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Original article

Innovative strategies in teaching programming languages with MATLAB to university students

Estrategias innovadoras en la enseñanza de lenguaje de programación con MATLAB en estudiantes universitarios

Estratégias inovadoras no ensino de linguagens de programação com MATLAB para estudantes universitários

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ABSTRACT

In the teaching-learning process, the use of different didactic tools that promote and improve learning in students at various educational levels is key. The objective of this article was to determine the influence of using MATLAB as a didactic tool on the development of meaningful learning in programming language courses for university students. The research design adopted a quantitative, descriptive, quasi-experimental approach, which included a pre- and post- test for two groups (control and experimental). Fifty-four students from two classrooms of 27 students each (control and experimental groups) at a university located in the central region of Peru participated. The study was conducted over 16 weeks, using MATLAB software as the didactic tool for the experimental group, while the control group received traditional instruction. The results indicate statistically significant differences between the pre- and post-tests for both groups, with the experimental group achieving a better score (15.111) compared to the control group (12.593). For hypothesis testing, the Mann-Whitney U test indicated a statistical significance of less than 0.05, demonstrating the effectiveness of using MATLAB software as a teaching tool. Finally, the use of MATLAB software as a teaching tool in the learning process fosters the development of meaningful learning, promoting consistency and understanding among students.

Keywords: meaningful learning; teaching tool; MATLAB; programming language.

RESUMEN

En los procesos de enseñanza-aprendizaje es clave el uso de diferentes herramientas didácticas que promuevan y mejoren los aprendizajes en estudiantes de los distintos niveles educativos. El objetivo de este artículo consistió en determinar la influencia del uso de MATLAB como herramienta didáctica en el desarrollo de aprendizajes significativos en las asignaturas de lenguajes de programación en estudiantes universitarios. El diseño de la investigación adoptó un enfoque cuantitativo de tipo descriptivo, cuasiexperimental, que incluyó una evaluación de pre y postest para dos grupos (control y experimental). Participaron 54 estudiantes de dos salones de 27 estudiantes cada uno (grupo control y experimental) de una universidad ubicada en la región central del Perú. El trabajo fue desarrollado en 16 semanas, empleando como herramienta didáctica para el grupo experimental el software MATLAB, mientras que el grupo control recibió clases tradicionales. Los resultados indican que existen diferencias estadísticas significativas entre el pre y postest para ambos grupos, con un mejor resultado en el grupo experimental (15,111) frente al grupo Control (12,593). Para el contraste de hipótesis la prueba de U de Mann Whitney indicó una significancia estadística menor a 0,05 evidenciando la efectividad del uso del software MATLAB como herramienta didáctica. Finalmente, el uso del software MATLAB como herramienta didáctica en el proceso de enseñanza favorece el desarrollo de aprendizajes significativos promoviendo una consistencia y comprensión de los estudiantes.

Palabras clave: aprendizaje significativo; herramienta didáctica; MATLAB; lenguaje de programación.

RESUMO

Nos processos de ensino e aprendizagem, o uso de diferentes ferramentas didáticas que promovam e aprimorem a aprendizagem de estudantes em diversos níveis educacionais é fundamental. O objetivo deste artigo foi determinar a influência do uso do MATLAB como ferramenta didática no desenvolvimento de uma aprendizagem significativa em cursos de linguagem de programação para estudantes universitários. A pesquisa adotou uma abordagem quantitativa, descritiva e quase-experimental, que incluiu um pré-teste e um pós-teste para dois grupos (controle e experimental). Participaram 54 estudantes de duas turmas de 27 alunos cada (grupos controle e experimental) de uma universidade localizada na região central do Peru. O estudo foi conduzido ao longo de 16 semanas, utilizando o software MATLAB como ferramenta didática para o grupo experimental, enquanto o grupo controle recebeu instrução tradicional. Os resultados indicam diferenças estatisticamente significativas entre as pontuações do pré-teste e do pós-teste para ambos os grupos, com o grupo experimental (15.111) apresentando melhores resultados do que o grupo controle (12.593). O teste U de Mann-Whitney para teste de hipóteses mostrou uma significância estatística inferior a 0,05, demonstrando a eficácia do uso do software MATLAB como ferramenta de ensino. Finalmente, o uso do software MATLAB como ferramenta de ensino no processo de aprendizagem fomenta o desenvolvimento de uma aprendizagem significativa, promovendo consistência e compreensão entre os alunos.

Palavras-chave: aprendizagem significativa; ferramenta de ensino; MATLAB; linguagem de programação.

INTRODUCTION

The use of technological resources and digital tools, such as MATLAB software, as teaching and learning tools in higher education are essential in teaching practice, improving students' academic performance (Arce *et al.,* 2024; Puji & Rahmawati, 2018; Tsai, 2019). Furthermore, it positively impacts learning, engagement, motivation, and content retention (Coelho *et al.,* 2023), facilitating participatory learning of programming languages (Sibbaluca *et al.,* 2020).

The teaching methods for programming languages have become a tangible problem in higher education (Tsai, 2019). The problem is quite serious, not only because of the difficulties it presents for students, but also because of the frustration that can result from failing and/or repeating the course, and ultimately, academic dropout (Narváez *et al.,* 2023; Tsai, 2019). Computer programming is difficult for beginners, and, as Winslow (1996) indicates, it is generally accepted that it takes about 10 years of practice to transform a novice into an expert programmer.

For these reasons, introductory programming language courses should be motivating, fun, and easy to understand (Campbell & Atagana, 2022); however, current evidence indicates that introductory courses are often the opposite. Another alternative, implemented in many other universities, is to offer introductory programming language courses that also enhance logical reasoning skills (Narváez *et al.,* 2023). This would provide students with the necessary knowledge to enter programming language courses with sufficient preparation.

In this sense, the problem has been posed as: to verify how the use of MATLAB as a didactic tool influences the development of meaningful learning in programming language subjects in university students; proposing as an alternative for improving the learning of programming languages of university students the use of the MATLAB software as a teaching tool.

One strategy implemented in this work is to integrate the use of MATLAB software into the development of programming language learning sessions to improve the insight and skills of university students, as mentioned by Puji and Rahmawati (2018). MATLAB was used because it allows the creation of algorithms more easily and quickly than conventional programming languages such as C, C++, or Fortran, without requiring variable declaration, memory allocation, or code compilation. Therefore, MATLAB is considered a unique, versatile, and essential tool in various fields of application (Niazai). *et al.,* 2023).

During the learning sessions, the influence of MATLAB's graphical interface was observed, improving and promoting student learning, as well as enhancing the teaching processes of instructors, resulting in an interactive learning module (Velasquez -Alarcón *et al.,* 2023). Considering the importance and preference for using MATLAB in the development of classes for different subjects, it constitutes a fundamental tool for teaching at the university level (Niazai). *et al.,* 2023; Velasquez -Alarcón *et al.,* 2023).

The research follows a quasi-experimental design with pre- and post-tests, as these can produce similar or greater educational benefits than other designs (Pan & Sana, 2021). A questionnaire with dichotomous scoring (correct answer = 1 point, incorrect answer = 0 points) is used as the instrument to measure the variation in students' knowledge, as suggested by Mendoza *et al.* (2012).

Ergash `s work *et al.* (2024), the findings demonstrate that the use of educational software such as MATLAB in the teaching and learning processes of programming contributes significantly to student learning, but it must be complemented with traditional teaching methods and adapted to the levels and needs of the students.

A significant challenge in engineering education today is incorporating and enhancing logical reasoning and programming skills for problem-solving and programming during professional training. Therefore, this study proposes to determine the influence of using MATLAB as a teaching tool on the development of meaningful learning in programming language courses for university students, through an approach focused on developing algorithms as a teaching tool for programming languages with MATLAB.

MATERIALS AND METHODS

A total of 54 students from two classrooms (27 students per classroom) in the fourth semester of an engineering program at a university in central Peru participated in the study. The majority of the students were from this region, although a small number came from other parts of the country. The sample was selected using non-random, purposive convenience sampling, choosing two classrooms that were taking a Programming Language course. The aim of the study was to determine the influence of using MATLAB as a teaching tool on the development of meaningful learning in programming language courses for university students.

The activities were carried out during the 2024-II semester, over 16 weeks, using MATLAB software as a teaching and learning tool in one classroom (experimental group), while the traditional teaching methodology was continued in the other (control group). Each student used their own computer, specifically a laptop, which met the software requirements in terms of operating system, processor, hard drive, RAM, and graphics card for installation and operation.

Data collection involved a 20-question assessment based on a dichotomous scoring system (correct answer = 1 point, incorrect answer = 0 points). This assessment was designed to evaluate students' knowledge of programming languages and, when administered at two specific points in time, provided a measurement of knowledge variation. The questionnaire was validated through expert review. Five experts assessed the questionnaire as applicable, according to Aiken's V test. Reliability was confirmed through a pilot test administered to 15 students in the same academic year but from a different major who were also taking the programming language course. Cronbach's alpha test was used to determine reliability.

The data collection procedures included an ethical declaration; therefore, the research project was reviewed and approved by the university where the researchers work, and with full knowledge of the institution's code of ethics, they submitted and accepted the corresponding commitment. Likewise, at the beginning of the academic term, and as part of the testing protocols, the research project was presented, and each student was given an informed consent form to sign in order to be included in the study.

Data collection began during the first week of the academic semester, at which time informed consent was obtained from the participants. A socioeconomic questionnaire was administered, and the necessary adjustments were made to the computer lab for the practical sessions. After five weeks of learning sessions, the pre-test questionnaire was administered to both the experimental and control groups. Up to that point, the learning sessions used MATLAB as a teaching tool for the experimental group, while the traditional teaching model was used for the control group. At the end of week 15 of the semester, the post-test was administered, consisting of a similar questionnaire with 20 dichotomous questions.

Descriptive and inferential statistical tools were used to analyze the research data. Descriptive statistics included calculating percentages, means, and standard deviations, selected based on the nature of the data. Inferential analysis employed the Mann-Whitney U test to test the hypotheses posed in the research. The significance level established for this analysis was 0.05.

RESULTS

The composition of the study groups is shown in Table 1. The 54 participants (27 in each group) consisted of 27.8% female students and 72.2% male students. In the control group, eight participants were female (29.6%) and 19 were male (70.4%); while in the experimental group, seven participants were female (25.9%) and 20 were male (74.1%). The gender distribution within each group was similar, with a marked predominance of male participants (Table 1).

Table 1. Cross-tabulation of sex vs. group for experimental and control groups

			Cluster		**Total**
			Control	**Experimental**	
Sex	**Female**	**Count**	8	7	15
		% within group	29.6%	25.9%	27.8%
	Male	**Count**	19	20	39
		% within group	70.4%	74.1%	72.2%
Total		**Count**	27	27	54
		% within group	100.0%	100.0%	100.0%

The descriptive statistics are summarized in Table 2. The control group had an average of 7,074 points and the experimental group a slightly higher average of 7,815 for the pretest assessment. However, in the post-test assessment, the control group obtained an average of 12,593 points and the experimental group 15,111 points, which could indicate that the methodology used in the experimental group may have had a more marked positive effect (Table 2).

Table 2. Descriptive statistics for the experimental and control groups

Statistical	Pretest		Posttest	
	Control group	Experimental group	Control group	Experimental group
Valid	27	27	27	27
Lost	0	0	0	0
Average	7,074	7,815	12,593	15,111
Standard deviation	1,141	1,111	1,394	1,219

Regarding the standard deviation in the pre-test, they show a similar moderate deviation (1.141 for the control group and 1.111 for the experimental group), meaning that the scores have very little dispersion around the average. Likewise, in the post-test, the control group obtained a standard deviation of 1.394 compared to 1.219 for the experimental group, indicating that this group had a more consistent response after the intervention.

Influence of the use of MATLAB on the development of meaningful learning in university students

Once the significant differences between the post-test and pre-test scores for the experimental and control groups were determined, the results were compared. According to these results, the average scores were 33.69 for the experimental group and 21.31 for the control group, indicating that the differences observed between the post-test and pre-test scores were greater in the experimental group.

Furthermore, the total sum of ranks was 909.50 for the experimental group and 575.50 for the control group, reinforcing the previous idea. However, although the data showed a difference in the average sums and ranks, it was necessary to verify whether these differences were statistically significant by analyzing the p-value; therefore, the Mann- Whitney U test was performed (Table 3).

The Mann-Whitney U statistic showed a value of 197,500, which reflects a significant difference in the ranks between both groups; in addition, as a complement, the Wilcoxon W statistic represents the sum of the ranks of the control group (575,500).

Similarly, the analysis yields a p-value of 0.003 < 0.05; that is, there are statistically significant differences between the control and experimental groups (Table 3).

Table 3. Mann-Whitney U test to check for differences between groups

Test statistic	Post-test - Pre-test Difference
Mann-Whitney U	197,500
Wilcoxon's W	575,500
Z	-2,920
p-value	0.003
a. Grouping variable: control and experimental group	

Based on this, it is possible to affirm that the use of MATLAB software has a significant influence on the development of meaningful learning in university students.

Improving programming data analysis with the use of MATLAB

The results indicate that the experimental group had an average range of 31.09 and the control group has an average range of 23.91, indicating that the differences observed between the post-test and pre-test measurements are greater in the experimental group.

Furthermore, the experimental group had a sum of ranks of 839.50 and the control group 645.50, reinforcing the previous idea. However, although the data showed a difference in the sums and average ranks, it was necessary to verify whether these differences were statistically significant by analyzing the p-value; therefore, the Mann- Whitney U test was performed (Table 4).

Table 4. Mann **-** Whitney U test to verify differences between groups for data analysis

Test statistic	Difference in data analysis
Mann-Whitney U	267,500
Wilcoxon's W	645,500
Z	-1,750
p-value	0.080
a. Grouping variable: control and experimental group	

The results indicate a value of 267,500 for the Mann-Whitney U statistic, which reflects the relative position of the ranks between the two groups, in addition as a complement the Wilcoxon W statistic represents the sum of the ranks of the control group (645,500).

Furthermore, the analysis yields a p-value of 0.08 > 0.05, indicating that there are no statistically significant differences between the groups.

Finally, it was determined that the use of MATLAB software does not significantly improve the analysis of programming data in university students.

The impact of using MATLAB is the construction of programming graphics

The results show that the experimental group has an average range of 24.13 and the control group 30.87, indicating that the differences observed between the post-test and pre-test measurements are greater in the experimental group.

Furthermore, the total sum of ranks for the experimental and control groups was 651.50 and 833.50 respectively, reinforcing the previous idea. However, although the data showed a difference in the sums and average ranks, it was necessary to verify whether these differences were statistically significant by analyzing the p-value; therefore, the Mann- Whitney U test was performed (Table 5).

Table 5. Mann-Whitney U test to verify differences between groups for graph construction

Test statistic	Difference in graph construction
Mann-Whitney U	273,500
Wilcoxon's W	651,500
Z	-1,646
p-value	0.100
a. Grouping variable: control and experimental group	

The results indicate a value of 273,500 for the Mann-Whitney U statistic, which reflects the relative position of the ranks between the two groups; in addition, as a complement, the Wilcoxon W statistic represents the sum of the ranks of the control group (651,500).

Similarly, the analysis yields a p-value of 0.1 > 0.05, indicating that there are no statistically significant differences between the control and experimental groups.

Based on this analysis, it was determined that the use of MATLAB does not significantly impact the construction of programming graphics in university students.

Effect of using MATLAB on calculations for learning programming languages

According to the results, the average ranges for the experimental and control groups were 33.13 and 21.87 respectively, indicating that the differences observed between the post-test and pre-test measurements are greater in the experimental group.

Furthermore, the total sum of ranks for the experimental and control groups were 894.50 and 590.50, respectively, which reinforces the previous idea. However, although the data showed a difference in the sums and average ranks, it was necessary to verify whether these differences were statistically significant by analyzing the p-value; therefore, the Mann- Whitney U test was performed (Table 6).

Table 6. Mann **-** Whitney U test to check for differences between groups for calculations

Test statistic	Difference for making calculations
Mann-Whitney U	212,500
Wilcoxon's W	590,500
Z	-2,661
p-value	0.008
a. Grouping variable: control and experimental group	

The results indicate a value of 212,500 for the Mann-Whitney U statistic, which reflects the relative position of the ranks between the two groups; in addition, as a complement, the Wilcoxon W statistic represents the sum of the ranks of the control group (590,500).

Similarly, the analysis yields a p-value of 0.008 < 0.05; that is, there are statistically significant differences between the control and experimental groups.

Based on this analysis, it was possible to indicate that the use of MATLAB has a significant effect on performing calculations for learning programming languages in university students.

DISCUSSION

The results obtained reinforce the value of educational tools such as MATLAB in the process of teaching programming languages to university students. The significant improvement observed in the post-test scores of the experimental group (15,111), compared to the control group (12,593), is consistent with previous studies that highlight the effectiveness of MATLAB software as a teaching tool for complex concepts, as noted by Chura *et al.* (2019).

Furthermore, the Mann-Whitney U test demonstrates statistically significant differences between the scores obtained in both the experimental and control groups. Therefore, it can be stated that using MATLAB software has a significant influence on the achievement of meaningful learning in university students, corroborating the results of similar studies such as those by Ergash. *et al.* (2024) and Puji and Rahmawati (2018) highlighted how the use of MATLAB in technical subjects, in addition to improving student performance, fosters greater confidence in students when tackling technical problems.

The reduction in score dispersion in the experimental group, evidenced by a lower standard deviation of 1.219 in the post-test compared to 1.394 in the control group, indicates that this methodology not only improves average results but also promotes a more homogeneous learning experience, as Campbell and Atagana (2022) argue, thus reducing comprehension gaps among students. These data also align with the findings of Tsai (2019) and Niazai. *et al.* (2023), who point out that visual and interactive tools increase students' self-confidence and understanding of topics initially perceived as difficult.

However, the limitations of this study must be considered. The sample was restricted to a single university and subject, which may limit the generalization of the findings. Furthermore, although significant improvements were observed, longitudinal studies would be needed to analyze the sustained effects of this methodology on advanced programming skills, as suggested by Pan and Sana (2021).

On the other hand, although the use of MATLAB showed a significant impact on the "calculation" dimension (p=0.008), no significant improvements were observed in the "data analysis" (p=0.080) or "graph construction" (p=0.10) dimensions, suggesting that the pedagogical design may need adjustments to address these learning areas, as recommended by Swancutt. *et al.* (2019).

In conclusion, it can be stated that the use of MATLAB promotes the achievement of meaningful learning in university students, and therefore its integration as a teaching tool improves academic results.

Although the experimental group showed slightly superior performance in the programming data analysis dimension, the effects were not statistically significant, suggesting that, while MATLAB facilitates certain aspects of analysis, its impact could depend on the pedagogical design employed or the complexity of the problems analyzed.

Furthermore, the analysis showed that there were no statistically significant differences in the programming graph construction dimension between the experimental and control groups, which may mean that in this area the intervention was not the most appropriate or that the students might require more time to master these specific skills.

Finally, the use of MATLAB had a significant effect on performing calculations for learning programming languages, demonstrating that the software is effective for teaching the logic and algorithms needed to solve mathematical and computational problems.

REFERENCES

Arce, F. J., Avilés, H., Valdez, M. D., & Corral, J. E. (2024). Centro de cómputo en un aula de educación primaria. *Mendive. Revista de Educación*, *22*(4). https://mendive.upr.edu.cu/index.php/MendiveUPR/article/view/3854

Campbell, O. O., & Atagana, H. I. (2022). Impact of a Scratch programming intervention on student engagement in a Nigerian polytechnic first-year class: Verdict from the observers. *Heliyon*, *8*(3), e09191. https://doi.org/10.1016/j.heliyon.2022.e09191

Chura, J. F., Limachi Viamonte, W. R., Soncco, W. M., & Chayña, O. (2019). Matlab Mobile as a Support Tool for The Performance of Students in Engineering. *2019 International Symposium on Engineering Accreditation and Education (ICACIT)*, 1-4. https://doi.org/10.1109/ICACIT46824.2019.9130340

Coelho, R. C., Marques, M. F. P., & de Oliveira, T. (2023). Mobile Learning Tools to Support in Teaching Programming Logic and Design: A Systematic Literature Review | Informatics in Education | Vilnius University Institute of Data Science and Digital Technologies. *Informatics in Education*, *22*(4), 589-612. https://doi.org/10.15388/infedu.2023.24

Ergash, Q. F., Gulruh, N., Malika, Q., Sevinch, A., & Tulqin, U. M. (2024). The Use of Educational Software and Tools for Teaching Programming. *International Journal of Innovative Science and Research Technology (IJISRT)*, *9*(10), 1981-1984. https://doi.org/10.38124/ijisrt/IJISRT24OCT1769

Mendoza, M., Miranda, J., Guillen, D., & Samalvides, F. (2012). Validación de una encuesta para medir conocimientos y creencias sobre epilepsia, en los padres de familia. *Revista Médica Herediana*, *23* (3), 160-165.

Narváez, L. E., Escalante, M., González, C. M., Miranda, C., & Canché, M. (2023). Propuesta metodológica para mejorar el desempeño académico de los estudiantes en fundamentos de programación. *Revista Iberoamericana para la Investigación y el Desarrollo Educativo*, *14*(27), 1-34. https://doi.org/10.23913/ride.v14i27.1714

Niazai, S., Rahimzai, A. A., & Atifnigar, H. (2023). Applications of MATLAB in Natural Sciences: A Comprehensive Review. *European Journal of Theoretical and Applied Sciences*, *1*(5). https://doi.org/10.59324/ejtas.2023.1(5).87

Pan, S. C., & Sana, F. (2021). Pretesting versus posttesting: Comparing the pedagogical benefits of errorful generation and retrieval practice. *Journal of Experimental Psychology: Applied*, *27*(2), 237-257. https://doi.org/10.1037/xap0000345

Puji, E., & Rahmawati, S. (2018). Integrating MATLAB in teaching linear programming at the university level. *International Journal on Teaching and Learning Mathematics*, *1*(2). https://doi.org/10.18860/ijtlm.v1i2.5882

Sibbaluca, B. G., Avila, V. E., & Militante, S. V. (2020). Coding Language-Based Multi-Platform Apps: Digital Learning Tools For Programming Language Courses - Consensus. *International Journal of Scientific & Technology Research*, *9*(4), 1313-1317.

Swancutt, L., Medhurst, M., Poed, S., & Walker, P. (2019). Making adjustments to curriculum, pedagogy and assessment. En *Inclusive Education for the 21st Century*. Routledge.

Tsai, C.-Y. (2019). Improving students' understanding of basic programming concepts through visual programming language: The role of self-efficacy. *Computers in Human Behavior*, *95*, 224-232. https://doi.org/10.1016/j.chb.2018.11.038

Velasquez-Alarcón, J. D., Mendez-Vergaray, J., Flores, E., Velasquez-Alarcón, J. D., Mendez-Vergaray, J., & Flores, E. (2023). Matlab en las aplicaciones de la matemática. *Horizontes. Revista de Investigación en Ciencias de la Educación*, *7*(31), 2555-2574.

Winslow, L. E. (1996). Programming pedagogy-A psychological overview. *SIGCSE Bull.*, *28*(3), 17-22. https://doi.org/10.1145/234867.234872

Conflict of interest

Authors declare no conflict of interests.

Authors' contribution

The authors participated in the design and writing of the article, in the search and analysis of the information contained in the consulted bibliography.