International Journal of Dental Research and Allied Sciences
2023, Volume 3, Issue 1, Page No: 65-71

Available online at: www.tsdp.net

ISSN: 3062-3502

Review Article

Implementing Challenge-Based Learning in Dental Education

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Received: 23 February 2023; **Revised:** 09 May 2023; **Accepted:** 15 May 2023

ABSTRACT

Challenge-based learning (CBL) is an innovative educational approach that promotes collaborative and interdisciplinary learning experiences. It engages students, educators, stakeholders, researchers, families, and communities in jointly identifying and addressing real-world problems. By participating in CBL, students gain a deeper and more comprehensive understanding of their subjects. The framework draws on multiple educational theories and methods, including problem-based and inquiry-based learning, with problem-based learning serving as its foundational model. Unlike traditional problem-based approaches, CBL requires students to define the challenges they will tackle and to develop actionable solutions. This model emphasizes the societal impact of ideas rather than merely focusing on commercial benefits. Consequently, CBL fosters enhanced learning depth and breadth, strengthens teamwork skills, and promotes awareness of ethical and quality considerations in decision-making. While widely adopted in universities, schools, and institutions globally—particularly in science, engineering, and medicine—CBL has yet to be applied in dental education. This paper aims to outline the principles, design, implementation, and supervision of a CBL framework within a dental course, illustrating its adaptation for dental training.

Keywords: Problem-based learning, Challenge-based learning, Dental education, Traditional

How to Cite This Article: Torres A. Implementing Challenge-Based Learning in Dental Education. Int J Dent Res Allied Sci. 2023;3(1):65-71. https://doi.org/10.51847/XqkfPFm6jZ

Introduction

In today's digital era, students can access information instantly through the internet and informal learning channels, which has diminished the effectiveness of traditional "chalk-and-talk" teaching in engaging learners and motivating them to achieve their objectives [1, 2]. Most current curricula are content-driven, meeting academic standards but lacking real-world applicability and opportunities for active student participation. To address these limitations, an accessible, effective, and practical educational framework is needed. Challenge-based learning (CBL), initially developed by Apple, has emerged as a progressive solution, now adopted in schools, universities, and institutions globally [2-4].

Research highlights the value of active learning strategies, which foster lifelong, self-directed, and collaborative learning, while promoting high-quality outcomes aligned with students' metacognitive and self-regulatory skills. Within this context, CBL represents a pedagogical approach rooted in experiential learning, where education begins with open-ended, real-world challenges [5]. As a multidisciplinary and engaging method, CBL encourages students to leverage contemporary technologies to address authentic problems. Unlike traditional teacher-centred methods—focused on lectures, readings, classroom activities, and rote repetition to transmit structured knowledge [6]—CBL immerses students in real-life situations, exposing them to uncertainty and complex problem-solving. Modern technologies further facilitate the identification of preferred learning styles and support diverse instructional approaches [7], enabling a shift from conventional classrooms toward real-world skill development [8].

CBL draws on multiple educational theories, including problem-based learning (PBL), inquiry-based learning (IBL), and the conceive-design-implement-operate (CDIO) framework. PBL, the principal precursor to CBL, has been extensively applied in medical and engineering education to enhance critical thinking, self-directed learning, transferable skills, and long-term knowledge retention [9, 10]. The ASK (attitude, skills, knowledge) model differentiates PBL from traditional methods [11], as students work collaboratively to solve research, design, or diagnostic problems [12, 13]. IBL is a student-centred approach where instructors guide learners through questioning, experimental design, and data interpretation, emphasizing knowledge creation and problem-based projects [14]. Although effective in improving research and problem-solving abilities, IBL can involve risk-taking and potentially lower student satisfaction [15]. The CDIO framework, primarily in engineering education, emphasizes integrating fundamental engineering knowledge with the design, implementation, and operation of real-world systems [16, 17].

Distinct from these models, CBL requires students to define the challenges they will tackle and promotes a multidisciplinary approach involving students, facilitators, stakeholders, families, and the wider community. CBL emphasizes the societal impact of solutions rather than merely corporate gains, broadening learning experiences, enhancing teamwork skills, and fostering ethical awareness and quality consciousness in decision-making. In designing future-oriented pedagogical systems such as CBL, educators must critically evaluate their approaches, examine the interplay of system components, and situate these frameworks within the broader context of existing educational structures [18].

Given its student-centred, community-based, real-world orientation, CBL offers significant potential to advance dental education. While medical and nursing programs have integrated CBL into their curricula [19–22], dentistry has yet to adopt this framework. This study aims to present a course design for implementing CBL in dental education, providing practical guidance, addressing common challenges, and facilitating the adaptation of this innovative learning strategy to the dental field.

CBL in the education system

Challenge-based learning (CBL) represents a collaborative, experiential, and student-centred educational approach, where learners engage with peers, teachers, communities, and global experts to deepen their understanding by identifying challenges and sharing outcomes with a wider audience. Evidence indicates that student-centred learning strategies significantly enhance educational outcomes [23, 24]. The initial CBL framework was introduced in a 2008 white paper [3], and since then, educators and institutions worldwide have progressively embraced it to enhance teaching and learning, enabling students to make meaningful contributions within their communities. In 2009, the New Media Consortium published a comprehensive classroom study, involving six schools, twenty-nine teachers, and 330 students across seventeen disciplines, which confirmed CBL's effectiveness in promoting learning [24]. The study was later expanded in 2011 to nineteen schools, ninety teachers, and 1,500 students across three countries, demonstrating that CBL effectively engages learners, aligns with curriculum standards, and develops essential twenty-first-century skills, making it suitable for students of all ages [4].

Implementing CBL requires significant cultural shifts within educational institutions, including professional development for teachers, upgrading infrastructure, and creating flexible administrative frameworks that accommodate change [25, 26]. The challenge-based approach itself is intuitive for students, as it mirrors familiar reality-show formats where participants tackle creative tasks by applying prior knowledge, acquiring new insights, collaborating with teammates, and working toward a goal, often motivated by a reward [27].

CBL has also been extended to new domains, such as workplace strategic planning and training [28] as well as mobile software instruction and development [29]. In 2016, the 'Digital Promise' team, together with the original CBL founders, updated the framework and successfully applied it to the 'Apple Classrooms of Tomorrow' initiative, impacting public middle schools, universities, and research organizations [30, 31]. This effort included the creation of a dedicated website and a published guide [2]. The CBL process is structured into three distinct phases **(Figure 1)**.

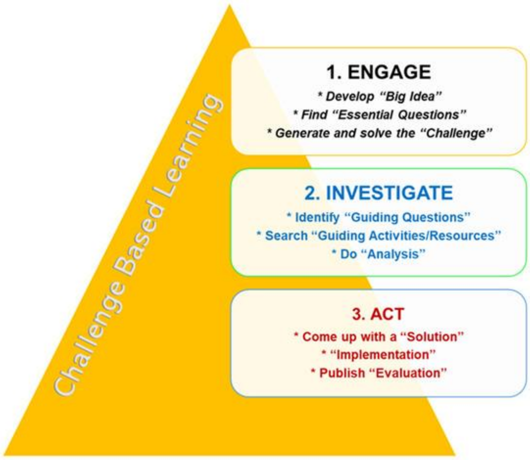

Figure 1. The three phases of CBL (adapted from Nichols *et al*., 2016) [2].

The CBL process unfolds in three sequential phases. The first phase, 'Engage', begins with essential questioning, guiding students from a broad concept to a well-defined, actionable challenge. The second phase, 'Investigate', involves students planning and participating in a structured exploration that generates the foundation for solutions while meeting academic objectives. The final phase, 'Act', focuses on developing evidence-based solutions that can be applied to real audiences, with evaluation based on their effectiveness.

Principles of CBL

CBL is a dynamic and adaptable framework capable of introducing innovative concepts, study designs, and learning models [2–4]. The core principles of CBL include:

- A flexible framework that can serve as a standalone pedagogy or complement other progressive learning methods;
- A scalable model allowing multiple entry points, starting small but capable of expansion;
- An open system free from proprietary restrictions or subscriptions;
- A process that empowers students to take control of their learning;
- An authentic learning environment that meets academic standards while fostering deep engagement with content;
- Emphasis on global concepts, meaningful challenges, and development of local, age-appropriate solutions;
- Integration of academic knowledge with real-world experience;
- A structure for cultivating twenty-first-century skills;
- Strategic use of technology for research, analysis, organization, collaboration, communication, publishing, and reflection;
- Opportunities for students to make meaningful contributions;
- Methods for documenting and assessing both learning processes and outcomes;
- An environment encouraging profound reflection on teaching and learning practices.

Design of CBL

Many contemporary problems are inherently multidisciplinary, requiring technical expertise, social understanding, and community insight. CBL incorporates diverse participants—including students, facilitators, stakeholders, families, and community members—each playing a distinct role [2–4].

Role of learners (Students)

Students in CBL are active participants rather than passive recipients. They collaborate with facilitators, researchers, entrepreneurs, and external stakeholders to explore and address real-world challenges. Student teams often include members from varied educational backgrounds, study levels, and programs.

Role of facilitators (Teachers)

Teachers function primarily as facilitators, offering guidance, knowledge, and real-world context. They support students throughout the CBL process, help define learning outcomes at the course level, and provide relevant content skills. Lesson content can remain flexible to accommodate individual student preferences.

Role of stakeholders

Stakeholders play a critical role, particularly in community-engaged learning. They may participate as guest lecturers or active partners in student projects, offering guidance and receiving feedback from students. Ideally, stakeholders act as collaborators, with students informing them of the potential benefits and challenges of proposed solutions.

Role of communities

Because students tackle real-world challenges, the active involvement of community members and stakeholders significantly enhances problem investigation and solution development.

Implementation of CBL

Effective CBL implementation follows a systematic process. Existing education system models provide tested designs that can be adapted, allowing straightforward integration of CBL into current curricula.

Redesigning existing courses

CBL can be integrated into current courses by translating challenges into real-life applications that align with the course objectives. When embedding challenges, it is essential to maintain flexible learning goals, as students are expected to make choices and take ownership of their learning process. In this framework, teachers function not only as subject-matter experts but also as facilitators, guiding students as they work on their challenges.

Extracurricular learning experiences

CBL can also extend to extracurricular activities, where students—or even external participants—focus on broad "big ideas." Students then engage in extracurricular projects alongside the core CBL curriculum, receiving guidance from experienced instructors. In this setting, the objectives and strategies are primarily defined by the students themselves, which supports evaluation and credit allocation later on.

CBL in dental education

Active learning approaches, such as CBL, encourage students to engage in meaningful discussions, critically analyse situations, and develop problem-solving skills, thereby enhancing the overall learning experience [32]. Problem-based learning (PBL), a widely used active learning method in medical and dental education, relies on real problems to stimulate inquiry and motivate students to actively participate and think critically [33], which also builds their confidence. CBL can be seen as an evolution of PBL, sharing many similarities while offering distinct features.

Students and educators familiar with PBL can more easily adapt CBL to dental education. By involving the entire learning team, CBL fosters collaborative strategies and facilitates the development of knowledge and skills through real-world problem identification and community engagement. **Table 1** presents a comparison of key characteristics between PBL and CBL.

Table 1. Learning methods of problem-based learning and challenge-based learning

Topics	Problem-Based Learning	Challenge-Based Learning
Learning	Students acquire up-to-date knowledge independently by working on structured problems, applying what they learn to address the specific issue [34].	Students gain in-depth understanding of the subject matter, with the challenge itself driving the creation of new knowledge and identification of necessary tools or resources [24].
Focus	Students are presented with a relevant problem, which is often hypothetical and does not demand a real-world solution [35].	Students face an open-ended, meaningful problem that requires a practical solution applicable in real-world contexts [2].
Product	Emphasis is placed on the learning process rather than the final solution [36].	Students are expected to develop a solution that results in tangible, actionable outcomes [2].
Process	Students engage with the problem to test reasoning and knowledge application, assessed according to their learning level [37].	Students analyse, design, develop, and implement the most effective solution, which is then evaluated by themselves and others [4].
Teachers' Role	Acts as a facilitator, guide, tutor, or professional advisor [38].	Functions as a coach, co-researcher, and designer, actively participating in the learning process [39].

A central feature of CBL is that learning is guided by challenges that allow multiple possible solutions [2–4]. While CBL curricula resemble those of PBL in structure, careful consideration must be given to the mindset of the educational team, as adopting this new strategy represents a significant shift in approach. CBL encourages students to become adaptable, critical thinkers capable of addressing complex and unpredictable tasks in the future. Within multidisciplinary teams, students engage with challenges that enhance teamwork, problem-solving, and solution-design skills, while also fostering self-directed learning and independent initiative. Moreover, CBL integrates interdisciplinary perspectives, enabling students to address issues related to environmental, social, health, educational, and economic sustainability. **Table 2** presents various CBL topics with their descriptions, and Appendix A provides an example of a CBL study design applied to dental education.

Table 2. CBL topics and description (adapted from Nichols *et al*., 2016) [2]

Topics	Description
Big Idea	A broad, overarching concept that can be explored in multiple ways and engages students in societal issues.
Essential Question	The process of identifying and personalizing the key aspects of the 'big idea' to guide learning.
Challenges	Action-oriented tasks collaboratively designed by teachers and students, aimed at generating tangible solutions.
Guiding Questions	Questions developed by the learning community to determine the knowledge and skills necessary for creating effective solutions.
Guiding Activities and Resources	The tasks students undertake and the resources they identify to answer guiding questions and support their inquiry.
Analysis	The process of examining responses to guiding questions, identifying patterns, themes, and concepts to form the basis of solutions.
Solution: Implementation	The creation and execution of concrete, actionable solutions to address the challenge, targeting an authentic audience.
Evaluation	The assessment of student activities based on the effectiveness of their implemented solutions and results.
Publishing Student Solution	Students document their experiences, reflections, challenge description, learning process, solutions, and implementation outcomes.
Publishing Student Reflection	Students share their work publicly, via online communities or through organized events, allowing broader dissemination and feedback.

In today's globalized, knowledge-driven economy, there is an increasing demand for individuals to cultivate creative thinking skills, which are essential across fields such as education, art, medicine, information and communication technology, and social media. Recent studies suggest that creative thinking can be taught and leveraged to enhance problem-solving abilities [40–42]. Within this context, CBL has emerged as an innovative approach that actively engages students in advanced, creative learning [4, 24, 31]. The framework integrates modern technology, teamwork, self-directed learning, peer collaboration, and real-world problem-solving. Its learning process extends beyond the classroom, reaching local and global communities, and has been shown to deepen understanding, enhance practical skills, and increase engagement [28]. Furthermore, CBL promotes stronger group interaction, concept integration, and synthesis, attracting educators due to its substantial learning outcomes [27, 43].

In CBL, students are expected to ask questions, review literature, conduct primary research, consult experts, and explore essential questions through hands-on inquiry. This process allows them to identify challenging problems, refine essential or guiding questions, and invest time in developing innovative yet feasible solutions, detailing necessary resources and activities. Students critically analyse "big ideas" and creatively uncover underlying issues. While initial implementation can be challenging, facilitators can adjust strategies to guide learning effectively. This approach nurtures students' innovation, encourages original thinking, and enables the application of creativity in practical dental contexts such as disease management, dental product selection, service optimization, and program development. Currently, there is no published literature on CBL in dental education; however, our institute plans to implement and evaluate this approach, which we anticipate will be highly effective. Given increasing life expectancy, equipping dental students to address real-world challenges is a global imperative.

Conclusion

In summary, CBL offers a collaborative, multidisciplinary framework for identifying and resolving real-world problems. Applied to dental education, it allows students to generate meaningful questions from "big ideas" and develop practical, evidence-based solutions. By gathering knowledge from diverse sources and working collaboratively, students can plan and implement solutions to complex challenges. CBL enhances understanding across dental specialties, promotes effective use of technology, encourages community engagement, and strengthens skills in managing and treating orofacial diseases. Ultimately, it equips dental students to meet the practical, real-world challenges they will encounter in their profession.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

References

1. Abah JA. An appeal in the case involving conventional teaching: emphasizing the transformation to enhanced conventional teaching in mathematics education. VillageMath Educ Rev. 2020;1(1):1-10.
2. Nichols M, Cator K, Torres M, Henderson D. Challenge based learner user guide. Redwood City (CA): Digital Promise; 2016. p. 24-36.
3. Nichols M, Cator K. Challenge based learning white paper. Cupertino (CA): Apple; 2008.
4. Johnson L, Brown S. Challenge based learning: the report from the implementation project. Austin (TX): The New Media Consortium; 2011.
5. Doulougeri K, Bombaerts G, Martin D, Watkins A, Bots M, Vermunt JD. Exploring the factors influencing students' experience with challenge-based learning: a case study. In: Proceedings of the 2022 IEEE Global Engineering Education Conference (EDUCON); 2022 Mar 28-31; Tunis, Tunisia. IEEE; 2022. p. 981-8.
6. Barr RB, Tagg J. From teaching to learning—a new paradigm for undergraduate education. Change Mag High Learn. 1995;27(6):12-26.
7. Bianchi S, Bernardi S, Perilli E, Cipollone C, Di Biasi J, Macchiarelli G. Evaluation of effectiveness of digital technologies during anatomy learning in nursing school. Appl Sci. 2020;10(7):2357.
8. Membrillo-Hernández J, Ramírez-Cadena MdJ, Caballero-Valdés C, Ganem-Corvera R, Bustamante-Bello R, Benjamín-Ordoñez JA, et al. Challenge-based learning: the case of sustainable development engineering at the Tecnologico de Monterrey, Mexico City Campus. Int J Eng Pedagog. 2018;8(4):137-44.
9. Lund B, Arfwedson AJ. PBL teachers in higher education: challenges and possibilities. In: Peters MA, ed. Encyclopedia of teacher education. Singapore: Springer; 2020.
10. Strobel J, Van Barneveld A. When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms. Interdiscip J Probl Based Learn. 2009;3(1):44-58.
11. Walton HJ, Matthews M. Essentials of problem-based learning. Med Educ. 1989;23(6):542-58.
12. Hmelo-Silver CE. Problem-based learning: what and how do students learn? Educ Psychol Rev. 2004;16(3):235-66.
13. Malmqvist J, Rådberg KK, Lundqvist U. Comparative analysis of challenge-based learning experiences. In: Proceedings of the 11th International CDIO Conference; 2015 Jun 8-11; Chengdu, China. p. 87-94.
14. Aditomo A, Goodyear P, Bliuc AM, Ellis RA. Inquiry-based learning in higher education: principal forms, educational objectives, and disciplinary variations. Stud High Educ. 2013;38(9):1239-58.
15. Archer-Kuhn B, MacKinnon S. Inquiry-based learning in higher education: a pedagogy of trust. J Educ Train Stud. 2020;8(4):1.
16. Crawley EF, Malmqvist J, Östlund S, Brodeur DR, Edström K. The CDIO approach. In: Rethinking engineering education. Cham: Springer; 2014. p. 11-45.
17. Al-Obaidi ASM. CDIO initiative: a guarantee for successful accreditation of engineering programmes. Indones J Sci Technol. 2021;6(1):81-92.
18. Veletsianos G, Kimmons R. Assumptions and challenges of open scholarship. Int Rev Res Open Distrib Learn. 2012;13(4):166-89.
19. Eraña-Rojas IE, Cabrera MVL, Barrientos ER, Membrillo-Hernández J. A challenge based learning experience in forensic medicine. J Forensic Leg Med. 2019;68:101873.
20. Tang ACY, Chow MCM. To evaluate the effect of challenge-based learning on the approaches to learning of Chinese nursing students: a quasi-experimental study. Nurse Educ Today. 2020;85:104293.
21. Tang ACY, Chow MCM. Learning experience of baccalaureate nursing students with challenge-based learning in Hong Kong: a descriptive qualitative study. Int J Environ Res Public Health. 2021;18(12):6293.
22. Yang Z, Zhou Y, Chung JW, Tang Q, Jiang L, Wong TKS. Challenge based learning nurtures creative thinking: an evaluative study. Nurse Educ Today. 2018;71:40-7.
23. O'Neill G, McMahon T. Student-centred learning: what does it mean for students and

lecturers. In: Emerging issues in the practice of university learning and teaching I. Dublin: AISHE; 2005.
24. Johnson LF, Smith RS, Smythe JT, Varon RK. Challenge-based learning: an approach for our time. Austin (TX): The New Media Consortium; 2009.
25. Olivares SLO, Cabrera MVL, Valdez-García JE. Aprendizaje basado en retos: una experiencia de innovación para enfrentar problemas de salud pública. Educ Médica. 2018;19(4):230-7.
26. Edu Trends. Monterrey (MX): Tecnologico de Monterrey; 2022. Available from: https://observatorio.tec.mx/redutrends/. Accessed December 27, 2022.
27. Cheung RS, Cohen JP, Lo HZ, Elia F. Challenge based learning in cybersecurity education. In: Proceedings of the International Conference on Security and Management (SAM); 2011 Jul 18-21; Las Vegas, NV. p. 1.
28. O'Mahony TK, Vye NJ, Bransford JD, Sanders EA, Stevens R, Stephens RD, et al. A comparison of lecture-based and challenge-based learning in a workplace setting: course designs, patterns of interactivity, and learning outcomes. J Learn Sci. 2012;21(1):182-206.
29. Santos AR, Sales A, Fernandes P, Nichols M. Combining challenge-based learning and scrum framework for mobile application development. In: Proceedings of the 2015 ACM Conference on Innovation and Technology in Computer Science Education; 2015 Jun 15-19; Trondheim, Norway. p. 189-94.
30. Apple Education. Challenge based learning: take action and make a difference. Cupertino (CA): Apple; 2022. Available from: http://ali.apple.com/cbl/global/files/CBL_Paper.pdf. Accessed December 27, 2022.
31. Apple Inc. Apple classrooms of tomorrow-today learning in the 21st century. Cupertino (CA): Apple; 2008.
32. Nelson LP, Crow ML. Do active-learning strategies improve students' critical thinking? High Educ Stud. 2014;4(2):77-90.
33. Dory V, Degryse J, Roex A, Vanpee D. Usable knowledge, hazardous ignorance–beyond the percentage correct score. Med Teach. 2010;32(5):375-80.
34. Baden MS, Major CH. Foundations of problem-based learning. London: McGraw-Hill Education; 2004.
35. Larmer J. Project-based learning vs. problem-based learning vs. X-BL. 2014 Mar 8 [cited 2024]. Available from: [source URL if available].
36. Larios FR, López-Virgen V, Morrill EIR, Muñiz JG. Significado social del aprendizaje basado en problemas en universitarios. EDU REVIEW Int Educ Learn Rev Rev Int Educ Aprendiz. 2014;2.
37. Barrows HS, Tamblyn RM. Problem-based learning: an approach to medical education. New York (NY): Springer Publishing Company; 1980. Vol. 1.
38. Ribeiro LRC, Mizukami MDGN. Problem-based learning: a student evaluation of an implementation in postgraduate engineering education. Eur J Eng Educ. 2005;30(1):137-49.
39. Baloian N, Hoeksema K, Hoppe U, Milrad M. Technologies and educational activities for supporting and implementing challenge-based learning. In: Proceedings of the IFIP World Computer Congress, TC 3; 2006 Aug 21-24; Santiago, Chile. p. 7-16.
40. Saliceti F. Educate for creativity: new educational strategies. Procedia Soc Behav 2015;197:1174-8.
41. Mahdi R, Sukarman S, Yok MCK. Fostering creativity through innovation engagement in science and technology education: case study of Universiti Teknologi MARA students. Procedia Soc Behav Sci. 2015;167:256-60.
42. Yoosomboon S, Wannapiroon P. Development of a challenge based learning model via cloud technology and social media for enhancing information management skills. Procedia Soc Behav Sci. 2015;174:2102-7.
43. Blevis E. Design challenge based learning (DCBL) and sustainable pedagogical practice. Interactions. 2010;17(3):64-9.