apertura Volumen 18, número 2, pp. 118-133 | Universidad de Guadalajara
http://doi.org/10.32870/Ap.v18n2.2898

Microlearning in Distance Robotics Education: Evidence from an Undergraduate Engineering Course

Microlearning en la enseñanza de robótica a distancia: evidencia de un curso universitario de ingeniería

Salvador González García* https://orcid.org/0000-0002-2418-8197
Gerardo Loreto Gómez** https://orcid.org/0000-0002-3960-8801
Jorge Rodríguez Arce*** https://orcid.org/0000-0003-0289-7061
Juan Pablo Cobá Juárez Pegueros**** https://orcid.org/0000-0001-7878-2346

Recepción del artículo: 30/03/2026 | Aceptación para publicación: 14/09/2026 | Publicación: 30/09/2026

ABSTRACT

This study analyzes the relationship between the use of microlearning and students' performance in an undergraduate robotics course delivered via distance learning. A total of 35 engineering students, enrolled in two pre-existing class groups, received the same theoretical and practical content on forward kinematics and the Denavit–Hartenberg method. Group A had access to complete recorded online sessions, whereas Group B worked with a microlearning-based instructional strategy that combined short videos focused on specific concepts and procedures with embedded reflection questions, focused synchronous discussions, and guided practice. Both groups also participated in synchronous sessions and practical activities supported by 3D simulations. At the end of the intervention, students completed the same remote assessment. The results showed that the group exposed to the microlearning-based strategy achieved higher performance in the overall exam, as well as in the theory and exercises sections, with large effect sizes. These findings suggest that organizing video-based content into short, focused instructional units is associated with better learning outcomes in distance robotics education, although the quasi-experimental design does not allow firm causal conclusions.

Keywords
Microlearning; Distance learning; Robotics education; Academic performance

RESUMEN

Este estudio analiza la relación entre el uso del microlearning y el desempeño académico de estudiantes de ingeniería en un curso de robótica impartido en modalidad a distancia. Un total de 35 estudiantes, inscritos en dos grupos de clase preexistentes, recibió el mismo contenido teórico y práctico sobre cinemática directa y el método de Denavit–Hartenberg. El grupo A tuvo acceso a las grabaciones completas de las sesiones en línea, mientras que el grupo B trabajó con una estrategia instruccional basada en microlearning que combinó microvideos centrados en conceptos y procedimientos específicos con preguntas de reflexión integradas, discusiones síncronas focalizadas y práctica guiada. Ambos grupos también participaron en sesiones síncronas y en actividades prácticas basadas en simulaciones 3D. Al final de la intervención, los estudiantes respondieron la misma evaluación de forma remota. Los resultados mostraron que el grupo expuesto a la estrategia basada en microlearning obtuvo un mejor desempeño en el examen global, así como en las secciones de teoría y de ejercicios, con tamaños del efecto grandes. Estos hallazgos sugieren que organizar el contenido audiovisual en unidades instruccionales breves y focalizadas se asocia con mejores resultados de aprendizaje en la enseñanza de robótica a distancia, aunque el diseño cuasiexperimental no permite establecer conclusiones causales definitivas.

Palabras clave
Microlearning; educación a distancia; enseñanza de la robótica; desempeño académico

SOBRE EL AUTOR

* Doctor en Ciencias en la Especialidad de Control Automático. Profesor asociado del Instituto Tecnológico y de Estudios Superiores de Monterrey Campus Hidalgo. ORCID: https://orcid.org/0000-0002-2418-8197, correo electrónico: sgg@tec.mx

** Doctor en Control automático por el Centro de Investigación y Estudios Avanzados del IPN (CINVESTAV). Profesor investigador del Tecnológico Nacional de Mexico/Instituto Tecnológico Superior de Urupan, Michoacan, México. ORCID: https://orcid.org/0000-0002-3960-8801, correo electrónico: gerardo.lg@uruapan.tecnm.mx

*** Doctor en Ingeniería Industrial por la Universidad de Navarra (España). Profesor investigador de la Facultad de Ingeniería de la Universidad Autónoma del Estado de México, México. ORCID: https://orcid.org/0000-0003-0289-7061, correo electrónico: jrodrigueza@uaemex.mx

**** Doctor en Ciencias de la Ingeniería por la Universidad Autónoma de Estado de México. Profesor de la Universidad Autónoma del Estado de México, México. ORCID: https://orcid.org/0000-0001-7878-2346, correo electrónico: jpc0683@gmail.com

INTRODUCTION

In recent years, higher education has experienced a sustained transformation driven by the expansion of digital technologies and the consolidation of online, blended, and distance learning modalities. This transformation has not only altered the technological means of delivering instruction but also raised important pedagogical questions about how educational content should be designed, organized, and delivered in virtual environments. Instructors are increasingly required to move beyond simply transferring face-to-face lectures to online platforms and instead develop learning experiences that are pedagogically effective, flexible, and responsive to the characteristics of contemporary learners. In this context, digital educational resources have become central elements in course design, particularly in subjects where conceptual understanding and procedural practice must be carefully articulated.

Among the many resources used in online education, instructional videos have become one of the most common tools for supporting teaching and learning. Videos allow instructors to explain theoretical concepts, demonstrate procedures, present worked examples, and offer asynchronous access to content that students can review at their own pace. In distance and online learning settings, videos can therefore function as substitutes for, or complements to, traditional lectures and written materials (Bower, 2017; Rackaway, 2010). Their value is especially evident in courses that involve step-by-step problem-solving or abstract processes that benefit from visual explanations. Furthermore, videos can increase flexibility for students, as they can be accessed anytime, anywhere, which is particularly relevant in higher education contexts where learners often need to combine formal study with other academic, personal, or professional responsibilities.

However, the educational effectiveness of videos depends not only on their availability but also on their instructional design. One of the most frequently discussed issues in literature is video length. Although recording and uploading complete online classes may appear to be a practical solution for providing access to content, long videos are often associated with reduced attention, lower motivation, and limited rewatching. Students may find it difficult to locate the specific concept they need to review when the material is

embedded in a long recording of an entire class session. Harrison (2020) reports that students often prefer shorter instructional videos, commonly between five and ten minutes, because these are easier to follow, more engaging, and more convenient for targeted reviews. This suggests that, in online education, the challenge is not merely to produce video content, but to structure it in ways that facilitate focused learning and efficient access to specific knowledge.

In this context, microlearning has emerged as a promising instructional approach for designing digital educational content. Microlearning is generally understood as a strategy that divides learning material into short, focused, and interconnected units that address a specific concept, skill, or procedure within a brief period (Giurgiu, 2017; Jomah *et al.*, 2016). Rather than presenting broad topics in lengthy lessons, microlearning emphasizes concise instructional units that can be consumed quickly and revisited easily. This approach is especially relevant in virtual learning environments, where students often need just-in-time access to knowledge and benefit from content that can be reviewed flexibly according to their immediate academic needs (Gabrielli *et al.*, 2006; Leong *et al.*, 2021).

Microlearning is generally understood as a strategy that divides learning material into short, focused, and interconnected units that address a specific concept, skill, or procedure within a brief period

The potential advantages of microlearning can be explained by well-established learning mechanisms. According to Cognitive Load Theory, learning is constrained by the limited capacity of working memory, and instructional designs that reduce unnecessary processing demands free cognitive resources for schema construction (Sweller *et al.*, 2019). Consistently, the segmenting principle of the Cognitive Theory of Multimedia Learning states that people learn more deeply from multimedia messages when these are presented in learner-paced segments rather than as a continuous unit (Mayer, 2021). Empirical evidence supports these mechanisms in video-based learning: segmenting educational videos into meaningful parts has been shown to reduce cognitive load and to improve engagement and academic achievement among distance learners compared with complete, single-piece videos (Altinpulluk *et al.*, 2020), and segmentation has proven particularly beneficial for procedural learning, helping novice learners build accurate representations of sequential procedures in memory (Biard *et al.*, 2018). In addition, short, self-contained units facilitate targeted, just-in-time review and support self-regulated learning, as students can identify and revisit exactly the content they need without searching through lengthy recordings (Taylor & Hung, 2022).

This theoretical rationale is consistent with recent syntheses of microlearning literature. The scoping review by Taylor and Hung (2022) reported generally positive effects of microlearning on learning and learner perceptions across academic and professional contexts. Alias and Razak (2023) systematically reviewed pedagogical practices of microlearning in higher education and identified content segmentation, clear learning objectives, and the integration of short assessments as recurring features of effective implementations. More directly related to the present study, the systematic review and meta-analysis by Senandheera *et al.* (2024), which synthesized twelve studies conducted in higher education, found that students

who learned through microlearning achieved significantly higher academic performance than students who learned through traditional long-format instruction, and identified the reduction of cognitive load, learning flexibility, and timely feedback as the main explanatory mechanisms. Finally, Monib *et al.* (2025) reviewed forty studies following PRISMA guidelines and proposed an instructional design framework for microlearning grounded in Cognitive Load Theory and Bloom's taxonomy, emphasizing bite-sized content, specific objectives, and interactive elements. Together, these reviews indicate that microlearning is a promising strategy in higher education, while also noting that further context-specific empirical evidence is still needed.

Students in digital environments frequently interact with content under fragmented time conditions and often need to revisit specific procedures or concepts rather than review an entire lesson from beginning to end. By organizing educational content into small, self-contained units, microlearning can support concentration, reduce cognitive overload, and enable more efficient information retrieval. Yildirim (2022) points out that microlearning may contribute to student motivation and better engagement, while other studies have reported benefits related to knowledge retention, confidence, and learning performance (De Gagne *et al.*, 2019; Mohammed *et al.*, 2018; Yin *et al.*, 2021). In addition, microlearning has shown potential across various educational fields, including technical education, health professions, and language learning, where content segmentation can support progressive mastery of complex material (Buhu & Buhu, 2019; Edge *et al.*, 2011).

Despite these promising findings, there remains a need for additional empirical evidence on how microlearning should be integrated into higher education courses, particularly in engineering subjects delivered via virtual or distance learning modalities. Much of the existing literature highlights the general advantages of short learning units, but fewer studies have examined

Students in digital environments frequently interact with content under fragmented time conditions and often need to revisit specific procedures or concepts rather than review an entire lesson from beginning to end

their impact in comparison with the more traditional practice of recording and sharing complete online sessions. This distinction is pedagogically relevant because it shifts the focus from the availability of technology to instructional organization. In other words, the question is not only whether videos are useful, but whether the way their content is segmented and managed is associated with students' academic performance.

This issue becomes especially significant in robotics education. Robotics is a core area in engineering programs such as mechatronics, electronics, and computer science, where students are expected to integrate mathematical reasoning, visualization skills, and analytical problem-solving to understand the behavior of robotic manipulators (Craig, 2009; Denavit & Hartenberg, 1965). Foundational topics such as the description of position and orientation of rigid bodies, homogeneous transformations, and forward kinematics often represent substantial challenges for students because they require both conceptual understanding and precise procedural application. These challenges may become even more pronounced in online or distance learning contexts, where students have fewer opportunities for spontaneous interaction and may rely

The aim of this study is to examine whether organizing instructional content into short, focused video units is associated with better academic performance compared with using full recorded sessions in a virtual robotics course

more heavily on asynchronous learning materials for reinforcement and review.

Previous work by the authors has shown that digital resources, such as 3D simulations, can effectively support the teaching of robotics. These studies reported that simulations help students visualize manipulator configurations, understand kinematic relationships, and connect theoretical content with practical applications (Loreto-Gómez *et al.*, 2018; González-García *et al.*, 2019; González-García *et al.*, 2020). Such findings suggest that the use of digital tools can strengthen robotics learning; however, they also point to the broader need to examine how different forms of content delivery relate to student learning in virtual settings. While simulations address visualization and interactive understanding, the pedagogical organization of video-based content remains a separate and equally relevant issue.

From this perspective, microlearning may offer specific advantages for robotics courses. Because many procedures in robotics, such as the Denavit-Hartenberg method, are sequential and conceptually dense, students may benefit from short videos focused on a single concept or step. This type of organization may allow them to identify gaps in understanding more quickly, revisit exact topics before solving exercises, and devote more time to practice rather than searching through long recordings. In contrast, complete session recordings may contain useful information, but their length and mixed content can make targeted review less efficient. Therefore, comparing these two approaches can provide meaningful evidence for the design of learning resources in engineering education.

Accordingly, the present study analyzes the relationship between the use of microlearning and students' performance in an undergraduate robotics course delivered via distance learning. Two groups of engineering students received the same theoretical and practical content on forward kinematics, including topics such as position and orientation of rigid bodies, homogeneous transformations, and the Denavit-Hartenberg convention. The main difference between the groups was the way video-based educational content was organized and delivered. One group had access to complete, recorded online sessions, whereas the other group worked with a microlearning-based instructional strategy built around short, focused videos. The aim of this study is to examine whether organizing instructional content into short, focused video units is associated with better academic performance compared with using full recorded sessions in a virtual robotics course. In this way, the study seeks to contribute empirical evidence to the discussion of the pedagogical value of microlearning for designing effective learning experiences in online engineering education.

METHODOLOGY

Participants

The study was conducted with 35 undergraduate engineering students enrolled in an introductory Robotics course delivered via distance learning at the same institution. The participants belonged to two pre-existing class groups (intact groups) that had been constituted by the institution before the

intervention and remained unchanged throughout the semester; therefore, students were not individually randomized to the experimental conditions. Instead, each class group was assigned to one of two conditions: Group A consisted of 18 students, while Group B consisted of 17 students. Both groups were taught by the same instructor and covered the same academic content during the intervention. The purpose of establishing two groups was to compare two approaches to managing and presenting video-based instructional content while keeping the remaining teaching conditions as equivalent as possible.

Because both groups belonged to the same institution, the same engineering program, and the same semester, their members had completed the same prerequisite coursework and followed the same curriculum, which provides indirect support for their comparability. However, no pretest or other direct measure of prior performance was administered before the intervention; consequently, the initial equivalence of the groups cannot be empirically verified. This aspect is acknowledged as a limitation of the study and is taken into account when interpreting the results.

All participants were taking the same course and studying the same unit of the syllabus related to the forward kinematics of robot manipulators. The topics addressed during the intervention included the description of the position and orientation of rigid bodies, rotation matrices, homogeneous transformations, and the Denavit-Hartenberg (DH) convention for calculating the forward kinematics of robotic manipulators. These topics are fundamental in robotics education because they provide a mathematical basis for describing and analyzing the motion of robot manipulators (Craig, 2009; Denavit & Hartenberg, 1965).

To ensure comparability between the two groups, the same instructor conducted all synchronous sessions and used the same instructional materials, including PowerPoint presentations, examples, exercises, and evaluation criteria. In both groups, the duration of the online sessions and the time devoted to theoretical explanation and practical problem-solving were the same. Thus, the main difference between the groups was not the content itself but how the video-based learning resources were organized and delivered to students.

Implementation

A quasi-experimental procedure was designed to examine the relationship between microlearning use and students' academic performance in a distance robotics course. Figure 1 shows the procedure and experimental groups. The intervention combined synchronous online sessions, asynchronous video resources, and practical activities supported by 3D simulations. In both groups, the course unit focused on forward kinematics and the application of the Denavit-Hartenberg method. The instructional design was organized so that both groups received the same theoretical and practical content, differing only in the format used to provide the video-based educational material.

The online working sessions lasted 2 hours in both groups. During these sessions, the same

Because both groups belonged to the same institution, the same engineering program, and the same semester, their members had completed the same prerequisite coursework and followed the same curriculum, which provides indirect support for their comparability

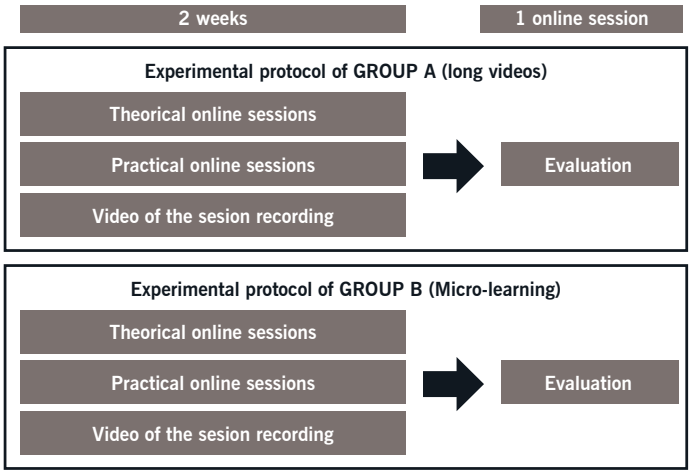


Figure 1. Procedure and experimental groups.

number of topics and exercises were addressed. In the theoretical part of the class, the instructor explained the mathematical foundations and conceptual procedures related to rigid-body position and orientation, homogeneous transformations, and forward kinematics. The explanation was supported by PowerPoint presentations, a virtual whiteboard, and worked examples. In the practical part of the class, students solved exercises proposed by the instructor, and the solutions were later reviewed and discussed with the whole group. This design was intended to ensure that the only relevant difference between the groups was the strategy used to present and manage the audiovisual content.

In Group A, the instructional strategy followed a more traditional approach for distance learning. The instructor delivered the online class synchronously, explained the topics in real time, and recorded the complete session. Each full session, approximately two hours long, was uploaded to the cloud so that students could watch it later as many times as necessary. In this way, students in Group A had access to complete class recordings as reinforcement material, while the videos preserved the original structure of the live session, including explanations, problem-solving, and feedback.

In Group B, the instructor implemented a microlearning approach. Instead of relying on complete session recordings, a set of short instructional videos was prepared and uploaded to the cloud. These microlearning videos lasted three to five minutes and were designed so that each addressed only one concept, procedure, or specific example related to forward kinematics. In total, 15 microlearning videos were produced to cover the intervention's instructional content. The topics included, among others, the introduction to the description of position and orientation of rigid bodies, rotation matrices, homogeneous transformation matrices, the definition of reference frames in robot manipulators, the parameters of the Denavit-Hartenberg method, the application of the DH method to compute forward kinematics, and the solution of example problems involving manipulators with different numbers of degrees of freedom.

Each microlearning video followed a consistent instructional structure. First, a brief introduction to the concept or problem was presented. Second, the theoretical concept or mathematical procedure was explained. Third, a short application example was developed. Finally, a brief question or exercise was included to encourage

reflection on the content presented. The criteria used to divide the content into micro-videos were the following: each video had to address a single concept or specific procedure, the explanation had to be delivered in no more than five minutes, a simple example had to be included, and the videos had to be organized sequentially so that each one progressively contributed to the understanding of the complete method.

The implementation procedure in Group B integrated both asynchronous and synchronous activities. Students first watched the micro-video corresponding to the topic to be studied, either during the online session or immediately before the synchronous discussion. After that, a short synchronous discussion of approximately 10 to 15 minutes was held, during which students could ask questions, make comments, and clarify doubts. The instructor also asked some students questions to verify their level of understanding. Subsequently, students solved exercises related to the topic presented in the video, and the instructor reviewed the solutions, explained the expected procedure, and provided feedback on the most common mistakes. This process was repeated iteratively until all scheduled topics for the session were covered.

It is important to emphasize that the condition implemented in Group B is best understood as a microlearning-based instructional strategy, and not merely as the use of shorter videos. In addition to content segmentation, the strategy included reflection questions embedded in each micro-video, short, focused synchronous discussions, and guided practice after each topic. Consequently, the results reported in this study refer to the strategy as a whole, and the observed differences between groups cannot be attributed exclusively to video length. This aspect is made explicit here and is further considered in the Discussion section.

In both groups, the practical sessions were supported by a 3D simulation platform developed by the authors in SimMechanics within Simulink. This platform allows students to model and analyze robotic manipulators with different configurations and degrees of freedom, define kinematic parameters, visualize robot motion, and verify forward-kinematics results. Previous studies by the authors have shown that such simulations can help students understand kinematic relationships and support robotics learning in engineering education (Loreto-Gómez *et al.*, 2018; González-García *et al.*, 2019; González-García *et al.*, 2020). In the present study, the simulations were used equally in both groups to reinforce the practical component of the course.

Assessment and grading

After two weeks of theoretical and practical sessions, students in both groups completed the same remote exam in order to evaluate their academic performance. The exam consisted of two problems involving the calculation of the forward kinematics matrix for two robot manipulators with different levels of complexity: a 2-DoF manipulator and a 5-DoF manipulator (see Figure 2). For each exercise, students were required to identify the number of links and joints, define the origin and coordinate axes, calculate the parameters d, θ, and α, and determine the corresponding rotation and translation transformations.

The exam was graded using a checklist-type scoring rubric that was identical for both groups. The rubric focused mainly on the methodological procedure followed to solve each problem (the correct identification of links and joints, the definition of reference frames, the computation of the Denavit-Hartenberg parameters, and the construction of the transformation matrices) rather than exclusively on the final numerical result, which carried a lower weight. This decision was made because the unit's instructional objective was for students to understand the theoretical concepts and apply them in the problem-solving procedure, which is difficult to assess in class alone. Each rubric item was graded on a scale

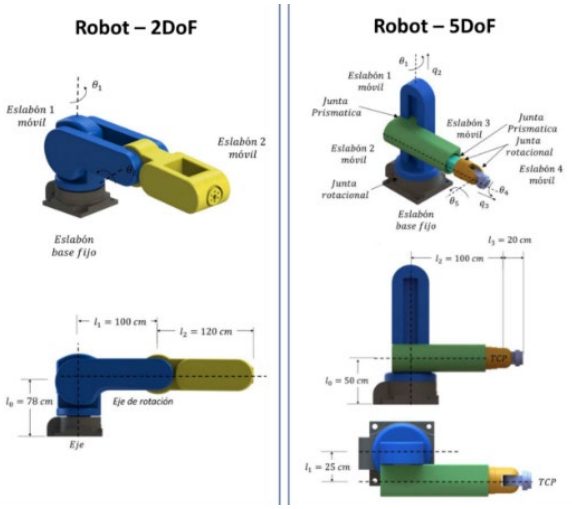


Figure 2. Participants of both experimental groups answered the same exam with two problems with different levels of complexity, 2DoF and 5DoF.

from 0 to 10, and the final grade for each student was calculated as the average of the scores obtained across all required elements, reported on a 0–100 scale.

The same instructor graded all the exams using the same rubric and the same criteria for both groups. Because the instructor also taught both groups, grading was not blind to group membership; this is acknowledged as a limitation in the corresponding section. To reduce the possibility of external assistance during the remote assessment, students were required to keep their webcams on during the exam and submit photographs of their procedures and calculations for each problem.

Data analysis

Academic performance was analyzed using descriptive statistics (means and standard deviations) for the overall exam score and for the theory and exercises sections separately. Group differences were examined using Welch's independent-samples t-test, which does not assume equal variances between groups, with a two-tailed significance level of $\alpha = .05$. For each comparison, the test statistic, degrees of freedom, the exact p-value, the 95% confidence interval of the mean difference, and Cohen's d as a measure of effect size are reported. Cohen's d was interpreted following the conventional benchmarks of 0.2 (small), 0.5 (medium), and 0.8 (large).

Qualitative observations

To complement the quantitative results, two sources of qualitative information were collected during the intervention. First, at the end of the course unit, students completed a brief online questionnaire (administered through Google Forms) about their experience with the video resources, including whether they perceived that the videos had helped them better understand the topics and how they had used them for review. Second, the instructor recorded field observations during the synchronous and practical sessions regarding students' participation, independence in problem-solving, and recurring difficulties. These qualitative data were gathered for exploratory purposes and did not follow a systematic qualitative

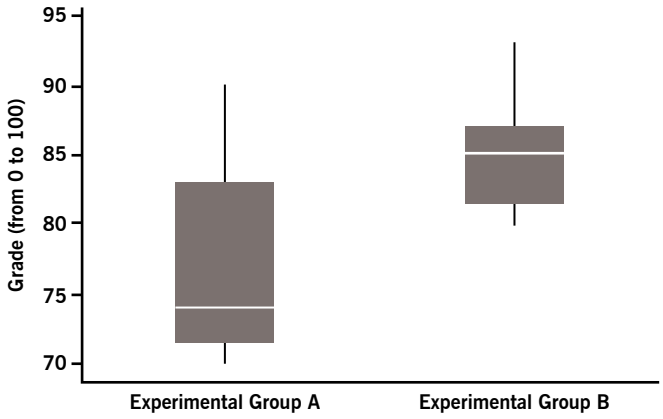


Figure 3. Boxplot of the exam evaluation.

research protocol; they are therefore reported as complementary observations that help contextualize the quantitative findings, rather than as formal qualitative evidence.

RESULTS

Quantitative results

The results of the study indicate that the group that received the instructional content through the microlearning-based strategy achieved better academic performance than the group that had access to complete recorded online sessions. After the two-week intervention, all students completed the same remote assessment on forward kinematics using the Denavit–Hartenberg method. The comparison of the final scores revealed a clear difference between the two experimental groups.

Students in Group A, who worked with full recorded sessions, obtained a mean score of 77 with a standard deviation of 7.17, whereas students in Group B, who used the microlearning-based strategy, obtained a mean score of 85 with a standard deviation of 3.76. The difference between the groups was statistically significant, with a large effect size (Welch's $t(26.0) = 4.17$, $p < .001$; 95% CI of the mean difference [4.05, 11.95]; Cohen's $d = 1.39$). These results indicate that, in the sample studied, organizing instructional content into short, focused videos as part of a microlearning-based strategy was associated with better overall performance on the evaluated robotics topics.

Figure 3 presents the boxplot of the final exam scores for both groups. As shown in the figure, the distribution of scores in Group B is not only higher in terms of central tendency but also more concentrated than in Group A. This pattern indicates that students exposed to the microlearning-based strategy tended to achieve better, more consistent results than those who had only access to the complete recordings of the online sessions.

In addition to the overall performance analysis, the results were also examined separately for the theory and exercises sections of the exam. This comparison was conducted to explore whether the use of microlearning was associated only with theoretical understanding or also with students' ability to solve forward kinematics problems. The results showed that Group B outperformed Group A in both components of the assessment, and the differences were statistically significant in both cases, with large effect sizes.

In the theory section, Group A obtained a mean score of 75 with a standard deviation of 7.68, while Group B obtained a mean of 84 with a standard deviation of 5.40 (Welch's $t(30.6) = 4.03$, $p < .001$;

95% CI [4.44, 13.56]; Cohen's d = 1.35). In the exercises section, Group A obtained a mean score of 77 with a standard deviation of 6.62, whereas Group B reached a mean of 87 with a standard deviation of 4.50 (Welch's $t(30.1) = 5.25$, $p < .001$; 95% CI [6.11, 13.89]; Cohen's d = 1.76).

Figure 4 shows the boxplots corresponding to the theory and exercises sections for both groups. In both sections, the scores of Group B are consistently higher than those of Group A. The difference is particularly relevant in the exercises section, where students were required to apply the Denavit–Hartenberg method step by step to manipulators of varying complexity. This result is important because it suggests that the microlearning-based strategy was associated not only with better conceptual understanding, but also with stronger procedural performance in problem-solving tasks.

Qualitative observations

The qualitative observations collected during the intervention, gathered through a brief end-of-unit questionnaire and the instructor's field notes (see Methodology), are consistent with these quantitative findings. Students in Group B indicated that the short videos encouraged them to review the material even when they did not have major doubts, and that the segmented format made it easier to identify the specific topics they had not fully understood during the synchronous sessions. Several students mentioned that this organization of the content allowed them to reinforce their knowledge more efficiently and spend more time on exercises rather than rewatching long recordings. They also expressed that they were not interested in investing time in lengthy videos when they only needed to review a specific concept or procedure.

The instructor's observations were consistent with the students' perceptions. Students in Group B appeared to identify the steps of the Denavit–Hartenberg method more quickly and made fewer mistakes when defining reference frames and determining the parameters required for forward kinematics calculations. During the practical sessions, these students also showed greater independence when solving exercises and participated more actively in the synchronous discussions. Because the theoretical explanations were already available in short videos, the synchronous meetings could be used more effectively to clarify doubts, review common errors, and guide problem-solving.

Taken together, the findings show a consistent advantage for the group that used the microlearning-based strategy in this particular course and sample. The students in this group obtained higher scores on the final assessment,

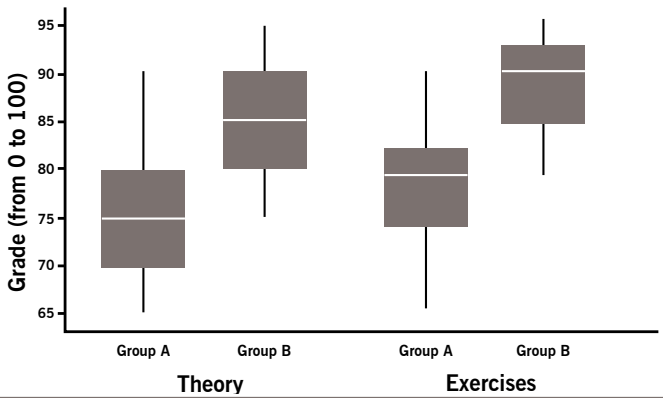


Figure 4. Boxplot of the evaluation of the theory and exercises sections.

higher performance in both theoretical and practical components, and more favorable qualitative observations regarding content review and problem-solving. These results provide empirical evidence of an association between organizing video-based content into short instructional units and academic performance in a distance-learning robotics course.

DISCUSSION

The findings suggest that using a microlearning-based instructional strategy is associated with significant pedagogical advantages in distance robotics education. Although both groups received the same theoretical explanations, solved the same exercises, worked with the same instructor, and used the same 3D simulation platform, the group that received the instructional content through short, focused videos achieved better performance than the group that relied on complete recorded sessions. This indicates that the difference was not simply due to content coverage but to how the content was structured and delivered. In this case, organizing the material into brief, specific units appear to have facilitated review of key concepts and procedures in forward kinematics and the DH method, which are often challenging for undergraduate engineering students.

These results are consistent with the theoretical mechanisms proposed in the literature. From the perspective of Cognitive Load Theory (Sweller *et al.*, 2019) and the segmenting principle of multimedia learning (Mayer, 2021), presenting content in short, self-contained units reduces unnecessary processing demands and allows students to allocate their cognitive resources to understanding each concept or procedure before moving to the next. The present findings also align with previous experimental evidence showing that segmented educational videos reduce cognitive load and improve achievement among distance learners (Altinpulluk *et al.*, 2020), and with studies indicating that segmentation is especially beneficial for procedural learning (Biard *et al.*, 2018), which is central to the step-by-step application of the Denavit–Hartenberg method. Furthermore, the direction and magnitude of the differences observed in this study are consistent with the meta-analytic evidence reported by Senandheera *et al.* (2024), who found that microlearning improves academic performance in higher education compared with traditional long-format instruction.

A possible explanation for these results is that microlearning allowed students to access the exact content they needed at the moment they needed it. Because each video addressed a single concept or procedure, students were able to identify specific gaps in their understanding and review only the relevant material instead of searching through an entire recorded lecture. This may have reduced cognitive overload and made the review process more efficient, particularly in a course where mathematical procedures must be followed step by step. The students' comments support this interpretation, since several participants indicated that short videos helped them reinforce their knowledge, revisit concepts more easily, and devote more time to solving exercises. In addition, the better performance observed in the exercises section suggests that the microlearning-based strategy was associated not only with theoretical understanding but also with procedural application and problem-solving.

At the same time, an important aspect must be explicitly acknowledged: the two conditions differed in more than video length. The microlearning condition combined short videos with embedded reflection questions, focused synchronous discussions, and guided practice after each topic, whereas the comparison condition relied on complete session recordings within a more traditional class structure. Therefore, the differences observed in this study should be attributed to the microlearning-based instructional strategy as a whole, and not exclusively to the

segmentation of the videos. In fact, this interdependence can be interpreted as one of the main pedagogical strengths of the approach: because theoretical explanations are available asynchronously in short videos, synchronous class time can be reorganized toward discussion, feedback, and deliberate practice; activities that are difficult to implement when the full theoretical explanation must be delivered live. From this perspective, microlearning does not merely shorten content; it enables a different, potentially more effective, distribution of learning activities between asynchronous and synchronous settings.

The instructor's observations also reinforce the educational value of the microlearning-based strategy. Students in Group B showed greater independence during the practical sessions, identified the steps of the DH method more quickly, and made fewer mistakes when defining reference frames and calculating parameters. Moreover, because the theoretical explanations were already available in short videos, the synchronous sessions could be used more effectively for discussion, clarification of doubts, and feedback on common errors. These observations, however, were collected through a brief questionnaire and field notes without a systematic qualitative protocol, and should therefore be interpreted as exploratory and complementary to the quantitative results.

Finally, the scope of these findings must be considered in light of the study's design. This was an exploratory study conducted with a small sample in a single course, using intact class groups without randomization, a pretest, or blinding. Consequently, although the results show a clear and statistically robust association between the microlearning-based strategy and academic performance in the sample studied, they do not allow firm causal conclusions. The findings should be interpreted as preliminary evidence of warranting further research using stronger experimental designs.

Compared with the traditional approach of recording and uploading complete online sessions, using short instructional videos focused on specific concepts and procedures (integrated with reflection questions, focused synchronous discussions, and guided practice) was associated with better results

CONCLUSIONS

The results of this study suggest that using a microlearning-based instructional strategy is associated with better academic performance in a distance-learning robotics course. Compared with the traditional approach of recording and uploading complete online sessions, using short instructional videos focused on specific concepts and procedures (integrated with reflection questions, focused synchronous discussions, and guided practice) was associated with better results on the final assessment. Students in the group that used the microlearning-based strategy achieved higher scores not only on the overall exam but also on both the theoretical and practical sections related to forward kinematics and the Denavit–Hartenberg method, with large effect sizes across all comparisons. These findings provide evidence that the way video-based educational content is structured and delivered is meaningfully related to students' learning in virtual environments.

From a pedagogical perspective, the study shows that microlearning may be particularly useful in engineering courses, where students

must master complex concepts and follow sequential problem-solving procedures. In robotics, dividing content into short, focused learning units appears to facilitate review of specific topics, reinforce conceptual understanding, and support the application of mathematical procedures. In addition, the combination of microlearning videos with synchronous sessions and 3D simulations seems to create a more effective learning environment, in which students can use asynchronous resources to study and review content while taking advantage of synchronous time for discussion, clarification of doubts, and guided practice; a reorganization of class time that the traditional format of complete recorded sessions does not readily enable.

The qualitative observations reported in the study also support the value of this instructional approach. Students indicated that short videos helped them identify topics they had not fully understood, review specific concepts more efficiently, and spend more time on exercises rather than watching long recordings. Similarly, the instructor observed that students exposed to the microlearning-based strategy participated more actively, showed greater independence during the practical activities, and made fewer mistakes when applying the Denavit–Hartenberg method. These observations, although exploratory, suggest that microlearning may be associated not only with better academic performance but also with more efficient use of online class time and a more focused learning experience.

Despite these promising results, several limitations should be considered when interpreting the findings. First, the number of participants was relatively small (35 students), and the intervention was conducted within a single undergraduate robotics course and focused on a specific topic of the syllabus, which limits the generalizability of the results. Second, the study followed a quasi-experimental design with intact class groups: students were not randomly assigned to the conditions, and no pretest was administered, so the initial equivalence of the groups cannot be empirically verified, and causal attributions must be made with caution. Third, the two conditions differed in more aspects than just video length, since the microlearning condition also included embedded questions, focused synchronous discussions, and guided practice; the observed effect therefore corresponds to the instructional strategy as a whole. Fourth, grading was carried out by the same instructor who taught both groups and was not blind to group membership, although a common checklist-type rubric was used to make the assessment criteria explicit and consistent. Fifth, because the videos were uploaded to a public platform, there was no precise record of how much time each student spent watching them, so the effective exposure to the instructional materials could not be measured. Finally, the qualitative observations were collected through a brief questionnaire and the instructor's field notes without a systematic qualitative research protocol, and should be regarded as complementary, exploratory information.

For these reasons, the present study should be considered an exploratory investigation whose findings provide preliminary, context-specific evidence of a favorable association between a microlearning-based instructional strategy and academic performance in distance robotics education.

FUTURE WORK

Future research should extend the present study by replicating the intervention with a larger number of participants and in different educational contexts. Since this experiment was conducted as an exploratory study with students from a single undergraduate robotics course, it would be valuable to examine whether the positive association between microlearning and academic performance remains consistent across other engineering subjects, institutions, and student populations. Working with a

larger number of class groups would also enable more robust statistical analyses and, ideally, designs that include random assignments and pretests to strengthen internal validity. In particular, future studies could analyze the implementation of microlearning in additional robotics topics, such as inverse kinematics, dynamics, trajectory planning, or control, to determine whether the benefits observed in forward kinematics generalize to other conceptually demanding areas.

Another important line for future work is to investigate student interaction with microlearning resources in greater depth. Because the videos in this study were hosted on a public platform, it was not possible to track how often students accessed the videos, how much time they spent watching them, or which specific videos were most frequently reviewed. Future studies could use learning platforms with analytics tools to monitor student engagement with the content and explore the relationship between viewing patterns and academic performance. It would also be valuable to examine the transfer of learning from video-based activities to real-world contexts, for example by analyzing whether students who learn through microlearning apply the Denavit–Hartenberg method more effectively when working with physical robots. In addition, it would be relevant to examine how microlearning can be integrated with other digital resources, such as interactive simulations, quizzes, or intelligent tutoring tools, to design richer online learning experiences in engineering education. Finally, future research could incorporate systematic qualitative methods, such as semi-structured interviews or focus groups, to gain a deeper understanding of how students perceive and use microlearning resources.

REFERENCES

Alias, N. F., & Razak, R. A. (2023). Exploring the pedagogical aspects of microlearning in educational settings: A systematic literature review. *Malaysian Journal of Learning and Instruction*, *20*(2), 267-294.

Altinpulluk, H., Kilinc, H., Firat, M., & Yumurtaci, O. (2020). The influence of segmented and complete educational videos on the cognitive load, satisfaction, engagement, and academic achievement levels of learners. *International Journal of Computers in Education*, *3*(2), 125-143. https://doi.org/10.1007/s40692-019-00151-7

Biard, N., Cojean, S., & Jamet, E. (2018). Effects of segmentation and pacing on procedural learning by video. *Computers in Human Behavior*, *89*, 411-417. https://doi.org/10.1016/j.chb.2018.01.002

Bower, M. (2017). *Design of Technology-Enhanced Learning*. Emerald Insight. https://doi.org/10.1108/9781787141827

Buhu, A., & Buhu, L. (2019). The applications of microlearning in higher education in textiles. *Proceedings of the International Scientific Conference eLearning and Software for Education*. https://doi.org/10.12753/2066-026X-19-189

Craig, J. J. (2009). *Introduction to Robotics: Mechanics and Control*. Pearson Education.

De Gagne, J. C., Park, H. K., Hall, K., Woodward, A., Yamane, S., & Kim, S. S. , (2019). Microlearning in health professions education: Scoping review. *JMIR Medical Education*, *5*(2). https://doi.org/10.2196/13997

Denavit, J., & Hartenberg, R. S. (1965). A kinematic notation for lower-pair mechanisms based on matrices. Transactions of the ASME. *Journal of Applied Mechanics*, 22(2), 215-221.

Edge, D., Searle, E., Chiu, K., Zhao, J., & Landay, J. A. (2011). MicroMandarin: Mobile language learning in context. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. https://doi.org/10.1145/1978942.1979413

Gabrielli, S., Kimani, S., & Catarci, T. (2006). The design of microlearning experiences: A research agenda. *Proceedings of Microlearning Conference 2005: Learning and Working in New Media*.

Giurgiu, L. (2017). Microlearning: An evolving e-learning trend. *Scientific Bulletin*, *22*(1), 18-23. https://doi.org/10.1515/bsaft-2017-0003

González-García, S., Rodríguez-Arce, J., Loreto-Gómez, G., & Montaño-Serrano, V. M. (2019). Designing a teaching guide for the use of simulations in undergraduate robotics courses: A pilot study. *International Journal on Interactive Design and Manufacturing*, *13*(3), 923-933. https://doi.org/10.1007/s12008-019-00551-0

González-García, S., Rodríguez-Arce, J., Loreto-Gómez, G., & Montaño-Serrano, V. M. (2020). Teaching forward kinematics in

a robotics course using simulations: Transfer to a real-world context using LEGO Mindstorms. *International Journal on Interactive Design and Manufacturing*. https://doi.org/10.1007/s12008-020-00670-z

Harrison, T. (2020). How distance education students perceive the impact of teaching videos on their learning. *Open Learning: The Journal of Open, Distance and e-Learning*. https://doi.org/10.1080/02680513.2019.1702518

Jomah, O., Masoud, A. K., Kishore, X. P., & Aurelia, S. (2016). Micro learning: A modernized education system. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience*, *7*(1), 103-109.

Leong, K., Sung, A., Au, D., & Blanchard, C. (2021). A review of the trend of microlearning. *Journal of Work-Applied Management*, *13*(1). https://doi.org/10.1108/JWAM-10-2020-0044

Loreto-Gómez, G., Rodríguez-Arce, J., González-García, S., & Montaño-Serrano, V. M. (2018). Analysing the effect of the use of 3D simulations on the performance of engineering students in a robotics course: Findings from a pilot study. *International Journal of Electrical Engineering Education*. https://doi.org/10.1177/0020720918790113

Mayer, R. E. (2021). *Multimedia Learning*. Cambridge University Press.

Mohammed, G. S., Wakil, K., & Nawroly, S. (2018). The effectiveness of microlearning to improve students' learning ability. *International Journal of Educational Research Review*, *3*, 32-38. https://doi.org/10.24331/ijere.415824

Monib, W. K., Qazi, A., & Apong, R. A. (2025). Microlearning beyond boundaries: A systematic review and a novel framework for improving learning outcomes. *Heliyon*, *11*(2), e41413. https://doi.org/10.1016/j.heliyon.2024.e41413

Rackaway, C. (2010). Video killed the textbook star? Use of multimedia supplements to enhance student learning. *APSA 2010 Teaching & Learning Conference*. https://doi.org/10.2139/ssrn.1547142

Senandheera, V. V., Muthukumarana, C. K., Ediriweera, D. S., & Rupasinghe, T. P. (2024). Impact of microlearning on academic performance of students in higher education: A systematic review and meta-analysis. *Journal of Multidisciplinary & Translational Research*, *9*(1), 10-25. https://doi.org/10.4038/jmtr.v9i1.2

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, *31*(2), 261-292. https://doi.org/10.1007/s10648-019-09465-5

Taylor, A., & Hung, W. (2022). The effects of microlearning: A scoping review. *Educational Technology Research and Development*, *70*(2), 363-395. https://doi.org/10.1007/s11423-022-10084-1

Yildirim, E. (2022). Perspective on the pros and cons of microlearning in health education. *Essays in Biochemistry*, *66*(1), 81-85. https://doi.org/10.1042/EBC20210047

Yin, J., Goh, T.-T., Yang, B., & Xiaobin, Y. (2021). Conversation technology with micro-learning: The impact of chatbot-based learning on students' learning motivation and performance. *Journal of Educational Computing Research*, *59*(1), 154-177. https://doi.org/10.1177/0735633120952067

Este artículo es de acceso abierto. Los usuarios pueden leer, descargar, distribuir, imprimir y enlazar al texto completo, siempre y cuando sea sin fines de lucro y se cite la fuente.

CÓMO CITAR ESTE ARTÍCULO:

González García, S., Loreto Gómez, G., Rodríguez Arce, J. y Juárez Pegueros, J. P. C. (2026). Microlearning in Distance Robotics Education: Evidence from an Undergraduate Engineering Course. *Apertura*, *18*(2), 118-133. http://doi.org/10.32870/Ap.v18n2.2898