivations, and understanding of subject matter. The measures included self-reported familiarity with the subject matter, word cloud analysis, and knowledge tests. Results indicated significant improvement in students' perception of online learning methods, particularly in an interactive and intercultural environment. The pre-test and post-test results showed that students significantly improved their understanding of the subject matter at the end of the course. These findings suggest promising effects of the COIL-BOPPPS model for online teaching and learning in an international setting.

Keywords: Collaborative online international learning BOPPPS; Transnational education; Intercultural competency

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Professor Agustin Valera-Medina has participated as PI/Co-I on 33 industrial projects attracting ~£13M in research revenue. He has published 225 papers (h-index 44), 97 of these specifically concerning ammonia power. He has participated as module leader and teaching support in more than 10 different modules over his 15 years of teaching experience, supporting 33 PhD thesis, 45 MSc projects and an even higher number of undergraduate last projects. He was Director of the MSc in Sustainable Energy (2013-2022), he is Co-Director of the Institute of Net Zero Innovation and Director of the Centre of Excellence on Ammonia Technologies (CEAT) at Cardiff University, UK. He is a Fellow of the Learned Society of Wales and Fellow of the Mexican Academy of Engineering.

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1. Introduction

In today's globalized world, the increasing connectedness and interdependence of world cultures and economies facilitated by booming trade and progress of technology has resulted in the growing demand for graduates who are globally competent (Marlina, 2013). This has motivated higher education institutions (HEIs) to include internationalization elements of intercultural competency and global perspective cultivation in their curriculum (Crawford et al., 2020). Hunter et al. (2006) defined global competence as "having an open mind while actively seeking to understand cultural norms and expectations of others, leveraging this gained knowledge to interact, communicate and work effectively outside one's environment".

The OECD's Programme for International Student Assessment (PISA) had included "global competence" as one of the assessment criteria (OECD, 2018). It also defined global competence as "a multi-dimensional construct that requires a combination of knowledge, skills, attitudes and values applied to global issues or intercultural situation", highlighting the importance of such attribute. Students are expected to acquire intercultural skills in order to become interculturally competent, but such skills are often not acquirable through conventional class. One effective way to acquire intercultural competency skills is through experiential learning, either through a highly internationalized classroom to provide a diverse cultural learning environment, or via study abroad program (Appiah-Kubi and Annan, 2020). The former requires substantial resources input from the university and the latter could be cost-prohibitive to less affluent students. To overcome such barriers, there is a growing interest in pedagogical strategies for increasing cultural competency (Ambrose et al., 2017, Reeves et al., 2004).

In recent years, joint inter-institutional collaboration in e-learning has attracted much attention, in particular, "collaborative online international learning" (COIL) (de Castro et al., 2019), which is a form of home-based internationalization approach useful to foster intercultural competence skills, with the use of technology to connect classrooms in different geographical regions via a virtual learning and teaching environment. This article will discuss the implementation and evaluate the perceptions, motivations and efficacies of an online collaborative course with COIL integration.

1.1. Collaborative online learning

Redmond and Lock (2006) proposed the "Online Collaborative Learning Framework" in 2006 which centers around technology-enabled learning environments. Such learning approach requires learning conditions that engages students in active learning and in using higher order thinking to foster personal meaning making (Lock and Redmond, 2021). The framework focuses on fostering collaborative and interactive environments which leads to an overall learning gain greater than the sum of the independent work of each learner (Redmond and Lock, 2006). In recent years, COIL is a form of online collaborative

learning with a strong focus on the internationalization of the curriculum and teaching and learning has gained much attention (de Wit, 2020). COIL is based on the online teaching and learning (T&L) platform that allows students to develop intercultural and collaborative competences in a diverse teaching and learning environment through experiential learning, regardless of background. The development of COIL programme usually starts off with the identification of potential course instructors from different geographical region and institution that has an acceptable cultural diversity and teaches almost similar syllabus with the same or overlapping goals (Naicker et al., 2022, Appiah-Kubi and Annan, 2020). Then, the instructors will jointly discuss the course syllabus, expected work, shared projects, assessment tools and expectations. Deliverables and milestones are assigned to the project teams, while the outputs are jointly assessed by the faculties.

A variety of COIL module adopting a different learning approaches have been implemented and reported. Mestre-Segarra and Ruiz-Garrido (2022) combined the ICLHE (Integrating Content and Language in Higher Education) with the COIL approach. The participants comprised of different nationalities underwent efficacy tests which covered linguistic ability, subject content, cultural diversity, and cross-disciplinary skills. Distance learning integrating with COIL component and experiential learning component that requires student collaboration can further enrich the learners' experiences (Esche, 2018). Students from the US and Ecuador worked in group to complete a food product analysis project in a 15-week COIL project (West et al., 2022). Lock and Redmond (2021) reported that embedding experts in the online collaborative learning can enhance the collaborative learning experience, bringing different perspectives and experiences into the class to complement the teaching. On top of learning the knowledge and know-how, COIL enables students to engage in a multicultural working environment that are difficult to achieve in traditional classroom. By using online learning platform, COIL program is regarded one of the most cost-effective ways to internationalize university curricular via home approach.

The cultural diversity through COIL program enables students to approach problems through different perspectives which can lead to better and more holistic solutions (Love et al., 2014). The collaborative elements are embedded not only at the students' level, but also at the tutors' level, thereby encouraging a diversity on perspectives and lead to synergism. Collaborative learning requires students to take substantive responsibility for working together, thus placing the responsibility on the students. Students engaged in collaborative learning are required to work in a culturally diverse environment while building knowledge through the assimilation of information (Naicker et al., 2022). Besides, COIL enables the support of the co-creation of knowledge and development of skills related to critical thinking, leadership, positive thinking, apart from interculture communication (Hautala and Schmidt, 2019). However, cross-border online collaboration can be challenging for the students in view of the linguacultural, time zone, and background knowledge differences (Appiah-Kubi and Annan, 2020). Vahed (2022) reported that the lack of pre-training on intercultural awareness, insufficient prior knowledge of discipline-specific content and the exclusion of gradable components in COIL are among the issues that reduce the effectiveness of COIL.

Despite the challenges, several studies have reported positive COIL outcome and experiences. Students reported that having an international partner is a motivation to maintain a good study habit, and the need to explain course content to international counterparts facilitate better understanding of the course content (Skagen et al., 2018). Students were reported to be more proactive during COIL and actively took charge of the progress of their learning, in spite of the nervousness experienced prior to the

commencement of COIL engagement (Naicker et al., 2022). Nursing students from Denmark and the US participating in COIL program have reported an increased awareness related to the role in different countries and increased their confidence to collaborate with individuals in other countries (House et al., 2022). Up to eighty percent of the students reported that COIL helped them achieve good academic performance in a joint nutrition and culinary class between the US and Ecuador (West et al., 2022). Amid the positive impacts of COIL, some challenges related to COIL need to be addressed in order to fully realize the opportunities. This includes the lack of efficacies assessment of the COIL program, limited number of participants, time-consuming planning, limited beneficiaries, challenges around technological and institutional support, among others (Naicker et al., 2022, Appiah-Kubi and Annan, 2020). Further studies are needed to validate the effectiveness of COIL across different disciplines. While COIL seems to be effective for increasing the cultural competency among students, there is a lack of research in evaluating the students' perspectives and learning experiences with COIL, and the lack of assessment tool for the efficacies of such online collaborative course.

1.2. BOPPPS model

The BOPPPS model is a teaching method based on constructivism proposed by Canadian Instructional Skills Workshop (ISW) originally developed in the late 1970s with the aim of training pre-service teachers in secondary schools with fundamental teaching skills (ISW, 2023). The BOPPPS teaching model focuses on learning objectives, students' participatory learning and teaching feedback that enables a more effective teaching and learning (Yin et al., 2022). The acronym of BOPPPS stands for Bridge-in, Objectives, Pre-assessment, Participatory learning, Post-assessment and Summary, of which all six components are interlinked to form a complete teaching methodology (Instructional Skills Workshop Network Executive, 2021). The teaching method was well received and soon was widely implemented at higher education (Zheng, 2023). Over the years, the BOPPPS model has evolved as researchers have adapted the BOPPPS model with established teaching theories, such as Learning Styles Theory (Wang, 2023), Case-based Learning (Chen et al., 2022), Blended Learning model (Dai et al., 2022), amongst others, to create a more localised learning environment in order to achieve teaching goals. Wunderlich (2015) reported that using mind maps can effectively enhance the element of "Bridge-in" in the BOPPPS teaching model, thus making the language course more effective. Wang (2023) reported that integrating learners' characteristics in the BOPPPS teaching model in an IT course to personalise the learning styles can be more motivating and engaging for the students. These examples reflect that BOPPPS model is adaptive to the nature of the course and learning environment for effective teaching and learning.

The advancement of internet and multimedia tools has seen an evolution in the education methods, such as the emergence of remote teaching, transnational education and online education (Li, 2018). The COVID-19 pandemic period has catapulted online learning to a level with high acceptance, with more classes being conducted online due to travel restrictions, albeit in different modes and teaching methodologies (Limbu and Pham, 2023). The learning environment over the internet is entirely different from offline courses, thus requiring a redesigning of the teaching methodology for effective learning. Wang et al. (2024) applied the BOPPPS model in an online medical course and analysed the classroom cognition, emotion and behaviour of the students. Despite an increase in the students' performance in cognition and behaviours, which implies the effectiveness of the teaching method, some "inactive" students may find the online model to be confusing due

to the inability to adapt to the interactive mode of online learning. Wu et al. (2021) applied BOPPPS model in a data structure course conducted in the form of MOOC, and concluded that higher order of cognitive ability of "analysis", "evaluation" and "creation" can be attained, which is useful in cultivating computational thinking skill in the students. By combining BOPPPS teaching method with small private online class (SPOC) and Flipped class in an oral histopathology class, improved teaching satisfaction and greater autonomous learning were attained by the teachers and students respectively, implying that embedding BOPPPS in online or hybrid courses can lead to a win-win scenario for both the course instructors and students.

In view of the growing interest in online education, there is a need to develop a teaching and learning model adaptable to the internet learning environment. Moreover, the effectiveness and efficacy of the online teaching methodology needs to be evaluated. In the present study, we developed an online collaborative course, i.e. Net Zero-Carbon Fuels, which is aligned with the principles of UN Sustainable Development Goals, and adopted the COIL method paired with the BOPPPS model for lesson planning. The objectives of the study are to evaluate students' perceptions and experience with online learning through the integrated COIL-BOPPPS model, as well as to evaluate the students' attainment of the learning outcomes.

2. Research design

2.1. Theoretical framework

For this study, we have decided to use a hybrid COIL-BOPPPS methodology by adapting the best elements from COIL and engulfing them into the lesson planning model of BOPPPS. Fig. 1 shows the hybrid COIL-BOPPPS model that is used in the study. Different from the more commonly known COIL which involves two institutions between two classes, the present COIL is an open course comprising of several course instructors and students from different institutions. This enables all students to synchronously join the class at a common online platform. Such borderless innovative teaching enables cross-cultural collaborative work, thereby facilitating cross-cultural and experience exchange, which is part of the objectives of the summer program (SJTU SDG July Camp, 2022). Based on the BOPPPS model, we adapted the methodology for lesson planning, i.e. to design the course activities for each class based on the BOPPPS element, as shown in Fig. 2. Such integration of COIL model with BOPPPS teaching model over the online learning environment is different from the typical class approach, where the course delivery is mainly teacher-centred, while students mostly assume the role of receivers. The integration of BOPPPS ensures not only participatory learning via group activities, but also integrated with pre- and post-tests to assess the level of understanding. Enhanced understanding can be attained by summarising the key points of the lessons.

The practical adaptations of the COIL model into this COIL-BOPPPS model include grading method, course availability, time duration and accreditation level. In our implementation of the COIL-BOPPPS model, the in-class tasks, assessments, and the final presentation are graded centrally by the instructor in charge of the session. This allows the subject matter expert among the instructor to grade the part of the course that they are most well-versed, whilst also providing instant or more immediate feedback.

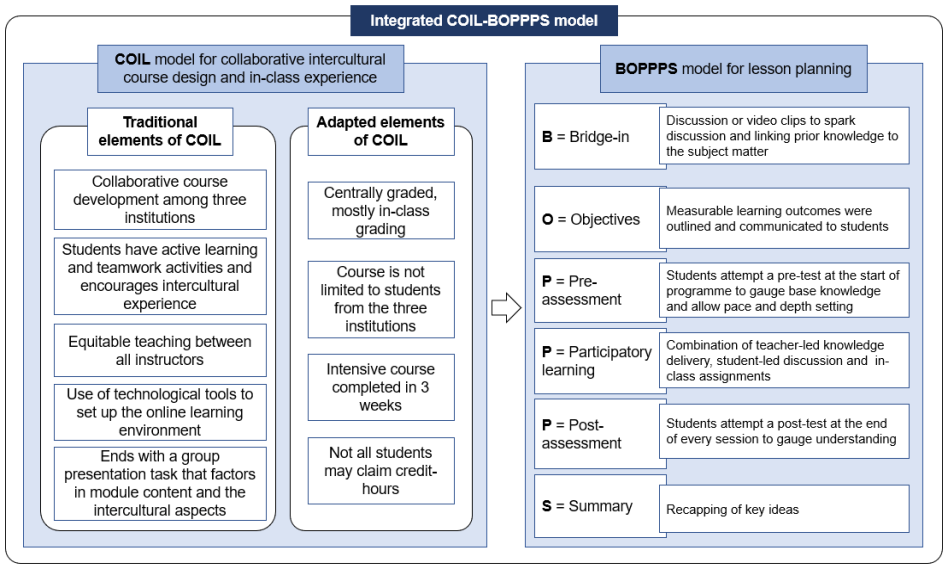

Fig. 1. Theoretical framework

The course is also opened to all undergraduate and postgraduate students, inclusive of those registered outside of the three partnering institutions. The outcome of this is an even more culturally diverse cohort. However, as a result of making the programme available to all students, it was not possible to offer credit hours to students outside of Shanghai Jiao Tong University. The course is also shorter than most courses modelled on COIL due to the purposeful decision to make this an intensive 3-week course. The decision to make it intensive is to coincide with as many summer break periods from various education calendar systems as possible.

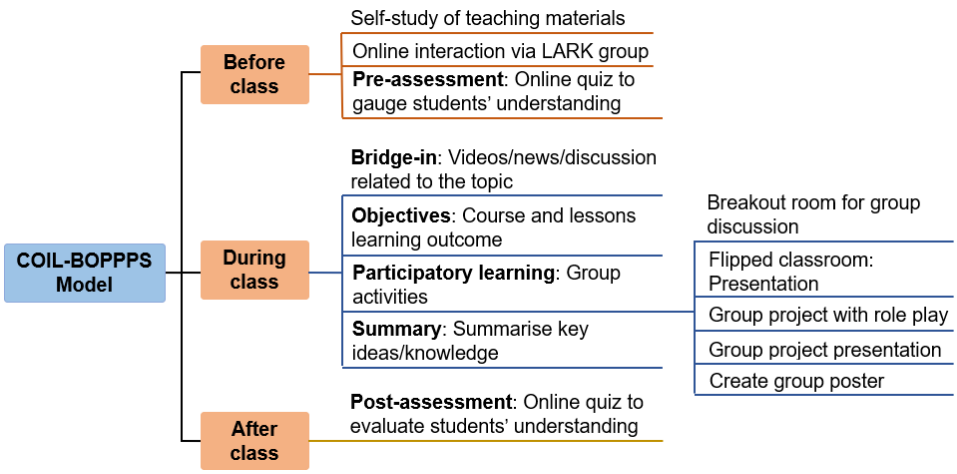

Fig. 2. Lesson planning using the COIL-BOPPPS model

2.2. Design of the BOPPP-based online collaborative course

Three instructors from three different universities (Shanghai Jiao Tong University in China), the University of Southampton Malaysia in Malaysia and Cardiff University in the UK) jointly designed and developed a 32 credit-hour course syllabus called "Net Zero-Carbon Fuels" as part of the SDG July Camp course series introduced by the International Affair Divisions of Shanghai Jiao Tong University in 2022 (SJTU SDG July Camp, 2022). The series of courses are opened to universities from the Association of Pacific Rim Universities (APRU) network, Universitas 21 (U21) network and all other non-affiliated universities. The objectives of the summer courses are to enhance the students' understanding on the values of Sustainable Development Goals (SDGs), foster intercultural competence while learning the subject matter content. All the courses are conducted online and are jointly developed by local academics and overseas partners. A total of 11 courses were introduced in the SDG July camp.

The Net Zero-Carbon Fuels course was run for three weeks consecutively during the summer break. Prior to the course, the instructors had several discussions to finalise the pedagogical approach and the learning activities for the course. A consensus was reached for the module content assigned to each instructor, coupled with different learning activities in the course to facilitate the intercultural interaction including ice-breaking session, random group discussion, group project, and virtual poster presentation. Two guest lectures were embedded in the module to provide perspectives from the industry and share their experiences. Using an online T&L platform (LARK, https://www.larksuite.com/zh_cn/), the classes were conducted in synchronous mode. Students were guided to download and use the software before the commencement of the class. Further, the students could use LARK to form group discussion for project after the class. In addition to communicating in the platform, the T&L files were also distributed using the in-built file repository service. All the sessions were conducted in English and recorded in the event if any students missed the synchronous session or would like to revise the lessons.

The teaching load was also distributed relatively evenly at a proportion of 37%, 34%, 29% for the China, Malaysia, UK instructors, respectively. The assignments were marked collaboratively as all the tasks involved the random mixing of students regardless of HEIs. This is to allow more intermingling among students from different cultures. This equitable team teaching allows the students to experience the T&L cultures from three distinct countries, while the students themselves experienced collaborative learning online. The 32-hour programme contained eight lectures, three topical review sessions and one final group project presentation which amounted to 23, 6, and 3 hours, respectively.

The overall research design framework is shown in Fig. 3. The Net Zero-Carbon Fuels course is implemented via COIL integrated with adapted BOPPPS model. Assessment of the effectiveness of COIL-BOPPPS model is conducted at the level of i) students' perception of learning methods, and ii) efficacies of the COIL-BOPPPS implementation. Understanding the students' behaviour is essential to gauge the level of acceptance of online teaching method and motivation to take up the summer course, which is important given the diverse background of the students. Next, the students' prior knowledge on the subject matter is evaluated to assess their pre-course understanding. Based on the assessments conducted via pre- and post-tests, the students' comprehension and cognition level is evaluated and aligned with the learning outcome attainment.

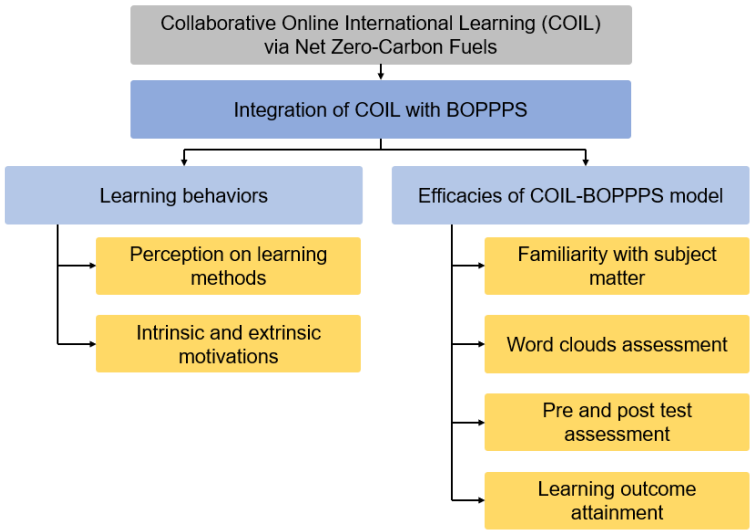

Fig. 3. Research design framework for evaluating the efficacies of COIL-BOPPPS model

2.3. Measure of student perception and motivations

Prior to the course, the students' perception of their preferred mode of learning and motivations were assessed via a pre-course survey. From the 14 different learning methods listed, students rated the methods on a 5-point Likert scale where 1 denotes "strongly disagree" and 5 denotes "strongly agree". The baseline on the students' perception of their preferred mode of learning was established. At the end of the programme, the students were asked again about their perception of the three online learning methods, in particular online discussion, online lectures and online group presentation. The students' motivations were evaluated from the perspectives of intrinsic and extrinsic motivations in the post-course survey on a 5-point Likert scale.

2.4. Measure of subject knowledge acquisition

We evaluated the students' acquisition of subject knowledge from the course by measuring their self-reported familiarity with subject matter, word cloud evaluation, and pre- and post-test analysis. The familiarity with subject matter is assessed via the pre- and post-course surveys, using the 5-point Likert scale. We also completed the self-reported familiarity with the concepts by asking students to list out keywords associated with SDG and net zero-carbon fuels. The word clouds were generated by asking students to describe the concepts and naming as many examples as they could. Students could write as many words as they can. While word clouds for use in education are presently more prevalent for teaching languages (Perveen, 2021), we believe that the same concept may be used to gauge the vocabulary that the students may associate with the subject matter. This provides a proxy for understanding. The final component in evaluating the efficacy of the programme is through a pre-test and post-test to objectively gauge the level of understanding. Students were given three choices for each multiple-choice questions and an additional option of "I don't know" to reduce the likelihood of guessing.

3. Research implementation

3.1. Participants

The subjects involved in this study are 43 undergraduate and postgraduate students from several countries. The national distribution of students is shown in Fig. 4. The students have an age range of 18-47 with a median and mode age of 21. The cohort is male-dominated (73.7%) with an overwhelming majority pursuing an engineering degree. The ratio of international students to local Chinese students are 3:1. It is to note that all students are proficient in English, which is a prerequisite for the course.

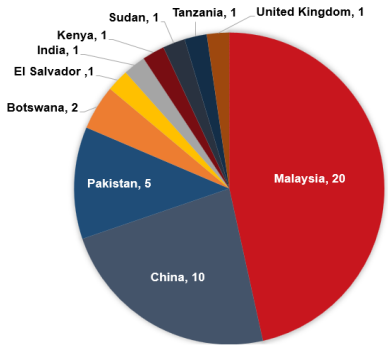

Fig. 4. Distribution of course participants by country

Despite the diverse geographical origin, the difference in time zone did not deter the students from joining the synchronous class. The classes were scheduled to start at 4pm Shanghai and Kuala Lumpur time, while the students in the UK joined the class at 9 am. The rest of the cohort resides in between the two extreme ends of the time zones, which leads to a favorable timing for learning.

3.2. COIL-BOPPPS model implementation

On a lesson planning and implementation level, the BOPPPS model was adapted for this summer course. The BOPPPS model is a teaching method based on constructivism proposed by Canadian Instructional Skills Workshop (ISW) (ISW, 2023). The BOPPPS focuses on learning objectives, students' participatory learning and teaching feedback. The purpose of the implementation of BOPPPS teaching method is to enable a more effective online teaching and learning (Yin et al., 2022).

Table 1 shows the learning activities associated with the BOPPPS components implemented in the class. As the programme is focused on sustainability and net-zero carbon fuels, all sessions within the programme started with a bridge-in that communicated how the two concepts are linked to the topic of the day. Brief video clips and recent news articles related to the development of net zero-carbon fuels were introduced. Subsequently, the objectives were outlined in the form of intended learning outcomes (ILOs). As a matter of good practice, all ILOs were written in the form that they must start with an action verb and must be measurable (Carr and Hardin, 2010; Chance and Peck, 2015).

Table 1
Learning activities associated with BOPPPS components

Component	Example of activities
B: Bridge-in	News and short video clips related to the development of fuel are introduced before the class.
O: Objective	The objectives, learning outcomes and relevance to SDG of each chapter are explained.
P: Pre-assessment	Answer course content-related questions.
P: Participatory learning	Random online group work, poster workshop, embedded experts, peer feedback on poster and group project presentation.
P: Post-assessment	Answer course content-related questions.
S: Summary	Review of the summary of each chapter.

While the classical BOPPPS conducts the pre-assessment at every session prior to the participatory learning, we conducted the pre-assessment for all topics at the start of the first session. This was intentional as the combined pre-assessment serves as a way to gauge baseline knowledge. The pre-test can also serve as a motivational tool and road map for students (Berry, 2008). There are drawbacks to this method as students will miss out on a lesson-by-lesson chance to recall prior knowledge. We believed that as the programme is conducted intensively over a 3-week period, students will still be able to assess their own strengths and be mindful of which areas they should be improving. Furthermore, as the pre-test results were analysed instantly due to using an online platform, the instructor could still exploit the analysis to adjust the pacing of the learning and provide more emphasis on parts where students had less prior knowledge.

The participatory learning primarily involved a combination of instructor-led knowledge delivery and student-led discussions and mini-assignments. The discussions and mini-assignments were designed collectively by the instructors so that learning outcomes were met if students completed the tasks (Biggs, 1996). Before the start of each discussion or mini-assignment, a detailed brief or rubric was shown on screen so that the students understood what was expected of them (Reddy and Andrade, 2010; Lipnevich et al., 2014). In the more complex assignments, examples or templates were shared with students to further improve the clarity of task expected of the students (Bacchus et al., 2020). Most of the tasks involved students being distributed into groups consisting of 5-6 students, with a time allocation of 10-20 minutes. The decision to randomise student groupings was made to allow cross-cultural interactions and share their experiences, particular about how they view sustainability and describe the net-zero carbon fuel scenario from their home country. Students were also assigned a long-term group for the final presentation.

At the end of every session, a post-assessment which repeated the questions from the pre-assessment were conducted. By analysing the results of the post-assessment, we could ascertain if the desired outcomes were accomplished. This is due to the pre-test and post-test being mapped to the ILOs. Upon completion of the post-assessment, the instructors also summarise the session by doing a recap of the key ideas.

3.3. Test alignment to the intended learning outcomes and topics

The pre-assessment and post-assessment are aligned to the intended learning outcomes (ILOs) and the topics. Upon completion of the course, students will be able to:

1. Describe the roles of alternative fuels for power and transportation sectors in the context of carbon neutrality and relate to the sustainable development goals.
2. Describe the production process, potential application, and limitations of alternative fuels in the context of power and transportation sectors.
3. Assess the impact of alternative fuel usage on the local resources, society, and nation in alignment of the sustainable development goals

Table 2 shows the constructive alignment between the assessment questions, ILOs, and the topics being taught. All questions are only mapped to a single learning outcome with an equal emphasis on net zero-carbon fuels and the carbon neutrality/SDG aspects. However, the taught topics may be double mapped against the SDG and net zero-carbon fuels. This is due to the intertwined nature of net zero-carbon fuels with SDG.

Table 2
Mapping of the assessment questions and their topics to the learning outcomes, SDG and net zero-carbon fuels

Question	Topic	Mapped to:				
		ILO1	ILO2	ILO3	SDG	NZCF*
1.1	SDG			X	X	X
1.2	SDG			X	X	
2.1	Biofuels		X			X
2.2	Biofuels		X			X
3.1	EWF	X			X	
3.2	SDG			X	X	X
4.1	Biofuels		X			X
4.2	Biofuels	X				X
5.1	Hydrogen fuels	X				X
5.2	Hydrogen fuels		X			X
6.1	Ammonia fuels		X			X
6.2	Ammonia fuels		X			X
7.1	Electrification of vehicles	X				X
7.2	Electrification of vehicles		X			X
8.1	Solar fuels		X			X
8.2	Zero-carbon fuels			X	X	X
Total		4/16	8/16	4/16	5/16	14/16

Note. *Net Zero-Carbon Fuels

4. Results and discussions

4.1. Students' perception

The COVID-19 pandemic has greatly changed the learning paradigm for students, with many students having faced abrupt disruption to their education due to lockdowns, curfews or other social distancing measures. The responses to the sudden requirements due to COVID-19 disruptions have led to HEIs dealing with the crisis by shifting most teaching to either fully online education or a hybrid of physical-virtual learning mode. There is a

further division in approaches where some HEIs either go fully synchronous or asynchronous, with many doing both depending on the availability of hardware and time zone issues. This leads to different views from students on what learning methods may be effective (Rapanta et al., 2021; Singh et al., 2021).

From the 14 different learning methods as shown in Fig. 5, with the exception of in-person group presentations and reading textbooks, students on aggregate prefer physical learning methods. From our interactions with this cohort of students, we deduced that screen fatigue, lack of interactions and the ease of being distracted during periods of passive learning all led to online learning methods being perceived unfavourably (Ganne et al., 2021; Alibudbud, 2021). However, we should not equate all forms of online learning to be homogeneous.

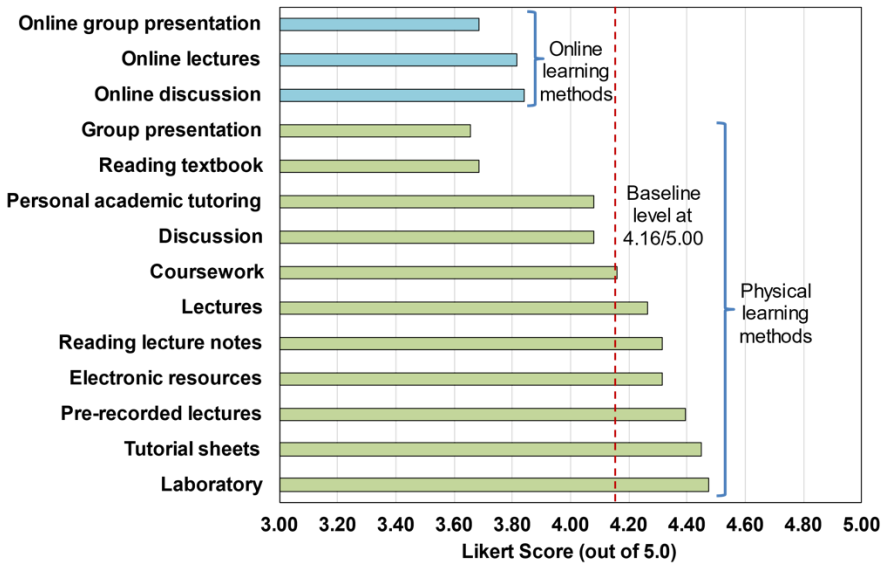

Fig. 5. Perception of learning methods at the start of programme

The gap between online and physical learning methods is substantial, with the online methods being rated at 3.68-3.84/5.00, while the physical methods have a Likert range of 3.66-4.47/5.00. This allows us to set the baseline level for learning methods in general to be at 4.16/5.00. Methods above 4.16/5.00 are considered to be above average. The three most preferred method are in-person laboratory session (4.47/5.00), solving tutorial sheets (4.45/5.00) and watching pre-recorded lectures (4.39/5.00). This is expected as laboratory sessions allow context to be affixed to the lecture contents, tutorial sheets will provide affirmation on understanding the lecture contents outside of examination conditions, and pre-recorded lectures allow flexibility in timing during a highly disruptive COVID-19 period.

At the end of the programme, the students were asked again about their perception of the three online learning methods, in particular online discussion, online lectures and online group presentation. The three methods were the primary methods used during the summer course. The programme was designed with interactivity in mind. For online discussions, students were placed in one-off randomised groupings to share their ideas and thoughts on mini-assignments related to the session. The online presentation groups were

permanent and revealed during the third session. This meant that students had more time to know each other and work together intensively over a two-week duration.

From Fig. 6, we found that students' perception of all online learning methods improved. In fact, all the three methods exceeded the baseline value of 4.16/5.00. The online discussion method improved from 3.84/5.00 at the start of the programme to 4.38/5.00 after being exposed to the COIL-BOPPPS model of summer course. Online group presentation showed an even greater improvement in perception going from 3.68/5.00 to 4.54/5.00. The perception of online group presentation method after the programme even exceeded that of physical laboratory sessions. This shows that a highly interactive and intercultural experiences over an intensive period greatly improves the learning experience of students. Such findings were also echoed for virtual reality and physical study tour modes of intercultural experiences (Dorsett et al., 2019; Liu and Shirley, 2021). We also found that students perception of online lectures improved from 3.82/5.00 to 4.54/5.00, which exceeded the physical lecture's Likert score of 4.26/5.00.

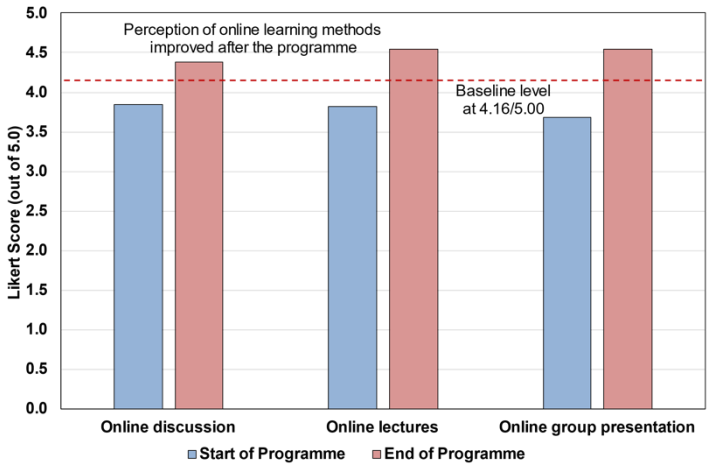

Fig. 6. Perception of online learning methods before and after the programme

4.2. Intrinsic and extrinsic motivations

Fig. 7 shows that students' opinions on net zero-carbon fuels and SDG improved to 4.65/5.00 and 4.62/5.00, respectively, which is higher compared with the baseline of 4.50/5.00. This ties in well with the other findings that the students displayed increased intrinsic motivation boost. Both their interest in learning more about net zero-carbon fuels and SDG after the programme concluded had the same Likert score of 4.73/5.00. We also found that the students' interests in the subject matter are not extrinsically motivated as students are less inclined to believe that what they learned over the three-week intensive summer course is likely to help them to improve examination performance at their respective universities. It should be cautioned that there might be some self-selection bias as the students who signed up for this course knew from the onset that was meant to enrich their understanding of the subject matter rather than being directly linked to their academic fields.

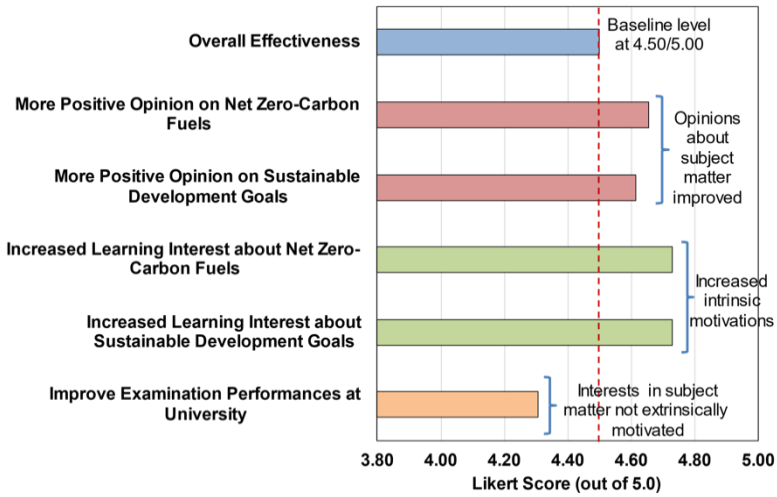

Fig. 7. Post-programme subject matter opinions and motivations

4.3. Students' acquisition of subject knowledge

Fig. 8 shows the familiarity of the subject matter before and after the programme. Familiarity with the SDG related to the course improved from 29% before the programme to a post-programme value of 88%. The improvement in the familiarity with net zero-carbon fuels was even greater, rising from 18% to 100%. This is not unexpected as the summer course focused on net zero-carbon fuels while merging in SDG concepts where relevant. Overall, the level of self-report familiarity is high for both key concepts of the summer course programme.

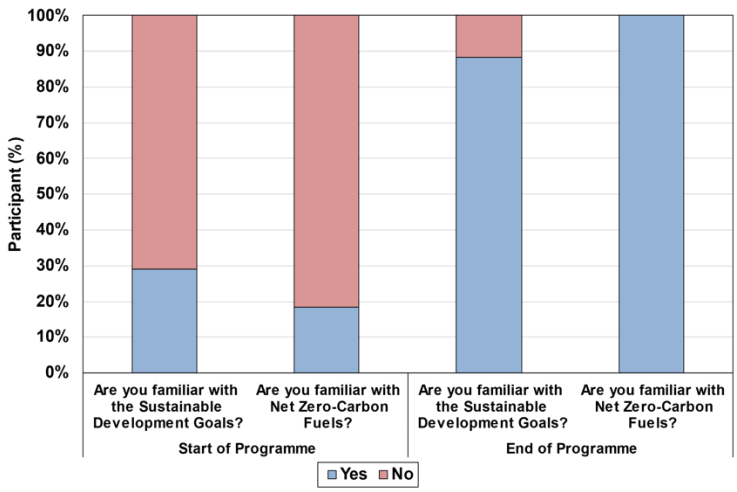

Fig. 8. Familiarity with subject matter before and after the programme

Fig. 9 shows the word clouds associated with the key concepts of the programme. At the start of the programme, students generally could not name many keywords associated with SDG. The most prominent keywords listed were 'sustainable, development,

develop, countries, future, generations, aspects, and world'. The keywords show that students generally only had a vague idea of SDG, linking it to a concept that concerns the world in the future. However, at the end of the programme, students were able to correctly provide relevant keywords associated with SDG. This time, there was coherence in the word cloud where it can be inferred that students understood that SDGs. The collection of keywords wand the written statements showed students knew that the globally agreed 17 SDGs were formulated by the United Nations to create a sustainable future.

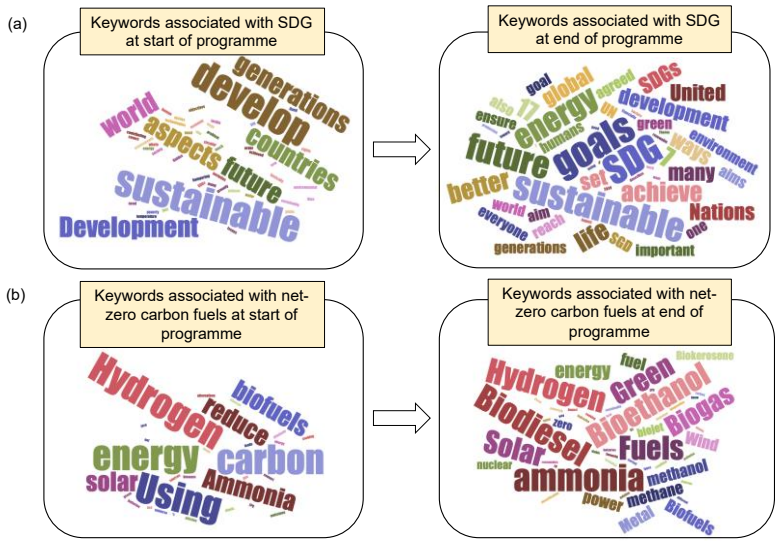

Fig. 9. Word clouds associated with (a) sustainable development goals (b) net-zero carbon fuels for the participant before and after the programmes

As for the net zero-carbon fuel word clouds, a noticeable growth in the range of keywords to listing the types of sustainable fuels was observed at the start and end of the programme. The word cloud only picked up four common sustainable fuels such as solar, hydrogen, biofuels and ammonia at the start of the programme. This shows that students knew about sustainable energy, albeit only at surface level. Upon completion of the programme, the word cloud showed 14 ways to sustainable energy. In fact, students now understood in depth as they could make the connection that biofuels can be further subdivided to biodiesel, bioethanol, and biojet fuels.

Fig. 10 illustrates the pre-test and post-test results for SDG and net zero-carbon fuels concepts tested. On average, students got exactly half of the questions correct for the pre-test, while getting 41% wrong, and 10% not attempting the questions. This average correct scores in the post-test improved to 73%, with 26% wrong answers, and the non-attempts fell to 1%. When analysing at a question level, we found that students understanding for 15 out of the 16 questions improved in the range of 4-58%. The remaining question had the same level of correct answers for both tests.

Table 3 shows the pre-test and post-test results when categorised by learning outcomes and course concepts. In all instances, the attainment level of the students increased from the pre-test baseline. At the end of the course, students' measurable attainment from the post-test were above 70% for all learning outcomes and concepts.

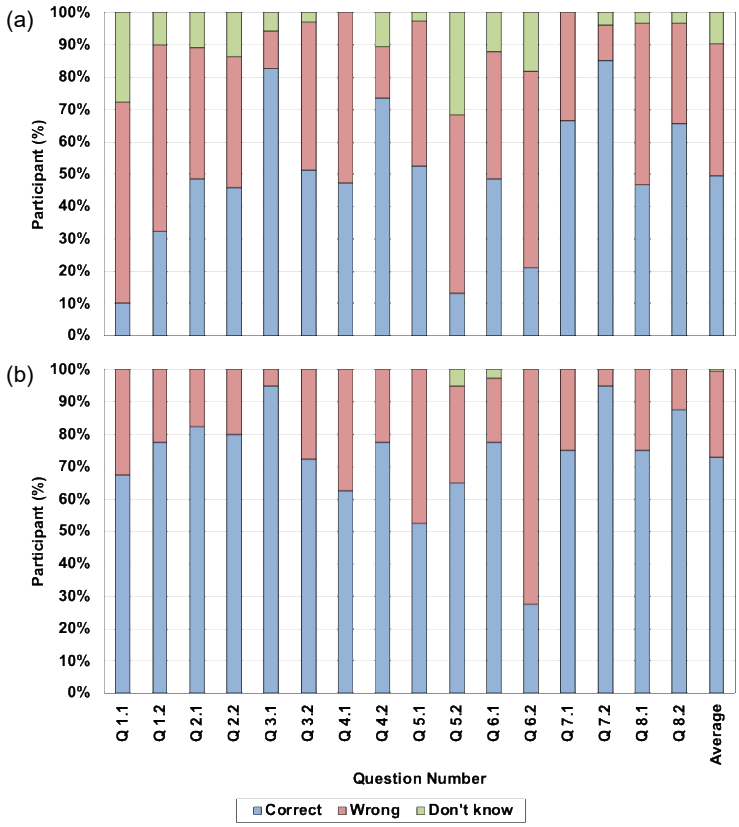

Fig. 10. (a) Pre-test (b) Post-test results for the SDG and Net-Zero Carbon Fuels concepts tested

Table 3
Pre-test and post-test percentages of correct answers by intended learning outcomes (ILO) and course concepts

Test	ILO1	ILO2	ILO3	SDG	Net Zero-Carbon Fuels
Pre-test	68.9%	44.6%	39.9%	48.5%	48.3%
Post-test	75.0%	70.6%	76.3%	80.0%	71.3%

To evaluate the statistical significance of the COIL-BOPPPS implementation within the summer course on student performance, a paired *t*-test was conducted using pre-test and post-test scores. Table 4 and Table 5 summarise the statistical results from the paired *t*-test. The results indicated a statistically significant improvement in scores following the intervention, with the mean post-test score (M = 73.13%, SD = 15.97%) substantially higher than the mean pre-test score (M = 49.52%, SD = 21.70%). The mean difference in scores was 23.61%, with a 95% confidence interval (CI) ranging from 14.93% to 32.29%, indicating that the true mean difference lies within this range. This suggests a consistent positive effect of the COIL-BOPPPS intervention across participants. The paired t-test results yielded a *t*-value of 5.77 and a *p*-value of < 0.001, confirming that the observed improvement was highly significant and unlikely to have occurred by chance. The null

hypothesis (H_0: μ_difference = 0) was rejected, providing strong evidence in support of the alternative hypothesis that the intervention produced a meaningful difference in student performance.

Table 4
Descriptive statistics for the pre-test and post-test

Sample	Mean	SD	SE
Pre-test	49.52%	21.70%	5.26%
Post-test	73.13%	15.97%	3.87%

Table 5
Estimation for paired difference of the pre-test and post-test

Mean	SD	SE	95% CI for Mean Difference	*t*	*p*
23.61%	16.88%	4.09%	(14.93%, 32.29%)	5.77	0.000

The improvement in post-test scores can be considered as statistically and practically significant. A mean difference of 23.61%, represents substantial improvement in the context of educational interventions and demonstrates that the COIL-BOPPPS model implementation of the summer course had a strong positive impact on students' learning outcomes. Additionally, the 95% confidence interval suggests that the programmes' effect size is robust, with a reliable estimate of the population mean difference rather than just a sample mean difference. Importantly, the confidence interval does not include zero, reinforcing the conclusion that the intervention was effective.

This result aligns with the aim of the COIL-BOPPPS implementation of the intensive summer programme, which aimed to enhance participants' knowledge and skills over a short period. The statistical significance, as indicated by the *p*-value, and the practical significance, as demonstrated by the large effect size and confidence interval, suggest that the course successfully addressed learning gaps and improved participants' academic performance. The *t*-value of 5.77 further indicates that the intervention had a large effect, reinforcing its practical relevance for future implementations. Typically, a value of 2 or higher will be considered to have sufficiently strong evidence against the null hypothesis.

Overall, the intensive COIL-BOPPPS implementation of the summer course demonstrated a significant positive impact on student outcomes, as evidenced by the substantial improvement in test scores. These findings highlight the effectiveness of short-term, intensive and multi-cultural educational interventions, suggesting that the methods employed in this course have the potential to be replicated or adapted in similar contexts to yield comparable improvements in student learning.

5. Conclusion

With the familiarity of online and hybrid education that were imposed on all students and instructors in this post COVID-19 new norm, we urge the educational research community to consider intercultural learning environments using online methods. The COIL-BOPPPS model allows flexibility for the instructors to collaborate and harness collective expertise, students to learn and exchange ideas without the limitations of physical boundaries, and

provides structured and consistent T&L sessions that allow on-the-fly pacing and depth adjustment while making quantitative measurements of course efficacy possible. We also believe that while the COIL model should be adapted more liberally to take into account the nature of the collaboration between instructors and the students that the courses want to attract.

The results of this study showed that the COIL-BOPPPS model improved the perception of online learning methods, increased the intrinsic motivations of students, and both self-reported and objective measured understanding of the subject matters. It might be too early to generalise the efficacy of COIL-BOPPPS across all student levels, academic fields and learning cultures. In the future, we intend to expand this study in terms of the instruments used for measuring efficacy, and emulating the study in a different setting.

Author Statement

The authors declare that there is no conflict of interest.

Acknowledgements

The authors gratefully acknowledge the effort from the International Affair Division of Shanghai Jiao Tong University in establishing the SDG July Camp program, and the funding provided by the Center for Teaching and Learning Development of Shanghai Jiao Tong University (CTLD22G0003).

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References

Alibudbud, R. (2021). On online learning and mental health during the COVID-19 pandemic: Perspectives from the Philippines. *Asian Journal of Psychiatry, 66*: 102867. https://doi.org/10.1016/j.ajp.2021.102867

Ambrose, M., Murray, L., Handoyo, N. E., Tunggal, D., & Cooling, N. (2017). Learning global health: A pilot study of an online collaborative intercultural peer group activity involving medical students in Australia and Indonesia. *BMC Medical Education*, *17*: 10. https://doi.org/10.1186/s12909-016-0851-6

Appiah-Kubi, P., & Annan, E. (2020). A review of a collaborative online international learning. *International Journal of Engineering Pedagogy (iJEP)*, *10*(1), 109–124. https://doi.org/10.3991/ijep.v10i1.11678

Bacchus, R., Colvin, E., Knight, E. B., & Ritter, L. (2020). When rubrics aren't enough: Exploring exemplars and student rubric co-construction. *Journal of Curriculum and Pedagogy*, *17*(1), 48–61. https://doi.org/10.1080/15505170.2019.1627617

Berry, T. (2008). Pre-test assessment. *American Journal of Business Education*, *1*(1), 19–22. Retrieved from https://files.eric.ed.gov/fulltext/EJ1052549.pdf

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education*, *32*(3), 347–364. https://doi.org/10.1007/bf00138871

Carr, J. W., & Hardin, S. (2010). The key to effective assessment: Writing measurable student learning outcomes. *Recreational Sports Journal*, *34*(2), 138–144. https://doi.org/10.1123/rsj.34.2.138

Chance, B., & Peck, R. (2015). From curriculum guidelines to learning outcomes: Assessment at the program level. *The American Statistician*, *69*(4), 409–416. https://doi.org/10.1080/00031305.2015.1077730

Chen, L., Tang, X.-J., Chen, X.-K., Ke, N., & Liu, Q. (2022). Effect of the BOPPPS model combined with case-based learning versus lecture-based learning on ophthalmology education for five-year paediatric undergraduates in Southwest China. *BMC Medical Education*, *22*: 437. https://doi.org/10.1186/s12909-022-03514-4

Crawford, E. O., Higgins, H. J., & Hilburn, J. (2020). Using a global competence model in an instructional design course before social studies methods: A developmental approach to global teacher education. *The Journal of Social Studies Research*, *44*(4), 367–381. https://doi.org/10.1016/j.jssr.2020.04.002

Dai, M., Qi, W., Chen, X., & Liao, M. (2022). Application and exploration of blended learning with BOPPPS teaching model in a veterinary infectious diseases course. *Journal of Biological Education*, *58*(4), 1010–1018. https://doi.org/10.1080/00219266.2022.2120904

De Castro, A. B., Dyba, N., Cortez, E. D., & Pe Benito, G. G. (2019). Collaborative online international learning to prepare students for multicultural work environments. *Nurse Educator*, *44*(4), E1–E5. https://doi.org/10.1097/nne.0000000000000609

De Wit, H. (2020). Collaborative online international learning in higher education. In P. N. Teixeira & J. C. Shin (Eds.), *The International Encyclopedia of Higher Education Systems and Institutions* (pp. 188–190). Springer. https://doi.org/10.1007/978-94-017-8905-9_234

Dorsett, P., Larmar, S., & Clark, J. (2019). Transformative intercultural learning: A short-term international study tour. *Journal of Social Work Education*, *55*(3), 565–578. https://doi.org/10.1080/10437797.2018.1548984

Esche, M. (2018). Incorporating collaborative online international learning (COIL) into study abroad courses: A training design. *Capstone Collection*, 3096. Retrieved from https://digitalcollections.sit.edu/capstones/3096/

Ganne, P., Najeeb, S., Chaitanya, G., Sharma, A., & Krishnappa, N. C. (2021). Digital eye strain epidemic amid COVID-19 pandemic – A cross-sectional survey. *Ophthalmic Epidemiology*, *28*(4), 285–292. https://doi.org/10.1080/09286586.2020.1862243

Hautala, J., & Schmidt, S. (2019). Learning across distances: An international collaborative learning project between Berlin and Turku. *Journal of Geography in Higher Education*, *43*(2), 181–200. https://doi.org/10.1080/03098265.2019.1599331

House, S. K., Nielsen, K., & Dowell, S. (2022). International collaboration using collaborative online international learning (COIL)/globally networked learning (GNL) model. *Teaching and Learning in Nursing*, *17*(4), 421–424. https://doi.org/10.1016/j.teln.2022.06.010

Hunter, B., White, G. P., & Godbey, G. C. (2006). What does it mean to be globally competent? *Journal of Studies in International Education*, *10*(3), 267–285.

https://doi.org/10.1177/1028315306286930
Instructional Skills Workshop Network Executive. (2021). *The instructional skills workshop (ISW) handbook part one: Workshop overview*. Retrieved from https://www.iswnetwork.ca/isw-handbook/.
ISW. (2023). *Instructional skills workshop network*. Retrieved from https://www.iswnetwork.ca/
Li, K. C. (2018). The evolution of open learning: A review of the transition from pre-e-learning to the era of e-learning. *Knowledge Management & E-Learning*, *10*(4), 408–425. https://doi.org/10.34105/j.kmel.2018.10.025
Limbu, Y. B., & Pham, L. (2023). Impact of e-learning service quality on student satisfaction during the Covid-19 pandemic: A systematic review. *Knowledge Management & E-Learning*, *15*(4), 523–538. https://doi.org/10.34105/j.kmel.2023.15.030
Lipnevich, A. A., McCallen, L. N., Miles, K. P., & Smith, J. K. (2014). Mind the gap! Students' use of exemplars and detailed rubrics as formative assessment. *Instructional Science*, *42*(4), 539–559. https://doi.org/10.1007/s11251-013-9299-9
Liu, Y., & Shirley, T. (2021). Without crossing a border: Exploring the impact of ahifting study abroad online on students' learning and intercultural competence development during the COVID-19 pandemic. *Online Learning*, *25*(1), 182–194. https://doi.org/10.24059/olj.v25i1.2471
Lock, J., & Redmond, P. (2021). Embedded experts in online collaborative learning: A case study. *The Internet and Higher Education*, *48*: 100773. https://doi.org/10.1016/j.iheduc.2020.100773
Love, A. G., Dietrich, A., Fitzgerald, J., & Gordon, D. (2014). Integrating collaborative learning inside and outside of the classroom. *Journal on Excellence in College Teaching*, *25*(3/4), 177–196.
Marlina, R. (2013). Globalisation, internationalisation, and language education: An academic program for global citizens. *Multilingual Education*, *3*: 5. https://doi.org/10.1186/2191-5059-3-5
Mestre-Segarra, M. Á., & Ruiz-Garrido, M. F. (2022). Examining students' reflections on a collaborative online international learning project in an ICLHE context. *System*, *105*: 102714. https://doi.org/10.1016/j.system.2021.102714
Naicker, A., Singh, E., & Van Genugten, T. (2022). Collaborative online international learning (COIL): Preparedness and experiences of South African students. *Innovations in Education and Teaching International*, *59*(5), 499–510. https://doi.org/10.1080/14703297.2021.1895867
OECD (2018). *PISA 2018 Global Competence*. Retrieved from https://www.oecd.org/pisa/innovation/global-competence/
Perveen, A. (2021). Use of word clouds for task based Assessment in asynchronous E-language learning. *Mextesol Journal*, *45*(2), 1–11. https://doi.org/10.61871/mj.v45n2-9
Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., & Koole, M. (2021). Balancing technology, pedagogy and the new normal: Post-pandemic challenges for higher education. *Postdigital Science and Education*, *3*(3), 715–742. https://doi.org/10.1007/s42438-021-00249-1
Reddy, Y. M., & Andrade, H. (2010). A review of rubric use in higher education. *Assessment & Evaluation in Higher Education*, *35*(4), 435–448. https://doi.org/10.1080/02602930902862859
Redmond, P., & Lock, J. V. (2006). A flexible framework for online collaborative learning. *The Internet and Higher Education*, *9*(4), 267–276.

https://doi.org/10.1016/j.iheduc.2006.08.003
Reeves, T. C., Herrington, J., & Oliver, R. (2004). A development research agenda for online collaborative learning. *Educational Technology Research and Development*, *52*(4), 53–65. https://doi.org/10.1007/bf02504718
Singh, J., Steele, K., & Singh, L. (2021). Combining the best of online and face-to-face learning: Hybrid and blended learning approach for COVID-19, post vaccine, & post-pandemic world. *Journal of Educational Technology Systems*, *50*(2), 140–171. https://doi.org/10.1177/00472395211047865
SJTU SDG July Camp. (2022). *2022 summer schools successfully held*. Retrieved from https://global.sjtu.edu.cn/news/view/1182
Skagen, D., McCollum, B., Morsch, L., & Shokoples, B. (2018). Developing communication confidence and professional identity in chemistry through international online collaborative learning. *Chemistry Education Research and Practice*, *19*(2), 567–582. https://doi.org/10.1039/c7rp00220c
Vahed, A. (2022). Factors enabling and constraining students' collaborative online international learning experiences. *Learning Environments Research*, *25*(3), 895–915. https://doi.org/10.1007/s10984-021-09390-x
Wang, Q. (2023). Design and application of personalized teaching model based on learning styles and BOPPPS. *International Journal of Learning and Teaching*, *9*(4). 318–322. https://doi.org/10.18178/ijlt.9.4.318-322
Wang, S., Li, F., Fan, H., Zhao, E., Liu, Y., & Bai, J. (2024). Influence of online modified BOPPPS teaching mode on classroom silence of medical students. *Medical Education Management*, *10*(1), 36–42. https://doi.org/10.3969/j.issn.2096-045X.2024.01.007
West, H., Goto, K., Borja, S. A. N., Trechter, S., & Klobodu, S. (2024). Evaluation of a collaborative online international learning (COIL): A food product analysis and development project. *Food, Culture & Society*, *27*(1), 152–173. https://doi.org/10.1080/15528014.2022.2069441
Wu, Y., Li, Z., Li, Y., & Liu, Y. (2021). Teaching reform and research of data structure course based on BOPPPS model and rain classroom. In J. Zeng, P. Qin, W. Jing, X. Song, & Z. Lu (Eds.), *Data Science* (pp. 410–418). Springer. https://doi.org/10.1007/978-981-16-5943-0_33
Wunderlich, I. (2015). *Bridge-ins. About building bridges at the beginning of a language lesson*. Retrieved from https://bora.uib.no/bora-xmlui/handle/1956/11711.
Yin, F., Li, C., Sun, D., & Zhou, L. (2022). Research on effective teaching based on the BOPPPS model under the background of engineering education professional certification. In Y. Wang, G. Zhu, Q. Han, L. Zhang, X. Song, & Z. Lu (Eds.), *Data Science* (pp. 406–411). Springer Nature. https://doi.org/10.1007/978-981-19-5209-8_27
Zheng, C. (2023). The BOPPPS instructional model: Development and implications for secondary science instruction. *Frontiers in Educational Research*, *6*(19), 35–41. https://doi.org/10.25236/FER.2023.061907