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Impact of active and passive instructor involvement in PBL on database design mastery

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Abstract
This study explores the impact of active and passive instructor involvement in Problem-Based Learning (PBL) on students' mastery of database design concepts. PBL is a student-centered teaching method that encourages learners to engage in real-world problems, fostering critical thinking and deeper understanding. The research investigates how varying levels of instructor involvement influence student outcomes in database design tasks. Active involvement refers to instructors guiding students through discussions, offering real-time feedback, and facilitating problem-solving strategies, while passive involvement means instructors provide resources and monitor progress without direct engagement. This study employs a mixed-methods approach, collecting both qualitative and quantitative data from a group of graduate students enrolled in a database design course. The results suggest that students in the active involvement group demonstrated significantly better performance in designing complex databases, showing higher conceptual understanding, problem-solving skills, and the ability to apply theory to practice. In contrast, the passive involvement group exhibited slower progression in mastering advanced design techniques, despite completing similar tasks. These findings emphasize the importance of instructor engagement in promoting student mastery of complex subjects like database design. The study offers insights into the effectiveness of PBL when combined with active or passive instructor roles, guiding educators in the design of more effective teaching strategies.

Keywords: Active involvement, passive involvement, instructor roles, PBL, database design, mastery, problem-solving, critical thinking, graduate students, teaching strategies

Introduction

Background and Context

The rapidly evolving landscape of education in the digital age demands teaching methodologies that not only impart knowledge but also foster critical thinking, problem-solving, and self-directed learning skills among students. Problem-Based Learning (PBL) has emerged as a prominent pedagogical approach that aligns with these educational goals. Rooted in constructivist theories, PBL shifts the traditional teacher-centered paradigm to a student-centered environment, where learners engage actively with real-world problems and collaboratively develop solutions (Barrows, 1986). This educational strategy is particularly relevant in technical fields such as computer science and information systems, where conceptual understanding and practical application go hand in hand.

Database design, as a core component of information systems education, demands both theoretical mastery and practical competence. The ability to model, structure, and optimize databases is crucial for the development of efficient information systems that underpin modern business and technological infrastructures. Traditional lecture-based teaching methods, while useful for disseminating theoretical knowledge, often fall short in equipping students with the hands-on skills and adaptive thinking required for complex database design tasks (Elmasri & Navathe, 2016). Hence, educators have increasingly turned to active learning strategies like PBL to bridge this gap.

Problem-Based Learning and Instructor Roles

PBL's effectiveness largely depends on how it is implemented, particularly the role instructors play throughout the learning process. The level of instructor involvement can significantly influence students' engagement, motivation, and mastery of the subject matter. Instructor involvement in PBL typically varies along a spectrum from passive to active engagement.

- Active instructor involvement entails continuous facilitation, guidance, and real-time feedback, where instructors act as mentors and co-learners, encouraging critical inquiry and collaborative problem-solving. They help students refine their problem-solving strategies, address misconceptions promptly, and scaffold learning experiences to promote deeper understanding (Hmelo-Silver, 2004) [6].
- Passive instructor involvement, on the other hand, sees instructors taking a more hands-off approach. They provide resources and define the problems but limit direct intervention, encouraging students to independently navigate the learning process. This approach is meant to foster autonomy and self-regulation, although it may risk insufficient support for learners struggling with complex concepts (Savery, 2006) [13].

Despite extensive literature on PBL, there is ongoing debate about which level of instructor involvement yields the best outcomes, particularly in highly technical domains such as database design. Understanding this dynamic is essential for optimizing instructional strategies that maximize student learning outcomes.

Importance of Database Design Mastery

Database design mastery involves a range of skills, including conceptual modeling (e.g., Entity-Relationship Diagrams), normalization, query optimization, and translating business requirements into efficient database schemas. Mastery is not simply about memorizing facts or processes; it requires deep comprehension, analytical thinking, and the ability to apply theoretical concepts to practical scenarios (Connolly & Begg, 2015).

Effective database design education must therefore balance theory with hands-on problem-solving activities that challenge students to think critically and adaptively. PBL is naturally suited for this task, as it immerses learners in authentic problems that mirror real-world database challenges. However, how instructors facilitate this immersion—actively guiding or passively observing—could shape how well students achieve mastery.

Research Gap and Significance

While previous research has established the benefits of PBL in general educational contexts, fewer studies have specifically examined how varying degrees of instructor involvement within PBL impact student mastery of complex technical subjects like database design. Moreover, most research focuses either on purely qualitative or quantitative outcomes, leaving a gap in comprehensive, mixed-methods investigations that capture both performance metrics and learner experiences.

Understanding the nuanced role of instructor involvement is especially crucial given the diverse student populations in higher education, where learners may differ widely in prior knowledge, motivation, and learning preferences. Identifying the optimal balance of instructor involvement can help educators tailor PBL environments that support all students effectively, thereby improving educational equity and outcomes.

Objectives of the Study

This study aims to:

1. Examine the impact of active versus passive instructor involvement in PBL on students' mastery of database design.
2. Analyze differences in students' conceptual understanding, problem-solving skills, and application abilities under different instructional approaches.
3. Explore students' perceptions and experiences of instructor involvement in PBL settings.
4. Provide actionable recommendations for educators designing PBL courses in database design and related fields.

Research Questions

The study addresses the following key questions:

1. How does active instructor involvement in PBL influence students' mastery of database design compared to passive involvement?
2. What are the differences in student performance and learning outcomes between active and passive instructor involvement?
3. How do students perceive and respond to different levels of instructor involvement during PBL activities?
4. What are the implications of these findings for instructional design in database education?

Structure of the Paper

Following this introduction, the paper reviews relevant literature on PBL, instructor involvement, and database design education. The methodology section details the mixed-methods approach, including participant selection, data collection, and analysis procedures. The results section presents findings from quantitative assessments and qualitative feedback. Finally, the discussion interprets these findings in the context of existing research, and the conclusion highlights key takeaways and future research directions.

Methods

Research Design

This study employs a mixed-methods research design, combining quantitative and qualitative approaches to comprehensively evaluate the impact of active and passive instructor involvement on students' mastery of database design within a Problem-Based Learning (PBL) framework. The mixed-methods approach enables the collection of robust numerical data on academic performance alongside rich insights into students' perceptions and experiences, thereby providing a holistic understanding of the phenomenon under investigation (Creswell & Plano Clark, 2017) [4].

Participants

The participants comprised 60 graduate students enrolled in an advanced database design course at a large university during the Fall semester of 2024. The sample was selected through purposive sampling to ensure all participants had foundational knowledge in database concepts but varied in their prior experience with PBL.

Participants were randomly assigned into two groups of 30 each:

- **Active Instructor Involvement Group (AIG)**

Instructors actively facilitated problem-solving sessions, provided continuous guidance, feedback, and engaged directly with students throughout the PBL activities.

- **Passive Instructor Involvement Group (PIG)**

Instructors provided the problem scenarios and resources but refrained from direct interaction during problem-solving, offering support only upon student request.

The demographic characteristics of the two groups were comparable in terms of age, gender, prior academic performance, and database experience, minimizing confounding variables.

Instructional Intervention

Both groups participated in a 10-week PBL curriculum designed specifically for this study, focusing on core database design topics, including:

- Entity-Relationship (ER) modeling
- Normalization techniques
- SQL query formulation
- Database schema optimization
- Case studies on real-world business database requirements

The PBL problems were authentic and designed to reflect complex, real-life scenarios requiring critical thinking and collaborative problem-solving.

- **Active Instructor Role:** Instructors guided discussions, prompted reflection, provided corrective feedback, and scaffolded learning processes during scheduled sessions. They encouraged students to articulate their reasoning, explore alternative solutions, and make connections between theory and practice.

- **Passive Instructor Role:** Instructors adopted a facilitative observer role, making themselves available for consultation but not actively intervening in group discussions or problem-solving processes unless explicitly asked by students.

Data Collection

Data were collected through multiple instruments to capture both objective learning outcomes and subjective experiences.

1. **Pre- and Post-Test Assessments**

- A standardized database design test was administered before and after the intervention.
- The test included multiple-choice questions assessing theoretical knowledge and practical tasks such as ER diagram construction and normalization exercises.
- Scores were used to quantitatively measure learning gains and mastery.

2. **Performance-Based Evaluation**

- Students submitted a final database design project requiring the application of all key concepts covered.
- Projects were assessed using a detailed rubric measuring conceptual accuracy, design complexity, normalization quality, and practical applicability.
- Two independent raters scored the projects to ensure reliability (inter-rater reliability was calculated using Cohen's kappa).

3. **Student Surveys**

- At the end of the course, participants completed a Likert-scale survey evaluating perceptions of instructor involvement, satisfaction with the PBL experience, perceived learning, and motivation.
- The survey included items related to clarity of guidance, opportunity for self-directed learning, and overall engagement.

4. **Focus Group Interviews:**

- Semi-structured focus groups were conducted separately with each group (6–8 students per group).
- Discussions explored students' experiences of instructor involvement, challenges faced during problem-solving, and the perceived impact on their learning.
- Interviews were audio-recorded, transcribed, and thematically analyzed.

Data Analysis

1. **Quantitative Analysis**

- Pre- and post-test scores were analyzed using paired sample t-tests within groups to assess learning gains.
- Independent samples t-tests compared the differences in post-test scores and final project scores between the active and passive groups.
- Survey responses were analyzed descriptively and compared using Mann-Whitney U tests for non-parametric data to examine differences in student perceptions.
- Effect sizes were calculated to determine the practical significance of findings.

2. **Qualitative Analysis:**

- Transcripts from focus group interviews underwent thematic analysis following Braun and Clarke's (2006) [2] six-step approach.
- Initial codes were generated inductively from the data, identifying recurring patterns related to instructor involvement, student autonomy, motivation, and challenges.
- Themes were refined and categorized to highlight differences in experiences between the two groups.
- Triangulation was achieved by cross-referencing survey responses and interview data to enhance credibility.

Ethical Considerations

Ethical approval was obtained from the university's Institutional Review Board (IRB). Participants were informed of the study's purpose, assured of confidentiality, and provided written consent. Participation was voluntary, and students were assured that their course grades would not be affected by their involvement in the research. Data were anonymized to protect participant identities.

Limitations

The study acknowledges some limitations:

- The sample size, though adequate for exploratory purposes, limits generalizability.
- The 10-week intervention may not capture long-term retention of mastery.
- The study is confined to graduate students in a single institution, which may not represent diverse educational contexts.
- Instructor variability was controlled by training, but subtle differences in facilitation style could influence outcomes.

Despite these limitations, the study's design provides valuable insights into the role of instructor involvement in PBL and its impact on database design mastery.

Results

This section presents the findings from both the quantitative and qualitative data analyses. Quantitative results include pre- and post-test scores, final project evaluations, and survey responses, while qualitative results summarize themes from focus group interviews.

Quantitative Results

Pre- and Post-Test Performance

Table 1 summarizes the mean scores and standard deviations for pre- and post-tests in both the Active Instructor Involvement Group (AIG) and Passive Instructor Involvement Group (PIG).

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Gain	p-value (paired t-test)
AIG	58.3 (9.2)	85.7 (7.4)	+27.4	<0.001
PIG	57.6 (8.8)	74.2 (9.1)	+16.6	<0.001

Both groups showed statistically significant improvement from pre- to post-test ($p < 0.001$). However, the active involvement group demonstrated a significantly higher gain (+27.4 points) compared to the passive group (+16.6 points). An independent samples t-test confirmed that the post-test scores of AIG were significantly higher than PIG ($t(58) = 5.48$, $p < 0.001$).

Final Project Evaluation

Final projects were scored using a detailed rubric assessing conceptual accuracy, normalization, design complexity, and practical application. Table 2 shows the average rubric scores for both groups.

Group	Mean Project Score (out of 100)	SD	p-value (independent t-test)
AIG	88.5	6.3	<0.001
PIG	75.4	8.7	

The AIG group outperformed the PIG group significantly ($p < 0.001$), indicating better mastery in applying database design principles to complex projects. Inter-rater reliability between the two evaluators was high (Cohen's kappa = 0.87), supporting the consistency of scoring.

Student Survey Results

Survey data were analyzed to compare student perceptions of instructor involvement and learning experience. Table 3 provides average ratings (on a 5-point Likert scale) for key survey items.

Survey Item	AIG Mean (SD)	PIG Mean (SD)	Mann-Whitney U p-value
Clarity of instructor guidance	4.6 (0.5)	3.2 (0.8)	<0.001
Opportunity for self-directed learning	3.9 (0.7)	4.5 (0.4)	0.002
Overall satisfaction with PBL experience	4.4 (0.6)	3.7 (0.9)	0.001
Perceived learning and mastery	4.7 (0.5)	3.8 (0.7)	<0.001
Motivation and engagement	4.5 (0.5)	3.9 (0.6)	0.004

Students in the active involvement group rated clarity of guidance, satisfaction, perceived mastery, and motivation significantly higher than those in the passive group ($p < 0.01$). Conversely, students in the passive group reported higher opportunities for self-directed learning ($p = 0.002$), reflecting greater autonomy in that setting.

Discussion

This study investigated the impact of active versus passive instructor involvement within a Problem-Based Learning (PBL) environment on graduate students' mastery of database design. The findings provide valuable insights into how different instructor roles shape learning outcomes, student perceptions, and engagement in complex technical education. This discussion interprets these results in the context of existing literature, explores theoretical and practical implications, and suggests directions for future research.

Interpretation of Key Findings

Active Instructor Involvement Enhances Mastery

Quantitative data clearly showed that students in the active instructor involvement group (AIG) outperformed their peers in the passive group (PIG) on both post-test assessments and final project evaluations. The mean gain in knowledge and skills was substantially higher for AIG, confirming that continuous instructor engagement plays a critical role in facilitating deeper understanding of database design concepts.

This supports prior research indicating that active facilitation helps scaffold learners' cognitive processes, especially in domains requiring complex problem-solving and application of abstract concepts (Hmelo-Silver, 2004; Kirschner, Sweller, & Clark, 2006) [6]. The active instructor's role in providing timely feedback, clarifying misconceptions, and guiding discussions appears to reduce cognitive overload and enhances students' ability to connect theory with practice.

In the context of database design, where tasks such as normalization and schema optimization are often conceptually challenging, instructor scaffolding likely helps students develop more accurate mental models and problem-solving strategies. These findings suggest that purely student-driven PBL may not be sufficient for mastering complex technical content without adequate instructor support.

Passive Instructor Involvement Promotes Autonomy but May Limit Depth

The passive involvement group reported greater opportunities for self-directed learning, reflecting the autonomy inherent in less guided environments. However, this came with trade-offs, as evidenced by their lower academic performance and more mixed qualitative feedback.

While autonomy is an important factor in adult learning and self-regulation (Zimmerman, 2002) [21], the results indicate that in highly technical fields like database design, students may struggle to fully capitalize on autonomy without sufficient scaffolding. The lack of proactive instructor guidance sometimes led to confusion, decreased motivation, and shallower problem-solving approaches.

This aligns with Vygotsky's (1978) [18] theory of the Zone of Proximal Development (ZPD), which emphasizes that learners perform best when supported just beyond their current capabilities. Passive instructor involvement may have left some students outside their ZPD, resulting in slower mastery and surface-level learning.

Student Perceptions Reflect the Balance Between Guidance and Independence

Survey and focus group data revealed that students in the active involvement group felt more motivated, satisfied, and confident in their learning, citing the instructor's presence as a key factor. Conversely, students in the passive group appreciated the freedom but sometimes felt overwhelmed and uncertain.

This dichotomy highlights the delicate balance educators must strike between providing enough guidance to promote success and allowing sufficient independence to develop self-directed learning skills. Too much control risks reducing motivation and creativity, while too little can lead to frustration and knowledge gaps.

These findings echo earlier studies emphasizing the importance of "guided autonomy"—an approach where instructors actively facilitate learning but gradually release responsibility to students as competence grows (Schunk & Zimmerman, 2012) [14].

Implications for Teaching Database Design in PBL

The results suggest several practical recommendations for educators designing PBL courses in database design and related technical fields:

1. **Adopt an Active Facilitation Role:** Instructors should actively engage with students during PBL activities, offering timely feedback and scaffolding complex concepts. This supports deeper understanding and reduces frustration.

2. **Balance Support with Encouragement of Independence:** While active involvement is critical, instructors should also encourage self-directed exploration and problem-solving, gradually fading support as students gain mastery.

3. **Use Formative Assessments to Guide Instruction:** Continuous monitoring of student progress allows instructors to tailor their involvement based on individual and group needs, targeting interventions where students struggle most.

4. **Provide Clear Problem Scenarios and Resources:** Structured, authentic problems coupled with relevant materials help focus student efforts and minimize cognitive overload, making active facilitation more effective.

Theoretical Contributions

This study contributes to PBL literature by empirically demonstrating how the degree of instructor involvement affects mastery in a technical domain. While prior work has recognized instructor roles in PBL broadly (Savery, 2006) [13], this research clarifies the differential impact of active versus passive facilitation on student outcomes.

Moreover, the findings reinforce the relevance of cognitive load theory (Sweller, 1994) [14] and Vygotsky's ZPD in the context of PBL, providing evidence that active instructor scaffolding is essential for managing intrinsic cognitive demands in complex learning tasks.

Limitations and Future Research

Despite its strengths, this study has limitations that should be acknowledged:

- **Sample Size and Context:** The study involved 60 graduate students from a single university, which may limit generalizability. Future research should replicate the design with larger, more diverse populations, including undergraduate learners and different institutional settings.

- **Duration of Intervention:** The 10-week course provided a snapshot of learning, but longer-term studies are needed to assess retention and transfer of database design mastery.

- **Instructor Variability:** Although efforts were made to standardize instructor training, subtle differences in teaching style may have influenced results. Future studies could control for this through multiple instructors or explore how instructor characteristics interact with involvement levels.

- **Measurement Scope:** While the study used multiple assessment methods, additional measures such as cognitive load questionnaires or neurocognitive assessments could deepen understanding of learning processes during PBL.

Conclusion

In summary, this study demonstrates that active instructor involvement in PBL significantly enhances graduate students' mastery of database design, leading to better academic performance, higher motivation, and greater satisfaction. Passive instructor roles, while promoting autonomy, may not sufficiently support learners in mastering complex technical skills.

These findings advocate for a balanced, guided approach to instructor involvement that combines active facilitation with opportunities for independent learning. Educators in technical disciplines can leverage this insight to design more effective PBL environments, ultimately improving student outcomes and preparing learners for real-world challenges.

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