# *Design and Implementation of an Intelligent SQL Learning Platform for Computer Engineering Students*

*Author: Jorge L Cruz Agosto*
*Advisor: Alfredo Cruz, Ph.D.*
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## Abstract

Database skills are a core competency for computer engineering students that they will need in their careers after graduation. In this era of Big Data, those with strong database skills will have an advantage. However, databases are a broad topic, so they cannot be covered in a single class. This may leave students with only basic knowledge and lingering doubts, especially if the instructor lacks the right tools. To enhance the students' learning experience, this paper proposed a learning website that would help students better understand databases and feature an artificial intelligence assistant that would act as a virtual tutor. The virtual tutor would support students by answering questions, clarifying doubts, and providing tailored explanations. It is important to note that the project did not aim to replace teachers. This combination of personalized content, practice exercises, and adaptive tutoring created a customized learning environment that enhanced engagement and knowledge retention.

## Introduction

Databases are a fundamental component of modern computing and a critical skill for computer engineering students. Effective database design and query optimization directly impact system performance, reliability, and operational costs. In the era of Big Data, where organizations manage rapidly growing volumes of structured and unstructured data, strong database knowledge provides a significant professional advantage [1].

At the same time, the adoption of e-learning and mobile learning platforms has increased substantially, offering flexible, accessible, and personalized learning opportunities. Prior research shows that interactive and mobile-based learning environments improve student engagement, motivation, and academic performance, particularly when combined with learner-centered pedagogical approaches [2]. Additionally, studies on database education highlight the need for interactive tools that bridge the gap between theoretical instruction and hands-on practice [3].

## Background

E-learning and mobile learning adoption has increased significantly, supported by widespread access to web and mobile technologies. Prior studies show that interactive and mobile-based learning environments improve student motivation, engagement, and academic performance, particularly in Computer Science and engineering education [4]. Studies conducted during the COVID-19 pandemic further demonstrated that well-designed e-learning systems significantly improve student motivation and learning outcomes, reinforcing the importance of interactive and engaging digital learning environments [5].

However, research emphasizes that technology alone is insufficient to guarantee effective learning outcomes. Strong pedagogical design, usability, and intuitive user interfaces are critical factors influencing student satisfaction and learning effectiveness. More recently, artificial intelligence has emerged as a key enabler of adaptive learning, with AI-driven tutoring systems demonstrating improved engagement, personalized feedback, and knowledge retention in higher education environments [6], [7].

## Problem

Databases are a broad and complex subject that cannot be fully covered within a single academic course. As a result, many computer engineering students complete database classes with only basic knowledge and unresolved doubts, particularly regarding real-world application of concepts [3]. Limited instructional time and resources further restrict opportunities for individualized support.

Although many e-learning platforms address database topics, several are not designed for beginners and fail to clearly explain the purpose and practical relevance of key concepts [3]. In addition, some platforms lack effective assessment strategies that promote higher-order thinking and problem-solving skills [8]. Without adaptivity, hands-on practice, and personalized guidance, students often struggle to bridge the gap between theory and practical database skills required by industry [4], [8].

## Methodology

This project followed a design-based research approach focused on the development and implementation of an educational platform rather than an empirical evaluation. The methodology was informed by principles of e-learning, mobile learning, and adaptive instruction to address the gap between theoretical database education and hands-on practice [3].

The platform was designed to support a cyclical learning model, as seen on Figure 1, in which students first study theoretical concepts, then reinforce their understanding through structured practice exercises, and finally apply their knowledge in a real SQL sandbox environment. This instructional flow aligns with established pedagogical strategies and supports the development of higher-order thinking skills, following Bloom's Taxonomy [8]. To address individual learning differences, artificial intelligence was incorporated in the form of a virtual tutor. AI-based intelligent tutoring systems have been shown to deliver adaptive, personalized guidance comparable to human tutoring in structured domains, making them suitable for supporting students outside the classroom [7], [8].

User experience and interface design were treated as critical components of the methodology. The system emphasizes simplicity, intuitive navigation, and visual clarity to reduce cognitive load and improve engagement. Prior studies have shown that strong usability and user-centered design significantly influence student satisfaction and learning outcomes in online learning environments [9].


**Figure 1: Learning flow diagram**

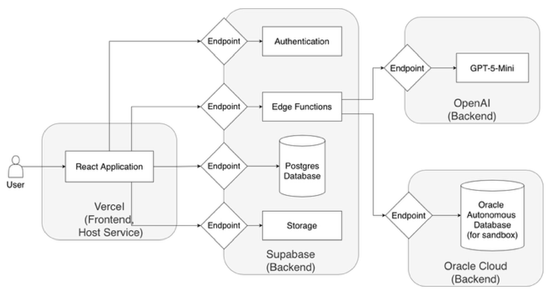


**Figure 2: Project architecture**

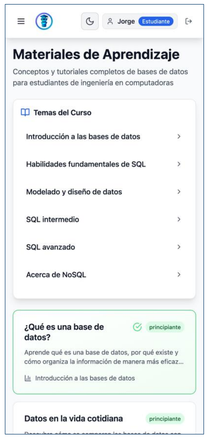


**Figure 3: Learning content screen**

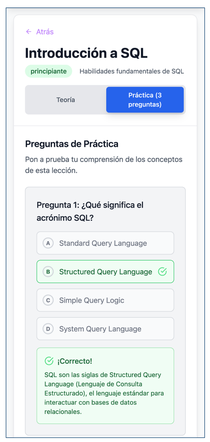


**Figure 4: Practice exercises**

## Results and Discussion

The system architecture, shown in Figure 2, highlights the integration of the frontend, backend services, database sandbox, and AI tutor. A React-based frontend ensured responsiveness across desktop and mobile devices, while Supabase provided reliable authentication, progress tracking, and secure data management. The Oracle Autonomous Database enabled the creation of isolated sandbox schemas for each student, allowing safe experimentation without affecting shared data. This design choice addressed a common barrier in database education by eliminating the need for local database setup while still providing real-world SQL experience.

The development of the DataMentor platform resulted in an integrated learning environment that combines theoretical instruction, structured practice exercises, hands-on experimentation, and artificial intelligence–based tutoring to support database education, as shown in the user interfaces of the Figures 3, 4, 5 and 6, respectively. The platform enables students to progress through self-paced learning modules, reinforce concepts using multiple-choice exercises, and apply their knowledge in a real SQL sandbox powered by an Oracle Autonomous Database.

The inclusion of an AI-powered virtual tutor enhanced the learning experience by offering immediate feedback, clarifying doubts, and providing contextual explanations tailored to the current lesson. This adaptive support aligns with prior research demonstrating that intelligent tutoring systems improve engagement and knowledge retention when integrated into structured learning environments [6], [7]. Recent studies also indicate that AI-driven adaptive learning systems improve personalization and student engagement in higher education environments [10].

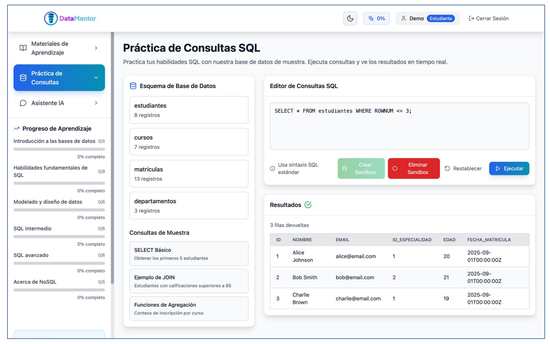


**Figure 5: Sandbox database**

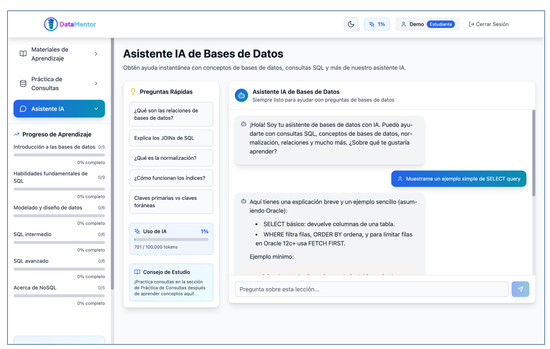


**Figure 6: AI Agent**

## Conclusions

This project demonstrated the feasibility of developing an intelligent, web-based learning platform to support database education for computer engineering students. The DataMentor platform integrates theoretical lessons, structured practice exercises, and a hands-on SQL sandbox, helping bridge the gap between academic instruction and practical database skills. By leveraging modern web technologies, the system achieves responsiveness, scalability, and accessibility across desktop and mobile devices. In addition, the inclusion of an AI-powered virtual tutor provides adaptive guidance and immediate feedback, supporting personalized learning and addressing individual student needs [7], [8].

## Future Work

Future development of the platform may focus on expanding the content library with additional modules covering advanced database topics and other SQL dialects, such as MySQL, PostgreSQL, and SQL Server. The platform could also be enhanced by integrating a dynamic content management system, allowing instructors to add or update lessons without developer intervention. Expanding language support beyond Spanish would improve accessibility for a broader and more diverse student population.

Further improvements to the AI assistant include the integration of retrieval-augmented generation (RAG) to provide more context-aware responses based on lesson content, as well as support for multiple AI models. Enabling dynamic model selection based on query complexity could enhance response quality and adaptability.

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## References

[1] Google Cloud, "What is big data?," Google Cloud. https://cloud.google.com/learn/what-is-big-data (accessed Aug. 19, 2025).

[2] J. Kang, "Benefits and challenges of mobile-learning brought to student learning outcomes in higher education: A systematic review from 2014–2023," International Journal of Academic Research in Progressive Education and Development, vol. 13, no. 1, p. 20698, 2024. https://doi.org/10.6007/IJARPED/v13-i1/20698

[3] M. Ishaq, A. Abid, M. S. Farooq, M. F. Manzoor, U. Farooq, K. Abid, and M. A. Helou, "Advances in database systems education: Methods, tools, curricula, and way forward," Education and Information Technologies, vol. 28, no. 3, pp. 2681–2725, 2023. https://doi.org/10.1007/s10639-022-11293-0

[4] L. Pedraja-Rejas, C. Muñoz-Fritis, E. Rodríguez-Ponce, and D. Laroze, "Mobile learning and its effect on learning outcomes and critical thinking: A Systematic Review," Applied Sciences, vol. 14, no. 19, p. 9105, 2024. https://doi.org/10.3390/app14199105

[5] F. Yahiaoui et al., "The impact of e-learning systems on motivating students and enhancing their outcomes during COVID-19: A mixed-method approach," Frontiers in Psychology, vol. 13, p. 874181, 2022. https://doi.org/10.3389/fpsyg.2022.874181

[6] R. Deng, M. Jiang, X. Yu, Y. Lu and S. Liu, "Does ChatGPT Enhance Student Learning? A Systematic Review and Meta-Analysis of Experimental Studies," Computers & Education, vol. 227, art. 105224, 2025.

[7] M. Zerkouk, M. Mihoubi and B. Chikhaoui, "A Comprehensive Review of AI-based Intelligent Tutoring Systems: Applications and Challenges," arXiv, arXiv:2507.18882 [cs.IR], Jul. 2025.

[8] S. Nurmatova and M. Altun, "A comprehensive review of Bloom's Taxonomy integration to enhancing novice EFL educators' pedagogical impact," Arab World English Journals, vol. 14, no. 3, Oct. 2023. [Online]. Available: https://ssrn.com/abstract=4593934

[9] T. K. Miya and I. Govender, "UX/UI design of online learning platforms and their impact on learning: A review," Int. J. Research in Business & Social Science, vol. 11, no. 10, pp. 316–327, Dec. 2022. DOI: 10.20525/ijrbs.v11i10.2236

[10] C. Merino-Campos, "The Impact of Artificial Intelligence on Personalized Learning in Higher Education: A Systematic Review," Trends in Higher Education, vol. 4, no. 2, art. 17, 2025. DOI: 10.3390/higheredu4020017