Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-025-05397-4 OPEN

Integrating mobile learning and problem-based learning in improving students action competence in problem-solving and critical thinking skills

Lin Cong[1] & Chinaza Solomon Ironsi[2]✉

This study investigates the integration of mobile learning and problem-based learning (PBL) to enhance students' action competence in problem-solving and critical thinking skills required for actualizing Sustainable Development Goal (SDG) mandates. The study employed a mixed-methods approach. The study combined quantitative assessments and qualitative feedback to evaluate the effectiveness of this integrated learning model. The participants were 120 undergraduate students from various disciplines who engaged in a series of PBL activities facilitated through mobile applications to support collaborative learning and critical inquiry. Results indicate significant improvements in students' problem-solving and critical thinking skills, as evidenced by pre- and post-intervention assessments. Although the students experience some technical challenges, the study revealed that this learning model and strategy is a valuable approach in equipping students with problem-solving and critical thinking skills required to contribute to sustainable development goals.

[1] School of Education, Shanghai Jiao Tong University, Shanghai, China. [2] Foreign Languages and English Preparatory School, Akdeniz Karpaz University, North Cyprus, Turkey. ✉email: Solomon.chinaza@akun.edu.tr

Introduction

Research recognizes that sustainable development goal 4 (SDG4) is a commitment to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. This objective serves as a crucial catalyst for beneficial transformation, highlighting the influential capacity of education in promoting a sustainable and fair world (UNESCO, 2017). It is envisaged that by 2030, all students will be expected to gain the necessary knowledge and skills to support sustainable development. Research acknowledges that critical thinking and problem-solving skills are essential for contributing to the achievement of the SDGs (Straková and Cimermanová, 2018; Xing and Ironsi, 2024). Nonetheless, recent studies affirm that students lack action competence in these skills and may struggle to contribute to SDGs (Sass et al., 2023). This must be considered to ensure that the above mandates are actualized.

Several authors define critical thinking as the active and proficient capacity to comprehend, analyze, and evaluate knowledge (Facione, 1995). Others further explained that critical thinking skills are vital cognitive competencies that enable individuals to process information efficiently and make informed judgments (Kalla et al., 2022). Research acknowledges the importance of critical thinking skills in contributing to the achievement of the sustainable development goals (SDGs) and the need to integrate this skill through education for sustainable development (ESD) (Giangrande et al., 2019).

On the other hand, some authors' assert that problem-solving entails identifying complex issues and executing appropriate solutions (Jonassen, 2000). Problem-solving skills are perceived as relevant to contributing to societal change and development (Chang et al., 2022). Research evidence highlights the immense contribution of evidence-based practices to resolving emerging societal issues, making them essential for the 21st-century workplace (Giangrande et al., 2019). However, some studies indicate that while students may possess knowledge of how to contribute to the SDGs, their action competence is lacking (Sass et al., 2023).

Similarly, there is evidence of a skill mismatch in the 21st-century workplace, as employees often lack competence in specific skills. For instance, prior studies assert that skill gaps exist within the United States, given that the curriculum does not align with the skill needs of society (Cappelli, 2015). Similarly, stakeholders in business enterprises provide evidence for the need for 21st-century skills, which is lacking in most 21st-century employees (Mahmud and Wong, 2022). Likewise, an exegesis of global employability skills reveals the limited nature of problem-solving and critical thinking skills in 21st-century workplaces (Tushar and Sooraksa, 2023). Skill mismatch and gaps require urgent attention if actualizing SDGs should be taken seriously.

Considering the above, one way to bridge the shortcomings may be to employ innovative pedagogical strategies that emphasize action competence in 21st-century skills. This way, students and university graduates can contribute to addressing social problems and work diligently towards achieving SDG mandates. Researchers acknowledge that strategies that eliminate the technology divide and foster mastery skill ideology should be considered when designing educational strategies to actualize the SDGs (Holmes et al., 2022). These innovative pedagogical strategies may include a blend of teaching approaches that help teach 21st-century skills.

For instance, some authors noted that education and learning could benefit from mobile applications developed for personalized learning or free web-hosted applications, especially for teaching sustainability (Criollo-C et al., 2022). Others provide evidence to show the effectiveness of problem-based learning (PBL) in skill-based courses (Fıtrıanı et al., 2020; Lou et al., 2012). Given the role of innovative approaches in enhancing instructional delivery, this study anticipates that a blend of these teaching strategies and approaches may help equip students with the required critical thinking and problem-solving skills. On these grounds, this study explores the potential of a blend of innovative pedagogical strategies in developing students' problem-solving and critical thinking skills through mobile learning (m-learning) and PBL.

Literature review

SDG4: quality education: implementation challenges. There are several challenges in implementing SDG4, which aims to ensure equitable and inclusive quality education and promote lifelong learning opportunities for all (Ghanem, 2020). The challenges cover a range of financial, infrastructural, political, social, and technical domains (Franco and Derbyshire, 2020). Many countries require additional financial resources to invest in developing educational infrastructure, training teachers, and acquiring learning materials (Ferguson et al., 2018). The global inequality in education funding is significant and requires increased financial support from both international and domestic sources (Unterhalter, 2019). Moreover, disparities in economic conditions within and between countries can lead to an unequal distribution of educational resources, exacerbating the disparities in the quality and availability of education (Archer and Muntasim, 2020). These matters should be well deliberated.

Infrastructure barriers could impede the attainment of SDG4. Research affirms inadequate school infrastructure in many areas, particularly in rural and neglected urban districts. This includes the absence of secure and conveniently accessible buildings, proper sanitation facilities, and reliable energy (Zickafoose et al., 2024). The digital divide, which denotes the disparity in internet access and the availability of digital gadgets, is a substantial impediment to students in their quest for contemporary education (Lawrence et al., 2020). This matter has been thoroughly examined and recorded in the broader body of literature.

In addition, implementing SDG4 is often hindered by bureaucratic inefficiencies, a lack of collaboration among stakeholders, and corruption (Hales and Birdthistle, 2022). Moreover, violence and political instability can potentially disrupt education systems, leading to the closure of schools, the displacement of students and instructors, and harm to educational infrastructure (Lawrence et al., 2020). Some societies enforce gender norms and cultural expectations that restrict educational opportunities, particularly for girls and marginalized people (Ghanem, 2020). Minority students, including those identified by their ethnicity, disability, or socio-economic status, may face discrimination that hinders their access to high-quality education (Hales and Birdthistle, 2022).

The global shortage of competent and accredited instructors has negatively impacted the quality of education, particularly in the acquisition of high-quality education (Archer and Muntasim, 2020). In addition, educators are presented with several opportunities for professional development to improve and update their skill sets (Franco and Derbyshire, 2020). The educational curricula in many nations need to be revised to provide students with the essential skills to meet the challenges of the 21st century (Unterhalter, 2019). The curricula must be revised to prioritize critical thinking, problem-solving, and digital literacy (Ghanem, 2020). To make significant progress in achieving SDG4, the international community should adopt a cohesive and synchronized strategy by integrating the required skills for contributing SDGs into the educational curriculum.

21st century skills. Research provides evidence to show the role of 21st-century skills in society's growth and development. Research on stance shows that critical thinking equips individuals with the capacity to examine, evaluate, and integrate information rationally and thoughtfully (Dlouhá et al., 2019; Chen and Liu, 2020). These authors emphasized the role of critical thinking skills in contributing to the achievement of the SDGs. Affirming this assertion, other studies further explained that this skill allows individuals to challenge assumptions instead of accepting them uncritically (Lohmann et al., 2021; Giangrande et al., 2019).

Aside from this, critical thinking skills enable individuals to assess evidence and arguments, determining their validity and potential bias (Schönstein and Budke, 2024). The authors believed that utilizing these skills could help individuals formulate logical conclusions based on solid reasoning. This helps people to exhibit open-mindedness while maintaining skepticism towards unsubstantiated assertions. Altogether, these skills are required if achieving SDGs through ESD is part of the goals in higher education.

On the other hand, problem-solving is the capacity to recognize, articulate, and resolve issues using a systematic methodology. Research maintains that it comprises identifying and articulating the issue, examining the underlying causes, and formulating potential solutions (Dlouhá et al., 2019). Furthermore, it involves assessing and selecting the optimal solution and executing and evaluating the results (Chen and Liu, 2020). In all, effective problem-solving involves both creative thinking and analytical thinking. Collectively, these competencies are essential in academic, professional, and other settings. They assist individuals in making informed decisions, adapting to changing circumstances, and resolving issues in an effective and ethical manner.

Action competence in problem-solving and critical thinking skills. Prioritizing the development of problem-solving and critical thinking skills through action competence is crucial for several reasons, as it directly impacts personal growth, societal progress, and tackling global issues (Torsdottir et al., 2024). Action competency enables individuals to make informed and logical decisions in complex situations, resulting in positive outcomes in both their personal and professional lives (Sass et al., 2020; Xing and Ironsi, 2024; Ironsi and Bostanci, 2023). People with strong problem-solving and critical thinking skills can successfully navigate and capitalize on the ever-changing challenges and opportunities in a dynamic world (Dlouhá et al., 2019). Moreover, developing these skills enhances individuals' confidence and effectiveness, empowering them to capitalize on opportunities and pursue their goals with greater determination (Chen and Liu, 2020).

Moreover, it has a substantial educational impact. By prioritizing action competence, students can enhance their comprehension and ability to retain knowledge (Lohmann et al., 2021). This is achieved through active involvement with the material and its practical application (Giangrande et al., 2019). Teaching students problem-solving and critical thinking skills can lead to their active engagement (Kalla et al., 2022; Ironsi, 2022). It facilitates active learning and student engagement, thereby improving the interactivity and efficacy of education (Schönstein and Budke, 2024). Furthermore, cultivating these aptitudes fosters a commitment to continuous learning as individuals persistently endeavor to enhance and adapt their expertise and capabilities (Dlouhá et al., 2019). These factors are crucial for the progress and development of society.

Societies benefit from individuals who can engage in critical thinking and exhibit creative problem-solving skills, contributing to societal progress. These individuals promote innovation and facilitate advancement in several fields (Sass et al., 2020). Enhancing individuals' problem-solving and critical thinking skills improves their ability to participate in democratic processes and community projects, hence promoting informed and engaged citizenship (Torsdottir et al., 2024). Moreover, it fosters social cohesion by fostering understanding and empathy as individuals grow more skilled at analyzing different perspectives and collaborating to address societal issues (Schönstein and Budke, 2024). These are indispensable for the thriving of society.

For civilizations to thrive, it is imperative to have a workforce comprised of individuals who are ready and willing to actively contribute to the advancement of society. Employers highly value problem-solving and critical thinking skills as they are essential for effectively managing the complexities of the modern work environment (Kalla et al., 2022). Therefore, those possessing these talents can identify inefficiencies, propose improvements, and increase production, significantly contributing to economic advancement (Giangrande et al., 2019). Moreover, individuals with exceptional critical thinking and problem-solving skills typically exhibit effective leadership and ingenuity, facilitating their ability to steer enterprises toward success and ensure long-term sustainability (Schönstein and Budke, 2024).

It is essential to have critical thinking and problem-solving capacity to address global issues effectively. Competence in taking action is essential in addressing global issues such as climate change, poverty, and inequality (Torsdottir et al., 2024). It involves examining issues, proposing feasible remedies, and implementing substantial measures (Ironsi and Bensen Bostanci, 2023). These skills facilitate efficient global collaboration and problem-solving, which are essential for resolving issues that transcend national borders (Chen and Liu, 2020). In the face of pandemics, environmental catastrophes, and geopolitical crises, action competence empowers individuals and communities to enhance their ability to anticipate, manage, and recover from these challenges (Kalla et al., 2022). It empowers individuals to navigate challenging circumstances, fosters creativity, and facilitates active and well-informed participation in all aspects of life.

Mobile learning and problem-based learning (PBL): the way forward. Mobile learning and PBL are very effective educational strategies that significantly enhance the development of critical thinking and problem-solving skills. Mobile learning allows students to conveniently access educational content and engage in learning activities, making it easier to incorporate education into their daily schedules (Ichinose, 2024; Chung et al., 2020; Chang et al., 2022). It provides opportunities for students unable to attend traditional classrooms due to geographical, economic, or social barriers (Nabila et al., 2023). Mobile learning encompasses various multimedia elements, such as films, interactive simulations, and gamified features, which contribute to increased engagement and effectiveness in the learning process (Sebastián-López and de Miguel González, 2020).

According to Hernández-Ramos et al. (2021), applications and online platforms can provide instant feedback on quizzes and exercises, enabling students to identify and correct any misunderstandings promptly. Mobile platforms can personalize content according to the learner's speed and proficiency, resulting in a customized learning experience that targets individual strengths and weaknesses (Ichinose, 2024; Istek and Ironsi, 2024). Students can take charge of their learning experience, exploring topics that interest them and advancing at their desired pace (Carrió Llach and Llerena Bastida, 2023).

Mobile learning facilitates collaboration through discussion forums, chat functionalities, and group projects, enabling

seamless interaction and engagement. These platforms enable students to learn from one another and enhance their communication skills (Kim, 2020; Ironsi and Bensen Bostancı, 2023). It enables students to form relationships and collaborate with peers and experts worldwide, broadening their perspectives and enhancing their problem-solving skills (Thomassen and Stentoft, 2020). Mobile devices can gather tangible information from the physical world, including photographs, movies, and geolocation data (Gudonienė et al., 2021; Ironsi and Ironsi, 2025). Subsequently, students might examine and utilize this data to resolve problems, leading to a more significant and applicable learning encounter (Yonanda et al., 2023). These skills are vital in modern life.

One fascinating characteristic of PBL is its capacity to shift the focus from teacher-led instruction to student-driven inquiry, promoting active engagement and facilitating deeper learning (Chen et al., 2023). By addressing complex and real-world problems, students must actively employ analytical thinking, thoroughly analyze data, and develop logical and well-supported responses (Carrió Llach and Llerena Bastida, 2023). PBL typically involves collaborative group assignments, fostering the development of students' interpersonal skills and competence in working with their peers (Ichinose, 2024). PBL facilitates the integration of information from multiple disciplines, enabling students to recognize connections and effectively apply their knowledge (Nabila et al., 2023).

According to Chen (2023), students develop the capacity to apply theoretical knowledge in practical situations, enhancing their problem-solving skills. By addressing practical concerns, the importance of the subject matter is increased, hence boosting student motivation and engagement (Sebastián-López and de Miguel González, 2020). PBL fosters a sense of accountability among students for their learning journey, increasing their motivation and dedication (Thomassen and Stentoft, 2020). PBL requires students to manage their time efficiently, set goals, and monitor their progress, fostering self-regulation and long-lasting learning habits.

Meanwhile, while these instructional strategies offer some potential, concerns exist about accessing an internet connection using mobile learning (Benali and Ally, 2020). Similar studies in the Gulf indicate that students may experience difficulty accessing a stable internet connection and other unforeseen issues synonymous with mobile phone issues (Al Murshidi, 2017). Another study found poor internet connection, access to mobile gadgets, and other issues as possible challenges to using mobile phones for teaching and learning (Al-Hunaiyyan et al., 2018). Nonetheless, these studies affirm that the above challenges do not underscore the potential of mobile learning in 21st-century education.

The present study. This study anticipates that mobile and PBL can enhance and magnify each other's advantages. Mobile platforms augment PBL activities by providing features for conducting research, facilitating collaboration, and enabling presentations. This enhances the dynamism and interaction of problem-solving. Mobile devices facilitate students' engagement in PBL activities, allowing them to participate at their convenience and from anywhere, thus enhancing adaptability and uninterrupted learning. Similarly, mobile learning enables individuals to access a wide range of materials and expert perspectives, thereby enriching the PBL experience and facilitating a thorough investigation of complex situations. Mobile learning technologies have been found to allow students to promptly apply ideas and receive rapid feedback, thereby improving their capacity for critical thinking and problem-solving while on the go (Thomassen and Stentoft, 2020). These tactics may enhance the accessibility and interactivity of learning while also equipping students with the skills to navigate and tackle real-world obstacles effectively.

Theoretical framework. The constructivist learning theory framework provides the most precise explanation for studying the possibilities of mobile learning and PBL in enhancing critical thinking and problem-solving skills. The constructivist learning theory posits that learners gain knowledge by actively creating it through their experiences and interactions with the world (Chuang, 2021). It emphasizes active, experiential learning in which learners are not passive consumers of knowledge but active participants in the learning process.

The core tenets of constructivism, particularly cognitive constructivism as advocated by Piaget, are strongly connected to mobile learning and PBL. Piaget's focus on learners actively developing their knowledge and understanding through experiences and interactions aligns with the hands-on approach (Carpendale, 2013), the inquiry-based approach of PBL, and the interactive and exploratory character of mobile learning. This viewpoint aligns with the cooperative nature of PBL and the interconnectedness facilitated by mobile learning.

Kolb's model of experiential learning, comprising a sequence of concrete experience, reflective observation, abstract conceptualization, and active experimentation (Sugarman, 1985), closely aligns with the iterative and reflective processes inherent in mobile learning and PBL. These theories offer a comprehensive framework for examining the impact of mobile learning and PBL on the development of students' critical thinking and problem-solving skills. This paradigm emphasizes the dynamic, situational, and collaborative elements of learning, which align with the educational approaches being examined.

Conceptually, this study anticipates that integrating mobile learning and PBL may help equip students with the critical thinking and problem-solving skills necessary to contribute to the achievement of the SDGs (see Fig. 1).

Given the potential of mobile and PBL, this study anticipates that implementing this strategy in teaching critical thinking and problem-solving skills may equip students with the necessary skills to contribute to the achievement of the SDGs. Furthermore, studies on utilizing these pedagogic strategies to develop students' action competence in critical thinking and problem-solving skills are still ongoing. This implies an understudied domain that requires more investigation. These empirical and knowledge gaps in the scientific literature can be bridged through this study. This study will provide insights into the potential of these pedagogic strategies for upskilling students' skill sets to contribute to the achievement of the SDGs. On these premises and to add to this special issue, this study decides to investigate the following research questions;

1. To what extent do mobile and PBL impact students' critical thinking and problem-solving skills?
2. How do students perceive using mobile and PBL to develop critical thinking and problem-solving skills?

Method

Research design. The study employed a mixed-methods research methodology. More specifically, this research employed a convergent parallel mixed-methods approach (Creswell and Plano Clark, 2023), in which quantitative and qualitative data were collected concurrently, evaluated separately, and then merged during interpretation to validate the results. This study uses posttests and interviews to gather qualitative and quantitative

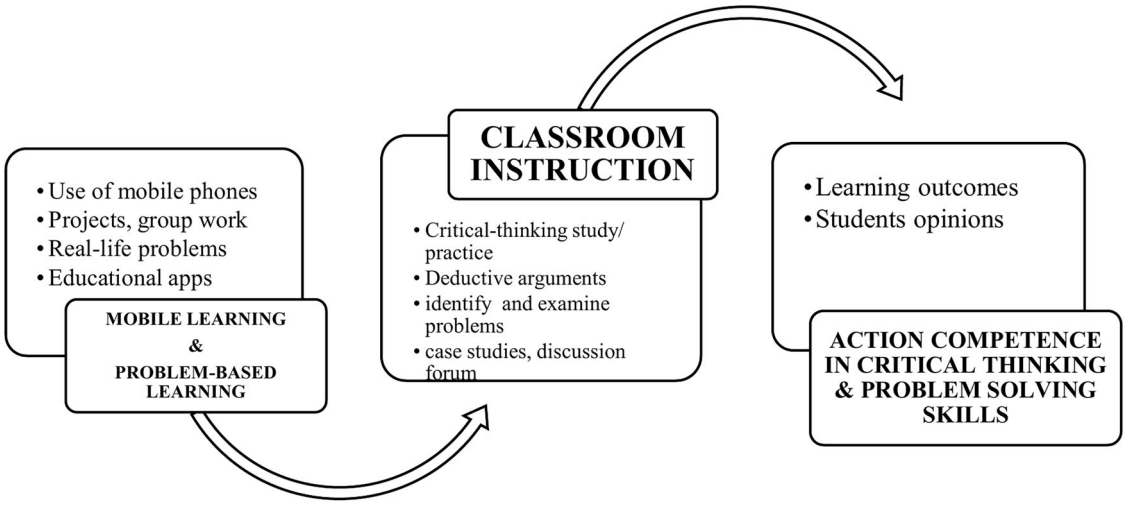

Fig. 1 The conceptual framework of the study.

data (McKendrick, 2020). This study anticipates that the chosen research design would be suitable for obtaining information from participants on the study's objective. The aim is to assess the impact of mobile and PBL on enhancing students' critical thinking and problem-solving skills, thereby contributing to the achievement of the SDGs. Additionally, the interviews offer valuable insights into students' perspectives on the possibilities of this educational methodology. This design utilized two experimental and control groups. The students received instruction in civic education.

Prior to commencing the course, the students underwent a pretest to guarantee uniformity in their initial level of knowledge. During the pretest, students were assessed on their knowledge level of critical thinking and problem-solving related to the civic education course. The control group received instruction through conventional teaching methods, whereas the experimental group utilized mobile and PBL approaches. Following the completion of the study, a posttest was conducted to evaluate their aptitude for critical thinking and problem-solving. Furthermore, they were questioned to elucidate their experiences utilizing mobile and PBL.

Procedures. The course EDE 208 was specifically developed to incorporate mobile and PBL methodologies into the study of civic education. The learning objectives were established, encompassing the analysis of information, the assessment of arguments, the making of decisions, and the generation of solutions. Subsequently, suitable mobile tools and platforms were selected, and the students were instructed to download the mobile application onto their mobile devices. This study utilized mobile programs such as the university learning management system (Moodle), Canvas, or Google Classroom, which are compatible with mobile devices and facilitate participatory learning. Furthermore, educational tools such as Socrative and Kahoot, which promote the development of critical thinking skills, were also utilized. Collaborative platforms such as Padlet, Trello, or Microsoft Teams were utilized for group projects and conversations.

Once the mobile-based system was established, PBL activities were uploaded for students to access. These exercises included case studies in which students were presented with real-world problems related to climate change, and they were required to analyze and solve the questions using mobile devices. Additionally, the researcher utilized applications that replicate authentic scenarios, such as augmented reality platforms embedded within Moodle, thereby fostering students' ability to apply their knowledge and engage in critical thinking. We utilized interactive quizzes on climate change issues and polls to promote critical thinking and provide timely feedback. We provided cooperative assignments on climate change where students can use mobile tools to communicate, exchange resources, and collectively generate solutions.

Additionally, we established virtual forums where students engage in debates and discussions, fostering a diverse range of viewpoints and promoting analytical thinking. During lectures, we used tools such as Mentimeter to engage students in active questioning and problem-solving activities. Additionally, we offered virtual office hours through mobile communication solutions, enabling students to inquire and receive assistance.

For the control group, participants attended lecture-based classes with weekly readings and instructor-led discussions. The same course, EDE 208, was developed and taught through traditional face-to-face teaching. The designated textbook for this course was used to provide daily lessons for the students, covering the relevant topics. Based on the instructional objectives, the teacher provided daily lessons to the students, including classwork and projects that contributed to the coursework. There were opportunities for group tasks during the classroom section, as this allowed for discussions among the students on several topics. At the end of the lessons, data were collected from the students based on the objective of this study.

Participants. One hundred twenty students were selected and enrolled for this study using a convenient sampling method. The individuals in question were enrolled as undergraduate students at a privately owned educational institution in Cyprus. The participants were divided into two groups: an experimental group of 60 students and a control group of 60 students. Both genders were represented, with individuals aged 18 to 26 years. Before initiating the study, participants were given verbal permission to participate or withdraw at any point. For the interviews, a total of 30 participants were randomly selected from the experimental group and assigned anonymous codes D1 through D30. The interview was captured and subsequently transcribed.

Data collection. The study employed pretest/posttest assessments and interviews as the primary methods for data collection. Before initiating the investigation, a pretest was conducted to verify that the necessary students were selected for participation in this study. This measure ensured that all students had equivalent proficiency before starting the study. Following the trial, the

students from both experimental and control groups underwent a posttest to assess any improvements in their critical thinking and problem-solving skills.

The posttest comprises open-ended and scenario-based questions that require students to apply their knowledge and skills rather than recollect information. The assessments necessitate the identification of issues and the suggestion of corresponding remedies. This helped determine the students' capacity to engage in critical thinking and resolve complex problems. Students were instructed to evaluate the nature and practicality of the proposed solutions carefully. Using projects and portfolios, we create rubrics to evaluate the proficiency of critical thinking and problem-solving skills. Following the examination, the scores were gathered and examined.

Semi-structured interviews were conducted to gather qualitative data, allowing participants to share their perspectives on mobile and PBL, which enhances students' critical thinking and problem-solving skills. The interviews were carried out remotely using the Zoom application. The participants consented to recording the interview session, which was then recorded and evaluated.

Data analysis. An assessment rubric based on competencies was utilized to analyze the projects and portfolio assessments submitted on Moodle. This rubric delineates the requirements for assessing critical thinking and problem-solving skills. The rubric encompasses the evaluation of analysis, creativity, reasoning, decision-making, and implementation. The evaluation focused on the precision of problem identification, the comprehensiveness of research, the viability of proposed remedies, and the efficacy of implementation strategies.

The researchers analyzed the student scores by computing the percentile and mean ratings. These were entered into Moodle. To ensure precision, a comprehensive assessment procedure was conducted. A threshold of 50% was established, categorizing students who achieved scores of 50% or higher as "pass" and those who scored below 50% as "fail."

Before adopting the rubric, it was developed by Bloom's Taxonomy and validated by three specialists in instructional design. The 50% criterion corresponds with university grading rules that delineate competency in skill display. Two separate graders assessed the rubric-based evaluations to ascertain their reliability. They obtained a Cohen's Kappa score of 0.84, signifying a substantial consistency. Following the collection of grades from Moodle, a separate external evaluator conducted a manual assessment of the students' answer samples to guarantee internal coherence. Once a consensus was reached, the final results were documented and displayed in tables.

Thematic analysis was employed to analyze the interview questions. Thematic analysis was employed throughout the interviews to reveal the participants' perspectives regarding using mobile learning and PBL to enhance their 21st-century skills. Following the data transcription, three skilled analysts participated in the analysis procedure. The interview questions underwent theme analysis, which involved examining the transcript to become acquainted with the dataset. The researcher mandated that all coders utilize the Braun and Clarke (2019) paradigm for theme analysis. This task necessitates a comprehensive understanding and meticulous analysis of the importance and patterns identified in the transcript. The researcher recommended that coders create codebooks to record their applications systematically.

Afterward, the separate codebooks were combined and analyzed to uncover the underlying patterns based on the consensus among the coders. The analyzed data was examined closely to detect repetitive patterns, and codes were initially created to represent the relevance and patterns discovered in the transcript. Themes were identified by interpreting codes that represented different aspects of the data while excluding codes that were not relevant. Due to the necessity of consensus in the coding process, the three coders were required to possess experience in qualitative analysis and coding. Additionally, when the codes were generated, one of the coders was excluded to minimize potential bias in the coding process. This strategy was developed to foster unanimity among the coders and mitigate potential bias in the resulting codes. The themes were examined comprehensively to ensure their congruence with the research goal and questions.

Another expert coder was summoned to resolve an issue with one of the themes. This strategy was implemented to eradicate any bias and improve the reliability of the analysis process. Additionally, member checking was used to improve the reliability of the results. Once the patterns became apparent, they were highlighted and documented. The data were carefully transcribed, and the interviewees were given the opportunity to review the transcriptions for verification. Subsequently, the themes were compared to the researcher's analysis, and the coders unanimously agreed. Ultimately, the themes were identified, categorized, and presented in tables.

To ensure the accuracy and thoroughness of the data collection procedure, the researchers developed clear and explicit research questions to enhance understanding in the relevant field. Furthermore, the study was conducted with great attention to detail, starting with the formulation of a thorough data collection strategy and the intentional selection of appropriate individuals who willingly gave informed consent to participate. While collecting data, information was systematically gathered over time, and all the coders used codebooks to document the codes generated. Member was checking during the aggregation of codes and development of themes.

Table 1 Descriptive statistics of mean scores across the pretest and posttest.

Control group	T1	T2	Experimental group	T1	T2
Critical thinking	42.26	50.05	Critical thinking	44.56	67.93
Problem-solving	28.45	45.68	Problem-solving	26.05	54.88

Findings

RQ1: How effective is mobile and PBL in improving students' critical thinking and problem-solving skills?

T1: Pretest, T2: Posttest. Table 1 provides a comprehensive review of the participants' pre- and posttest results in the experimental and control groups. Before initiating the study, the students in the control group achieved an average score of 42.26 on the critical thinking evaluation and 28.45 on the problem-solving assessment. The experimental group scored 44.56 on the critical thinking evaluation and 26.05 on the problem-solving assessment. This suggests that both groups were at an equivalent level before initiating the study. However, following the implementation of the study, the tables show that the students in the control group achieved an average score of 50.05 on the critical thinking exam and 45.68 on the problem-solving evaluation. In contrast, the experimental group scored 67.93 on the critical thinking exam and 54.88 on the problem-solving evaluation.

The table indicates improvements in students' critical thinking and problem-solving skills in both groups. Nevertheless, the

disparity in average scores necessitates conducting an ad hoc test to ascertain the significance level of the scores. A normality test was conducted on the tiny sample size to assess the ad hoc test and check if the distribution followed a normal pattern. Table 2 displays this information.

Table 2 presents the normality test. The table suggests that the *p*-value was greater than 0.05, as indicated by the value ($w(119) = 0.885$, $p = 0.75$) obtained. This indicates that the population was normally distributed. Given this, a parametric test (Independent *t*-test) was administered to determine if there was a significant difference in students' test scores across the groups. This is presented in Table 3.

Table 3 presents a paired sample t-test analysis of the test scores across the experimental and control groups to determine if a significant difference exists. The table shows that when an independent *t*-test was run at a 95% confidence level, a value of $t(63.15) = 68.92$, $p = 1.000$ was obtained. This table indicates a significant difference in the participants' test scores across the groups. This implies that the experimental group outperformed the control group across all the language skills assessed. Equally, a Cohen's alpha score of $d = 1.25$ was obtained, indicating a large effect size.

Interviews

RQ2: How do students perceive using mobile and PBL to develop critical thinking and problem-solving skills?

Table 4 presents a thematic analysis of the student's perceptions regarding the use of mobile and PBL to develop critical thinking and problem-solving skills. The table highlights three key themes: *effective approach, improved skills, and specific challenges*. The themes obtained are discussed below;

Theme 1: effective approach

The theme highlights that the students saw mobile and PBL as a potent means of enhancing their critical thinking and problem-solving skills. This theme supports students' stance on using mobile devices and PBL. Several of their remarks suggest this. Here are a few of their responses:

> *This is a valuable learning platform that helps me understand critical thinking and problem-solving concepts. This is good. D10*

> *Learning was made easier during this semester. We used online learning platforms to access learning materials. Using mobile made it (learning) more enjoyable. D19.*

Another added:

> *Using mobile phones to access lessons is cool; the applications make the lessons easy to understand and comprehend. D22*

These were some of the comments of the students that reflect this theme.

Theme 2: improved skills

The theme suggests that the students perceived an enhancement in their critical thinking and problem-solving skills through mobile and PBL. This theme aligns with the study's objective. It presents findings on students' perspectives regarding the effectiveness of mobile and PBL in enhancing their critical thinking and problem-solving skills. Below are a few remarks that exemplify this theme.

> *Given the numerous practical exercises we completed using mobile applications, my critical thinking skills have improved. This is good, D18.*

Other participants added,

> *Due to constant practice, my problem-solving skills have improved, and I aim to utilize them again during the next semester, D30.*

> *My problem-solving skills have developed, and I have noticed that my critical-thinking skills have improved as well. We used many mobile applications during our lessons in D21.*

The participants noted that their critical thinking skills improved due to the ease with which they accessed lesson materials at their convenience. Here are some of their comments;

Even at work, I can access the materials, study them, and do my assignments at my convenience. This kind of learning helped develop my critical thinking skills D3.

The mobile learning is easy and allows for easy learning. This improved my problem-solving and critical thinking skills D9.

The above comments suggest that mobile learning and PBL assisted in improving the students' 21st-century skills. These were their comments, which reflect this theme.

Theme 3: certain challenges

Although the students opined that using mobile devices and developing problem-solving skills improved their critical thinking and problem-solving abilities, they indicated that they

Table 2 Normality test.

	Shapiro–Wilk test			Skewness	Kurtosis
	Statistic	df	p		
Posttest	0.885	119	0.75	1.326	3.109

Table 4 Thematic analysis of students' opinion of using mobile and problem-based learning to develop critical thinking and problem-solving skills.

Themes	Codes
Effective approach	Useful, made learning easy, good for learning, productive
Improved skills	Assisted, developed, advanced
Certain challenges	Difficulties, setbacks, struggles, malfunction

Table 3 Independent *t*-test of the posttest scores of the participants across the groups.

								95% CI for mean difference		
Measure 1		**Measure 2**	***t***	**df**	***p***	**Mean difference**	**SE difference**	**Lower**	**Upper**	
GP1	-	GP2	63.15	119	1.000	27.08	1.505	53.045	69.231	∞

Cohen's $d = 1.25$.

experienced some challenges. This also provides insights into students' potential and possible challenges while learning through mobile learning. Here are some of their response;

I had issues with the internet connection, which sometimes disrupted the lessons. D28

Sometimes, accessing the Internet for lessons required effort, even though I had paid a lot for an internet connection. D16

The students also encountered other problems. For instance, some students complained about their gadgets malfunctioning during the lessons. Here are some of their comments;

My telephone would sometimes malfunction, which was not easy to deal with.

My phone had memory storage issues, which sometimes caused it to lag. D7

I store many files on my mobile phone, which makes my phone heat up every day. This switch on my mobile was challenging for me. D9

The participants' comments made it clear that, although this instructional strategy yielded gains, the students encountered some challenges. The findings are discussed in the next section.

Discussion

Upon meticulous examination of the data, the following results were unveiled. The study revealed that using mobile learning with a problem-based educational strategy significantly enhanced students' critical thinking and problem-solving skills, which are essential for contributing to the SDGs. This finding supports the idea that, in this educational setting, the use of mobile learning and PBL enables students to control their learning experience and enhance their communication and problem-solving skills. Importantly, research acknowledges that critical thinking and problem-solving skills are essential for contributing to the achievement of the SDGs (Straková and Cimermanová, 2018).

Nonetheless, recent studies affirm that students lack action competence in these skills and may struggle to contribute to SDGs (Sass et al., 2023). The study findings confirm that, with this learning approach, students can apply the skills they have acquired to contribute to the achievement of the SDGs. This finding is consistent with the results of previous studies conducted by Carrió Llach and Llerena Bastida (2023), Kim (2020), and Thomassen and Stentoft (2020), which affirm that practical learning approaches can be used to equip students with the skills necessary to contribute to achieving the SDGs.

Surprisingly, the study observed improvements in students' skills in the controlled groups. A potential explanation for the control group's improvement might be the testing effect, wherein frequent exposure to evaluative instruments boosts performance (Roediger and Karpicke, 2006), or the Hawthorne effect, in which individuals alter their behavior due to the awareness of observation. Another explanation could be that alternative teaching methods can enhance students' 21st-century skills. However, mobile learning and a problem-based instructional strategy have the potential to significantly enhance their skills. Incorporating mobile learning and PBL can serve as a significant technical tool for achieving SDG 4.7, which aims to ensure that all learners gain the necessary information and skills to promote sustainable development, as suggested by UNESCO reports in 2017. This learning strategy may be an effective tool for attaining the above mandate.

This innovative discovery aligns with the findings of other studies, suggesting that students can analyze and apply this data to solve problems, resulting in a more meaningful and practical learning experience (Yonanda et al., 2023). There is evidence from studies to show the need for 21st-century skills, which is lacking in most 21st-century employees (Mahmud and Wong, 2022; Tushar and Sooraksa, 2023). Given the outcome of our study, a more meaningful and practical learning experience, as employed in this study, may equip students with the skills to analyze and solve complex issues, which are essential for contributing to the achievement of the SDGs.

Notably, this study is among those that provide empirical data on the use of mobile learning and a problem-based instructional method to enhance students' critical thinking and problem-solving skills, which are essential for contributing to the achievement of the SDGs. The results are consistent with research indicating that incorporating sustainability into higher education curricula promotes students' capacity for analytical thinking, ability to solve complex problems, and awareness of their global obligations (Sass et al., 2023). The experimental investigation revealed a significant enhancement in the students' learning outcomes when comparing the pretest and posttest results.

Meanwhile, this finding aligns with previous research indicating that mobile learning and a problem-based instructional method have a positive impact on learning outcomes related to specific skills (Chen et al., 2023; Kim, 2020). Furthermore, researchers acknowledge that strategies that eliminate the technology divide and promote mastery skill ideology should be considered in designing educational strategies to achieve the SDGs (Holmes et al. 2022). Drawing on the findings of this study, utilizing mobile phones to bridge the technology divide in a PBL approach, which fosters skill development, may be an effective pedagogical strategy for achieving the SDG 4 mandate.

Moreover, this study's results demonstrate that using mobile learning and a problem-based instructional strategy significantly enhances their critical thinking and problem-solving skills. This finding supports the authors' claims regarding the successful utilization of this learning paradigm to enhance learners' knowledge and skills (Nabila et al., 2023). The study has already revealed an enhancement in the students' critical thinking and problem-solving skills. Similarly, as emphasized by comparable research conducted by Sebastián-López and de Miguel González (2020) and Kim (2020), students expressed that the use of mobile learning and PBL enhanced their critical thinking and problem-solving skills, as indicated in the interviews.

Similarly, the outcome supports the claim that incorporating sustainability education that includes 21st-century skills (such as problem-solving and critical thinking skills) development into curricula is crucial for equipping students to tackle current global issues (Sass et al., 2023). Students can utilize these talents to make meaningful contributions towards achieving the SDGs. Nonetheless, this may be possible using the study learning approach. This finding offers innovative perspectives for implementing proven pedagogical teaching and learning strategies to teach critical thinking and problem-solving skills, which have been underrepresented in scientific research.

Moreover, the interview uncovered specific obstacles. For example, the findings indicated that students perceived obtaining an internet connection as a challenging task. Research has indicated that limited internet access is a significant constraint in technology-based learning, as observed in our study (Benali and Ally, 2020; Al-Hunaiyyan et al., 2018). This can hinder instruction that may equip students with 21st-century skills. This specific finding was unexpected as the university provided a stable internet connection during the implementation of this study. Prior research has consistently emphasized the need for

substantial expenditures in technology infrastructure to establish online learning platforms (Ironsi, 2022; Al Murshidi, 2017). It is envisaged that by 2030, all students will be expected to gain the necessary knowledge and skills to support sustainable development (UNESCO, 2017).

Nonetheless, there is a need for technology infrastructural support to ensure that the mobile and PBL are implemented without hitches. Again, mobile learning was considered, given that it was believed that most students possessed good mobile devices. Nonethelessdevices. Nonetheless, the researchers could have conducted a small poll to elicit information on the quality of students' mobile devices before conducting the study. This could have assisted in appraising the nature of their mobile devices before commencing the study and in determining the need to make substantial provisions for mobile devices before the study began. The results indicate that combining mobile learning with a problem-based instructional strategy has several advantages. However, the described difficulties can hinder its implementation and stall educational processes that are essential for the actualization of the SDGs.

Conclusion

The study aimed to investigate the effectiveness of mobile learning and PBL in enhancing students' ability to think critically and solve problems, which are essential for contributing to the achievement of the SDGs. Upon careful examination of the data, the following inferences were drawn: The study concludes that mobile learning and PBL can effectively help students develop critical thinking and problem-solving skills. Students can utilize critical thinking and problem-solving skills to contribute to the achievement of the SDGs. This result is derived from enhanced student achievement through mobile and PBL methodologies. Mobile learning and PBL can enhance students' critical thinking and problem-solving skills, which are essential for achieving the SDGs.

Moreover, this study inferred from the interviews that students derived advantages from utilizing mobile and PBL to enhance the skills above. This approach is a highly effective teaching style for helping students in higher education actively pursue SDGs. Nevertheless, this study asserts that students may encounter difficulties utilizing this learning model. Firstly, the report asserts that students may require assistance from additional technical personnel to effectively utilize mobile learning. Additionally, this study suggests that establishing mobile learning necessitates a substantial investment in providing technological assistance. With such help, students can acquire the necessary technology and internet connections, which are crucial for the effectiveness of this learning approach. These and many other factors must be considered before introducing mobile learning and PBL in higher education.

Implications

The findings suggest that educational institutions should adopt competency-based methodologies, prioritizing the acquisition of skills to enhance students' abilities and prepare them to make significant contributions towards achieving the SDGs. The study proposes integrating mobile learning and PBL into traditional degree programs, creating hybrid educational models that combine academic knowledge with practical skills. By implementing this technique to update the curriculum, the achievement of SDG 4 will be ensured.

The study highlights the capacity of mobile learning and PBL to establish stronger connections between educational accomplishments and labor market requirements. This, in turn, addresses skill deficiencies in various industries and bridges the skill gaps in the 21st-century workplace. This highlights the application of ESD strategies in pursuit of achieving the SDGs. This study examines the potential of ESD-based strategies, such as the study's learning model, in equipping students with the relevant skills necessary to contribute to the achievement of the SDGs.

Moreover, it emphasizes the importance of continuous learning, continually encouraging individuals to enhance their skills through mobile and PBL. Mobile learning and PBL programs need increased support and funding from the government and institutions. It is recommended to encourage interdisciplinary research that explores the intersection of education, technology, and workforce development. Investigating the efficacy of mobile learning and PBL settings in fostering 21st-century skills leads to a fundamental transformation in education, empowering learners, catering to the needs of an ever-evolving labor market, and building more comprehensive and streamlined learning systems. This aligns with the core objectives of SDG4.

However, this study suggests that further research is needed to validate the results in a different educational setting, despite the crucial insights these new findings provide regarding the impact of mobile learning and PBL on learning outcomes. This study predicts that future research in different educational settings will yield interesting discoveries on similar topics. This study focused on critical thinking and problem-solving skills, which are only two 21st-century skills. Further studies on other 21st-century skills may provide profound insights into this issue.

Future research in this field should investigate the use of mobile learning and PBL with a large sample of participants. The limited number of participants can be attributed to the small size of our university. Conducting studies with a larger number of participants will yield more comprehensive insights into the possibilities of mobile learning and PBL. Furthermore, the convenience sampling technique adopted for this study may be a significant limitation; alternative sampling techniques that are less biased may be used in future studies. Most notably, this study found that combining mobile learning and PBL can enhance students' thinking and problem-solving skills. Additionally, it offers valuable insights into the advantages and disadvantages of this approach.

Received: 26 August 2024; Accepted: 20 June 2025;
Published online: 02 August 2025

References

Al-Hunaiyyan A, Alhajri RA, Al-Sharhan S (2018) Perceptions and challenges of mobile learning in Kuwait. J King Saud Univ Comput Inf Sci 30:279–289
Al Murshidi G (2017) Opportunities and challenges of mobile learning that university students encounter in the UAE. Int Res High Educ 2:18–37
Archer D, Muntasim T (2020) Financing SDG 4: context, challenges, and solutions. In Grading goal four. Brill p 170–193
Benali M, Ally M Towards a conceptual framework highlighting mobile learning challenges. Int J Mob Blended Learn 12(1):51–63
Braun V, Clarke V (2019) Reflecting on reflexive thematic analysis. Qual Res Sport Exerc Health 11(4):589–597
Cappelli PH (2015) Skill gaps, skill shortages, and skill mismatches: evidence and arguments for the United States. ILR Rev 68:251–290
Carpendale J (2013) An explication of Piaget's constructivism: implications for social cognitive development. In The development of social cognition. Psychology Press, p 35–64
Carrió Llach M, Llerena Bastida M (2023) Exploring innovative strategies in problem-based learning to contribute to sustainable development: a case study. Int. J. Sustain High Educ 24:159–177
Chang HY, Chung CC, Cheng YM, Lou SJ (2022) A study on the development and learning effectiveness evaluation of problem-based learning (PBL) virtual reality course based on intelligence network and situational learning. J Netw Intell 7:1–20

Chen SY, Liu SY (2020) Developing students' action competence for a sustainable future: A review of educational research. Sustainability 12(4):1374
Chen FF, Wang QS, Umar M, Zheng L (2023) Towards sustainable resource management: The role of governance, natural resource rent and energy productivity. Resour Policy 85:104026
Chung CC, Huang SL, Cheng YM, Lou SJ Using an iSTEAM project-based learning model for technology senior high school students: design, development, and evaluation J Technol Design Educ 32:905–941
Chuang S (2021) The applications of constructivist learning theory and social learning theory on adult continuous development. Perform Improv 60(3):6−14
Creswell JW, Plano Clark VL (2023) Revisiting mixed methods research designs twenty years later. Handb Mix Methods Res 1(1):21−36
Criollo-C S, Altamirano-Suarez E, Jaramillo-Villacís L, Vidal-Pacheco K, Guerrero-Arias A, Luján-Mora S (2022) Sustainable teaching and learning through a mobile application: A case study. Sustainability 14(11):6663
Dlouhá J, Heras R, Mulà I, Salgado FP, Henderson L (2019) Competences to address SDGs in higher education—a reflection on the equilibrium between systemic and personal approaches to achieve transformative action. Sustainability 11:3664
Facione PA, Sanchez CA, Facione NC, Gainen J (1995) The disposition toward critical thinking. J Gen Educ 44(1):1–25
Ferguson T, Iliško D, Roofe C, Hill S (2018) SDG4–quality education: inclusivity, equity and lifelong learning for all. Emerald Publishing Limited
Fıtrıanı A, Zubaıdah S, Susılo H, Al Muhdhar MHİ (2020) The effects of integrated problem-based learning, predict, observe, explain on problem-solving skills and self-efficacy. Eurasia J Educ Res 20:45–64
Franco IB, Derbyshire E (2020) SDG 4 quality education: governing education for sustainable development: towards inclusive and equitable quality education. Actioning the Global Goals for Local Impact: Towards Sustainability Science, Policy, Education and Practice, p 57–68
Ghanem S (2020) E-learning in higher education to achieve SDG 4: benefits and challenges. In 2020 second international sustainability and resilience conference: technology and innovation in building designs (51154) IEEE, p 1–6
Giangrande N, White RM, East M, Jackson R, Clarke T, Saloff Coste M, Penha-Lopes G (2019) A competency framework to assess and activate education for sustainable development: addressing the UN sustainable development goals 4.7 challenge. Sustainability 11:2832
Gudonienė D, Paulauskaitė-Taraševičienė A, Daunorienė A, Sukackė V (2021) A case study on emerging learning pathways in SDG-focused engineering studies through applying CBL. Sustainability 13:8495
Hales R, Birdthistle N (2022) The sustainable development goals–SDG# 4 quality education. In attaining the 2030 sustainable development goal of quality education, Emerald Publishing Limited, p 1–8
Hernández-Ramos J, Pernaa J, Cáceres-Jensen L, Rodríguez-Becerra J (2021) The effects of using socio-scientific issues and technology in problem-based learning: a systematic review. Educ Sci 11:640
Holmes W, Porayska-Pomsta K, Holstein K, Sutherland E, Baker T, Shum SB, Koedinger KR (2022) Ethics of AI in education: Towards a community-wide framework. Int J Artif Intell Educ 32(3):504-526
Ichinose T (2024) An Approach Towards Enhancing the Capacity Development of Disaster and Climate Risk Education in Pre service Teacher Training. In: Disaster and Climate Risk Education: Insights from Knowledge to Action. Springer Nature Singapore, Singapore, pp. 363–376
Ironsi CS (2022) Navigating learners towards technology-enhanced learning during post COVID-19 semesters. Trends Neurosci Educ 29:100189
Ironsi CS, Bensen Bostancı H (2023) Utilizing mobile-learning and CAP (E) lesson framework in improving the productive skills of learners in a hybrid environment. Educ Train 65:232–252
Ironsi CS, Bostanci HB (2023) Applying modified TATE framework in equipping learners with action competence on future skills: towards learners' future-readiness. Asia Pac J Educ 43:775–789
Ironsi CS, Ironsi SS (2025) Efficacy of micro-credential learning environments for developing students' 21st century skills: toward achieving sustainable development goals. Int J Educ Manag 29(4)
Istek E, Ironsi CS (2024) Incorporating mobile learning and the CAP (E) framework in improving the receptive skills of students. Libr Hi Tech 42:711–729
Jonassen DH (2000) Toward a design theory of problem solving. Educ Technol Res Dev 48(4):63-85
Kalla M, Jerowsky M, Howes B, Borda A (2022) Expanding formal school curricula to foster action competence in sustainable development: a proposed free-choice project-based learning curriculum. Sustainability 14:16315
Kim J (2020) Voices of youth in reconceptualizing and repositioning the role of mobile learning for sustainable development. Inf Technol Dev 26:711–727
Lawrence AW, Ihebuzor N, Lawrence DO (2020) Some challenges militating against developing countries achieving SDG 4 on targets: Nigeria as case study. Mod Econ 11:1307–1328
Lohmann J, Breithecker J, Ohl U, Gieß-Stüber P, Brandl-Bredenbeck HP (2021) Teachers' professional action competence in education for sustainable development: a systematic review from the perspective of physical education. Sustainability 13:13343
Lou SJ, Chung CC, Dzan WY, Shih RC (2012) Construction of a creative instructional design model using blended, project-based learning for college students. Creat Educ. 3:1281
Mahmud MM, Wong SF (2022) Stakeholders' perspectives on twenty-first-century skills. Front Educ 7:931488
McKendrick JH (2020) In: Kobayashi A (ed) International Encyclopedia of Human Geography, vol. 1, 2nd ed. Elsevier BV, p. 125–131
Ministry of Health (Türkiye Sağlık Bakanlığı) (2023) Beşerî Tıbbi Ürünlerin Klinik Araştırmaları Hakkında Yönetmelik [Regulation on Clinical Trials of Medicinal Products for Human Use]. Resmî Gazete, No. 32203. https://www.resmigazete.gov.tr/
Nabila N, Tapilouw MC, Sucahyo S (2023) Biology learning innovation in the water pollution sub material based on sustainable development goals (SDGs) using the problem-based learning. BIO-INOVED J Biol Inov Pendidik 5:297–306
Roediger III HL, Karpicke JD (2006) Test-enhanced learning: Taking memory tests improves long-term retention. Psychol Sci 17(3):249−255
Sass W, Boeve-de Pauw J, Olsson D, Gericke N, De Maeyer S, Van Petegem P (2020) Redefining action competence: the case of sustainable development. J Environ Educ 51:292–305
Sass W, De Maeyer S, Boeve-de Pauw J, Van Petegem P (2023) Honing action competence in sustainable development: what happens in classrooms matters. Environ Dev Sustain 25:3649–3670
Schönstein RF, Budke A (2024) Teaching action competence in education for sustainable development–a qualitative study on teachers' ideas, opinions, attitudes and self-conceptions. Front Educ 8:1256849
Sebastián-López M, de Miguel González R (2020) Mobile learning for sustainable development and environmental teacher education. Sustainability 12:9757
Straková Z, Cimermanová I (2018) Critical thinking development—A necessary step in higher education transformation towards sustainability. Sustainability 10:3366
Sugarman L (1985) Kolb's model of experiential learning: Touchstone for trainers, students, counselors, and clients. J Couns Dev 64:264–268. https://doi.org/10.1002/j.1556-6676.1985.tb01097.x
Thomassen AO, Stentoft D (2020) Educating students for a complex future–why integrating a problem analysis in problem-based learning has something to offer. The Interdiscip J Probl Based Learn 14(2):n2
Torsdottir AE, Olsson D, Sinnes AT (2024) Developing action competence for sustainability–do school experiences in influencing society matter? Glob Environ Change 86:102840
Tushar H, Sooraksa N (2023) Global employability skills in the 21st-century workplace: a semi-systematic literature review. Heliyon 9:e21023
Unterhalter E (2019) The many meanings of quality education: politics of targets and indicators in SDG 4. Glob Policy 10:39–51
UNESCO (2017) Life skills and lifelong learning. Asia-Pacific end of decade notes on education for all. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf000022502
Xing X, Ironsi CS (2024) Implementing action competence teaching model as a framework for achieving sustainable development goals: insights from students. Int J Sustain High Educ 25:1048–1065
Yonanda HD, Istiana R, Prasaja D (2023) The influence of problem-based learning (pbl)-based student worksheets on sustainable development goals (SDGs) to improve students' critical thinking skills. J Biol Educ Res 4:51–62
Zickafoose A, Ilesanmi O, Diaz-Manrique M, Adeyemi AE, Walumbe B, Strong R, Dooley K (2024) Barriers and challenges affecting quality education (sustainable development goal# 4) in sub-Saharan Africa by 2030. Sustainability 16:2657

Author contributions

All authors contributed equally to this study.

Competing interests

The authors declare no competing interests.

Ethical approval

The authors confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere. Before initiating the study, ethical approval dated 24.07.2024 was obtained from the ethics committee of Akdeniz Karpaz University with reference number AKUN/2024/77345TR. After reviewing the proposal, the ethical committee approved the proposal as the methods and procedures align with ethical rules and regulations for scientific research. The ethical committee confirmed that the procedures used in this study adhere to the

tenets of the Declaration of Helsinki of 1964. In Turkey, the requirement that researchers must get informed permission from subjects before requesting clearance from an ethical committee is established in national legislation governing clinical research and biological investigations. This policy is supported by the Turkish Ministry of Health under the authority granted by the Turkish Medicines and Medical Devices Agency (TİTCK). In line with Article 6 of the *Beşerî Tıbbi Ürünlerin Klinik Araştırmaları Hakkında Yönetmelik* (Ministry of Health, 2023), informed consent is obtained before ethical review submission. This stipulation specifies that informed consent—detailing objectives, risks/benefits, confidentiality, voluntary participation, right to withdraw—must be obtained prior to any research procedures or submission to the Ethics Committee. This ensures participant autonomy and voluntariness and guarantees that the Ethics Committee reviews a protocol already aligned with ethical principles in how participants' rights are respected.

Informed consent

A written informed consent was obtained from the participants by the corresponding author on 02.05.2024 where they declared their willingness to participate or withdraw from the study. The participants provided consent to the authors to publish the conclusions of the research in journals and conference proceedings. They provided consent for the data derived from this study to be used for research purposes and shared with the consent of the authors. The participants were informed that their identities would be protected by anonymizing their identities as the research would not pose any harm to them. These were included during the ethical approval application in line with the ethical consideration requirements and policies of the Graduate School of Akdeniz Karpaz University.

Additional information

Correspondence and requests for materials should be addressed to Chinaza Solomon Ironsi.