PROJECT-BASED LEARNING: A PANACEA TO BRIDGING THE GAP BETWEEN RESEARCH AND PRACTICE IN CHEMISTRY EDUCATION

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Abstract

The existence of a gap between research and practice in chemistry education has been the topic of many discussions. In recent years, many efforts have been to overcome this gap, one of which is the use of Project-Based Learning (PBL) in teaching. Project-Based Learning is a student-centered, inquiry-based educational approach in which students design and execute projects that address meaningful challenges. It has been adopted across various educational levels, disciplines, and cultural contexts, leading to a diverse body of knowledge. It is crucial to systematize existing research to identify well-established aspects and areas that require further explorations. In this study, PBL processes, advantages, challenges, and strategies on how its use can help bridge the gap between chemistry education research and its practices were discussed. Also, recommendations on how the use of PBL can help bridge the gap between research and practice are also discussed.

Keywords: Project-Based Learning, Chemistry Education, Research, Practice

Introduction

Chemistry plays a crucial role in various scientific advancements and technological developments that enhance the quality of life. Chemistry stands as a cornerstone of scientific progress, providing the foundation for innovations in medicine, engineering, environmental science, materials, and industrial processes. Traditional instructional methods, which often emphasize rote memorization and isolated theoretical exercises, fall short in engaging students and teachers to research data and findings in chemistry education research. One of the goals of chemistry education is to provide students with excellent instructional and educational experiences. The gap between Chemistry education studies and how they can be implemented in real life nevertheless continues to be a source of worry. The discrepancy is a substantial obstacle to ensuring that the useful knowledge generated from research investigations is successfully transferred into real advancements in educational practices (Mehmood, *et al*, 2023).

Chemistry education research has provided a great deal of data and has supported particular groups of aspects of professionals especially those involved in curriculum development or assessment design. Teachers' considerable evidence indicates a continuing gap between research findings and its practices in teaching and learning (De Jong, 2004; Nuthal, 2004). Research is often seen by teachers as too theoretical, too idealistic, or too general to relate to the practical reality of classroom life (Hiebert *et al*, 2022). This disconnection of theoretical knowledge from practical application has created a pressing need for innovative pedagogical approaches that can bridge this gap and prepare teachers and students for the demands of modern science and industry (Shazia, *et al*, 2025). The Project-Based Learning (PBL) has emerged as a promising educational approach to address these challenges.

PBL is a student-centered teaching method where learners gain knowledge and skills by working for an extended period to investigate and respond to an authentic, engaging, and complex questions, problems, or challenges. It focuses on active hands-on inquiry, collaboration, and critical thinking, culminating in a public product or presentation. Project-Based Learning is a student-centered teaching method that encourages learning through engaging real-world curriculum related questions or challenges (Guido, 2025). It boasts classroom engagement and has direct impact on how well students are prepared to enter the workforce once they graduate. Additionally, Project-Based Learning is an effective learning method in which students can learn through real-life experience to develop desirable knowledge and skills. It is a student focused process in which students learn about a specific subject by working in groups to resolve real-world problems (ISHCMC, 2024). It enables students gain knowledge to address open, authentic, and challenging problems (Kumari, 2025). The students learn by actively engaging in real-world and meaningful projects.

In Project-Based Learning, the purpose is to study the problem well, see where you need more knowledge, and find workable solutions. The teacher mainly serves as a helper, letting students explore research, analyze, and consider ideas together. As a result, the students become involved in their own learning. This helps students sharpen their motivation while working with others, handling time efficiently, and making decisions. This helps contribute to developing important skills for both high achievement and daily life. Thus, PBL enhances Chemistry education by fostering critical thinking, collaboration, and creativity through real-world problem solving. Key features of PBL include focus on complex task, interdisciplinary, active exploration, autonomy, engagement and motivation.

Elements of Effective Project-Based Learning

The following are key elements to effective PBL:

1. **Teacher as Facilitator**: The teacher acts as a coach guiding the process, asking probing questions, and supporting students' inquiry rather than just delivering information.
2. **Student-Centered Inquiry:** Students take ownership of their learning, actively defining the problem, brainstorming solutions, and identifying what they need to learn.
3. **Application of Knowledge:** Learning is context-based where new information is immediately applied to the problem
4. **Collaboration and Teamwork**: Students work in groups to analyze information, share perspectives and develop solutions enhancing social and communication skills.
5. **Real-World Structured Problem**: The core is an open-ended, complex, and relevant problem that requires research and multiple perspectives to solve.
6. **Self-Directed Learning:** Students become independent learners, finding and evaluating resources to fill knowledge gaps.

Process of Project-Based Learning (PBL)

The process of PBL allows learners to develop essential skills in modern education and encourages engagement. The process often follows a cycle of stating the problem, analyzing it, engaging in self-directed study, synthesizing information, and presenting findings with peer review. The following steps, if performed well, can bring multiple benefits to the students (Kumari, 2025):

1. **Statement of the Problem**: A complex and well-structured problem should be presented in the beginning of the learning effort so that students will explore ideas that are new to them. It needs to be about things that matter, yet be vague enough for people to see it differently.
2. **Analysis of the Problem:** Students explain their knowledge of the problem and suggest different ways it might be solved. They find out what they don't know and plan learning tasks to address those gaps.
3. **Self-Directed Learning:** Using the goals they have set, students either investigate by themselves or in groups. They may depend on textbooks, research papers, interviews, or different sources. Students are required to be information literate and accurately evaluate what they use.
4. **Development of Solutions**: With the information they have, students create useful solutions for the problem. Depending on the subject and location, these projects could be written documents, presentations, models, and experiments.
5. **Synthesis of Information:** Once they are done with their research, students rejoin their groups to discuss their findings and combine their data. Together, they break down, organize, and revise what they know about the problem and start designing solutions.
6. **Present Study with Peer Review:** Students demonstrate how to solve issues to other peers. Participants have the chance to discuss and improve their work at this time. The process helps to ensure accuracy and expands how researchers think.
7. **Reflecting and Assessing**: Both looking at yourself and talking with a group are essential. Learners review what they found out, their problem-solving techniques, and what they plan to improve going forward. They both look at the outcome and how individuals cooperated, thought creatively, and questioned what they were doing to improve.
8. **Continue to Learn Regularly:** When PBL is done right, it is broken into cycles and these experiences help students improve their skills as they continue to work on each one. It also challenges students to revise their past learning experiences in different ways.

Advantages of Project Based-Based Learning

Project-based learning can better prepare students with life skills that set them up for future success (Shaffer, 2018). Thus, PBL is important for:

1. **Problem Solving:** In PBL, students are bound to face obstacles as they work through a project. Through practice, they learn how to take a breath,

reflect on what's not working, and try again with a new approach. Each challenge becomes an opportunity to experiment, learn from mistakes, and build confidence in their ability to figure things out.

2. **Collaboration:** Working in groups in PBL gives students the chance to share ideas, listen to others, and build something together. In the process, they begin to realize that the best teamwork happens when everyone feels heard and valued.
3. **Critical Thinking:** In PBL, students learn to ask better questions, look deeper into problems, and make thoughtful choices based on what they discover. Instead of memorizing, they practice analyzing, comparing, and reasoning, and this kind of thinking leads to real understanding.
4. **Communication:** Every project gives students a reason to speak up and share their ideas. They learn how to explain their thinking, listen carefully to others, and work towards a common understanding. Whether they are giving a presentation or talking through next steps with teammates, PBL helps students communicate with clarity, confidence, and purpose.
5. **Subject Knowledge:** PBL helps students see how what they learn in class connects to real life. Instead of memorizing facts, they apply their knowledge in meaningful ways- testing ideas, gathering information, and solving authentic problems. Learning becomes something they build through experience, not just something they hear or read about.
6. **Creativity:** Creativity, like many skills, can be developed through practice. In PBL, projects are open-ended, giving the students the freedom to explore their own ideas, follow their curiosity, and bring their imagination to life. As students experiment and create, they often discover new interests or hidden talents they didn't know they had. This process not only builds confidence but also helps them find joy and meaning in learning.
7. **Self-Confidence:** When students see their ideas come to life, their confidence grows. PBL gives students opportunities to take initiatives, share their work, and learn from feedback. They discover that progress matters more than perfection and that with persistence and creativity, they are capable of more than they thought.
8. **Project Management:** Through PBL, students learn how to set goals, organize their ideas, and manage their time and materials. They practice breaking big tasks into smaller steps, communicating with teammates, and adjusting when things don't go as expected. Over time, they see that planning and persistence are what turn great ideas into real results—both in

school and in life.

9. **Adaptability:** Projects don't always go as planned and that's where some of the best learning happens. In PBL, students learn how to adjust their approach, explore new strategies, and stay positive when things change. They discover that flexibility is strength, not a setback. Each time they adapt, they build confidence in their ability to handle challenges and keep moving forward.

PBL, whether in the classroom or through enrichment programs, lays the foundation for creativity, collaboration, and resilience, and gives every child the confidence to thrive, no matter what comes next.

How Problem-Based Learning Can Help Bridge the Gap between Research Findings and Chemistry Education

PBL (Problem-Based Learning) bridges the gap between chemistry research and classroom practices by shifting from rote memorization to authentic inquiry, allowing students to apply theoretical concepts to real-world problems. It fosters critical thinking, hands-on scientific skills, and collaborative student-centered learning that mirror professional research environments (Saulet*et al.,* 2025). Hence, PBL can help bridge the gap through:

1. **Developing Research Skills:** Students act like scientists by investigating, analyzing data, and finding solutions to real-world problems. This includes developing laboratory skills which increases motivation and interest in the subject.
2. **Contextualizing Theory with Practice:** PBL enables students to connect abstract chemical principles (e.g., organic compound separation) to practical applications, making complex topics more engaging and accessible.
3. **Encouraging Collaboration and Communication**: Students work in small groups, promoting teamwork, sharing experimental workload, and enhancing their ability to communicate findings.
4. **Promoting Sustainability and Social Awareness:** Projects often focus on environmental and real-world issues, helping students understand the practical impact of chemistry on society.
5. **Improving Learning Outcomes:** Research indicates that chemistry students taught using PBL techniques achieve higher performance, better analytical capabilities, and stronger critical thinking skills compared to traditional methods.

Reasons for the Gap between Chemistry Education Research and Practices

1. **General Nature of Research**: The conclusion of some chemistry education research tends to be very general. Most chemistry teachers are faced with specific content-related difficulties in teaching and learning. This discrepancy also contributes to the persistence of the research-teaching gap.
2. **Mutual Expectation Issue**: Teachers may be prone to thinking that research should provide quick final solutions for their teaching difficulties, while researchers may believe that teachers are able to understand their reports and transform research outcomes into useful ideas for teachers.
3. **The Need to Survive Issue:** Teachers believe that they do not have enough time to read research articles because they are already too busy with their teaching in the classroom. Researchers, on the other hand, are required by their universities to publish in highly ranked journals, whereas for teachers, publishing in journals does not provide rewards in terms of research output.
4. **The Innovative Strategy Issue**: Chemistry education reforms have often been introduced by using the Research-Development-Diffusion (RDD). According to this top-down approach, research projects launched at universities or other research institutions and the results obtained are used for developing new curricula and teaching-learning materials in separate institutions, which also oversee the further dissemination of the end products. The teacher's role consists only of executing the new programs, thereby creating a sharp distinction between researchers and teachers, instead of strategies that contribute to bridging the research-teacher gap should be implemented. The research programmes for chemistry education have been strongly influenced by content free theories of teaching and learning.

Challenges to Bridging the Gap between Chemistry Education Research and Classroom Practice Using Project-Based Learning

Bridging the gap between research and practice in chemistry education through Project-Based Learning (PBL) involves transitioning from teacher-centered, didactic methods to student-centered, inquiry-driven approaches. Despite the proven benefits of PBL in enhancing student's motivation, engagement, and understanding of chemical concepts, several systemic, pedagogical, and social barriers hinder its implementation. These challenges include:

1. Pedagogical and Teacher-Related Challenges

a. **Lack of Training and Confidence:** Many teachers have not received proper training on how to facilitate PBL, leading to difficulties in scaffolding projects, managing time, and conducting assessments.

b. **Translating Research to Practice:** Educational research is sometimes viewed by practitioners as too theoretical, idealized or complex to implement in real, messy classroom (Aldabus, 2018)

c. **Resistance to Change:** Some educators are reluctant to shift away from traditional teacher-directed methods, viewing unfamiliar methods as obstacles.

d. **Role Transition Stress**: Teachers find it difficult to move from being a "lecturer" to a "facilitator," often struggling to find the balance between providing too much or too little guidance to students.

2. Student-Related Factors

a. **Skill Gaps**: The need for students to take ownership of their learning can be challenging for those who rely heavily on teacher-led instruction.

b. **Group Collaboration Challenges:** Students often lack the skills needed for effective teamwork, leading to unequal participation, social conflict, and "free-rider" problems.

c. **Resistance to New Learning Styles:** Students accustomed to passive learning may struggle with the increased responsibility and autonomy that PBL requires, often preferring traditional methods.

3. Communication and Environmental Gaps

a. **Parental/Community Misunderstanding**: Parents may underestimate the value of PBL, expecting traditional homework and tests instead of PBL-based assessments.

b. **Disconnected Communities**: Researchers and teachers often belong to different communities of practice with different goals and communication styles, which hampers collaboration and knowledge sharing.

4. Systemic and Institutional Constraints

a. **Large Class Sizes**: High student-to-teacher ratios make it difficult for teachers to supervise, guide, and assess students, especially when conducting hands-on chemical experiments.

b. **Time and Curricular Rigidity:** A major barrier is the lack of time in school schedules to implement in-depth, long-term projects. Rigid, content-heavy curricula make it difficult for teachers to move away from traditional, efficiency-focused instruction.

c. **Resources and Financial Limitations:** Authentic, high-quality chemistry projects often require specialized laboratory equipment, materials, and technology, which are frequently unavailable or limited in schools.

d. **Assessment Misalignment**: Standardized tests often focus on content memorization rather than the 21st-century skills (such as problem-solving and critical thinking) cultivated by PBL. This misalignment creates conflict for teachers who are accountable for test scores.

Strategies Promoting Bridging of the Gap between Chemistry Education Research and Classroom Practices

This includes using approaches such as fostering collaborative partnerships, enhancing the accessibility of evidence and action-oriented strategies promoting a culture of inquiry within schools (Wahlgren &Aarkog, 2021). This can be achieved through

1. **Collaborative Partnership (Research-Practice Partnership):** Establishing long-term collaborations between researchers and practitioners help address practical classroom specific issues. These can be done through
2. **Action Research and Research Circles:** Teachers and researchers work together over extended periods to identify problems, design, and evaluate interventions in the classroom. This in-service training allows teachers to test findings immediately.
3. **Co-creation of Knowledge**: Involving practitioners as equal partners in the research design ensures findings are usable, relevant, and trustworthy.
4. **Leveraging School-University Partnership**: Establishing long-term structural collaborations for many years helps normalize research as a regular part of teaching (OECD, 2024).
5. **The Profiles Project**: A model promoting inquiry-based chemistry education through teacher networking and enhanced self-efficacy in adopting new research-informed methods.

2. Professional Development and Cultivating Inquiry

a. **Mentoring-Based Training:** Utilize experts, teachers, or researchers to mentor peers on the implementation of new research-based pedagogies. Implementing professional development that focuses on active learning such as micro-teaching helps teachers build confidence in applying new pedagogical strategies.

b. **Professional Learning Communities**: Using existing school structures to discuss and test new research findings.

c. **Digital Learning Materials:** Using online networks and resources to provide teachers with easy access to new research.

d. **Formative Assessment and Evidence-Based Pedagogy:** This involves training teachers in continuous monitoring of students' understanding in chemistry to provide immediate feedback.

3. Shifting Teacher and Institutional Roles

a. **Teachers as Researchers:** Encouraging educators to view themselves as producers of knowledge, not just consumers; this will increase ownership of research-based interventions.

b. **Incorporation of Research in Teacher Education**

4. Technological Integration: Research shows that visualization tools help students grasp abstract, submicroscopic concepts (like molecular interactions) that cannot be observed in the lab. This can be achieved through

a. **Flipped Classroom Models:** Students watch instructional videos at home, freeing up class time for hands-on, research-informed activities (Alberto, Viviana, Vladimir, and Fernando, 2024).

b. **Virtual Labs & Simulations:** These provide a safe, repeatable, and accessible environment for experiments, fostering curiosity without the risks of physical chemistry.

c. **Augmented Reality (AR) and Virtual Reality (VR):** These technologies create immersive learning experiences that enhance student understanding of 3D structures and dynamic processes.

5. Collaborative Professional Development: Engaging teachers and researchers in shared, long-term partnerships.

6. Modifying Projects: Adapting projectsto fit availableresources and using local low-cost materials in teaching.

Conclusion

PBL is important in Chemistry education because it helps students approach meaningful learning opportunities with curiosity, which they can carry into real-world skills they will use for the rest of their lives**.** PBL acts as a crucial link for preparing students with practical career-ready skills in chemistry. It fosters active learning and prepares research-oriented students in Chemistry education in particular and STEM education in general. It boosts classroom engagement and has a direct impact on how well students are prepared to enter the workforce once they graduate.

PBL encourages students to attempt to solve problems by engaging in research-related findings from various sources and experts in particular areas. The learners will fully understand and return to apply these findings to resolve the problems and acquire needed discipline-specific knowledge. This method makes students professionally capable and increasingly independent in their educational pursuit. Thus, bridging the gap between chemistry education research and classroom practices requires moving beyond the traditional one directional teaching towards evidence-based collaborative and student-centered approaches.

Recommendations for Bridging the Research-Practice Gap in Chemistry Education

The following recommendations were made:

1. Researchers and teachers should engage the community, including stakeholders, as equal partners in the utilization of community-based interventions.Also scientific evidence and community knowledge should be integrated into intervention planning.
2. Journal editors should allow a focus on implementation methods in scientific articles that deal with community interventions.
3. Negative findings warrant careful exploration to determine whether the research failed to find an effect as a result of program design, implementation, or evaluation.

The inquiry field should have an equal focus on theory, research practice and training including the followings:

1. Universities should make it a priority that the next generation of researchers and practitioners acquire real experience in community-based programs.
2. Existing practitioners should receive quality training and opportunities for skills development to enhance their ability to apply scientific evidence and community knowledge at every stage of intervention development, adaptation, implementation, and evaluation.
3. Funding guidelines should support the acquisition of comprehensive knowledge by requiring strong formative and process information and outcome data.

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