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Can the traditional class be replaced by the Worked Example in the teaching of Radiology?

A aula tradicional pode ser substituída pelo Worked Example no ensino da Radiologia?

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ABSTRACT

Introduction: During the last decade, the traditional model of medical education was widely debated, and recently, the Covid-19 pandemic added new challenges in teaching and learning in medical education. The Worked Example is an instructional tool in which an expert shows a detailed problem solution for a learner.

Objective: This study aimed to compare, in an experimental study with medical students, lectures in online format with Worked Example for teaching chest tomography.

Method: Experimental study through an educational intervention with medical students in the initial and final stages of clinical practice.

Result: Analysis of variance of repeated measures (ANOVA) was used in the statistical analysis. There was a significant difference between the grades before and after training ($F1; 74 = 46.008$; $p < 0.001$) and between the course phases studied ($F2; 148 = 19.452$; $p < 0.001$). There was no statistically significant difference between the groups ($F2; 74 = 1.401$; $p = 0.240$). There was no significant difference in mental effort reported in the comparison between groups ($F1; 69 = 0.092$; $p = 0.762$), but students in the 2th year had a significantly higher effort score.

Conclusion: Worked Example, which is a good technique for students and suitable for digital formats, was equally effective as lecture, a well-known instructional method for teaching radiology.

Keywords: Radiology; Medical Education; Tomography.

RESUMO

Introdução: *Durante a última década, o modelo tradicional de ensino médico foi amplamente debatido, e, há pouco tempo, a pandemia da Covid-19 impôs novamente mudanças, iniciadas em caráter de urgência em todo o mundo, trazendo novos desafios à formação médica no que concerne ao ensino e à aprendizagem. A estratégia de ensino conhecida como Worked Example é uma ferramenta instrucional na qual um especialista mostra a solução de um determinado problema para um aprendiz de forma pormenorizada.*

Objetivo: *Este estudo teve como objetivo comparar as aulas expositivas em vídeo com a técnica Worked Example para ensino de tomografia de tórax.*

Método: *Trata-se de um estudo experimental realizado, por meio de uma intervenção educacional, com alunos do curso de Medicina em fases iniciais e finais da prática clínica.*

Resultado: *A análise de variância de medidas repetidas (ANOVA) foi usada na análise estatística. Houve diferença significativa entre as notas antes e depois do treinamento ($F1; 74 = 46{,}008$; $p < 0{,}001$) e entre as fases do curso ($F2; 148 = 19{,}452$; $p < 0{,}001$). Não houve diferença estatisticamente significativa entre os grupos ($F2; 74 = 1{,}401$; $p = 0{,}240$). Não houve diferença significativa no esforço mental referido na comparação entre grupos ($F1; 69 = 0{,}092$; $p = 0{,}762$), porém os alunos do segundo ano apresentaram um escore de esforço significativamente maior.*

Conclusão: *O Worked Example, uma técnica com boa aplicabilidade para estudantes da graduação e adequada para formatos digitais, mostrou-se igualmente eficaz a aula expositiva, técnica consagrada no ensino de radiologia.*

Palavras-chave: *Radiologia; Educação Médica; Tomografia.*

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INTRODUCTION

Over the last decade, the traditional model of medical education has been widely debated, questioned and tested, and new teaching strategies centered on the student, with active learning models, which prioritize social learning have been elected, replacing instructional methods based on didactic lectures. Recently, the COVID-19 pandemic once again enforced changes to medical education, initiated as a matter of urgency all over the world and bringing challenges to teaching and learning in medical training[1-3]. This sudden rupture imposed by social distancing resulted in a transition from classrooms, laboratories, outpatient clinics and even hospitals, to virtual and online resources, in addition to the incorporation of technologies and teaching strategies and probably inaugurating a period of transition to a new format of teaching and learning [1,3].

It would be no different for the teaching of radiology in undergraduate courses. Even before the pandemic, the teaching of medical image interpretation showed to be the focal point of questions and discrepancies between medical schools worldwide, differing from the absence of the formal teaching of radiology in curricula to the presence of mandatory internships[4-6]. Moreover, a growing need to optimize the teaching methods in medical image interpretation has been observed[7-9].

Nevertheless, in recent decades, lectures as a pedagogical resource have been subject to several criticisms, especially because they are related to a passive transfer of information, with little cognitive gain [7-12]. In emergency remote teaching, this discussion is incorporated into others, bringing greater relevance, for instance, to the increased time of exposure to electronic device screens in populations from all age groups and the possible harm related to sleep disorders and their correlation with learning[13,14], decrease in social interaction between peers with its recognized benefits, in addition to the physical and mental well-being of students [1,2,15].

Kok et al. demonstrated, after reviewing the literature on the teaching of medical image interpretation, that instructional studies in education with student-centered, active learning, were successfully implemented in image interpretation, surpassing the teacher-centered teaching model, based on lectures; however, studies have shown little evidence on specific techniques to optimize learning[9].

The teaching strategy known as Worked Example is an instructional tool, in which an expert demonstrates the solution of a given problem to a learner in details[16-19], that is, all the successively necessary movements towards the solution of a problem are provided from the systematization of a complex instruction or skill[18]. The solution of the problem by the specialist becomes a model for the student to learn and reproduce the acquired knowledge[16-19]. Therefore, this instructional method manipulates the cognitive loads, facilitating the construction of mental scripts and improving teaching by reducing the cognitive effort during skill acquisition, when compared to problem-solving strategies, showing to be more effective and efficient. This would occur by dedicating the available working memory capacity to build a cognitive schema that guides the resolution of future problems[20].Considering the teaching of medical image interpretation in undergraduate courses, this characteristic would be extremely favorable, since it is a complex cognitive task, which requires the learner to interact with several elements, such as anatomical knowledge, the pathophysiology of diseases, in addition to the radiological knowledge itself, therefore, with a high intrinsic cognitive load[18-20].

Based on the concept of the Worked Example, we developed a reading material with a step-by-step guide for the basic interpretation of chest CT scans with pediatric particularities and we developed an experimental study with medical students to compare this strategy and the use of lectures.

METHODS

This is an experimental study carried out through an educational intervention at the Faculty of Medicine of UFMG with undergraduate medical students, regularly enrolled in the 2nd year attending the 4th semester in one group and in the other, 6th year medical students, attending internships in medical specialties.

Procedures

The participants were allocated into two groups according to the year of the medical course they were attending and were randomly distributed into two subgroups according to the type of training they received: one for those who watched the recorded online lecture - traditional class (TC) and in the other, the students who performed the guided reading of the printed material – the Worked Example (WE) group. The experiment was divided into three phases:

a) Phase 1: assessment of prior knowledge through the pre-test.

b) Phase 2: training phase. A 50-minute recorded lecture or guided study of the printed material called 'Worked Example'.

c) Phase 3: immediate post-test, promptly after the training phase.

After the training phase, the participants were asked to rate the mental effort made to carry out the proposed tasks,

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according to the allocated group, choosing a number on a scale ranging from 1 to 10, where 1 was very, very low effort, and 10 was a very, very high mental effort.

Two different tests were developed for application in the different phases of the study, both with the same dynamics of performance and with contents that covered the three domains of knowledge proposed in the didactic material: basic knowledge about the formation of tomographic and anatomical images, mediastinal diseases and patterns of alterations in the lung parenchyma, in an equal number of open-ended questions by content, with different questions in the two tests, but with the same level of difficulty, whose answers should be briefly described. The identification of normal and pathological images in axial tomographic sections and related theoretical knowledge were addressed, with the projection of tomographic images on a computer screen. The answers and scores per question were validated by another radiologist, a specialist in Pediatric Radiology with experience in Thoracic Radiology.

Inclusion and exclusion criteria

Regularly enrolled students, whose participation was voluntary and extracurricular, were included in the study. Students who attended years other than the abovementioned ones or who expressed their desire not to carry out the proposed phases of the research were excluded from the analysis.

Statistical analysis

The Analysis of Variance (ANOVA) for Repeated Measures was used to assess the effect/influence of variables on student performance in the pre-test and immediate post-test. Student's *t* test was used to compare paired/dependent samples. To evaluate the effect/influence of the course year and group factors on the mean effort score related to the training, analysis of variance based on a two-factor model was used. The p-value considered statistically significant was < 0.05.

Ethical aspects

The study protocol and the free and informed consent form were approved by the Research Ethics Committee of Universidade Federal de Minas Gerais under number 2,638,289. All participants signed the Free and Informed Consent Term (FICT).

RESULTS

A total of 78 students participated in the research, 46 of them in the beginning of clinical practice, regularly enrolled in the 4th semester (2nd year) – 24 in the online Traditional Class (TC) group and 22 in the Worked Example (WE) group; and 32 students attending the internship (6th year) – 15 students in the TC group and 17 in the WE group.

For students who carried out the Worked Example, the time spent studying the material was recorded. The minimum time obtained was 19 minutes and the maximum was 92 minutes. The average time spent studying the material was 48.7 minutes (95%CI: 42.1; 55.3).

Chart 1 shows the average of the students' grades in the two phases of the study in relation to the group and stage of the course.

The scores obtained in the immediate post-test, stratified by the three included topics (anatomy, diseases of the mediastinum and lung parenchyma), are shown in Chart 2. As expected, there is a significant effect between the scores and the course year ($F_{1;74} = 46.008$; $\mathbf{p < 0.001}$) and the study phase ($F_{2;148} = 12.222$; $\mathbf{p < 0.001}$), as well as the interaction between the study phase and year ($F_{2;148} = 19.452$; $\mathbf{p < 0.001}$), with the grades of the pre-test, on average, being lower than the scores of the immediate post-test, both for the overall score, which consists of the sum of scores by topic, and for the separate evaluation of the three assessed topics.

The interaction between the groups (WE x TC) was not statistically significant ($F_{2;74} = 1.401$; $p = 0.240$), not even when associated with other variables: course year ($F_{1;74} = 1.091$; $p = 0.300$), study phase ($F_{2;148} = 3.001$; $p = 0.053$), and phase and year altogether ($F_{2;148} = 0.309$; $p = 0.734$).

The interaction of grades with the topic variable was statistically significant, with $P < 0.001$.

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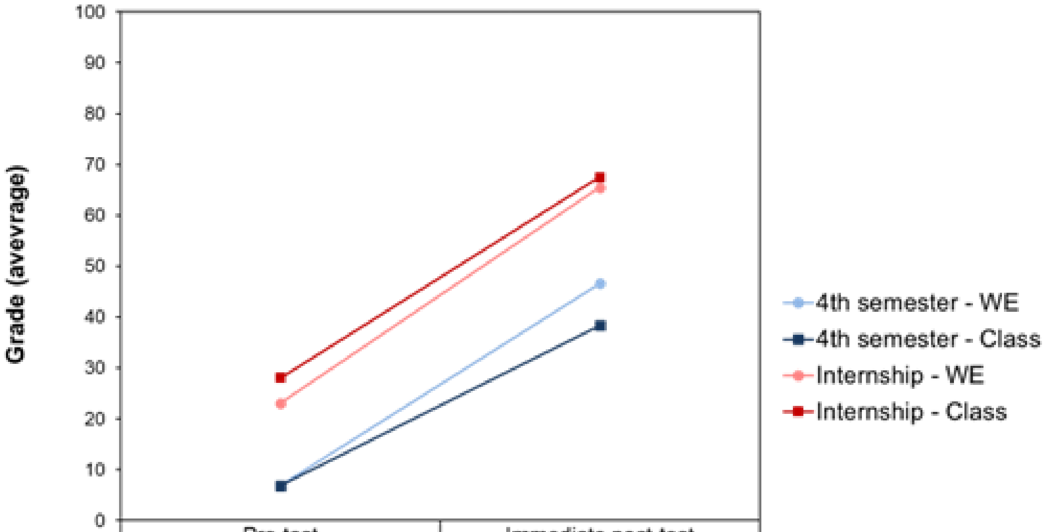
Chart 1. Averages of students' grades in relation to the study phase and group.

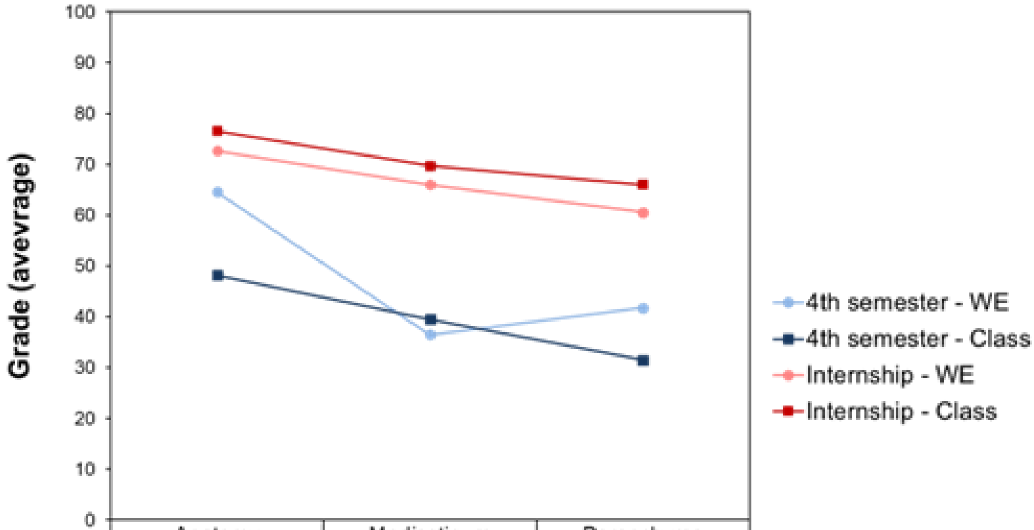


	Pre-test	Immediate post-test
4th semester - WE	6.9	46.6
4th semester - Class	6.9	38.4
Internship - WE	23.1	65.5
Internship - Class	28.1	67.5

Study phase

Source: prepared by the authors.

Chart 2. Averages of students' grades in the immediate post-test based on the three topics in relation to the Group and the Course year.



	Anatomy	Mediastinum	Parenchyma
4th semester - WE	64.6	36.5	41.8
4th semester - Class	48.2	39.5	31.5
Internship - WE	72.7	66.0	60.6
Internship - Class	76.6	69.7	66.0

Diagnostic topics

Source: prepared by the authors.

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Assessment of mental effort for the training phase

There was no statistically significant difference in mental effort reported by students who took the traditional classes when compared to WE ($F_{1;69} = 0.092$; $p = 0.762$). The mental effort scale reported after the training phase showed that there is a statistically significant influence only in the course year ($F_{1;69} = 5.776$; $p = 0.019$). The 2nd-year students had a significantly higher effort score when compared to the 6th-year students, regardless of the group they were allocated to ($F_{1;69} = 2.083$; $p = 0.153$).

DISCUSSION

Overall, the results found in the present study did not show a significant difference between traditional online classes and Worked Example. Furthermore, as expected, there was a significant increase in the average of the scores between the pre- and immediate post-test phases, with significant differences between the phases of the course (beginning x final), showing scores after the training phase, on average, higher than the average of the scores in the pre-test phase.

However, it is important to point out some findings when the grade averages are stratified by topic. In this analysis, the averages obtained by the students at the end of the course were significantly higher than the averages of the 2nd-year students' grades only in the lecture group. In the WE group, this pattern only occurred for the topics "Parenchyma" and "Mediastinum".

Additionally, as expected, the 2nd-year students in both groups had significantly higher average grades for the topic "Anatomy" than the averages of the other topics, probably because they were taking the anatomy course during the semester when they performed the task, although without correlation with tomographic images as in the task performed in the study, demonstrating the students' ability to combine simple ideas into more complex ones, developing the so-called 'mental scripts'[20].

In a complementary way, in this phase of the course, the lecture group showed the lowest averages for the topic "parenchyma", a fact that may be related to the content being shown at the end of the video, beyond the initial 20 minutes, as some authors showed to be the best moment. for learning[11,12]. This was not observed among 6th-year students, probably due to the students' greater familiarity with the topic, as they already had the associated mental scripts[20].

As for the students at the end of the course, it was observed that only the grade averages for the topic "Anatomy" were higher in the WE group, with a significant difference compared to the other topics. Moreover, the comparison of the grade averages taking into account the topics and the phase of the course, showed that statistically significant differences were observed only for the 2nd-year students, in the evaluation of the topics "anatomy" and "parenchyma", between the two groups, where the students of the WE group showed grade averages for each of the topics that were significantly higher than the students of the "Lecture" group.

These results indicate a better performance of the 'Worked Example' as a teaching method for the anatomy topic in our study, especially for students at the beginning of the course. This finding corroborates the findings in the literature on education, which point out that such strategy is more important in the early stages of cognitive skill acquisition, as reported by Atkinson et al. in a review of studies using Worked Example in the most varied fields of knowledge, such as basic mathematics, music, programming, and chess, among others[16].

According to the cognitive load theory, the learning process occurs with the processing of new information in working memory to build schemas in long-term memory, or mental scripts [17-20]. In turn, working memory can be affected by the nature of the task, called intrinsic load, the way the task is presented, external load, and the way learning actually occurs, called 'pertinent load'[18]. Van Merriänboer et al., after a review of studies in education of health professionals, concluded that Worked Examples could reduce the intrinsic load and the external load, optimizing learning[20], as our results indicate. In this context, our study is relevant for evaluating the performance of complex cognitive tasks, such as the interpretation of medical images, especially in students in the initial phase of clinical practice.

On the other hand, the so-called "expertise reversal effect" must also be considered, which results from the interaction of several basic cognitive effects and demonstrates that instructional methods that work well for beginners may not be suitable for more experienced learners[18].

The average time spent by students to perform the Worked Example was similar to the duration of the theoretical class and there was no statistically significant difference for the effort reported by students to perform the tasks between the two groups. As expected, for the present study, the mental effort reported by students with less expertise was significantly greater than that reported by students at the end of the course, probably related to the lack of prior knowledge, or mental scripts, requiring greater effort to perform the proposed activities. This is an important piece of information when considering the teaching of radiology in undergraduate courses regarding the timing of the inclusion of the disciplines in the course. Other authors have shown the benefits of the early inclusion of radiology content in undergraduate curricula[21,22].

The literature review carried out using the words "medical education, radiology and Worked Example" showed

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no studies that directly demonstrated the use of the Worked Example technique for the teaching of radiology. One should also consider that instructional studies with radiological contents differ in terms of results when lectures are used in the methodology.

El-Ali et al. carried out a randomized, controlled study with 47 pediatric internship students comparing the use of a traditional lecture based on clinical cases with the use of the flipped classroom methodology in the teaching of pediatric radiology[23]. In this study, the researchers found higher test scores among students who used the flipped classroom methodology[23]. On the other hand, Afzal et al. compared this methodology and the traditional class with 40 3rd-year students for the teaching of chest radiography, finding no significant difference between the groups; however, the results showed the students' good acceptability regarding the method[24].

The methodology used by El-Ali and Afzal et al. to prepare students for their individual study before the class is similar to the Worked Example proposal; however, they are not comparable because it associates knowledge acquired in practice with the teacher.

Courtier et al., in a study with 100 students, evaluated the teaching of pediatric radiology in a module on gastrointestinal tract diseases for undergraduate students in their internship years[25]. In this study, they compared lectures and the application of an interactive digital game in a popular format among the students and found better learning levels among the students who attended the classes[25].

Stein et al. compared the use of lectures with the Team-based learning (TBL) strategy for teaching the application of the American College of Radiology (ACR) criteria in choosing radiological exams in different clinical situations[26]. As in our study, a significant difference was found between the pre-test scores and the tests performed after the training phase; however, they did not find a statistically significant difference between the study groups, either[26]. In this study, the aim was to evaluate the opinion of students attending internship at the University of California about the radiology lectures held during a year, and Jen et al. applied questionnaires after the lectures held during that period, with the participation of 77 students and found positive and negative evaluations about the lectures[27]. The characteristics that are most related to the classes classified with higher grades and, therefore, considered better, were 'interactive', 'fun/engaging' and 'practical/relevant content'. The characteristics related to the worst evaluations were: "lack of interactivity", "poor structure" (probably related to the way the content was presented), "excessive information"[27].

Considering these research results that involved lectures on methodology and radiology, it is likely that the acceptance by the students and the learning could be influenced both by the format of the lecture and the methods that were compared.

The present study has the small number of participants as a limitation. However, studies within this perspective have a similar or even smaller number of participants, such as the studies by Ali et al., Jen et al., and Stein et al. in the late phase[23, 27, 26], all reported above. Likewise, as it was a study carried out with volunteers who performed an extracurricular activity, the participants' knowledge about the research could be a source of bias; however, both groups were submitted to the same limitation.

It should also be considered that further studies are necessary to compare the effect between different teaching strategies and the ability to retain knowledge in the long term, with the incorporation of late tests into the methodology.

In short, the choice of the radiology teaching technique for medical students must be individualized in each institution, as it depends on several factors, such as time available for the disciplines, phase of the course in which the disciplines are included, availability of teachers and resources. However, when the radiology content is considered, there are advantages in the transition to distance learning, as the digital formats are adequate and easily transposable when compared to other disciplines[3]. Additionally, as stated by Darras et al. after a review on radiology teaching during the COVID-19 pandemic, we consider this an opportune time to critically think about radiology teaching strategies for undergraduate medical students[3].

The Worked Example technique allows an individualized, student-centered teaching that can be directed by the teacher to what is the most relevant content. In addition, it can be very interesting for early stage students, potentially used in digital formats and used as preparation for practical classes, whether in radiology or in the clinical practice during internships in other medical specialties. All these favorable characteristics of the method are widely applicable and reproducible and, in our study, they showed to be equally effective in a consolidated teaching format in image interpretation, such as video lectures.

AUTHORS' CONTRIBUTION

Cássio da Cunha Ibiapina: Conceptualization, coordination, methodology, analysis and manuscript writing. No conflicts of interest. Leandro Malloy Diniz: conceptualization, advisory, supervision and analysis. Paola Isabel Silva Barros: study conceptualization and performance, analysis and manuscript writing. Bruno Morais Damião: study performance and methodology.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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