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Integrating online and offline teaching to promote creativity for STEM learners

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Abstract. This research extends previous findings by proposing an online and offline integrated teaching framework to enhance creativity for STEM learners. The framework integrates key elements from both modalities, featuring a combination of virtual and physical resources to support a comprehensive learning experience. The study introduces a "smart flowerpot" project as a practical application, detailing the instructional design, learning resources, and assessment strategies. It highlights the challenges in resource selection and the increased workload for teachers transitioning from traditional classroom settings. While the framework offers a promising approach, it acknowledges the need for empirical testing and consideration of external factors that may influence its effectiveness. The research advocates further exploration to validate the framework and its potential to transform STEM education.

Keywords: online and offline, integrated teaching, creativity, STEM learners

1. Introduction

With the development of technology and its extended application in many fields, educators try to reform teaching through technology in an attempt to achieve a qualitative change in education. Online teaching is a way of using technology to change education, which breaks through the limitations and requirements of traditional teaching in terms of time and space and gives learners great convenience in learning. In particular, in 2020, the COVID-19 pandemic made social distancing and lockdown measures necessary, significantly impacting the development of traditional classroom teaching [9, 14]. Teachers have had to temporarily move their teaching online as a substitute for face-to-face instruction. Online learning has never been so reusable.

1.1. Online and offline teaching

Both online and offline teaching have advantages and disadvantages. Different studies have drawn different conclusions on which one has a better teaching effect regarding online and offline teaching. The research from Bowman [3] showed that online instruction's effectiveness was on par with that of traditional classroom-based teaching regarding skill development. However, Hurlbut [8] proposed that students enrolled in the traditional classroom setting typically attained marginally better grades and assignment ratings than those enrolled in the online instruction. Meanwhile, the consensus among studies on the effectiveness of both is that online teaching tends to provide a more relaxed and freer learning environment. Students

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participating in online teaching tend to prefer interaction and communication more than those engaging in offline teaching [8, 11]. It is generally believed that students in online teaching feel comfortable and experience less pressure and greater freedom in interpersonal relationships, especially teacher-student relationships. And that when compared to traditional offline teaching methods, online teaching does not compromise the level of student satisfaction [1]. Specifically, in studying science and engineering, especially experimental or hands-on skills, although students say that online learning will still be beneficial, the actual effect is not convincing [15]. In addition, for reading, most students prefer to read traditional paper books rather than electronic documents [12, 16].

1.2. Creativity for STEM learners

The complexity and diversity of issues confronting society are escalating with the exponential growth of scientific and technological advancements and the evolving nature of social structures. These encompass environmental preservation, resource management, economic development, societal equity, and cultural disparities. Creativity holds the key to addressing these increasingly intricate societal challenges [6]. Therefore, it is imperative for education to prioritise the cultivation of students' ability to identify and resolve ambiguous problems, fostering a mindset that perceives the dynamic world through fresh perspectives and innovative thinking [4].

STEM education, which integrates knowledge from multiple disciplines, serves as a vehicle to develop students' capacity in creatively addressing practical challenges [10]. STEM education represents a significant approach to fostering creativity. Numerous studies have demonstrated that STEM education effectively enhances students' cognitive processes and problem-solving strategies [2, 13]. Consequently, the creativity of STEM learners deserves greater attention and exploration. By enhancing our understanding and appreciation of the role of creativity in STEM education, we can further refine and optimise teaching practices, ultimately fostering a generation of innovative thinkers capable of addressing the complexities of our contemporary world.

1.3. The present study

The seamless integration of online and offline educational advantages represents a prevailing trend in educational development, gradually evolving into a ubiquitous phenomenon across diverse educational settings and levels. Concurrently, this integration offers auspicious conditions to foster creativity for STEM learners. The pivotal focus of contemporary education lies in leveraging both online and offline platforms to enhance creativity among STEM learners and, ultimately, to catalyse an educational revolution in talent cultivation. The core objective of this study is to delve into the strategies for integrating online and offline teaching methodologies to optimise their respective strengths, thereby promoting creativity for STEM learners. Two primary research questions are proposed:

1. What effective strategies can be employed to seamlessly integrate online and offline teaching methodologies?
2. How can this integration be leveraged to promote creativity for STEM learners?

2. Online and offline integrated teaching

This study is an extension of the author's previous research, "Factors Associated with Creativity among STEM Learners: A Structural Equation Modeling Approach" [5], building upon its findings and further exploring the topic. This section below will introduce what online and offline integrated teaching is and how to define its main components. It also addresses the first question raised in this study, namely, how to integrate online and offline teaching methodologies.

To clarify the meaning of the proposed online and offline integrated teaching, this study compares it with the definition of blended learning. In the book "Blended: Using Disruptive Innovation to Improve Schools", Horn and Staker [7] points out that blended learning needs to meet the following three conditions:

1. Blended learning is a formal educational program in which students engage in at least some learning activities online and can independently control the time, place, path, or progress of their learning during the online period.
2. Students' learning activities are conducted at least partially in a supervised physical place outside the home.
3. The learning path modules for a specific course or subject should be related to an integrated learning experience.

This study's concept of online and offline integrated teaching emerged primarily from the exigency of online instruction at home, necessitated by the COVID-19 pandemic. The transition to online teaching at home has revealed both the strengths and weaknesses of this mode of instruction, prompting educators to reassess the advantages of online teaching and gain a clearer understanding of the principles underlying the integration of online and offline teaching methodologies. Consequently, the online and offline integrated teaching approach proposed in this research encompasses four distinct learning scenarios: online campus, traditional classroom, online at home, and offline at home. These four diverse learning scenarios involve various methods of presenting learning resources and facilitating communication and interaction. These primarily encompass digital resources, virtual STEM programs, online communication, paper resources, real STEM activities, and face-to-face communication. These six elements encapsulate three fundamental dimensions – interaction, resources, and projects – in both online and offline environments, collectively constituting the core components of online and offline integrated teaching.

Blended learning emphasises formal education, physical learning spaces outside the home, and an integrated learning experience. In contrast, online and offline integrated teaching does not prioritise physical learning spaces outside the home. Instead, it requires that both online and offline elements must include at least one element from each group. Based on the principles of permutation and combination, 18 possible combinations represent the original online and offline integrated teaching forms. The origin of these six elements and their combination methods answer the first question posed in this study: how to integrate online and offline teaching. Compared to blended learning, the definition of online and offline integrated teaching is broader in scope and more specific and tangible in terms of its constituent elements. This approach offers a more comprehensive framework that leverages the strengths of both online and offline modalities while addressing their respective limitations, thereby enhancing the quality of teaching and learning, promoting student engagement, and fostering the development of 21st-century creative skills in a manner that is adaptive and responsive to the changing educational landscape.

3. Online and offline integrated teaching framework

The study "Factors Associated with Creativity among STEM Learners: A Structural Equation Modeling Approach" by Fan and Sarfo [5] yielded results from confirmatory factor analysis and reliability estimations on the survey data, which delineated online and offline learning resources into two separate factors. This bifurcation indicates that the factors are autonomous and non-correlated, highlighting a significant disjunction between online and offline resources. Consequently, this finding engenders challenges and quandaries for the amalgamation of online and offline pedagogical approaches, compelling a reassessment of the efficacy and imperative of their integration.

Fan and Sarfo [5] articulates the correlational dynamics between activity rules, personal characteristics, the division of tasks, and the enhancement of creativity among STEM learners, as delineated in figure 1:

- activity rules had the greatest influence on the cultivation of creativity for STEM learners;

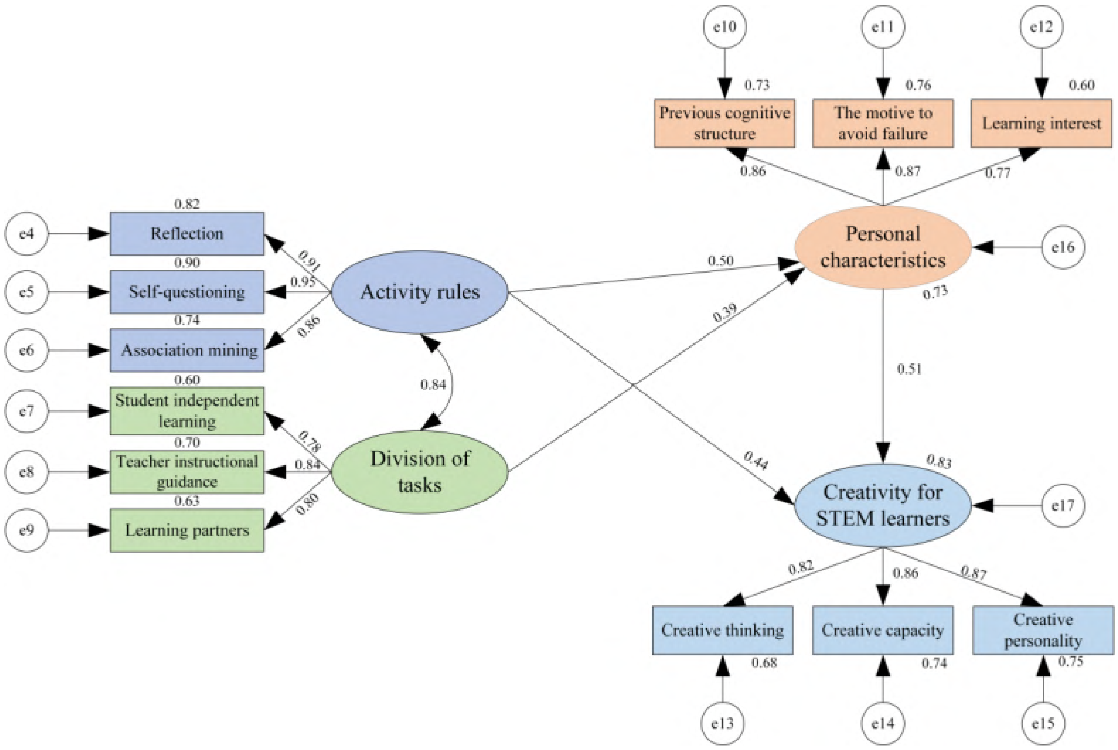

Figure 1: The graph of normalised path coefficient.

- the motive to avoid failure can stimulate the learners' desire to innovate;
- compared to the division of tasks, activity rules had a stronger effect on personal characteristics;
- the direct influence value of activity rules on personal characteristics is larger than that of creativity for STEM learners;
- the division of tasks was mediated by personal characteristics, which indirectly positively affects creativity for STEM learners but only weakly affects both personal characteristics and creativity for STEM learners.

In light of the aforementioned research outcomes and the inherent fragmentation of online and offline teaching resources, this study posits that these resources serve as the bedrock for executing educational activities. Their influence on fostering creativity in STEM learners is mediated through the constructs of activity rules, personal characteristics, and division of tasks. The comprehensive framework is visually represented in figure 2. Consequently, within the prototypical design of the online and offline integrated teaching framework, it is imperative to deliberate on the strategic selection and distribution of online and offline teaching resources encapsulated within the six elements of activity tools, cognizant of their determinative roles in the enhancement of creativity for STEM learners as influenced by activity rules, division of tasks, and personal characteristics.

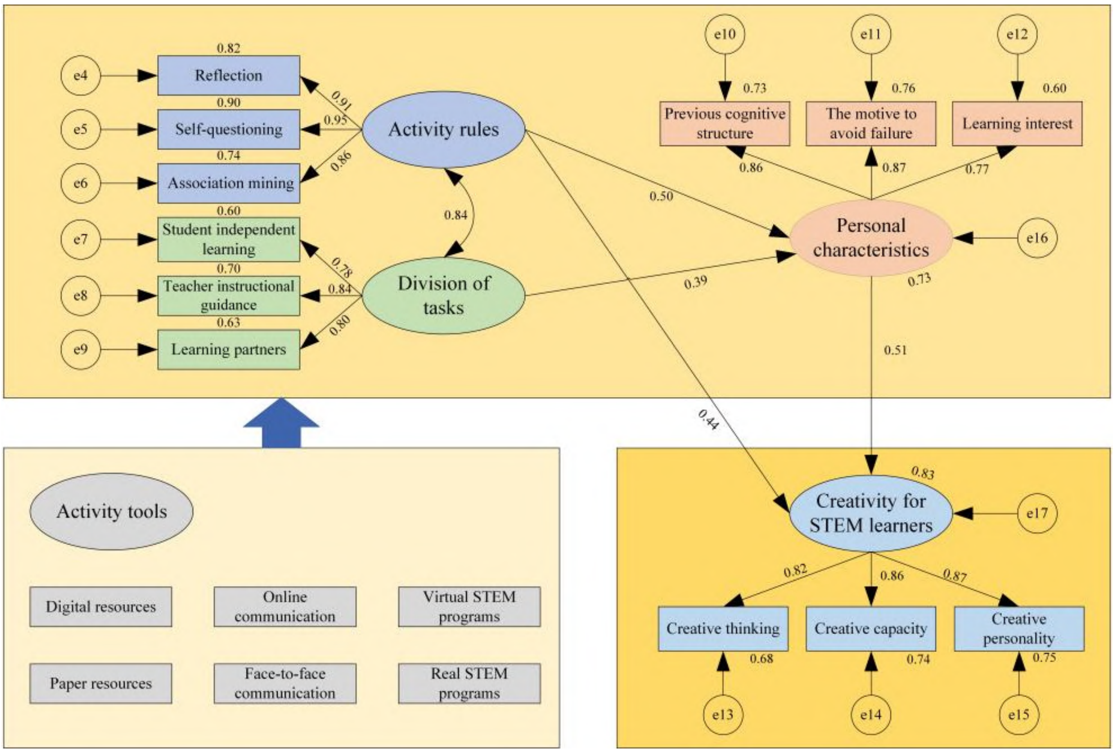

Figure 2: Prototype design idea diagram for online and offline integrated teaching framework.

After comprehensively considering the interdependencies among the constituent elements and their respective influences on the enhancement of creativity among STEM learners, this research articulates the design of the online and offline integrated teaching framework as illustrated in figure 3.

As illustrated in figure 3, this study delineates the online and offline integrated teaching framework into two major segments: pre-class and in-class, encompassing five distinct phases. Each phase is intricately linked, building upon the previous one to address the issues it generates. The pre-class tasks are primarily designed to harness the advantages of the flipped classroom model, emphasising student autonomy in learning and fostering a sense of responsibility for their own educational journey, empowering learners to take charge of their education rather than passively receiving instruction. Virtual platforms support the pre-class activities, while the in-class sessions are dedicated to hands-on practical projects. This framework leverages the strengths of both virtual and physical, digital and non-digital resources, ensuring that online and offline elements complement each other effectively.

The pre-class learning is task/goal-oriented and self-directed, supplemented by peer learning. Peer interactions can occur online or in person. Students are provided with both physical and digital resources to choose from, with content focusing on the instructional design, objectives, and tasks for the upcoming class. Students must understand what they will learn, how they will learn it, and what they aim to achieve before class. A virtual project platform should also be available for students to practice operations. During pre-class learning, students should identify their existing knowledge, new information, and potential issues that arise from integrating new knowledge with their existing cognitive structures. They should enter the class with these questions in mind.

The in-class clarification and doubt resolution phase typically lasts about 10 minutes, where teachers address questions arising from students' pre-class learning. This process helps students connect knowledge and re-establish links between complex concepts through reflection on their learning process and self-questioning. Brainstorming and discussions with peers can also be effective in resolving issues.

The in-class lecture by the teacher is based on the premise that pre-class learning and in-class doubt resolution are founded on self-study. The lecture aims to interpret knowledge from the teacher's perspective, allowing students to validate their thinking and whether they have followed a suitable, efficient, logical approach to understanding the content. The lecture also reiterates the knowledge from the class, highlighting key points and common misconceptions that students may encounter during self-study.

Subsequently, teachers assign tasks in practical projects, considering students' learning interests, such as selectable project content, learning formats (individual or group study), and various learning resources. A learning incentive mechanism can be designed to allow students to set personalised learning goals, provide individualised support, and explain the practical applications of the class content in real life, thus helping students understand the true purpose of learning.

The in-class project practice phase tests students' mastery and application of knowledge and the teacher's ability to apply knowledge to address various real-world questions flexibly. Students analyse existing and new knowledge and how the new information is assimilated into their existing cognitive structures. Cognitive difficulties may arise during this process,

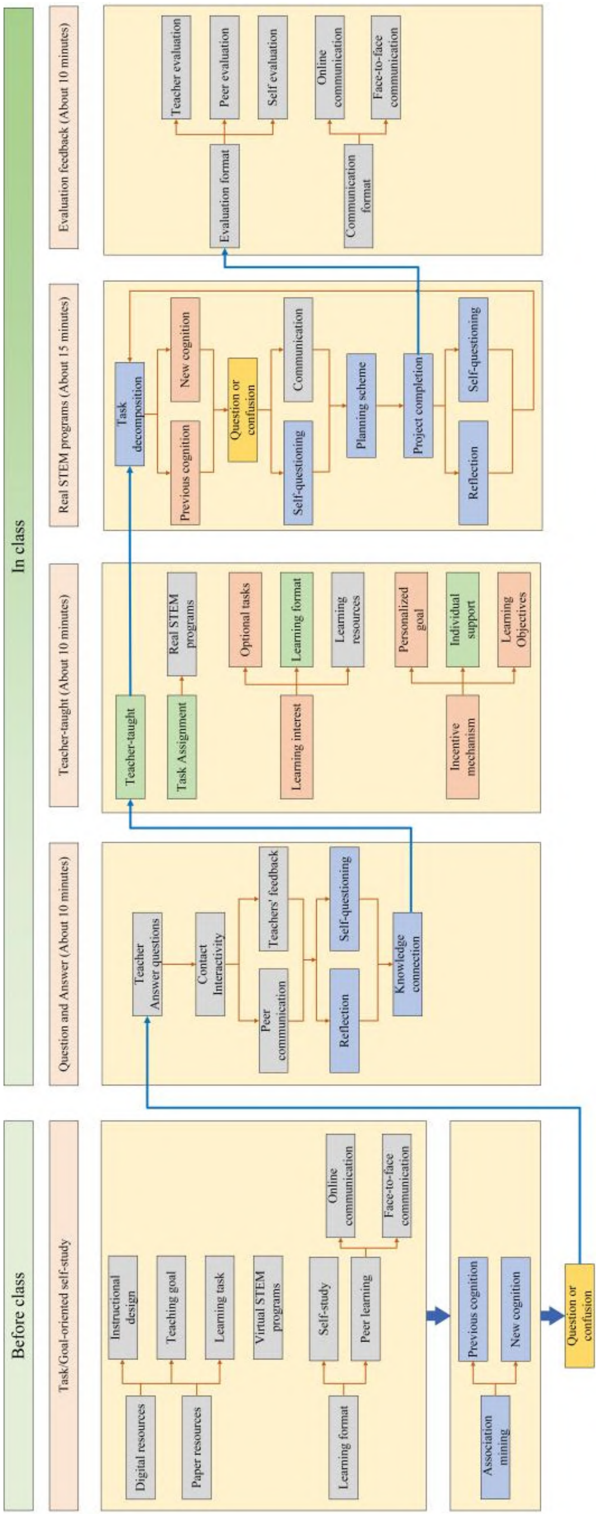

Figure 3: Online and offline integrated teaching framework to promote creativity for STEM learners.

and students can engage in discussions through self-questioning and peer interactions to find solutions and re-establish connections between new and existing knowledge. Once all questions are addressed, students can formulate a clear project plan, document it, and complete the project. Before formal assessment, students can reflect on the entire project process and identify any oversights.

The in-class assessment and feedback phase can involve teacher, peer, or self-assessment, with communication occurring through face-to-face interactions in class or follow-up discussions outside of class. Assessment serves not only as a means to gauge student learning outcomes but also as a vital source of information for improving instructional design. Teachers can identify shortcomings in their teaching strategies, potential improvements, and issues that may arise in actual teaching, warranting attention in subsequent classes. The assessment aims to refine the teaching process for enhanced educational effectiveness.

4. Instructional design

4.1. Learning objectives

The practical objective of online and offline integrated teaching is to apply the designed framework to promote creativity for STEM learners. This aim is to verify the rationality of the framework design through specific practices and identify issues for improvement. Additionally, the practical and theoretical components jointly constitute the entire knowledge system of online and offline integrated teaching. This also answers the second research question proposed in this study, namely, how to integrate online and offline teaching to promote creativity for STEM learners.

The course activity centred on the theme of "Designing and making a smart flowerpot", aiming to introduce students to the basic principles of plant growth and the application of smart home technology, cultivate their innovative thinking and practical abilities, and enhance their problem-solving skills. The specific content of the activity involved designing and creating an automatic watering flowerpot. When the soil moisture level is low, it can automatically water the plant until the desired moisture level is reached. This feature addresses the issues of long-term unattendedness or forgetting to water while also achieving precise watering to prevent overwatering that can lead to root rot and water waste.

4.2. Learning resources

Based on the online and offline integrated teaching framework designed above and the content of this class activity, the following are the potential learning resources that may be required:

- **online learning resources:**
  - *instructional design*;
  - *teaching objectives*;
  - *learning tasks*;
  - *virtual learning platform*;
- **offline learning resources:**

– *experimental equipment*: soil moisture sensors, temperature sensors, water pumps, microcontrollers, LED lights, etc.;
– *teaching aids*: flowerpots, plant seeds, soil, etc.;
– *learning materials*: STEM-related study materials, case studies, etc.;
– *venue*: laboratories or maker spaces that provide a place for students to conduct practical operations.

In fact, the screening of virtual learning platforms is a particularly challenging task in the process of learning resource design. The author has collected several relevant simulation platforms or STEM learning platforms, such as https://wokwi.com/, https://shumeipai.nxez.com/, https://www.sciencebuddies.org/, and https://www.exploratorium.edu/. Some practical issues with the online and offline integrated teaching design for STEM learners have been identified during this screening process.

Firstly, it is difficult to find resources that fully align with the content of this course, as most of them do not match perfectly. Secondly, redesigning a platform that matches the content of the activity would be unprofitable, requiring too much time and effort. Lastly, the screening of virtual simulation platforms also poses a significant challenge to teachers' professional capabilities, as they need to thoroughly understand and master the required components and their respective functions and learn how to use them effectively to filter out available virtual platforms.

Furthermore, the design of textual learning resources is not as straightforward as traditional teaching content. Teachers need to possess professional knowledge related to the STEM content of this lesson, a mature understanding of teaching, and familiarity with and recognition of the online and offline integrated teaching framework mentioned in this study. On this basis, collaboration among teacher teams may also be required to complete the task. If one teacher were to complete this lesson's entire teaching design and practice, it would likely consume significant time and energy.

It should be noted that in the design of real experiments, teachers need to pay special attention to issues such as the acquisition of experimental equipment, the selection of experimental venues, and the safety of personnel during the experimental process.

Compared to traditional classrooms, an online and offline integrated teaching lesson would significantly increase teachers' workload. It is not merely an extension or expansion of traditional classrooms but a disruption and reconstruction of the traditional classroom order. It not only requires teachers to update their teaching philosophies and enhance their work skills but also necessitates the establishment of an effective collaborative teaching mechanism.

4.3. Learning assessment

The assessment design is integral to gauging and providing feedback on the efficacy of instructional strategies. In accordance with the outlined online and offline integrated teaching framework, the evaluation of learning outcomes is meticulously structured, including the following assessment criteria and methods.

Assessment criteria

The assessment criteria can be evaluated from three perspectives: functionality, robustness, and innovativeness of the automatic watering flowerpot.

The following criteria can be used to assess the *functionality* of flowerpots:

1. Accuracy of soil moisture detection: the system can accurately detect soil moisture and respond correctly to different humidity levels.
2. The effectiveness of the automatic watering mechanism: the system can automatically start and stop watering according to soil moisture, and the watering process should be smooth, without blockage or leakage.
3. Reliability of water level control: the system has a water level monitoring function to prevent the tank from drying out or overflowing, and issue an alarm or automatically close when the water level of the tank is insufficient.
4. Energy consumption and efficiency: the system has good energy consumption performance, including standby and working power consumption, as well as working efficiency and response speed under different humidity conditions.

The following criteria can be used to assess the *robustness* of flowerpots:

1. Material durability: the material used in the system is durable, can withstand specific physical impact and wear, and is harmless to soil, water, and plants.
2. System stability: the system can operate stably under different environmental conditions (such as temperature, humidity, light, etc.) without failure or performance degradation.
3. Safety: the system has waterproof, anti-electric shock and other safety functions to ensure safety during use.
4. Easy maintenance: the system is easy to clean, maintain and replace parts, and clear maintenance guidelines and easily accessible parts should be provided.

The *innovativeness* of flowerpots can be assessed by the following criteria:

1. Design creativity: flowerpot design has novelty and uniqueness, considering user experience and aesthetics.
2. Technical implementation: students use novel technologies or methods to achieve automatic watering functions to ensure the technical implementation is efficient, reliable and easy to expand.
3. Scalability: the system is scalable, supporting the addition of other sensors (such as light, temperature, etc.) to optimise the plant growth environment, as well as linkage with other smart home devices.
4. Environmental protection: the system uses environmentally friendly materials and energy-saving technology to reduce the waste of water resources.

Assessment methods

The assessment methods can consider the free combination of practical tests, group review, teacher grading and user feedback.

1. Practical testing: students must test their work in a real environment to verify its functionality, robustness and innovation. The teacher or jury will observe the testing process, record the test results, and give a score according to the evaluation criteria.
2. Group review: organise students to evaluate each other, and each group will evaluate the works of other groups and give evaluation opinions and suggestions. Group reviews will be part of the assessment results, reflecting the student's collaborative spirit and critical thinking skills.
3. Teacher grading: teachers grade students' work according to the assessment criteria and provide detailed feedback and suggestions. Teacher ratings combine the results of the actual tests and group reviews to give the final overall score and ranking.
4. User feedback: if conditions permit, you can invite some users (such as gardening enthusiasts) to test the work and collect their feedback. User feedback will be used as a reference for the evaluation results, reflecting the work's performance in actual use and user satisfaction.

Indeed, the aforementioned assessment criteria and methods should be adaptively implemented in real-world educational contexts. For instance, adjusting the assessment criteria, either by diminishing or enhancing them, and selecting pertinent assessment methods tailored to specific scenarios can enhance the practical applicability of the assessment process and yield more insightful information that informs the optimisation of teaching efficacy.

5. Discussion and conclusion

The objective of this study is to leverage the respective strengths of online and offline modalities with the aim of devising a pedagogical framework designed to enhance creativity in STEM learners. The research synthesises six constitutive elements of the online and offline integrated teaching approach and identifies 18 potential combinations of these elements. The online and offline integrated teaching framework is constructed upon this foundation. This research extends the existing research [5] and presents an innovative teaching model. Although this study does not yet address iterative optimisation or practical applications of instructional frameworks, it provides new perspectives on instructional design and reveals potential implementation challenges.

Contributions

The study presents a new framework combining online and offline teaching to enhance creativity in STEM education. Despite being limited to a single instructional design cycle without implementation or refinement, it still identifies design challenges and anticipates possible obstacles in teaching execution.

The selection of participants for practical engagement must meet specific standards, such as having a foundational understanding of STEM disciplines and being cognizant of the participants' existing knowledge base. Misalignment in the selection could compromise the integrity of the learning experience and the productivity within the classroom environment.

Furthermore, the choice of thematic content for STEM activities should be commensurate with the student's competencies to ensure efficacy in learning outcomes. Failure to match the content with the student's abilities may diminish the quality of education and the effectiveness of classroom activities.

Additionally, the procurement and preparation of digital resources, especially the selection and integration of virtual simulation platforms, may present a significant challenge in facilitating STEM activities. This aspect of resource development requires careful consideration and expertise to ensure that the chosen tools are pedagogically sound and technologically accessible for the intended educational purposes.

Limitations

The study's theoretical nature means that the proposed framework has not been empirically tested or validated through practical application, which may limit its immediate applicability.

The absence of an iterative refinement process may result in underestimating the challenges that may arise when implementing the framework in real-world educational settings.

The study's focus on the framework's design does not address the potential impact of external factors, such as institutional policies, resource availability, and teacher training, which could influence the framework's effectiveness.

The findings' generalizability may be constrained by the lack of diverse contexts and learner populations considered in the framework's development.

While this study presents a promising pedagogical framework for enhancing creativity in STEM learners, further research is needed to empirically validate its effectiveness and explore its applicability across different educational contexts.

6. Selection and participation

This study does not involve participants, precluding any ethical considerations stipulated by ethical guidelines for research publication.

Declaration of competing interest

The researcher asserts that no conflicts of interest or personal ties could potentially affect the impartiality of the findings presented in this study.

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