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EVALUATING USABILITY AND COGNITIVE LOAD: A COMPARATIVE STUDY OF CLOUD-BASED AND LOCAL DATABASE SYSTEMS IN HIGHER EDUCATION

Gustavo Gutiérrez Carreón | Universidad Michoacana de San Nicolás de Hidalgo, Morelia, México | gustavo.gutierrez@umich.mx

* Corresponding author

ABSTRACT

Aim/Purpose	The need for this paper arises from the lack of comprehensive studies comparing the impact of cloud-based versus local database systems on student learning outcomes. Specifically, there is a need to understand how these different approaches affect usability and cognitive load in educational settings, which are critical factors for effective learning in database courses.
Background	This paper addresses the problem by conducting a comparative study that evaluates student satisfaction, usability, and cognitive load when using cloud-based versus local database systems in a controlled educational environment. By analyzing these factors, the study provides evidence on which approach better supports student learning in database courses.
Methodology	The paper employs a quantitative research design, utilizing surveys to assess usability and cognitive load among students. The research sample consists of 100 undergraduate students enrolled in a Database Systems course, divided equally into a control group using local database installations and an experimental group using cloud-based services. Both groups completed the same set of tasks, and their experiences were measured and compared using standardized questionnaires.
Contribution	This paper contributes to the body of knowledge by empirically demonstrating how cloud-based database systems can significantly improve usability and reduce cognitive load for students compared to traditional local installations. It fills a research gap by directly comparing these two approaches within an educational context. It provides actionable insights that can influence how technology is integrated into database education to enhance learning outcomes.

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Findings	The paper's major findings reveal that students using cloud-based database services experienced significantly higher usability and lower cognitive load compared to those using local installations. These results suggest that cloud-based systems provide a more effective and user-friendly learning environment for students in database courses.
Recommendations for Practitioners	Practitioners are recommended to integrate cloud-based database services into their courses to enhance student learning outcomes, as these platforms have been shown to improve usability and reduce cognitive load. By adopting cloud technologies, educators can provide students with more accessible, efficient, and user-friendly tools that better support their learning process. Additionally, it is advisable to offer guidance and support during the transition to cloud-based systems to ensure that all students can fully leverage the benefits of this technology.
Recommendations for Researchers	For researchers, this paper recommends further investigation into the long-term impacts of cloud-based database systems on student learning outcomes, particularly in diverse educational contexts and with varying levels of student expertise. Additionally, future studies should explore the integration of other emerging technologies with cloud services to determine their combined effects on cognitive load and usability. Researchers are also encouraged to conduct qualitative studies to gain deeper insights into student experiences and identify potential challenges and opportunities in adopting cloud-based systems in education.
Impact on Society	The larger implications of the paper's findings suggest that the adoption of cloud-based database systems in education could lead to a broader transformation in how technical courses are taught, making them more accessible and efficient for students. As cloud technologies reduce cognitive load and enhance usability, they have the potential to improve learning outcomes across various disciplines, not just in database courses. This shift could drive a wider acceptance of cloud-based tools in educational institutions, promoting a more flexible and scalable approach to learning that can better meet the needs of a diverse student population in an increasingly digital world.
Future Research	Following the advancements made by this paper, future research should focus on exploring the impact of cloud-based database systems on long-term academic performance and retention of knowledge. Additionally, studies should examine how these systems can be effectively integrated into other areas of the curriculum beyond database courses and whether similar benefits are observed. Researchers should also investigate the scalability of these findings across different educational institutions, including those in resource-constrained environments, to determine the broader applicability of cloud-based technologies in education. Finally, it would be valuable to explore student perceptions and experiences with hybrid models that combine local and cloud-based resources to identify the optimal balance for enhancing learning outcomes.
Keywords	cloud computing, database systems, cognitive load, usability, higher education

INTRODUCTION

The integration of cloud computing into education has transformed how students and educators engage with digital resources, particularly in courses requiring complex software systems such as databases. However, despite its advantages, the shift to cloud-based services also introduces challenges in balancing foundational knowledge development and reducing extraneous cognitive load for effective learning. In higher education, technical courses like database systems often demand significant mental effort to navigate complex tools, potentially hindering the learning process (Sweller et al., 2011). This underscores the need for tools that minimize technical barriers while supporting essential skill acquisition.

Cloud computing, defined as the delivery of computing services – including databases, storage, and applications – over the Internet, allows users to access resources remotely without the need for local installations (Qasem et al., 2019). In the context of database education, cloud-based platforms such as Google Cloud SQL provide managed environments that alleviate the burden of software setup and maintenance, enabling students and educators to focus on core learning activities (Bilgin & Alper, 2022). This paradigm shift aligns with educational goals by offering scalable and accessible alternatives to traditional installations while enhancing usability and reducing the cognitive demands associated with technical complexity (Odeh et al., 2015).

Usability and cognitive load are pivotal factors in determining the effectiveness of educational tools. Usability, which reflects the ease of interaction with a system, directly influences student satisfaction and productivity (Brooke, 1996). High usability ensures that students can complete tasks efficiently without unnecessary frustration, an essential consideration for technical courses requiring extensive software use (Bangor et al., 2009). At the same time, cognitive load theory emphasizes the importance of reducing extraneous cognitive demands – mental effort unrelated to learning goals – to optimize the allocation of cognitive resources toward meaningful learning (Sweller et al., 2011).

This study addresses these critical considerations by investigating the impact of cloud-based database services on student learning outcomes in higher education. Specifically, it evaluates whether these services improve usability and reduce cognitive load compared to traditional local installations of MySQL. The findings aim to provide actionable insights for educators and institutions, highlighting the potential of cloud-based platforms to enhance the balance between fostering foundational knowledge and reducing barriers to learning.

RESEARCH OBJECTIVES AND QUESTIONS

The primary objective of this study is to evaluate the impact of cloud-based database services on student learning outcomes in higher education, specifically focusing on usability and cognitive load compared to traditional local installations. By analyzing these factors, the study aims to determine which method better supports student engagement, efficiency, and overall satisfaction in database courses. Ultimately, the research seeks to provide evidence-based recommendations for educators and institutions on how to optimally integrate cloud technologies into the curriculum to enhance the educational experience.

RESEARCH QUESTIONS

Usability: How does the usability of cloud-based database services compare to traditional local installations in the context of higher education?

Cognitive Load: What is the impact of cloud-based database services on the cognitive load experienced by students compared to traditional local installations?

This article is structured as follows. After this introductory section, the Literature Review provides a comprehensive overview of existing research on cloud computing in education, with particular emphasis on studies related to usability and cognitive load. This section establishes the theoretical foundation and identifies gaps in the current literature that this study seeks to address. The Methodology section outlines the research design, detailing the sample population of 200 undergraduate students, the division into control and experimental groups, and the procedures for data collection using standardized questionnaires. It also describes the statistical methods used to analyze the data. In the Results section, the findings of the study are presented, including detailed comparisons of usability and cognitive load between the cloud-based and locally installed database systems. This section includes tables, figures, and statistical analyses to illustrate the key outcomes. The Discussion section interprets the results, comparing them with findings from previous studies, and explores the implications for educational practice. This section also addresses the limitations of the study and suggests areas for future research. Finally, the Conclusion section summarizes the main findings, reiterates the significance of the research, and offers practical recommendations for educators and institutions considering the adoption of cloud-based database systems in their curricula.

LITERATURE REVIEW

The integration of cloud computing into educational environments has garnered significant attention over the past decade, with numerous studies exploring its impact on learning outcomes, usability, and cognitive load. This section reviews the existing literature on cloud-based education, focusing on key themes such as the effectiveness of cloud-based learning environments, the usability of these systems, their impact on cognitive load, and the specific challenges of learning database systems.

Learning database systems presents significant challenges for students, particularly in navigating the technical complexity of setting up and managing database environments. Traditional local installations often require students to have advanced technical knowledge in areas such as software configuration, dependency management, and troubleshooting, which can detract from the primary learning objectives (Bilgin & Alper, 2022). Moreover, the steep learning curve associated with mastering query languages and database design principles adds to the cognitive load, making it difficult for students to balance foundational knowledge acquisition with practical application (Y.-P. Cheng et al., 2022).

Collaborative and team-based learning approaches have proven effective in mitigating some of these challenges; for example, Y.-P. Cheng et al. (2022) demonstrated that content-based knowledge awareness and team learning in cloud classrooms help reduce cognitive load and student anxiety, fostering more effective engagement with technical material. Similarly, Du et al. (2023) found that well-designed cloud systems enhance collaborative problem-solving by minimizing cognitive demands, thereby improving learning outcomes. These findings emphasize the importance of integrating cloud-based database tools to simplify technical processes without sacrificing opportunities for deep learning and skill acquisition.

Cloud computing has been increasingly adopted in educational settings, offering numerous benefits such as scalability, accessibility, and cost-effectiveness. Alam (2023) highlights how cloud-based e-learning environments provide an adaptive and flexible learning ecosystem, which can be particularly beneficial for institutions with limited resources. This adaptability is further supported by Qasem et al. (2019), who conducted a systematic review of cloud computing adoption in higher education institutions, finding that cloud services significantly enhance educational outcomes by providing consistent access to resources.

Bilgin and Alper (2022) conducted a study on a cloud-based blended learning environment, demonstrating that students in such environments show higher achievement, persistence, and reduced cognitive load compared to traditional learning settings. These findings align with the research by Abichandani et al. (2019), who explored the use of a cloud-based virtual reality system in solar energy education. Their study found that the cloud-based system not only improved students' understanding of complex concepts but also made the learning process more engaging and interactive.

The adoption of cloud-based database services has been proposed as a solution to alleviate the challenges of learning databases. By providing managed environments with preconfigured tools, cloud platforms such as Google Cloud SQL reduce the technical overhead required to set up and maintain database systems, enabling students to focus more on learning core concepts (Qasem et al., 2019). However, concerns remain about whether these platforms sufficiently support foundational knowledge development, particularly for students who may rely heavily on automated features rather than developing the technical skills needed for independent database management (Du et al., 2023). This duality emphasizes the importance of balancing usability with the pedagogical goal of fostering deep learning and technical competence.

Usability is a critical factor in the success of cloud-based educational tools. The System Usability Scale (SUS), developed by Brooke (1996), remains a widely used tool for assessing the usability of various systems. Bangor et al. (2009) further refined the SUS by adding an adjective rating scale, allowing for a more nuanced interpretation of usability scores. Lewis and Sauro (2018) provided item benchmarks for SUS, making it easier to compare usability scores across different systems.

Y.-M. Cheng (2020) explored the usability and satisfaction of cloud-based e-learning systems, emphasizing the role of interactivity and course quality in enhancing students' learning experiences. Similarly, Shorfuzzaman et al. (2015) demonstrated the effectiveness of a cloud-based collaborative learning framework, showing that high usability can significantly improve learners' experiences by making the platform more accessible and easier to navigate.

Cognitive load theory, as proposed by Sweller et al. (2011), suggests that reducing extraneous cognitive load can enhance learning by allowing students to focus more on essential tasks. In cloud-based learning environments, the reduction of cognitive load is a significant advantage. Du et al. (2023) conducted a multimodal analysis of college students' collaborative problem-solving in virtual experimentation activities, finding that well-designed cloud-based systems can minimize cognitive load and enhance learning outcomes.

Tawfik et al. (2023) explored the relationship between usability and cognitive load in data science education, finding that cloud-based platforms that are easy to use also tend to reduce cognitive load, leading to better learning outcomes. This relationship is crucial, as it highlights the importance of designing cloud-based systems that are both user-friendly and cognitively efficient.

Despite the advantages, the adoption of cloud computing in education is not without challenges. Odeh et al. (2015) conducted a SWOT analysis of cloud computing adoption in higher education institutions, identifying several barriers, such as security concerns, data privacy, and the need for reliable Internet connectivity. These challenges must be addressed to realize the benefits of cloud-based education fully.

Furthermore, the role of cloud computing in enhancing accessibility and equity in education is a critical area for future research. Okai-Ugbaje et al. (2020) highlighted the potential of cloud-based mobile learning (m-learning) to overcome infrastructural limitations and enhance learning in resource-constrained settings. Similarly, Wu and Plakhtii (2021) emphasized the importance of e-learning based on cloud computing in providing equal opportunities for students across different geographical regions. By focusing on these nuanced outcomes, this study contributes to the growing discourse on the role of cloud technologies in education, addressing gaps related to their impact on deeper learning and skill acquisition (Tawfik et al., 2023).

METHODOLOGY AND RESEARCH METHODS

This study employs a quantitative research design to compare the effectiveness of cloud-based database services with traditional local installations in enhancing student learning outcomes in higher education. The methodology is structured to assess two primary factors: usability and cognitive load, which are critical in determining the efficiency and satisfaction of students engaging with database systems.

RESEARCH DESIGN

A quasi-experimental design was chosen for this study, allowing for the comparison between two groups of students: those using cloud-based database services (experimental group) and those using traditional local installations (control group). The quasi-experimental approach is particularly suitable for educational settings where random assignment may not be feasible due to logistical constraints (Leavy, 2022). This design enables the researchers to assess the impact of the independent variable – the type of database system (cloud-based vs. local) – on the dependent variables, which are usability and cognitive load.

PARTICIPANTS

The study sample consists of 100 undergraduate students enrolled in a Database Systems course at a large public university. The participants were divided into two groups: 50 students in the experimental group, who utilized cloud-based database services, and 50 students in the control group, who worked with locally installed database systems. The participants were selected through convenience sampling, a method often employed in educational research due to its practicality in accessing a readily available population while maintaining research validity (Etikan et al., 2016). The demographic characteristics of the participants, including age, gender, and prior experience with database systems, were collected to ensure that the groups were comparable.

DATA COLLECTION INSTRUMENTS

Data collection involved the use of standardized instruments to measure usability and cognitive load. Usability was assessed using the System Usability Scale (SUS), a widely used tool in usability research that provides a reliable measure of overall system usability through a 10-item questionnaire (Brooke, 1996). The SUS has been validated in numerous studies and is recognized for its simplicity and effectiveness across diverse contexts, including educational technology (Lewis & Sauro, 2018). The SUS questionnaire includes the following items:

Q1: I think that I would like to use this system frequently.

Q2: I found the system unnecessarily complex.

Q3: I thought the system was easy to use.

Q4: I think that I would need the support of a technical person to be able to use this system.

Q5: I found the various functions in this system were well integrated.

Q6: I thought there was too much inconsistency in this system.

Q7: I would imagine that most people would learn to use this system very quickly.

Q8: I found the system very cumbersome to use.

Q9: I felt very confident using the system.

Q10: I needed to learn a lot of things before I could get going with this system.

These items are rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The SUS score is calculated by converting each item's response to a new scale and summing these scores to produce a final usability score, which can range from 0 to 100, with higher scores indicating better usability (Bangor et al., 2009).

Cognitive load was measured using a custom-designed questionnaire specifically tailored for this study, which consisted of 10 items aimed at evaluating different aspects of the cognitive load experienced by students during the course activities. The questionnaire was developed (Gutiérrez-Carreón, 2020) based on cognitive load theory (Sweller et al., 2011) and included the following items:

Q1: I think the instructions and guidelines for experimenting were clear.

Q2: I think it was understood how the solution to the problem is found, the expected results, and the evaluation process.

Q3: I think the informative sessions and the material presented helped me solve the problem.

Q4: I think this activity will be useful for the development of future projects with the tools presented.

Q5: I believe that the development of this activity challenges my abilities to solve these types of problems.

Q6: I think that solving the problem itself is a significant achievement.

Q7: I can solve this problem and others, more complicated, of the same type.

Q8: I think this experiment is relevant to the course and my curriculum.

Q9: I believe that communication, discussions, or debates with my classmates and the teacher are essential.

Q10: I think this type of activity encourages me to develop solutions for myself.

Responses were recorded on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). This cognitive load questionnaire was designed to capture students' perceptions of the clarity, challenge, and relevance of the tasks, as well as their confidence in solving similar problems in the future.

EXPERIMENT DESIGN

Total Participants: 100 students enrolled in a Database Systems course at a university.

Group Division: The students will be randomly divided into two groups of 50 each:

Control Group: Will use MySQL through a local installation on their laptops or personal computers.

Experimental Group: Will use Google Cloud SQL to access a MySQL database instance in the cloud.

Initial setup

Control Group: Students will install MySQL Workbench and MySQL Server on their local machines. This process includes downloading the installers, configuring credentials, and creating an initial database to work with.

Experimental Group: Students will create a Google Cloud account (using the free credit provided by Google), set up a Cloud SQL instance with MySQL, and access it via the Google Cloud web interface or MySQL Workbench.

Tasks to perform

Both groups will perform an identical set of tasks related to database management:

- *Creating databases and tables:* Create a database and multiple tables with relationships between them.

- *Inserting and querying data:* Insert data into the tables and execute SQL queries to extract specific information.
- *Transaction management:* Perform transaction operations, including commit and rollback.
- *Backup and restore:* Perform a complete backup of the database and restore it in the case of simulated data loss.

Evaluation

Usability: The System Usability Scale (SUS) will be used to evaluate students' perceptions of the ease of use of the system they utilize.

Cognitive Load: This will be assessed using a custom questionnaire designed to measure the clarity of instructions, the perceived difficulty of tasks, and the relevance of the work done for their learning.

After finishing the assigned tasks, students will complete the usability and cognitive load questionnaires.

PROCEDURE

The study was conducted over a 12-week period during the academic semester. Both the experimental and control groups received the same instructional content and were required to complete identical tasks related to database management. The only difference between the groups was the platform used: the experimental group accessed a cloud-based database service, while the control group worked with a locally installed database system.

During the first week, students were introduced to the course material and provided with instructions on how to access and use their respective database systems. In the subsequent weeks, students completed various assignments and projects designed to test their understanding and application of database concepts. Data collection occurred in the final week of the study, where students completed the SUS and cognitive load questionnaires.

DATA ANALYSIS

Data were analyzed using statistical methods to determine the differences in usability and cognitive load between the two groups. Descriptive statistics were used to summarize the data, including means and standard deviations for each measure. Inferential statistics, specifically independent samples t-tests, were employed to compare the mean scores of the SUS and cognitive load questionnaire between the experimental and control groups to test the hypotheses. This method is commonly used in educational research to compare the means of two independent groups and is considered robust for assessing differences in such contexts (Field, 2018).

Additionally, Pearson's correlation coefficient was calculated to examine the relationship between usability and cognitive load within each group. This analysis helps to determine whether higher usability is associated with lower cognitive load, which would support the hypothesis that cloud-based services provide a more efficient learning environment (Gutiérrez-Carreón, 2020).

While the quasi-experimental design allows for the comparison of different educational technologies, it does have limitations, including the potential for selection bias due to the non-random assignment of participants (Maciejewski, 2020). Additionally, the use of self-reported measures such as the SUS and the custom cognitive load questionnaire may introduce response biases. Future research could address these limitations by employing a fully randomized controlled trial and incorporating objective measures of cognitive load, such as eye-tracking or physiological monitoring (Grier, 2015).

RESULTS

The results of this study provide a comparative analysis of the usability and cognitive load experienced by students using cloud-based database services versus those using traditional local installations. Data was collected from 100 undergraduate students (50 in the experimental group using cloud-based services and 50 in the control group using local installations) through standardized questionnaires: the System Usability Scale (SUS) for usability and a custom-designed cognitive load questionnaire. The data was analyzed using descriptive and inferential statistics to identify significant differences between the two groups.

USABILITY RESULTS

The usability of the cloud-based and local database systems was assessed using the SUS, with scores ranging from 0 to 100. Higher scores indicate better usability. The mean SUS score for the experimental group (cloud-based services) was 82.4 (SD = 7.5), while the mean score for the control group (local installations) was 70.2 (SD = 8.1) (Figure 1). An independent samples t-test revealed that the difference in SUS scores between the two groups was statistically significant, $t(198) = 11.09$, $p < 0.001$, indicating that students found the cloud-based system significantly more usable than the traditional local installations. Table 1 provides a summary of the descriptive statistics for the SUS scores across both groups.

Table 1. Mean and standard deviation of SUS scores for experimental and control groups

Group	N	Mean SUS score	Standard deviation
Cloud-Based (Experimental)	50	82.4	7.5
Local (Control)	50	70.2	8.1

Further analysis of individual SUS items indicated that students in the experimental group rated the system as more integrated (Q5: “I found the various functions in this system were well integrated.”) and easier to use (Q3: “I thought the system was easy to use.”). These aspects contributed significantly to the overall higher usability score for the cloud-based system.

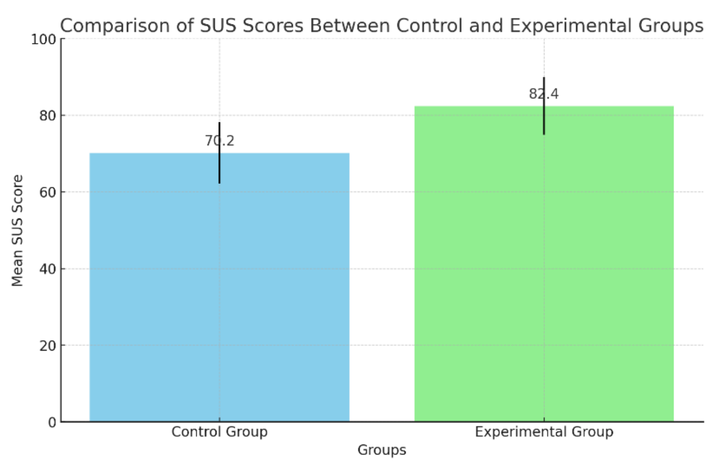

Figure 1. Comparison of System Usability Scale (SUS) scores between control and experimental groups

Cognitive Load Results

Cognitive load was measured using a 10-item questionnaire tailored to assess different dimensions of cognitive demand, such as clarity of instructions, perceived difficulty, and relevance of the tasks. Each item was rated on a 5-point Likert scale, with lower scores indicating lower cognitive load.

The mean cognitive load score for the experimental group was 2.8 (SD = 0.6), while the control group had a mean score of 3.6 (SD = 0.7) (Figure 2). The independent samples t-test showed a statistically significant difference in cognitive load between the two groups, $t(198) = -9.41$, $p < 0.001$, indicating that students using cloud-based services experienced significantly lower cognitive load compared to those using local installations. Table 2 summarizes the descriptive statistics for the cognitive load scores across both groups.

Table 2. Mean and standard deviation of cognitive load scores for experimental and control groups

Group	N	Mean cognitive load score	Standard deviation
Cloud-Based (Experimental)	50	2.8	0.6
Local (Control)	50	3.6	0.7

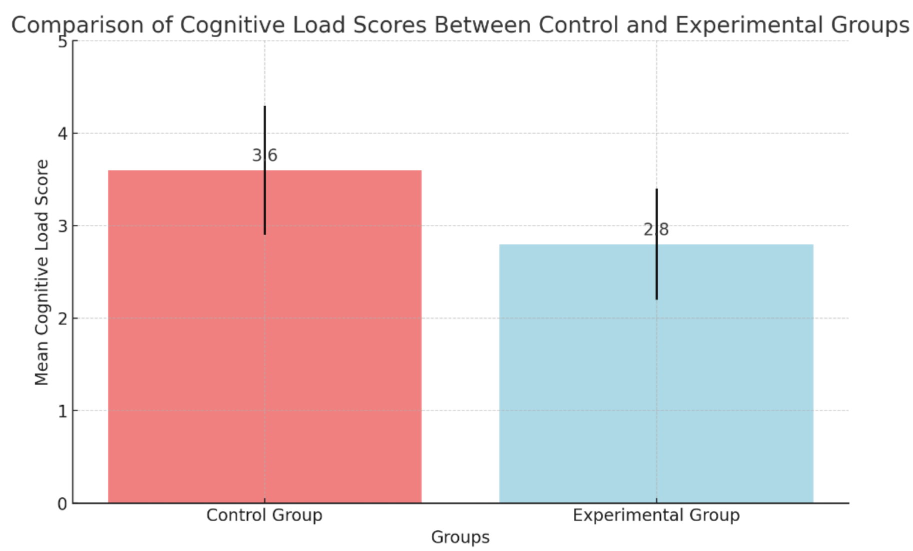

Figure 2. Comparison of cognitive load scores between control and experimental groups

The analysis of individual cognitive load items revealed that students in the experimental group reported greater clarity in instructions (Q1: "I think the instructions and guidelines for experimenting were clear.") and a stronger belief that the activity was useful for future projects (Q4: "I think this activity will be useful for the development of future projects with the tools presented.") compared to the control group. These findings suggest that the cloud-based environment not only reduced cognitive demand but also enhanced the perceived relevance and applicability of the tasks.

Correlation Between Usability and Cognitive Load

A Pearson correlation analysis was conducted to examine the relationship between usability and cognitive load within each group. In the experimental group, a significant negative correlation was found between SUS scores and cognitive load scores, $r(98) = -0.67$, $p < 0.001$, indicating that higher usability was associated with lower cognitive load. In contrast, the control group showed a weaker negative correlation, $r(98) = -0.42$, $p < 0.01$ (Figure 3).

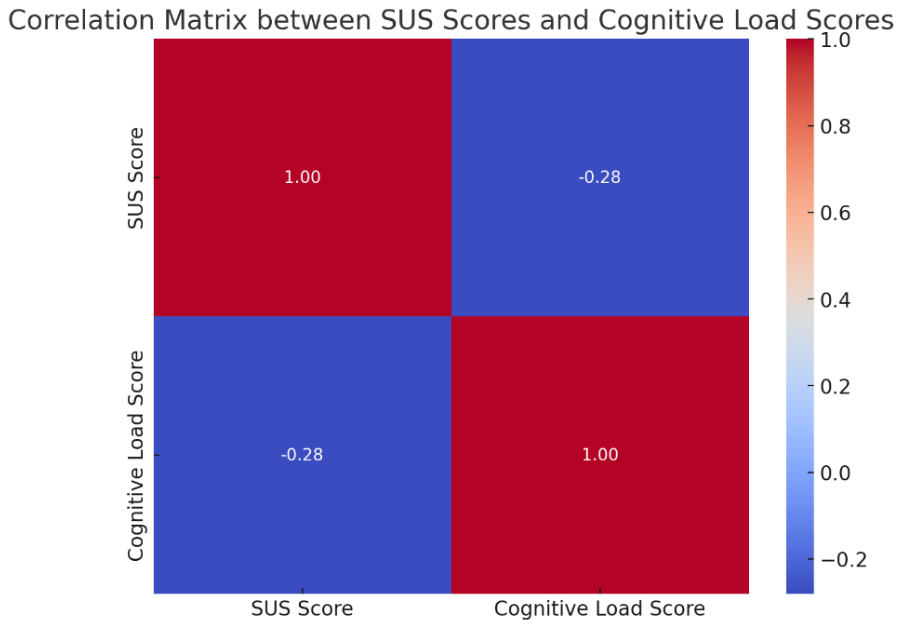

Figure 3. Correlation matrix between SUS scores and cognitive load scores

This suggests that the usability of the cloud-based system played a more substantial role in reducing cognitive load compared to the local installations. The higher correlation in the experimental group underscores the efficiency of cloud-based services in creating a more user-friendly and cognitively accessible learning environment.

The density plot of the commitment indicator scores for both the control and experimental groups provides a visual representation of the distribution of scores within each group. The plot clearly demonstrates that the experimental group, which utilized cloud-based database services, exhibited a higher concentration of scores towards the upper end of the scale compared to the control group, which used traditional local installations.

The experimental group's density curve is centered around a higher mean score, indicating that students in this group reported a stronger sense of commitment during the course activities. In contrast, the control group's scores are more spread out and centered around a lower mean, suggesting a lower overall commitment level.

This visual representation reinforces the statistical findings, where the experimental group scored higher on the commitment indicator and showed less variability in their responses. The increased commitment observed in the experimental group may be attributed to the enhanced usability and reduced cognitive load the cloud-based services provide, which likely facilitated a more engaging and supportive learning environment.

This evidence supports the conclusion that cloud-based services can significantly enhance student commitment, potentially leading to better learning outcomes and higher levels of student satisfaction.

The density plot in Figure 4 illustrates the distribution of commitment indicator scores for students in both the control and experimental groups. The plot provides a visual comparison, showing how frequently different levels of commitment were reported across the two groups.

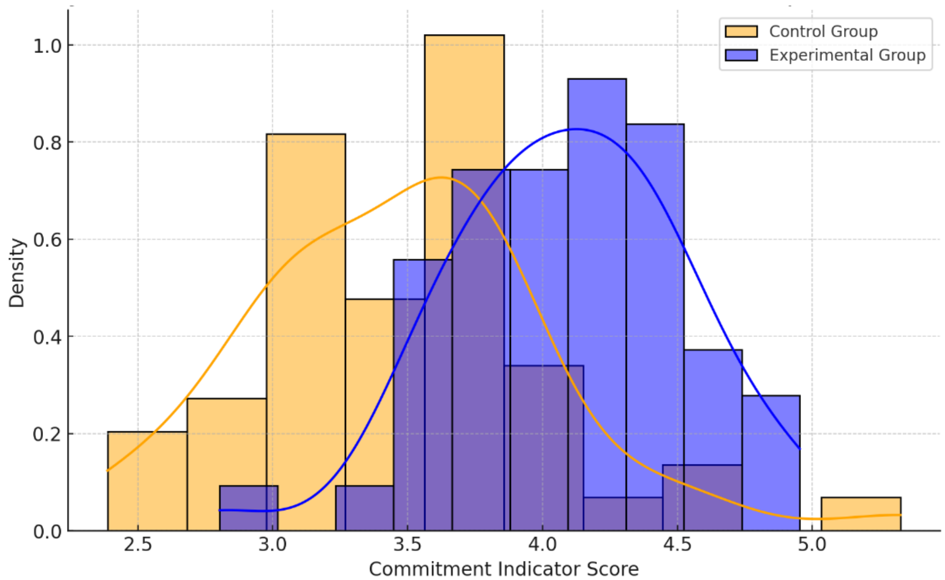

Figure 4. Density plot of commitment indicator scores for control and experimental groups

In the plot, the experimental group, which utilized cloud-based database services, shows a higher concentration of scores towards the upper end of the commitment scale. This indicates that students in this group generally reported higher levels of commitment during the course activities. The peak of the density curve for the experimental group is noticeably shifted to the right compared to the control group, suggesting that the cloud-based environment positively influenced students' engagement and commitment.

In contrast, the control group, which relied on traditional local installations, displays a more spread-out distribution with a lower peak. The density curve for the control group is centered around a lower mean score, indicating a wider variability in reported commitment and generally lower levels of engagement compared to the experimental group.

This visual evidence supports the hypothesis that cloud-based educational tools not only enhance usability and reduce cognitive load but also foster higher levels of student commitment, which is crucial for successful learning outcomes.

The density plot effectively highlights the difference in commitment between the two groups, reinforcing the advantages of using cloud-based services in educational settings.

The findings from this study clearly demonstrate that cloud-based database services provide a more usable and less cognitively demanding environment for students compared to traditional local installations. The significant differences in both SUS and cognitive load scores between the two groups highlight the advantages of adopting cloud technologies in educational settings, particularly in courses that require extensive use of complex software such as database systems.

Discussion

This study aimed to compare the effectiveness of cloud-based database services with traditional local installations in enhancing student learning outcomes in higher education, focusing on two key factors: usability and cognitive load. The findings provide clear answers to the research questions posed at the outset and offer significant insights into the implications of adopting cloud-based technologies in educational settings.

Research Question 1: How does the usability of cloud-based database services compare to traditional local installations in the context of higher education?

The results of this study indicate that cloud-based database services are significantly more usable than traditional local installations. The experimental group, which used cloud-based services, reported a mean SUS score of 82.4, significantly higher than the control group's mean score of 70.2. This finding aligns with previous research that has highlighted the enhanced usability of cloud-based platforms due to their user-friendly interfaces, ease of access, and reduced technical complexities (Li et al., 2022). The higher usability scores suggest that cloud-based systems are better integrated and more intuitive for students, allowing them to focus more on learning content rather than on managing the technical aspects of the software (Lewis & Sauro, 2018).

The significant difference in usability scores between the two groups underscores the potential of cloud-based services to improve the overall learning experience in database courses. Given that usability is a critical factor in educational technology, this finding supports the adoption of cloud technologies in higher education as a means to enhance student engagement and satisfaction (Okai-Ugbaje et al., 2020).

Research Question 2: What is the impact of cloud-based database services on the cognitive load experienced by students compared to traditional local installations?

The study also found that students using cloud-based database services experienced significantly lower cognitive load compared to those using traditional local installations. The mean cognitive load score for the experimental group was 2.8, while the control group reported a mean score of 3.6. This significant difference suggests that cloud-based systems are more effective in reducing the cognitive demands placed on students, allowing them to concentrate more on problem-solving and understanding the material rather than on overcoming technical obstacles (Sweller et al., 2011; Thavi et al., 2024).

These results are consistent with the cognitive load theory, which posits that reducing extraneous cognitive load – such as the mental effort required to navigate complex software – can free up cognitive resources for more meaningful learning. The lower cognitive load associated with cloud-based systems may also explain the higher usability scores, as students likely perceived the cloud platform as more supportive and less burdensome, thus enhancing their overall learning experience (Du et al., 2023).

The study further examined the relationship between usability and cognitive load and found a significant negative correlation in both groups. However, the correlation was stronger in the experimental group ($r = -0.67$) compared to the control group ($r = -0.42$). This suggests that the usability of the cloud-based system had a more pronounced effect on reducing cognitive load. This finding highlights the importance of usability in designing educational technologies that not only engage students but also reduce unnecessary cognitive strain, thereby optimizing learning outcomes (Mertler et al., 2021).

The stronger correlation in the experimental group indicates that cloud-based systems, by being more user-friendly, are more effective in minimizing the cognitive load experienced by students. This has important implications for educators and institutions considering the adoption of cloud-based platforms for teaching database systems and other complex subjects.

The findings from this study have several important implications for educational practice. First, the significantly higher usability and lower cognitive load associated with cloud-based systems suggest that these platforms can provide a more supportive and effective learning environment for students. Educators should consider integrating cloud-based technologies into their curricula, particularly in courses that require the use of complex software, such as database systems. This integration could lead to improved student engagement, satisfaction, and performance (Y.-P. Cheng et al., 2022).

Second, the strong correlation between usability and cognitive load emphasizes the need for educational technologies that are not only functional but also easy to use. Institutions should prioritize the adoption of platforms that reduce cognitive barriers, allowing students to focus on learning rather than on navigating the technology itself (Grier, 2015).

Finally, the results suggest that cloud-based systems can facilitate a more equitable learning experience by providing all students with access to the same high-quality tools and resources, regardless of their individual technical expertise or the capabilities of their personal hardware (Wu & Plakhtii, 2021). This could help level the playing field in courses that require extensive use of software, ensuring that all students have the opportunity to succeed.

The superior usability observed in cloud-based systems can be attributed to several specific features inherent to their design and functionality. One critical aspect is the intuitive user interface offered by platforms such as Google Cloud SQL. These interfaces are designed with user experience in mind, employing streamlined workflows, guided setup processes, and clear visual representations of database structures. These features reduce the complexity often associated with traditional local installations, enabling students to navigate tasks with minimal instruction. The accessibility of cloud-based systems, including compatibility with multiple devices and operating systems, further enhances usability by allowing students to work seamlessly from different locations without the need for extensive setup or configuration.

Another factor contributing to lower cognitive load in cloud-based systems is the seamless integration of various database management functions within a single platform. Tasks such as creating, querying, and maintaining databases are consolidated and automated to a significant extent, which reduces the extraneous cognitive demands on students. For instance, cloud platforms often provide real-time feedback and error diagnostics, enabling learners to identify and correct mistakes without extensive troubleshooting. Additionally, these systems typically include preconfigured security measures and performance optimization, eliminating the need for students to manage these aspects manually. This automation allows learners to focus on mastering fundamental concepts and practical applications rather than being overwhelmed by technical minutiae.

These design and functionality elements not only explain the enhanced usability and reduced cognitive load observed in this study but also highlight the potential of cloud-based platforms to create a supportive learning environment. By minimizing barriers to entry and technical challenges, these systems align well with pedagogical goals, enabling students to build competence and confidence in database management. Future research should investigate how specific design elements of cloud platforms can be further optimized to enhance educational outcomes, particularly in complex technical fields.

The findings of this study align with broader research on the use of cloud-based tools in other STEM fields, highlighting the universal benefits of these platforms in technical education. For example, Bilgin and Alper (2022) demonstrated that cloud-based blended learning environments in computer science courses improved student achievement and reduced cognitive load by simplifying the technical setup process and enabling focused engagement with learning tasks. Similarly, Abichandani et al. (2019) explored the application of cloud-based virtual reality systems in solar energy education. These tools increased student motivation and conceptual understanding by offering intuitive interfaces and interactive simulations. These parallels suggest that the advantages observed in this study – enhanced usability and lower cognitive load – may extend beyond database systems to other disciplines where technical complexity can impede learning.

Contrasting these findings with research on cognitive load in different educational contexts further underscores the unique role of cloud-based tools in STEM education. Tawfik et al. (2023) explored the interplay between usability and cognitive load in data science education, noting that platforms with intuitive design and integrated features reduced extraneous cognitive demands and improved problem-solving skills. However, studies in more traditional learning environments, such as those by Sweller et al. (2011), highlight the persistent challenges of balancing cognitive load when students are required to manage complex technical tasks independently. This contrast reinforces the value of cloud-based tools in minimizing these barriers, enabling students to focus on essential learning objectives while gradually building technical competence.

By drawing these parallels and contrasts, this study contributes to the growing discourse on the effectiveness of cloud-based tools in education. The findings not only validate existing research but also extend the understanding of how such tools can be tailored to optimize usability and cognitive load across various technical disciplines. Future studies could further explore these comparisons, investigating whether the observed benefits vary depending on the complexity of the technical tasks and the level of student expertise.

The long-term effects of using cloud-based systems in database education extend beyond immediate usability and cognitive load benefits, influencing students' career readiness and adaptability to diverse database environments. Familiarizing students with cloud-based platforms, such as Google Cloud SQL, equips them with practical skills that align with industry trends where cloud technologies are increasingly prevalent. However, reliance on these platforms may impact students' ability to work with traditional on-premises database systems, potentially limiting their versatility in handling diverse technical environments. This duality suggests a need for balanced curricula that incorporate both cloud-based and local systems, ensuring that students gain comprehensive exposure to different database technologies. Furthermore, the integration of cloud platforms into teaching methods could transform how database courses are delivered, promoting more collaborative, project-based learning while reducing technical barriers. Future research should explore these long-term implications to optimize the design of database education for both immediate learning outcomes and future professional success.

While the findings of this study are compelling, there are some limitations that should be acknowledged. The quasi-experimental design, while suitable for educational research, may introduce selection bias due to the non-random assignment of participants. Additionally, the use of self-reported measures, such as the SUS and cognitive load questionnaire, may be subject to response biases.

Future research could address these limitations by employing a fully randomized controlled trial and incorporating objective measures of cognitive load, such as eye-tracking or physiological monitoring. Additionally, longitudinal studies could explore the long-term impact of using cloud-based systems on student learning outcomes and retention of knowledge.

CONCLUSION, LIMITATIONS, AND FUTURE WORK

This study aimed to evaluate the effectiveness of cloud-based database services compared to traditional local installations in terms of usability and cognitive load within a higher education context. The findings demonstrate that cloud-based services significantly enhance the usability of database systems and reduce cognitive load for students, leading to a more supportive and efficient learning environment. The experimental group, which utilized cloud-based services, reported higher SUS scores and lower cognitive load scores than the control group using local installations. These results highlight the potential benefits of adopting cloud-based technologies in educational settings, particularly for courses that involve complex software applications like database systems. The strong negative correlation between usability and cognitive load further underscores the importance of user-friendly technologies in optimizing learning outcomes.

While the results of this study are promising, several limitations should be acknowledged. First, the quasi-experimental design, although appropriate for the educational context, may introduce selection bias due to the non-random assignment of participants. The use of convenience sampling, while practical, may also limit the generalizability of the findings to broader populations. Additionally, the reliance on self-reported measures, such as the System Usability Scale (SUS) and the custom cognitive load questionnaire, introduces the possibility of response biases. Students' perceptions of usability and cognitive load may not fully capture the objective effectiveness of the systems being compared.

Furthermore, the study was conducted within a single course at one university, which may limit the applicability of the findings across different educational settings and disciplines. The relatively short duration of the study (12 weeks) may not fully capture the long-term effects of using cloud-based services on learning outcomes and knowledge retention.

Future research should address the limitations identified in this study by employing a fully randomized controlled trial to minimize selection bias and improve the robustness of the findings. Additionally, future studies could benefit from incorporating objective measures of cognitive load, such as eye-tracking or physiological monitoring, to complement self-reported data and provide a more comprehensive assessment of student experiences.

Longitudinal studies are also needed to explore the long-term impact of cloud-based database services on student learning outcomes, retention of knowledge, and overall academic performance. Expanding the research to include multiple courses across different disciplines and educational institutions would help determine the generalizability of the findings and provide insights into the broader applicability of cloud-based technologies in education.

Moreover, exploring the integration of cloud-based services with other emerging educational technologies, such as artificial intelligence and adaptive learning platforms, could reveal additional benefits and challenges. Investigating how these technologies can be combined to enhance usability further and reduce the cognitive load in complex learning environments would be a valuable area of research.

In conclusion, while cloud-based database services offer clear usability and cognitive load advantages, ongoing research is essential to fully understand their potential and guide their effective implementation in educational settings.

REFERENCES

Abichandani, P., Mcintyre, W., Fligor, W., & Lobo, D. (2019). Solar energy education through a cloud-based desktop virtual reality system. *IEEE Access*, *7*, 147081-147093. https://doi.org/10.1109/ACCESS.2019.2945700

Alam, A. (2023). Cloud-based e-learning: Scaffolding the environment for adaptive e-learning ecosystem based on cloud computing infrastructure. In S. C. Satapathy, J. C. W. Lin, L. K. Wee, V. Bhateja, & R. M. Rajesh (Eds.), *Computer communication, networking and IoT* (pp. 1-9). Springer. https://doi.org/10.1007/978-981-19-1976-3_1

Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of Usability Studies*, *4*(3), 114-123.

Bilgin, M. M., & Alper, A. (2022). The effects of a cloud-based blended learning environment on students' achievement, persistence and cognitive load. *Kastamonu Education Journal*, *30*(4), 728-746. https://doi.org/10.24106/kefdergi.789730

Brooke, J. (1996). *SUS: A "quick and dirty" usability scale*. In P. W. Jordan, B. Thomas, I. L. McClelland, & B. Weerdmeester (Eds.), *Usability evaluation in industry*. Taylor and Francis.

Cheng, Y.-M. (2020). Students' satisfaction and continuance intention of the cloud-based e-learning system: Roles of interactivity and course quality factors. *Education + Training*, *62*(9), 1037-1059.

Cheng, Y.-P., Shen, P.-D., Hung, M.-L., Tsai, C.-W., Lin, C.-H., & Hsu, L. C. (2022). Applying online content-based knowledge awareness and team learning to develop students' programming skills, reduce their anxiety, and regulate cognitive load in a cloud classroom. *Universal Access in the Information Society*, *21*, 557-572. https://doi.org/10.1108/ET-10-2019-0245

Du, X., Dai, M., Tang, H., Hung, J. L., Li, H., & Zheng, J. (2023). A multimodal analysis of college students' collaborative problem solving in virtual experimentation activities: A perspective of cognitive load. *Journal of Computing in Higher Education*, *35*(2), 272-295. https://doi.org/10.1007/s12528-022-09311-8

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1-4. https://doi.org/10.11648/j.ajtas.20160501.11

Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). Sage.

Grier, R. A. (2015). How high is high? A meta-analysis of NASA-TLX global workload scores. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *59*(1), 1727-1731. https://doi.org/10.1177/1541931215591373

Gutiérrez-Carreón, G. (2020). Benefits of cloud services in education: A perspective of database system students. *Proceedings of the First International Computer Programming Education Conference*, *81*, 13:1-13:7.

Leavy, P. (2022). *Research design: Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches.* Guilford Publications.

Lewis, J. R., & Sauro, J. (2018). Item benchmarks for the system usability scale. *Journal of Usability Studies*, *13*(3), 158-167.

Li, G., Dong, H., & Zhang, C. (2022). Cloud databases: New techniques, challenges, and opportunities. *Proceedings of the VLDB Endowment*, *15*(12), 3758-3761. https://doi.org/10.14778/3554821.3554893

Maciejewski, M. L. (2020). Quasi-experimental design. *Biostatistics & Epidemiology*, *4*(1), 38-47. https://doi.org/10.1080/24709360.2018.1477468

Mertler, C. A., Vannatta, R. A., & LaVenia, K. N. (2021). *Advanced and multivariate statistical methods: Practical application and interpretation.* Routledge. https://doi.org/10.4324/9781003047223

Odeh, M., Warwick, K., & Garcia-Perez, A. (2015). The impacts of cloud computing adoption at higher education institutions: A SWOT analysis. *International Journal of Computer Applications*, *127*(4), 15-21. https://doi.org/10.5120/ijca2015906367

Okai-Ugbaje, S., Ardzejewska, K., Imran, A., Yakubu, A., & Yakubu, M. (2020). Cloud-based m-learning: A pedagogical tool to manage infrastructural limitations and enhance learning. *International Journal of Education and Development using Information and Communication Technology*, *16*(2), 48-67.

Qasem, Y. A., Abdullah, R., Jusoh, Y. Y., Atan, R., & Asadi, S. (2019). Cloud computing adoption in higher education institutions: A systematic review. *IEEE Access*, *7*, 63722-63744. https://doi.org/10.1109/ACCESS.2019.2916234

Shorfuzzaman, M., Alelaiwi, A., Masud, M., Hassan, M. M., & Hossain, M. S. (2015). Usability of a cloud-based collaborative learning framework to improve learners' experience. *Computers in Human Behavior*, *51*, 967-976. https://doi.org/10.1016/j.chb.2014.10.002

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory.* Springer. https://doi.org/10.1007/978-1-4419-8126-4

Tawfik, A. A., Payne, L. A., Olney, A. M., & Ketter, H. (2023). Exploring the relationship between usability and cognitive load in data science education. *The Journal of Applied Instructional Design*, *12*(3). https://doi.org/10.59668/515.13078

Thavi, R., Jhaveri, R., Narwane, V., Gardas, B., & Jafari Navimipour, N. (2024). Role of cloud computing technology in the education sector. *Journal of Engineering, Design and Technology*, *22*(1), 182-213. https://doi.org/10.1108/JEDT-08-2021-0417

Wu, W., & Plakhtii, A. (2021). E-learning based on cloud computing. *International Journal of Emerging Technologies in Learning*, *16*(10), 4-17. https://doi.org/10.3991/ijet.v16i10.18579

AUTHOR

Gustavo Gutiérrez Carreón is an associate professor of Information Technology Management at the UMSNH, Mexico. He holds a PhD in Information and Knowledge Societies from the Open University of Catalonia, Barcelona, Spain. He holds a master's in Electronics and Computer Science from INAOE, Mexico, and a bachelor's in electronic engineering from the Technological Institute of Morelia, Mexico. His research interests are Learning Analytics, Cloud Learning Applications, Online Teaching Laboratories, and Internet of Things Applications.