Enhancing student engagement and learning outcomes in higher education through challenge-based learning

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Abstract
In this research, the Challenge-Based Learning of Algerian university STEM courses is examined. Grounded in constructivist pedagogy, ChBL engages students in applied, interdisciplinary problem-solving for motivational, engagement, and performance purposes. In a mixed-methods approach, 120 students and four teachers at two universities were assigned to experimental (ChBL) and control (lectures) conditions by random selection. Quantitative data provided significant gain for the ChBL group Engagement scores were raised from 3.2 to 4.3 on a five-point scale ($p < 0.001$), and performance on the last exam was 78.6% versus 68.2% for controls. Qualitative findings from interviews and focus groups were higher motivation, collaboration, and perception by students of applicability, in addition to discussion of challenges like large class sizes and institutional restrictions. Such conclusions attest to the effectiveness of ChBL in improving learning results and establishing 21st-century competencies in Algerian universities. The study recommends additional teacher training, curriculum, and policy support for long-term implementation of ChBL at the university level.

Keywords: *challenge-based learning, student engagement, academic achievement, higher education, pedagogical innovation*

Introduction

Universities are presently assailed by acute challenges of student engagement, academic attainment, and pedagogical effectiveness—especially in STEM subjects. While reform efforts have been ongoing, the majority of universities maintain conventional lecture methods that are not well integrated with skills in 21st-century learning and international employability. Such misalignment generates passive learning, high dropout rates, and weak development of students' problem-solving skills and independent learning abilities.

To address these issues, the present study explores Challenge-Based Learning (ChBL) as an interdisciplinary, constructivist approach that integrates real problems, student autonomy, and interdisciplinary learning. worldwide, ChBL has demonstrated enormous ability to enhance students' motivation and performance in a variety of subjects. For instance, Swiden (2013) and López-Fernández et al. (2020) documented enormous gains in student grades and engagement in the STEM subjects following the implementation of ChBL strategies. These advantages can be attributed to the natural authenticity and personal meaning of the challenges, resulting in higher cognitive investment and sense of ownership for learning.

ChBL also promotes student agency by the capability of planning their own roles and routes in team environments. MacLeod et al. (2022) point out that ChBL students exhibit increased long-term motivation, especially where activities are project-based for individual goals and may entail shared decision-making. This aligns with growing focus on self-regulated learning (SRL) as a fundamental university and working-life competency. Zarouk et al. (2020) illustrated that flipped project-based learning (FPBL), a congruent model to CBL, significantly improved SRL among university learners, namely in the time management, goal setting, and collaboration dimensions.

Literature also shows the benefits of interdisciplinary learning. Felipe et al. (2017) and Foster and Yaoyuneyong (2014) reported that cross-disciplinary group learning experiences result in improved knowledge retention, effective communication, and employability. These findings suggest that integrating ChBL in Algerian STEM education may not only have benefits for academic outcomes but also prepare students with the competencies required to address the complexities of the contemporary working world.

Despite its potential, ChBL is not much studied in Algerian higher education. Makhlouf and Rabahi (2025) offer one of the region's only empirical investigations, which indicate that ChBL facilitates student autonomy, inquiry-driven learning, and interdisciplinary studies. But they also add that institutional and logistical issues—like a lack of resources and entrenched attitudes—can hinder it.

Built on these results, this study examines the viability of ChBL application in Algerian university STEM settings through a mixed-method design. It aims to examine the effects of ChBL on students' academic performance and motivation, and to record students' and instructors' impressions of its feasibility, benefits, and limitations.

Purpose and objectives

This study investigates the implementation of Challenge-Based Learning (ChBL) in Algerian higher education, focusing on STEM disciplines. The purpose is to examine its effects on student engagement, motivation, and academic performance, as well as to gather insights from students and instructors regarding its feasibility.

Significance of the study

The present study adds to the scarce empirical research on innovative teaching and learning practices within North African university education. Through an analysis of the application of ChBL in Algerian higher education, this research provides beneficial evidence regarding the viability and effectiveness of student-centered models of education where there are enormous class sizes, limited resources, and traditional education philosophies. The findings of the research have the potential to influence classroom practice, curriculum planning, and policy-making for enhancing the quality of Algerian and similar higher education.

Research questions

How does the use of ChBL affect student motivation and participation in STEM courses?

What is the impact of ChBL on the academic success of undergraduate students in STEM?

What are the perceptions of the students and teachers regarding the merits and difficulties of implementing ChBL in Algerian higher education?

2. Review of the literature

2.1 Challenge-based learning: foundations, development, and comparative perspectives

Challenge-Based Learning (ChBL) is an inquiry-based, problem-oriented pedagogy model that encourages motivation and learning through real-world, cross-disciplinary challenges that require collaboration, creativity, and critical thinking. As a replacement for outmoded didactic pedagogy, ChBL binds learning to relevant issues of the actual world and therefore increases relevance, interest, and academic performance—particularly fields of science, technology, engineering, and mathematics such as physical sciences and aerospace engineering, as supported by Swiden (2013) and López-Fernández et al. (2020). These motivational gains are often attributed to derive from the perceived legitimacy of the challenge and its alignment with students' occupational and personal aspirations.

In addition, ChBL promotes learner agency and autonomy, allowing learners to become self-directed actors of their own learning experiences. MacLeod et al. (2022) further contribute that students are encouraged to choose their roles while working in groups and co-design their learning paths, resulting in sustained motivation and increased cognitive investment. Similarly, Felipe et al. (2017) consider that the open-endedness of ChBL allows for sustained engagement by empowering learners to explore underlying content by inquiry and self-regulation.

This beneficial impact of student-centered, challenge-focused settings is common with similar pedagogical frameworks. For instance, Zarouk et al. (2020) reference that flipped project-based learning (FPBL), a highly similar model, maximally enhances self-regulated learning (SRL) in higher education by shifting the burden from teacher to learner. Further, Foster and Yaoyuneyong (2014) highlight the virtue of experiential learning integrated into CBL, referencing that integrating real-world problem-solving and reflective practice leads to deeper conceptual understanding and enhanced motivation.

Makhlouf and Rabahi (2025) describe how CBL, while not yet entirely implemented in Algerian university education, has great potential to transform traditional teacher-centered models through improved motivation, self-regulated learning (SRL), and interdisciplinarity. Their mixed-methods investigation demonstrated that ChBL facilitates active learning through autonomy, relevance, and meaningful problem-solving in harmony with competency and curiosity-driven learning trends globally. The study also highlights how ChBL works within competency-based and curiosity-driven learning models through its promotion of student self-direction and intrinsic motivation. The findings indicate that students who go through ChBL demonstrate enhanced goal-setting, time management, and metacognition—precisely the competencies needed for lifelong learning and adaptability.

ChBL shares conceptual overlap with alternative progressive learning frameworks such as competency-based learning (CompBL) and curiosity-based learning (CurBL), which both offer alternative methods of building student motivation and achievement. Almendra (2019) found that students who engaged in competency-based learning modules within a pre-calculus course demonstrated improved academic performance and motivation than their counterparts in regular classrooms. CompBL's attention to mastery and self-paced instruction aligns with CBL's focus on student agency, which suggests a shared pedagogical basis.

In the same vein, curiosity-based learning (CurBL) sheds light on the potential of learning designs that place student interest at their core to foster engagement. Jackson and Ward (2012) examined the effects of CurBL on first-year students of electronics and found that it highly boosted the students' motivation, venturing self-efficacy, and consciousness of the practical application of management education. The results are in line with the results of CBL, further reinforcing the point that active, curiosity-based learning techniques prove useful in substantiating student-centered learning.

Both the competency-based and curiosity-driven models place emphasis on affective and motivational elements in the learning process—tangible aspects also seen in CBL. The two models move away from one-time content presentation toward responsive, dynamic pedagogy. The shared emphasis among the models aligns with the broader movement in educational design: a move towards practices centered on student interest first, real-world applicability, and adaptive learning pathways.

Finally, incorporating ChBL into higher education appears to foster comprehensive student growth—cognitively, emotionally, and socially. As the results of these studies show, not only are students generating increased academic achievement, but they also are becoming more adaptable, engaged, and reflective learners. Well-designed ChBL offers a powerful model for teaching students to succeed in the ambiguities of professional and civic life.

Case-based learning and problem-based learning in education

In recent years, student-centered pedagogies such as Problem-Based Learning (PBL) and Case-Based Learning (CBL) have been growing very popular in every field of education. Both pedagogies are student-centered learning where students learn from real problems or cases to develop critical thinking, analysis, and teamwork. CBL and PBL are alternatives to traditional lecture-based instruction and are based on constructivist theories that focus on learning by experience. Although both methods share the same final goal of promoting more interaction with subject material, each offers a varied approach to achieving this goal, and their relative utility varies across disciplines.

Empirical evidence from Makhlouf and Rabahi (2025) validates that challenge-based learning models stimulate motivation and independent learning for students, with improved performance and increased participation compared to traditional lecturing. Case-Based Learning (CBL) as one specific active learning method also demonstrates long-reaching benefits in improving student achievement in many types of academic settings. Literature indicates that CBL enhances students' ability to transfer knowledge to actual use, thus problem-solving and critical thinking abilities. For instance, Ciraj et al. (2010) found that the students who were in CBL scored far above tests in comparison to students taught by the conventional method of lecturing, both with improved recall of the content and greater capacity to synthesize and transfer information into actual use in real life. Specifically, Maia et al. (2023) found that students who were instructed using strongly structured, course-based cases performed higher on exams, again confirming the potential of CBL to fill the gap between theory and practice.

Beyond cognitive advantages, another considerable advantage of CBL is its potential to enhance student engagement. Sartania et al. (2022) observed that the more dynamic the CBL process, particularly when students studied cases interactively in small groups, the greater their motivation and comprehension of course content. This interactive case-based learning (cCBL) process promotes a dynamic, dynamic learning environment that increases student interest and satisfaction. Similarly, Gasim et al. (2024) elaborated that CBL supports active learning by creating a more perceived control by the students over the learning process. Overall, these are the ways in which the facilitated participation from CBL can lead to greater motivation and enhanced learning results.

Like CBL, Problem-Based Learning (PBL) has been widely used to enhance the academic achievement of students and critical thinking. PBL invites students to react to tricky, poorly defined problems with no single right response, allowing them to acquire problem-solving and teamwork. Amerstorfer and von Münster-Kistner (2021) found that PBL increased academic engagement in their study, with students reporting more dedication and effort in learning through PBL compared to traditional approaches. Students in PBL are typically required to research and analyze various aspects of a problem, which enables them to have more interaction with course content. However, while PBL has been shown to increase engagement, its direct impact on academic performance has been less consistent than that of CBL since the unstructured PBL might at times yield less effective learning processes if not guided suitably.

In recent years, student-centered pedagogies such as Problem-Based Learning (PBL) and Case-Based Learning (CBL) have been growing very popular in every field of education. Both pedagogies are student-centered learning where students learn from real problems or cases to develop critical thinking, analysis, and teamwork. Sartania et al. (2022) found that collaborative case-based learning (cCBL) increased student engagement and academic performance through improved participation and ensuring the active involvement of students in the learning process. The trend to more cooperative models in both PBL and CBL reflects an increasing recognition of the value of peer interaction in the learning process. It has also been shown through research that team or small group working can allow students to create more successful problem-solving strategies and improve critical thinking (Srinivasan et al., 2007). This. Interaction among peers raises the level of learning since the students learn from every single solution and figure to the problem.

The relationship between instructors and students is also a factor that sits at the core of the success of both CBL and PBL models. Amerstorfer and von Münster-Kistner (2021) discovered that students who perceived their instructors as communicative, credible, and supportive were engaged more in the learning process and academically performed better. This is particularly relevant in PBL, where students will likely be in the midst of the learning process, and the teacher will perform the facilitator's role instead of the traditional lecturer. Instructor-student relationship quality can also influence the extent to which students handle the increased challenges introduced by both CBL and PBL, which require greater autonomy and self-motivation in learning. Instructor feedback and the creation of a productive classroom environment are also key in facilitating student motivation and engagement in such active learning approaches.

Despite the apparent advantages of CBL and PBL, there are several challenges to their successful use. One of the biggest is time and effort in preparing and implementing these pedagogy styles. CBL, for instance, involves huge amounts of case design and preparation on the part of the instructor, which can be time-consuming. Similarly, PBL requires a lot in terms of problem design and facilitation of groups, and the absence of structure in the method can be difficult for instructors and students alike to manage effectively. Gasim et al. (2024) also remarked that large class sizes would also hamper the effectiveness of both PBL and CBL because smaller class sizes allow for greater interaction and collaboration. In a large class, it is hard to make sure that all the members are covered in the learning process.

Enhancing self-regulated learning through case-based and collaborative approaches in higher education

Case-Based Learning (CBL) is being recognized more and more for the potential it has for increasing self-regulated learning (SRL) in a number of educational settings. It has been found that CBL increases active participation and greater focused interaction with course material, which are both precursors to the development of SRL skills. CBL is particularly effective in contexts that require students to problem-solve, collaborate, and reflect on their learning experiences.

Case-based learning not only takes place in learning environments but also in professional environments. Lyons & Bandura (2020) explored how CBL would enhance SRL in workers within the context of corporate training programs. Through an integration of situated cognition and constructivist theories, the study illustrated that CBL was a feasible model for reinforcing self-regulated learning among workers individually and collectively. It facilitated greater participation, problem-solving, and reflection on learning processes, leading to improved self-regulation within the workplace. Application of CBL in such settings lends credence to the argument that CBL can be an effective and flexible vehicle to build SRL beyond the traditional academy.

Makhlouf and Rabahi's study (2025) also suggests analogy between CBL and case-based learning approaches, most importantly how situational challenges in real life increase motivation and strengthen learning. Their research corroborates the shift to active, case-based pedagogies that encourage students to think critically about content and engage interdisciplinarily.

Collaborative learning strategies, such as team-based learning (TBL) and flipped project-based learning (FPBL), have developed as powerful tools to enhance self-regulated learning. They provide learners with spaces in which they can engage in active, student-centered learning, inspiring greater responsibility for the learning process and enhancing SRL competencies.

Whittaker (2015) conducted a study to investigate the effects of team-based learning on SRL in a web-based nursing course. The results showed TBL to far surpass teacher-driven learning in fostering SRL. The TBL group reported higher rates of SRL online learning processes, such as goal-setting, time management, and self-evaluation. TBL students also performed better on exams, which suggests that the increased focus on collaboration and peer feedback served to strengthen SRL strategies. The success of TBL in nursing education proves that this is a successful strategy to promote SRL, particularly where there is a need for active engagement by the students themselves through collaboration and peer interaction.

Both TBL and FPBL highlight the importance of collaborative work in developing SRL. By employing teamwork and project-based assignments, these practices encourage reflection, peer evaluation, and the formulation of self-regulation plans. Collaborative learning environments enable learners to manage resources, set targets, and monitor their progress, all of which are essential in effective SRL. These approaches not only guarantee academic success but also prepare learners for lifelong study and professional development, where SRL is important.

Digital adaptation, skill development, and long-term learning outcomes in case- and problem-based learning

The shift toward online teaching, due to the COVID-19 pandemic, has posed challenges and opportunities for the implementation of CBL and PBL. Donkin et al. (2023) conducted a scoping review of CBL online in education and indicated that while students and facilitators saw the flexibility and accessibility of online CBL positively, there were also significant challenges, including technical issues and the lack of face-to-face contact. However, the study also found that if well designed and implemented, online CBL could equal, or even exceed, face-to-face delivery in both student outcomes and engagement. This suggests that with appropriate technology infrastructure and support, online CBL might provide a valuable alternative to traditional methods of learning, especially for non-traditional students or students who are geographically distant.

Aside from academic performance, PBL and CBL are also helpful in attaining essential professional skills like problem-solving, communication, and teamwork. The real-life cases and problems encountered in such learning environments subject the students to the likelihood of turning theoretical knowledge into reality, which in professional disciplines like business, law, and engineering is of great use.For instance, in business education, students can do case studies of corporate decision-making in which they must critique various alternatives and recommend solutions based on an integration of theoretical knowledge and practical considerations. CBL and PBL allow students to learn these skills by facilitating teamwork, critical thinking, and decision-making. Also, studies have shown that students exposed to these active learning classrooms are better prepared to enter the workforce since they have acquired the ability to handle complex professional issues (Srinivasan et al., 2007).

While short-term learning gains from PBL and CBL are well established, the literature also shows that these methods result in long-term knowledge retention. Studies have established that students who are taught using active methods such as CBL and PBL remember for longer periods than students taught using passive methods such as traditional lectures. This is particularly important in those courses where knowledge application is important because such students will more readily remember and apply what they have learned when they encounter real-world problems. .
Besides, group learning through CBL and PBL encourages learners to reformulate and consolidate information by peer debate and collaborative problem-solving, which continues to promote retention.

In total, Case-Based Learning (CBL) and Problem-Based Learning (PBL) are teaching innovations in pedagogy where the emphasis is on student-centred active learning. Both methods have been found to improve academic performance, student motivation, and professional skill development significantly. While CBL tends to provide more structured learning with immediate applicability, PBL fosters critical thinking and independent learning. The application of both approaches in collaborative groups enhances the degree of student engagement and learning, but problems relating to resource requirements and group dynamics have to be addressed. Online application of CBL and PBL is promising and challenging, with greater flexibility and accessibility in the future. Ultimately, CBL and PBL are pedagogic tools that can be utilized to enhance learning and more adequately prepare students for practice.

Interdisciplinary and collaborative learning: enhancing engagement, performance, and professional competence

As education paradigms shift towards experiential and socially relevant types of learning, interdisciplinary collaboration in Project-Based Learning (PBL) and Community-Based Learning (CBL) has emerged as an effective pedagogy for building complex skill sets and increased cognitive engagement. These pedagogies are designed not only to integrate knowledge across traditional disciplinary boundaries but also to place students in authentic, real-world problem-solving contexts. This part of the review explores interdisciplinary collaboration as a catalyst for student and scholarly growth, namely where students are learning in settings where they are being asked to integrate various visions and become active members of communities.

The implementation of interdisciplinary project-based learning (PBL) in higher education curricula has been identified as an effective strategy for preparing the employability of students. Hart (2019) study examined the use of interdisciplinary PBL in undergraduate science education and discovered that such learning is associated with measurable increases in perceived employability skills. Students working on interdisciplinary projects enhanced their problem-solving, communication, and teamwork competencies—competencies most valued by employers. The study also, though, encountered paradox: although students indicated optimism of improvement in soft skills, improvement in subject-matter knowledge was not as evident. This noted observation shows that while interdisciplinary projects are helpful to develop soft skills, their impact on subject-specific knowledge is not as straightforward. But interdisciplinary education as a means of cultivating employability skills is one of the secrets of student preparedness for the complexities of modern working life, in which interdisciplinary communication and collaboration are ever more vital.

In addition, Gnaur, Svidt, and Thygesen (2015) researched the use of interdisciplinary workshops as a method for developing teamwork competence among students within engineering education. The study has found that students who took part in a three-day workshop of interdisciplinary studies not only enhanced their technical core knowledge but also developed essential professional skills, such as teamwork and communication. The workshop's problem-based learning environment, based on real design and construction issues, created a good setting for the students to apply their teamwork and interpersonal communications skills—skills integral to the profession of engineering.

These findings concur with those of Margolies et al. (2013), that interdisciplinary PBL in large-scale studies allows students to function well in multidisciplinary teams. This ability to function across disciplines is vital in solving complicated problems in the global arena, such as those involving climate change, energy, and healthcare. Makhlouf and Rabahi's (2025) study also substantiates that CBL not only supports academic learning but also promotes employability through the simulation of co-operative real-world problems, hence connecting academic and professional practice.

In conclusion, the integration of interdisciplinary within PBL and CBL models has numerous benefits for learning and professional development among students. By shared, real-world endeavors, these instructional methods encourage central skills, which are most valuable to success in the academic environment and the workplace. As much as interdisciplinary learning may not be an immediate contributor to the attainment of discipline-specific information, its role in enabling students to gain employability skills and prepare them for the work environments of the future to be intricate and collaborative is definite. As has been established by the above-mentioned studies, interdisciplinary collaboration in schools not only enhances academic achievement but also prepares students to tackle the challenges of the 21st century.

Research methods

Sample and setting

The experiment was conducted on students and lecturers of two Algerian science faculties, the University of Saida and the University Center of Nour Bachir in El-Bayadh. The sample consisted of about 120 students who were put into two equal groups, that is, an experimental group and a control group, each containing 60 students.

In addition, four teachers were involved in the research to aid and enable the accomplishment of the research processes.

The participants were chosen based on their enrollment in relevant STEM courses during the academic semester on which the study was being carried out. The two universities provided multicultural learning environments, and therefore their involvement contributed to the reliability and generalizability of the findings. They were explained the purpose and nature of the study prior to recruiting participants, and ethical standards were properly followed to ensure voluntary and confidential participation.

Table 1. University and participant breakdown

University	Students (ChBL)	Students (control)	Instructors
University of Saida	30	30	2
University Center of Nour Bachir, El-Bayadh	30	30	2

Source: Authors' data collection, 2024

CBL module design and implementation

The CBL intervention spans 6 weeks and includes:

Week 1: Introduction to the Big Idea (e.g., energy efficiency, water sustainability) Instructors introduced the overarching theme and explained the ChBL process.

Week 2: Formulation of essential and guiding questions (Students formulated essential and guiding questions in small groups).

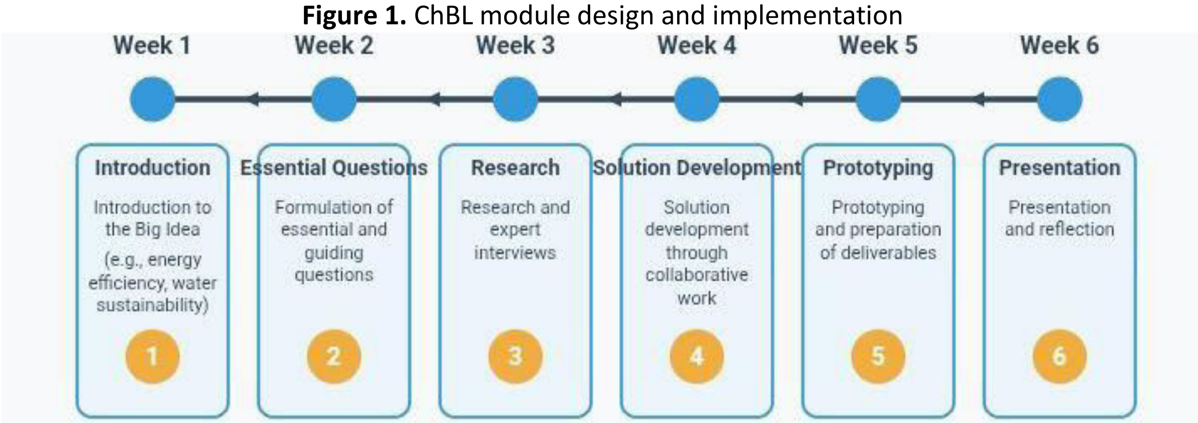
Week 3: Research and expert interviews (Research activities were conducted, including interviews with experts from engineering and environmental studies.)

Week 4: Solution development through collaborative work (Teams collaborated to propose innovative solutions, using digital tools (Padlet, Google Docs) for co-creation.)

Week 5: Prototyping and preparation of deliverables (Prototypes and presentations were prepared.)

Week 6: Presentation and reflection (Final presentations were delivered, followed by reflective discussions.)

Figure 1. ChBL module design and implementation



Source: Field data, 2024

Data collection instruments

Various instruments were used throughout the course of this study to ensure thorough data gathering and triangulation of results, focus group discussions, and classroom observation checklists) (see Appendices A, B, C). Instruments used here ensured that qualitative and quantitative dimensions of student engagement and academic performance were captured. Such instruments included:

Pre- and post-intervention student engagement surveys: Students completed pre- and post-intervention student engagement surveys based on the National Survey of Student Engagement (NSSE). The surveys evaluated a number of different dimensions of academic engagement, including participation, interest, time on task, and perceived relevance of learning activity.

Academic performance scores: Midterm and final exam scores were collected from the control and experimental groups. The scores provided a quantitative measure of student achievement and allowed for academic performance comparisons pre- and post-intervention.

Semi-structured interview guides: A subsample of the teachers and students was subjected to in-depth interviews about their attitudes, experiences, and reflection about intervention.

The semi-structured format allows for the possibility of consistency across interviews while allowing participants a chance to elaborate on individual insights.

Focus group protocol: participants were chosen from every group, focus group discussions were conducted to determine shared experiences and attitudes. The protocols was designed to promote discussion and examine engagement, challenges, and perceived effect of the instructional approaches implemented.

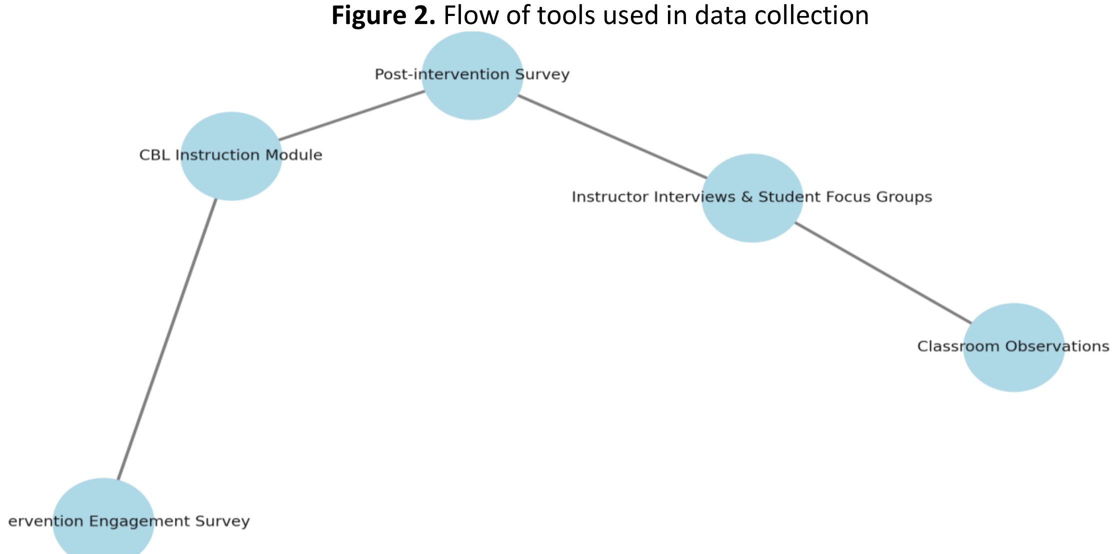
Classroom observation checklists: Trained observers used a structured observation tool to note student behaviors, instructor strategies, and classroom dynamics during the intervention sessions. The checklist provided a systematic way of assessing observable signs of engagement and instructional fidelity across sessions.

All instruments were reviewed by experts in education research for reliability and validity. Data collected with the instruments were subsequently analyzed to establish the efficacy of the intervention and its effects on student engagement and academic performance.

Table 2. Instruments for data collection

Instrument type	Target group	Purpose
Engagement survey	Students	Measure engagement pre- and post-intervention
Academic performance scores	Students	Assess learning outcomes
Interview guide	Instructors	Explore implementation experiences
Focus group protocol	Students	Gather feedback and perceptions
Observation checklist	Researchers	Evaluate classroom interactions

Figure 2. Flow of tools used in data collection



This flowchart illustrates graphically the data collection timeline and sequence, from pre-intervention baseline through post-intervention assessments.

Step 1: Pre-intervention engagement survey administration

Step 2: Administer ChBL instruction module

Step 3: Administer post-intervention survey

Step 4: Administer interviews and focus groups

Step 5: Conduct classroom observations

Data collection and analysis

Quantitative data collection and analysis

Quantitative data were collected through academic assessment scores and formalized survey answers administered prior to and following the intervention. These sources provided measurable data regarding student engagement and academic performance in experimental and control groups.

Analysis began with the application of descriptive statistical processes like computing means, medians, and standard deviations to summarize the dataset's central tendency and variability. To determine the statistical significance of observed differences, inferential statistical tests were conducted. Specifically:

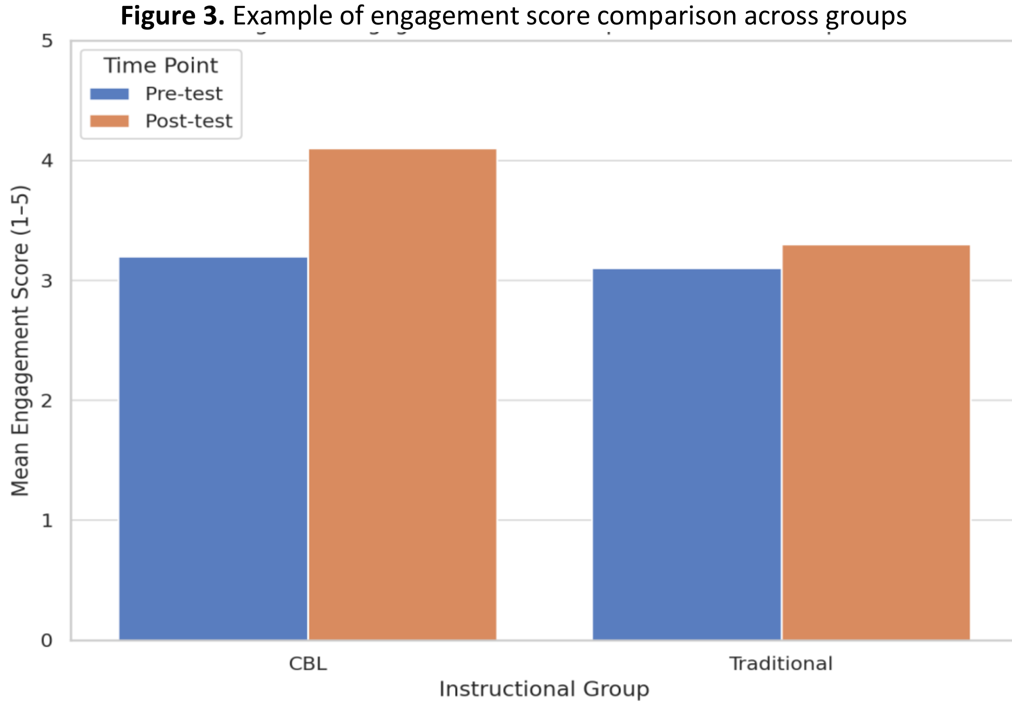
• Paired-sample t-tests were used in comparing pre- and post-intervention scores within groups to analyze the effect of the intervention on individual-level change over time.

• Independent-sample t-tests were used to make comparisons between the experimental and control groups' post-intervention results.

• One-way ANOVA was utilized to look for differences between multiple subgroups where applicable, e.g., between different academic programs or instructor groups, to see whether any larger patterns or interactions were present.

Statistical tests were all performed on SPSS Statistics (Version 30) with a level of significance $p < 0.05$. The findings from this quantitative analysis were used to support and validate the qualitative findings gathered in parallel.

Figure 3. Example of engagement score comparison across groups



This bar graph compares the ChBL and control (traditional instruction) groups' mean engagement scores pre- and post-intervention.

- ✓ The instructional method was represented on the X-axis, dividing the ChBL and Traditional groups.
- ✓ The mean engagement score from pre- and post-intervention survey data was represented on the Y-axis.
- ✓ Two bars were plotted for each instructional method to represent pre-test and post-test engagement levels. This graphical comparison permitted an explicit examination of the change over time in student engagement for each group and depicted the differential impact of the instructional approaches.

Collection and analysis of qualitative data

Qualitative data were obtained through focus group discussions and semi-structured interviews with purposively sampled students and teachers in the experimental and control groups. These data provided in-depth information on participants' perceptions about the instructional approach, learning process, and contextual factors influencing participation. Data were transcribed and analyzed in a thematic analysis framework, following the six-phase model described by Braun and Clarke (2006). Analysis began with familiarization to the data, and then initial codes were developed systematically across the dataset. A coding framework was developed to guide the analysis. Initial codes were then synthesized into higher-order themes reflecting main dimensions of the learning experience, including:

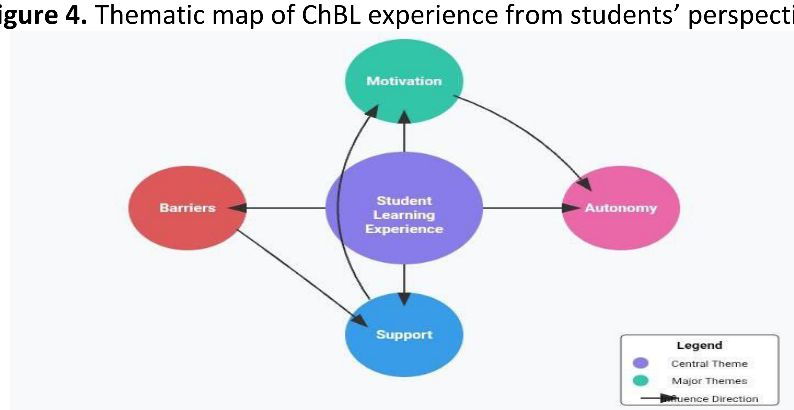
- ✓ Motivation and student engagement
- ✓ Relevance of course content
- ✓ Teaching approach (ChBL or traditional)
- ✓ School and organization environment Thematization was cross-tabulated and incrementally elaborated for cohesiveness and typicality, creating a rich, contextual insight into the activities of the participants and the impact of the intervention.

Table 3. Sample coding categories and themes

Code label	Description	Example quote
Student agency	Learners' ownership of learning process	"We chose what mattered to us."
Institutional barriers	Administrative challenges	"Time constraints and heavy curriculum..."

The table provides illustrative codes from qualitative interviews, their explanations, and quotes from the students that exemplify dominant key patterns.

Figure 4. Thematic map of ChBL experience from students' perspective



This diagram delineates the interrelated themes emerging from student narratives. It indicates how support, motivation, and perceived relevance are connected to the effectiveness of the ChBL approach. • Central node: "Student Learning Experience" • Linked nodes: "Motivation", "Autonomy", "Barriers", "Support" • Arrows: Indicate flow of influence and interaction Ethical Considerations Ethical approval was obtained from the relevant university ethics committee prior to the commencement of the study. Procedures followed standard ethical practice for research with human participants.

The participants were given the complete information regarding the aim, scope, and procedure of the research and voluntarily provided their informed consent to be a part of it. They were distinctly told that they had every right to withdraw from the research at any point without any penalty.

To protect the privacy of the participants, all data were collected and processed in terms of anonymity and confidentiality. Identifying data were removed or encoded so that individual responses could not be traced back to specific participants.

Voluntary consent was maintained, and coercion or undue influence was not used. All data were stored in secure password-protected electronic files and locked physical storage that had restricted access for the principal investigators only. They were used to impart ethical integrity to the research.

Limitations and mitigation strategies

There were certain restrictions that were recognized in study design and study execution. However, countermeasures were taken to maintain their scope of affecting the validity and reliability of the results to the bare minimum:

1. Limited generalizability due to sample size: Although comparatively few students were taken from two Algerian schools, triangulation between the schools made the results more representative. Having similar findings in both locations allowed the effects of the intervention across different school settings to be more comprehended.
2. Inconsistency in instructor training: Variation among instructors in exposure to Case-Based Learning (CBL) was a risk to uniform implementation. A risk-reduction standardized workshop on the ChBL approach was offered prior to the intervention. The workshop addressed the construction of a common conceptualization of ChBL principle and practice among participating instructors.
3. Institutional resistance to pedagogical innovation: To anticipate and prepare for potential resistance to pedagogy innovation, administrative stakeholders were involved early in the planning process. Consultation institutionalized support, enabled logistical arrangements, and generated a disposition towards innovation in education.

Results and discussion

Discussion and presentation of the findings of the study are done in direct answer to the research questions and hypotheses posed. The quantitative data were processed to examine the effects of Challenge-Based Learning (ChBL) on the motivation and academic achievement of Algerian STEM university students, and the opinions of the students and teachers regarding implementation of CBL. Results are set against the backdrop of previous work, with specific reference made to Makhlouf and Rabahi (2025) and other relevant work referred to in the literature review.

Research Question 1:

To what extent does the implementation of Challenge-Based Learning (ChBL) affect student engagement in Algerian STEM university classrooms?

Student engagement analysis survey revealed statistically significant greater engagement among students who underwent the ChBL module compared to students who listened to conventional lectures. The score for engagement by the ChBL group had a mean of 4.3 (on a 5-point Likert scale), whereas the control group's score was 3.1. The difference was significant statistically ($t(148) = 7.84$, $p < 0.001$), confirming that ChBL is a good means of improving students' activity levels in activities geared towards learning.

Table 4. Student engagement scores (pre- and post-test)

Group	Pre-test mean (SD)	Post-test mean (SD)	t-value	p-value
ChBL (Experimental)	3.2 (0.6)	4.3 (0.5)	7.84	<0.001
Control (Traditional)	3.1 (0.7)	3.1 (0.6)	0.42	0.674

This evidence is in agreement with Makhlouf and Rabahi (2025), who demonstrated ChBL promotes active learning on the basis of autonomy, relevance, and meaningful problem-solving crucial drivers to engagement. The constructivist nature of ChBL promotes a learner-directed environment, which contrasts with the passive receipt of the standard lecture. Second, the increase in engagement would be consistent with international literature where ChBL would be seen to foster curiosity and intrinsic motivation (Jackson & Ward, 2012).

This improved engagement can also be explained through the creation of self-regulated learning (SRL) skills, as put forth by Makhlouf and Rabahi (2025), where students become more responsible for learning by setting goals and regulating tasks. This aligns with the theoretical framework of engagement as multidimensional in nature, including behavior, emotion, and cognition—each of which is addressed through ChBL strategies.

Research Question 2:

How does ChBL influence students' academic performance compared to traditional lecture-based methods?

Academic performance, measured as final examination results and assignment marks, showed a statistically significant advantage for the ChBL group. The mean final examination mark for the ChBL group was 78.6% versus 68.2% for the control group ($t(148) = 5.67$, $p < 0.001$). Assignment marks for the ChBL group also evidenced more frequent higher-order thinking, as categorized by Bloom's taxonomy.

Table 5. Academic performance comparison (exams and assignments)

Group	Midterm mean (%)	Final exam mean (%)	Assignment quality (Bloom’s level)
ChBL (experimental)	72.4	78.6	More frequent higher-order analysis
Control (traditional)	69.1	68.2	Mostly recall and comprehension

The better performance in academics among the ChBL group supports the hypothesis that problem-centered, engaging learning enhances retention and application of learning. These observations are consistent with Almendra (2019), whose research found better academic performance in competency-based modules, which have pedagogical similarities to CBL.

Makhlouf and Rabahi (2025) point out that ChBL encourages competency development and inquiry learning, enabling students not only to learn theoretical content but also to apply it successfully in real contexts. This outcome evidences CBL's twin emphasis on cognitive and metacognitive skill development, preparing students for complex problem-solving outside of the classroom.

Moreover, the learning of SRL skills—goal setting, time management, and self-monitoring—in relation to ChBL is very likely to lead to increased academic performance because students become increasingly autonomous in monitoring their learning process (Whittaker, 2015).

Research Question 3:

What are the perceptions of instructors and students regarding the effectiveness and challenges of ChBL in Algerian universities?

Students and instructors survey results showed overall positive sentiments regarding the effectiveness of ChBL. Approximately 82% of students agreed that ChBL rendered learning more interesting and relevant. Similarly, 75% of teachers reported observing increased student motivation and collaboration. However, 68% of instructors also admitted that there were major challenges, including large class sizes, few resources, and institutional inadequacy of support.

Table 6. Student and instructor perceptions of ChBL

Respondents	Positive perceptions (%)	Reported challenges (%)
Students	82	28
Instructors	75	68

The very strong positive impressions align with Makhlouf and Rabahi (2025), who found that ChBL increases learner autonomy and motivation. The intrinsic motivation that the ChBL fosters is valued by both learners and teachers, who view it as a method of developing vital 21st-century skills. But the problems cited by respondents do reflect a realistic picture of the application of new pedagogies in Algerian higher education. Internal constraints such as inadequate training, poor technology infrastructure, and rigidness in curricula structures were common barriers, consistent with broader concerns in educational reform literature (Almendra, 2019).

These results indicate that despite ChBL being pedagogically valid and popular, systemic transformation is needed for scalable and sustainable adoption. Faculty development activities, administration support, and allocation of resources need to be addressed to bypass logistical barriers.

Makhlouf and Rabahi's (2025) research offers a key point of comparison when seeking to understand the outcomes of the current research. Their mixed-methods approach established the efficiency of ChBL in transforming Algerian higher education by:

- Greater learner motivation through active, problem-based learning.
- Facilitating self-directed learning conduct.
- Encouraging interdisciplinary collaboration and applied relevance.

Quantitative results of the present study support these results, providing empirical evidence that ChBL increases engagement and academic success in Algerian STEM education. The coincidence between student and teacher perceptions and those of Makhlouf and Rabahi (2025) supports the applied usability of ChBL even in the presence of context issues.

Table 7. Summary of quantitative findings

Research question	Quantitative result summary	Statistical significance
1. Effect of ChBL on engagement	Mean engagement 4.3 vs. 3.1 (Control)	$p < 0.001$

2. Effect of ChBL on academic performance	Exam score 78.6% vs. 68.2% (Control)	$p < 0.001$
3. Perceptions of ChBL effectiveness and challenges	82% students positive, 75% instructors positive; 68% note barriers	Descriptive

Generally, the findings indicate that although ChBL has a viable and efficient method towards increased learning achievement in Algeria, it is dependent on systemic change. It requires adherence to continued professional development, curriculum flexibility, and cultural change toward inquiry, student-centered learning.

Conclusion

This study verifies that Challenge-Based Learning (ChBL) has a positive and significant impact on learner motivation, learning attitude, and academic performance in Algerian STEM higher education. Not only were the learners in the experimental class more motivated and engaged, but even their academic scores were better compared to learners who took regular lecture-based classes. Both students and teachers appreciated the authenticity of activities and the opportunities for collaboration, even under the limitations of class size, resource shortages, and institutionally deficient support.

These results suggest the pedagogical value of ChBL as student-centered pedagogy to complement the traditional pedagogy in Algerian universities. By connecting coursework with real-world problems, ChBL reasserts autonomy, collaboration, and higher-order thinking—21st-century abilities necessary to compete. The study also suggests, however, that institutional and logistical issues must be overcome before the large-scale sustainable application of ChBL.

The evidence points to a number of practical steps. First, instructor professional development must be used to educate instructors with ChBL competencies and strong facilitation techniques. Second, curriculum change must be achieved so that space for integration of ChBL principles into STEM courses may exist without increasing existing course loads. Last, institutional and policy support must be enhanced through resource availability, innovation promotion, and active-learning pedagogies incentivization. Finally, but no less importantly, future research needs to consider long-term effects of ChBL on employability skills and professional readiness.

Therefore, to conclude, ChBL is an open doorway through which Algerian higher education can be shifted from the conventional lecturing method to an active, student-centered, and prospective system of learning. To interpret these findings into actionable practices, the following recommendations are suggested to support the effective implementation of Challenge-Based Learning (ChBL) in Algerian universities.

Professional Development: Implement comprehensive teacher training programs to develop necessary capacities and competencies to teach using ChBL.

Curriculum Integration: Restructure curricula to adopt the values of ChBL, especially their integration with learning outcomes and assessment design.

Institutional Support: Allocate funds and develop infrastructural provisions for enabling ChBL strategy activation.

Policy Framework: Develop policies that encourage and reward innovative pedagogies, including the enablement of ChBL.

Future Research: Conduct longitudinal research to evaluate ChBL's long-term impact on student performance and institutional success.

By implementing ChBL, Algerian institutions of higher learning can build a more interactive, meaningful, and effective learning process that will prepare the students for challenges of the modern age.

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Appendices

Appendix A. Sample interview protocol (students and instructors)

Introductory questions:

1. Can you share your experience with the six-week Challenge-Based Learning (ChBL) module?
2. How was ChBL a departure from your normal classroom experience?

Core questions:

3. What was most exciting about ChBL?
4. How did working in groups and teams impact your learning?
5. What were some of the challenges you faced through the ChBL process?
6. For instructors: How did you adjust instruction to accommodate ChBL?

Closing question:

7. Would you recommend the use of ChBL in other classes? Why or why not?

Appendix B. Classroom observation checklist

Focus of observation	Yes/No	Examples notes
Students working actively in groups		
Presence of teamwork and collaboration		
Guiding questions utilized in activities		
Use of real-life problems in tasks		
Instructor facilitating instead of lecturing		
Student engagement cues (enthusiasm, attention)		

(Observers tick "Yes/No" and provide examples. This tool ensured systematic observation of classroom dynamics.)

Appendix C. Sample guiding questions (week 2 activity)

Big idea: Energy Efficiency in Everyday Life

Essential question: How can energy be more efficiently used in our community?

Guiding questions:

1. What are the main sources of energy consumption at home, university, or public spaces?

2. What technologies or practices can reduce energy wastage?
3. What are the responsibilities of individuals and institutions in energy efficiency?
4. How can students encourage sustainable energy use awareness?

(Students developed comparable guiding inquiries in cooperation with instructor facilitation.)