

Google Sites as an innovative e-learning tool for methodical electrocardiogram interpretation: A randomized study among pre-graduate students at the Faculty of Medicine of Tunis

Google Sites comme outil innovant d'apprentissage en ligne pour l'interprétation méthodique de l'électrocardiogramme : Une étude randomisée chez des étudiants pré-gradués de la Faculté de Médecine de Tunis

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ABSTRACT

Introduction-Aim: At the Faculty of Medicine of Tunis (FMT), several active learning methods are employed to teach electrocardiogram (ECG) interpretation to first year second-cycle medical students (tutorial sessions, ECG portfolio, clinical learning...). However, these approaches remain insufficient and are often dependent on learner's motivation and tutor's availability. This study aimed to evaluate the pedagogical value of a Google Sites platform as a complementary tool, alongside the conventional methods implemented by the FMT, for methodical ECG learning.

Methods: we conducted an open-label, single-center, cluster-randomized study involving first year second-cycle medical students completing their cardiology rotation at a university hospital of Tunis. Two parallel groups were compared: one had access to Google Sites designed for methodical ECG interpretation "Google Sites (+)", while the other followed conventional methods, "Google Sites (-)". The primary outcome was the score out of 20 on a post-rotation evaluation test, aligned with Level 2b of the modified Kirkpatrick model.

Results: A total of 46 students were included. The median number of ECGs interpreted on Google Sites was 28 (IQR: 26–30). The mean evaluation score was 14.0±1.7 in the "Google Sites (+)" group and 9.3±2.7 in the "Google Sites (-)" group ($p=9.10^{-9}$). The mean score difference between groups was 4.7±0.7 ($p=9.10^{-9}$; 95% CI [3.4–6.0]).

Conclusions: Google Sites offers flexibility, interactivity, and rich content support for ECG interpretation learning. We recommend the use of Google Sites as a central learning support tool, complementing tutorial sessions for direct supervision and the ECG portfolio for individualized progress monitoring.

Key words: active learning, pre-graduate medical training, electrocardiogram, digital learning resources

RÉSUMÉ

Introduction – Objectif : À la Faculté de Médecine de Tunis (FMT), plusieurs méthodes actives d'apprentissage de l'interprétation de l'électrocardiogramme (ECG) sont destinées aux apprenants en DCEM1 (travaux dirigés, portfolio ECG, apprentissage en milieu clinique). Bien que fondamentales, ces approches restent tributaires de la motivation des apprenants et la disponibilité des tuteurs. Cette étude visait à évaluer l'intérêt de l'outil Google Sites comme moyen d'apprentissage complémentaire de l'interprétation de l'ECG chez les apprenants en DCEM1.

Méthodes : Il s'agissait d'une étude interventionnelle, monocentrique, randomisée en grappes, menée auprès des apprenants ayant effectué leur stage de cardiologie dans un centre hospitalo-universitaire tunisien. Deux groupes parallèles ont été comparés : un groupe utilisant l'outil Google Sites pour l'apprentissage de l'interprétation méthodique de l'ECG, et un groupe contrôle bénéficiant uniquement des méthodes classiques d'enseignement. Le critère de jugement était la note sur 20 obtenue à un test d'évaluation en fin de stage.

Résultats : 46 apprenants ont été inclus. Le nombre médian d'ECG interprétés sur Google Sites était de 28(26, 30). La moyenne des notes sur 20 obtenues au test d'évaluation était de 14,0±1,7 et 9,3±2,7 respectivement dans les groupes «Google Sites (+)» et «Google Sites (-)», $p=9.10^{-9}$. L'écart moyen entre les moyennes des notes entre les deux groupes était de 4,7±0,7 ($p=9.10^{-9}$; IC95% [3.4-6.0]).

Conclusion : Google Sites constitue un support pertinent d'apprentissage complémentaire et présente un avantage significatif dans l'apprentissage de la lecture de l'ECG grâce à sa flexibilité, son interactivité et la richesse de son contenu.

Mots-clés : apprentissage actif, formation médicale prégraduée, électrocardiogramme, ressources numériques éducatives

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INTRODUCTION

The acquisition of electrocardiogram (ECG) interpretation skills is a fundamental component of medical training. A structured and progressive training approach is essential to ensure effective acquisition of this critical competency (1). At the Faculty of Medicine of Tunis (FMT), several active learning strategies have been implemented to teach ECG interpretation to first year second-cycle medical students (MS3) including:

- Tutorial Sessions: These comprise three interactive, small-group teaching sessions of twelve hours during which learners deepen their understanding under tutor supervision. Sessions are designed to help students develop a structured approach to ECG interpretation through progressive training using real clinical cases of increasing complexity and covering a range of pathologies.

- A nine-step ECG interpretation worksheet: During these sessions, students are provided with a nine-step ECG interpretation worksheet, which is explained in detail. The objective is to standardize and facilitate ECG interpretation, both during tutorial sessions and throughout the clinical cardiology rotation.

- ECG portfolio: This is a structured self-directed learning tool that allows students to collect and analyze ECG tracings over the five-week cardiology rotation. The portfolio serves as a record of learner's progress in ECG interpretation, incorporating tracings and clinical vignettes encountered during clinical rotation, along with feedback from tutors. At FMT, the ECG portfolio is included as a formal objective within the clinical rotation logbook. It requires students to methodically interpret eight ECG tracings obtained during patient care activities, such as ward rounds, emergency shifts, and routine clinical observations.

However, despite these educational strategies, their effectiveness has been limited by learners' motivation and availability of tutors.

Recently, Google Sites, a web development tool offered by Google, has been introduced as a tool for active learning that allows users to easily create, organize, and share interactive websites integrating documents and multimedia content (e.g., images, videos) without requiring any programming skills. It enables educators to provide students with resources that can be explored at their own pace promoting self-directed learning, enhancing student engagement and autonomy, and improving student-teacher collaboration.

The aim of this study was to assess the usefulness of Google Sites as a complementary learning tool, alongside the existing strategies implemented by the FMT, in facilitating the methodical learning of ECG interpretation among MS3 students.

METHODS

We conducted an open-label, single-center, cluster-randomized interventional study comparing two parallel groups assessing the educational value of an active learning approach using a dedicated Google Sites

platform for the methodical ECG interpretation targeting MS3 at the FMT, in comparison with conventional learning methods currently implemented (ECG-focused tutorial sessions, ECG portfolio, and routine ECG interpretation activities during case presentations, bedside visits, and on-call shifts).

In this study, we utilized the free Google Sites application, part of the "Google Workspace for Education" suite, with access via institutional accounts of the format: *firstname.lastname@fmt.utm.tn* or *firstname.lastname@etudiant.fmt.utm.tn*.

We developed a dedicated Google Site for the methodical interpretation of ECGs, structured in a homepage and ECG bank containing 30 ECG tracings accompanied by their corresponding clinical vignettes. The homepage defined the target audience (MS3 at the FMT) and outlined the functional principles of using the ECG interpretation bank. It provided guidance on the expected work progression over the recommended three-week period, explained the debriefing method, and included a downloadable version of the nine-step ECG interpretation worksheet. The Google Site was then shared, and access was provided to students. Additionally, we created and published separate Google Sites that provided weekly responses to the interpreted ECG tracings.

Among groups of MS3 rotating through cardiology department at a university hospital of Tunis, four consecutive groups were randomly selected to participate in the study, consisting of 10 to 15 students each, and were randomly assigned to form two intervention groups using the Google Sites tool, designed as "Google Site (+)" group, and two control groups designed as "Google Site (-)" group. Randomization was performed using an urn containing four assignments; two Google Site (+) and two Google Site (-). For each of the four groups, an assignment was drawn without replacement prior to the start of the study.

We later excluded students who did not complete the interpretation of at least 24 out of 30 ECG tracings, those accumulating more than 10% absenteeism during their clinical rotation and those who didn't attend the weekly debriefing sessions nor the evaluation test at the end of the study period.

In the "Google Site (+)" group, the Google Site dedicated to ECG interpretation was used in addition to conventional teaching methods routinely implemented by the FMT. During the final three weeks of the clinical rotation periods, each student was required to interpret two pre-selected ECG tracings per day from the ECG bank, following the nine-step ECG interpretation worksheet. At the end of each week, a debriefing session was held to review and discuss the ten designated tracings. One student was assigned per ECG to present his interpretation, which was corrected by the supervising tutor and then answers for the selected ten ECGs were provided weekly to students on other dedicated Google Sites. In the "Google Site (-)" group, the learning of methodical ECG interpretation was delivered through the conventional methods routinely applied by FMT.

The primary outcome was the score out of 20 obtained on an evaluation test consisting of a 50-minute written

examination focused on the methodical interpretation of five ECG tracings representing various pathologies (10 minutes per tracing). The tests were scored blindly, using the same scoring rubric for the two groups. The mean scores obtained on this evaluation were compared between the two groups.

Statistical Analysis:

Qualitative variables were presented as frequencies and percentages. Comparisons of proportions between independent groups were performed using Pearson's chi-squared test. When the chi-squared test was not valid and the comparison involved two proportions, Fisher's exact two-tailed test was used. Quantitative variables were expressed as mean $\pm$ standard deviation or as median with interquartile range (IQR), as appropriate. Comparisons of means between two independent groups were performed using the independent samples t-test or using the Mann–Whitney U test when normality was not met. For all statistical tests, a significance level of 0.05 was used.

RESULTS

During the study period, 46 patients were included. The flow chart of the study is represented in figure 1.

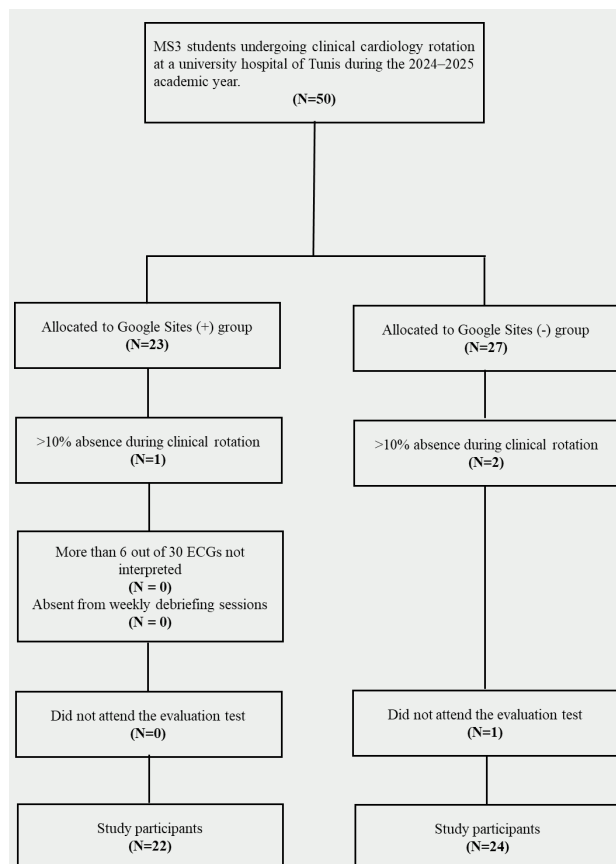


Figure 1. Flowchart of the study population.

students, rotating through cardiology department) were randomly assigned to two groups: "Google Sites (+)" group (n=23) and a "Google Sites (-)" group (n=27). We subsequently excluded students cumulating more than 10% absenteeism during their clinical rotation (N=3), as well as those who didn't attend the evaluation test at the end of the clinical rotation period (n=1). In total, 46 learners, allocated to the "Google Sites (+)" (n=22) and "Google Sites (-)" (n=24) groups, were considered for the analysis of the primary outcome, defined as the score out of 20 on the evaluation test administered at the end of each clinical rotation. The number of ECGs interpreted per student in the Google Site (+) group is presented in figure 2.

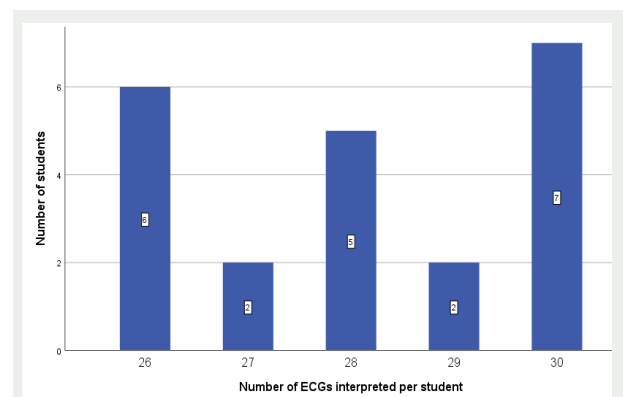


Figure 2. Bar chart showing the number of students by the number of ECGs interpreted during the study period in the "Google Sites (+)" group.

Comparative study of evaluation test scores between the two groups: The mean score out of 20 on the evaluation test was 14.0 ± 1.7 and 9.3 ± 2.7 in "Google Sites (+)" and "Google Sites (-)" groups, respectively ($p=9.10^{-9}$) (Table 1). The mean difference between the average scores of the two groups was 4.7 ± 0.7 ($p=9.10^{-9}$; 95% CI [3.4,6.0]). This evaluation test involved methodical interpretation of five ECG tracings dealing with various pathologies and was scored using a criterion grid.

The mean scores (out of 20) obtained for each of the ECG tracings (1 to 5) in the two groups are shown in table 1 and figure 3.

Table 1. Comparison of mean scores (out of 20) obtained for each of the five ECG tracings, along with the mean overall score on the evaluation test, between the two groups.

	Google Sites (+)	Google Sites (-)	P
Mean overall score	14.0 ± 1.7	9.3 ± 2.7	9.10^{-9}
Mean scores ECG 1	13.4 ± 2.3	10.8 ± 3.0	0.002
Mean scores ECG 2	12.9 ± 2.2	7.9 ± 3.8	0.000003
Mean scores ECG 3	15.4 ± 2.8	10.5 ± 3.7	0.000007
Mean scores ECG 4	14.6 ± 2.3	11.1 ± 3.5	0.0002
Mean scores ECG 5	13.8 ± 2.1	6.0 ± 2.7	9.10^{-14}

At the beginning of the academic year, 50 students (issued from the four consecutive groups of 10 to 15

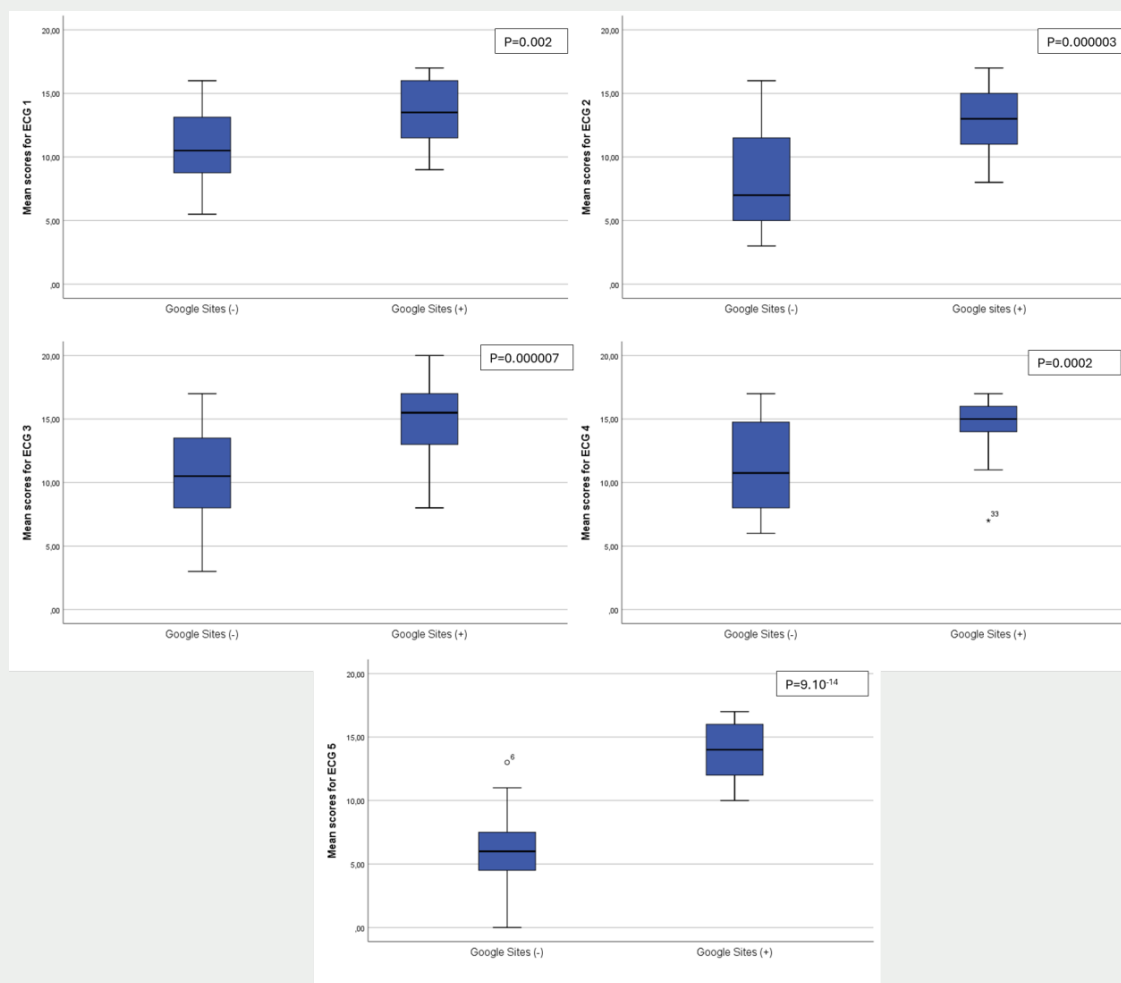


Figure 3. Box plots showing the distribution of scores (out of 20) obtained for each of ECG tracings 1 to 5 among study participants.

Furthermore, all learners in the “Google Sites (+)” group reported having used the nine-step ECG interpretation worksheet provided by the FMT from the first ECG tutorial session, which was applied systematically, both in the context of the study and during routine clinical activities. In contrast, 37.5% of learners in the “Google Sites (-)” group reported not using the worksheet for ECG interpretation during their clinical cardiology rotation (Figure 4).

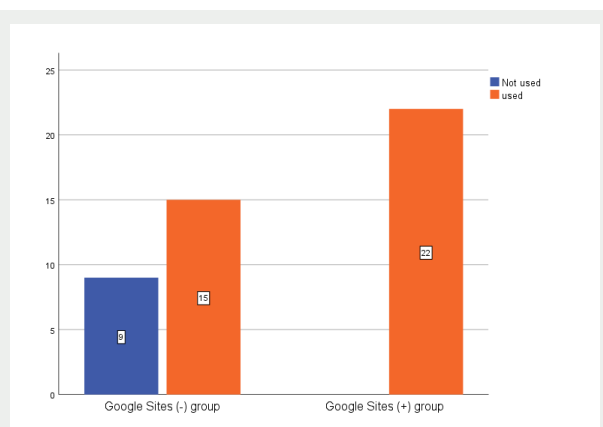


Figure 4. Bar charts illustrating comparison of the use of the nine-step ECG interpretation worksheet provided by the faculty of medicine of Tunis between the two groups.

Students using ECG interpretation worksheet achieved mean score of 12.5 ± 2.8 compared with 7.9 ± 2.1 among those who did not ($p < 0.001$), suggesting that the use of the worksheet is associated with better performance.

DISCUSSION

This single center randomized study, involving 46 students, highlighted the benefits of implementing a Google Site specifically designed for the systematic interpretation of ECGs in competence acquisition among MS3.

Despite being time-consuming, this active and autonomous learning approach proved to be an essential complement to the 12 hours of ECG-focused tutorial sessions conducted at the FMT, as well as to conventional clinical teaching methods.

We demonstrated the effectiveness of this approach through a competence evaluation test, administered at the end of the clinical rotation. This test revealed a significant difference in scores between students in “Google Sites (+)” group compared to the control group. The integration of a digital platform via Google Sites into ECG learning in our study led to a significant improvement in academic performance, with an average difference of nearly five points on the evaluation test between

the two groups. The magnitude of this effect, which is uncommon in medical education, suggests that the benefit of the platform extends beyond the availability of educational resources, reflecting a synergy between resource accessibility, standardization and simplification of methods through the nine-step ECG interpretation worksheet, and opportunities for repeated practice. These findings are consistent with several randomized controlled trials demonstrating the superiority of e-learning or blended learning over traditional lecture-based teaching for the acquisition of clinical skills. Montassier et al. (2) conducted a randomized trial comparing structured online ECG modules with traditional classroom lectures in undergraduate medical students, demonstrating that e-learning was non-inferior to lecture-based teaching while offering a flexible and effective alternative for skill acquisition. Similarly, Viljoen et al. (3) compared blended learning, combining lectures with a web-based application, to lectures alone and reported significant improvements in both immediate and delayed test scores, as well as increased student confidence, indicating the superiority of blended approaches over conventional teaching. More recently, the multicenter EDUCATE trial confirmed, in an international context, the efficacy of web-based, self-directed interventions for enhancing ECG interpretation skills and confidence across healthcare professionals (4). Moreover, the recommended nine-step ECG interpretation worksheet provided by the FMT during ECG tutorial sessions was consistently used by all students in the "Google Sites (+)" group, since it was the same used in our study, as opposed to only 62.5% in the control group.

In the "Google Sites (+)" group, the positive impact on evaluation test scores was amplified by the integration of the structured worksheet into a guided learning pathway with rich and diverse content provided by the Google Sites platform. The structured worksheet goes beyond being a simple reference; it provides a framework that promotes active learning. In the control group, the worksheet was available, but without pedagogical guidance. It could be perceived as a static resource. Improvement was still possible, but less pronounced, as evidenced by the lower scores on the evaluation test for this group, given that structured worksheet effectiveness depended on the individual's motivation and ability to utilize the tool independently.

Several recent publications highlighted the effectiveness of structured online learning for acquiring ECG interpretation skills. Olvet et al. demonstrated that asynchronous e-learning modules enabled first-year medical students to achieve higher post-test scores and increased engagement (5), while Elkammash et al. reported that case-based online modules improved confidence and reduced perceived difficulty among junior medical trainees (6). These findings support the notion that accessible digital resources, combining guided instruction and repeated practice, as implemented via our Google Sites platform, can effectively enhance the learning and consolidation of clinical ECG competencies.

Demonstrated advantages of Google Sites in the

literature: In general, Google Sites is a versatile and effective tool for promoting active learning. It facilitates the creation and sharing of diverse interactive resources (texts, images, videos, presentations, and links to other materials) through a clear and organized structure. It encourages student engagement and collaboration, supports self-directed and self-paced learning, and ensures constant accessibility. Furthermore, it aligns well with various active learning pedagogies (7–9). In recent years, the use of Google Sites has become increasingly widespread within healthcare education programs (10). The literature identifies several advantages of using Google Sites as a learning tool in medical education (11), including centralization of various resources (multimedia, lecture notes, evaluation questions...) in a readily accessible platform, encouragement of active learning (e.g. with clinical case studies, or interpreting diagnostic results in their clinical context), ease of use and creation, without requiring advanced programming or technical skills, enhancement of learning experience by integration of shared documents, evaluation forms, and educational videos, support for learners' autonomy and responsibility for their own learning (learners can explore the learning contents at their own pace, which triggers the seeking of information and deeper looking for knowledge apart from course materials).

In a study published by Parmar et al. (8), the effectiveness of an online forensic medicine teaching module developed via Google Sites was evaluated among undergraduate students. The study involved a pre-test, access to the module, and an identical post-test. Results showed that post-test scores were significantly higher than pre-test scores. Furthermore, students appreciated the flexibility, clarity of content, and the ability to review material at their own pace.

To date, few studies have been published on the impact of Google Sites as a learning tool in medical education. To our knowledge, no randomized studies have compared Google Sites with other conventionally used educational tools. Therefore, the randomized and comparative design of the present study provides a high level of evidence.

A particularly noteworthy finding was that Google Sites not only enhanced overall competency but also encouraged consistent and rigorous use of the nine-step ECG interpretation worksheet recommended by the faculty of medicine, underscoring the importance of pedagogical alignment between online resources and the learning objectives outlined in the clinical rotation logbook.

Google sites also reinforces principles of modern medical education that emphasize active learner engagement in the learning process (12,13) and may have offered students a flexible space for in-depth practice and review at their own pace, thereby compensating for the limited time allocated to tutorial sessions.

A key advantage of Google Sites demonstrated by a high-level of Kirkpatrick modified model: one of the strengths of our study lies in its primary outcome, which was based on the assessment of learners' acquired competencies, corresponding to Level 2b of the hierarchical Kirkpatrick modified model (14).

Comparison with the Existing Literature: Although our study focused on a specific tool namely, the structured learning of methodical ECG interpretation, its findings are consistent with existing literature regarding the effectiveness of e-learning and web-based resources in promoting active learning, particularly in the field of cardiology (15,16). The results highlight increased learner engagement and improved knowledge acquisition associated with the use of interactive online platforms. Thanks to its flexibility and ease of integrating multimedia content, Google Sites succeeded in creating a rich and stimulating learning environment, providing deeper understanding and a more methodical application of ECG interpretation skills.

Educational Implications: The findings of this study support the integration of complementary digital resources, such as Google Sites, into active learning strategies. Although time-consuming to develop, the tool appears to offer a significant pedagogical return on investment in terms of skill acquisition and the adoption of rigorous working methods, while also providing learners with flexibility and the opportunity to work at their own pace.

Study Limitations: Several limitations of this study should be acknowledged, including its single-center design and the relatively small sample size (n=46). Multicenter studies with larger cohorts would strengthen the generalization of these findings. Furthermore, the assessment of competency was limited to a post-clinical rotation evaluation test (Level 2b of the Kirkpatrick model). A longer-term follow-up of skill acquisition and its application in clinical settings would be valuable. Moreover, the development of the ECG bank and corresponding answers was also time-consuming. A more in-depth analysis of perceived workload and engagement with the tool could provide valuable insights for its future optimization. Finally, although the study was not blinded for students or evaluators, the same evaluation test was administered to both groups, scored using an identical scoring rubric, and grading was performed blind to group assignment, thereby minimizing the risk of assessment bias.

CONCLUSIONS

Google Sites offers a significant advantage in learning ECG interpretation because of its flexibility, interactivity and rich content. It allows learners to study at their own pace, access a diverse and regularly updated database, and benefit from self-assessment tools and collaborative features between learners and teachers.

While tutorial sessions remain essential for in-person learning and direct interaction, and the ECG portfolio constitutes an excellent tool for monitoring learners progress throughout the clinical rotation, Google Sites provides an ideal complementary platform for regular practice, structured learning and continuous assessment. We recommend the use of Google Sites as a central learning resource, complementing tutorial sessions for direct supervision and the ECG portfolio for individualized

progress monitoring.

REFERENCES

1. Fent G, Gosai J, Purva M. Teaching the interpretation of electrocardiograms: which method is best? *J Electrocardiol.* 2015;48(2):190-3.
2. Montassier E, Hardouin JB, Segard J, Batard E, Potel G, Planchon B, et al. e-Learning versus lecture-based courses in ECG interpretation for undergraduate medical students: a randomized noninferiority study. *Eur J Emerg Med Off J Eur Soc Emerg Med.* avr 2016;23(2):108-13.
3. Viljoen CA, Millar RS, Manning K, Burch VC. Effectiveness of blended learning versus lectures alone on ECG analysis and interpretation by medical students. *BMC Med Educ.* 3 déc 2020;20(1):488.
4. Kashou AH, Noseworthy PA, Beckman TJ, Anavekar NS, Cullen MW, Angstman KB, et al. EDUCATE: An international, randomized controlled trial for teaching electrocardiography. *Curr Probl Cardiol.* mars 2024;49(3):102409.
5. Olvet DM, Sadigh K. Comparing the effectiveness of asynchronous e-modules and didactic lectures to teach electrocardiogram interpretation to first year US medical students. *BMC Med Educ.* 22 mai 2023;23(1):360.
6. Elkammash A, Ahmed MW, Alsinan M, Madi K. The Effectiveness of Online Learning in Improving the Electrocardiogram Interpretation Skills of Junior Medical Trainees: A Mixed Methods Observational Study. *Cureus.* juill 2023;15(7):e42320.
7. Roodt S. USING GOOGLE SITES AS AN INNOVATIVE LEARNING TOOL AT UNDERGRADUATE LEVEL IN HIGHER EDUCATION.
8. Parmar1 P, Patond2 S, Rathod3 G, Ninave4 S. Google Site as a Tool for Teaching Undergraduate Students in Forensic Medicine. *Indian J Forensic Med Toxicol.* 29 oct 2020;14(4):427-31.
9. Halim AA, Halim NDA. EXPLORING THE INTEGRATION AND IMPACT OF GOOGLE SITES IN TEACHING AND LEARNING: A STRUCTURED SCOPING REVIEW. *Quantum J Soc Sci Humanit.* 28 déc 2024;5(S1):110-24.
10. Aryee GFB, Amoadu M, Obeng P, Sarkwah HN, Malcarm E, Abraham SA, et al. Effectiveness of eLearning programme for capacity building of healthcare professionals: a systematic review. *Hum Resour Health.* 2 sept 2024;22:60.
11. West J, Malatji MJ. Technology Integration in Higher Education: The use of Website Design Pedagogy to Promote Quality Teaching and Learning. *Electron J E-Learn.* 30 déc 2021;19(6):pp629-641.
12. Michael J. Where's the evidence that active learning works? *Adv Physiol Educ.* déc 2006;30(4):159-67.
13. Prince M. Does Active Learning Work? A Review of the Research. *J Eng Educ.* juill 2004;93(3):223-31.
14. Harden RM, Grant J, Buckley G, Hart IR. BEME Guide No. 1: Best Evidence Medical Education. *Med Teach.* 1999;21(6):553-62.
15. Stępień A, Pacia M, Janiec S, Chemielak W. Randomized study to compare two methods of e-learning of ECG interpretation among medical students. *Porto Biomed J.* 1 sept 2017;2(5):195.
16. Nilsson M, Fors U, Östergren J, Bolinder G, Edlbring S. Why Medical Students Choose to Use or Not to Use a Web-Based Electrocardiogram Learning Resource: Mixed Methods Study. *JMIR Med Educ.* 11 juill 2019;5(2):e12791.