E-learning Modules to Improve Clinical Reasoning and Practice: a Prospective Comparative Study

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Abstract

Background: Controversy remains about how successfully e-learning can improve clinical skills and knowledge acquisition. Our study's main objective was to compare the effects of e-learning versus traditional education on medical students' reasoning and how they applied their knowledge to clinical skills by evaluating their performance in a pediatrics exam based on key features. Our secondary objectives were to assess the factors associated with e-learning that might influence exam scores and to evaluate medical students' satisfaction with these two learning methods.

Methods: Prospective observational study of two pediatric clerkship cohorts (2016–17 and 2017–18) of fourth-year medical students at the University of Geneva's Faculty of Medicine, Switzerland. All students participated in a standardized program of traditional seminars and e-learning using case-based scenarios. To compare the two learning methods, we taught two subjects using traditional seminars in 2016–17 and then using e-learning modules in 2017–18. To evaluate factors that might have influenced e-learning's effects, we monitored the use of all the e-learning modules studied in the months preceding the pediatric exam. Student satisfaction was evaluated using a questionnaire of four-point Likert scale-like items.

Results: We included 299 medical students. Students using interactive e-learning modules had the same median scores for exam questions associated with e-learning as students who attended traditional seminars (median 80%, IQR 67%–100% vs. median 80%, IQR 67%–100%; p=0.975). A linear regression model showed an association between the scores for exam questions associated with e-learning and the number of quizzes taken and sex. Even though the overall satisfaction with the two learning methods was similar, students claimed that they learned more in e-learning than in traditional seminars, that learning objectives were better explained in e-learning modules, and that traditional seminars were better integrated into the curriculum.

Conclusions: We found no evidence of a difference in students' reasoning and how they applied their knowledge to clinical skills between e-learning and traditional seminar-based methods. The number of quizzes taken and being a female student were factors associated with better scores. Overall, students were satisfied with both learning methods, but they claimed that they learned more with e-learning.

Background:

The processes of teaching and learning are domains in constant development. Previous studies have shown that traditional educational models have several limitations, mainly temporal and spatial.[1] For more than a decade, medical schools have been working to transform teaching by reducing the number of lectures and implementing team-based learning, and self-directed learning or promoting individualized, interprofessional education.[2, 3]

Computers and the internet are used more and more in educational settings. Although e-learning means different things to different people, in its broadest sense, it is the use of the internet for education. E-

learning's pedagogical approach typically aspires to being flexible, engaging, and learner-centered. It overcomes students' and teachers' geographical and temporal constraints and encourages collaboration and communication.[4]

Virtual learning programs, available any time, facilitate access to knowledge and add interactivity to study, encouraging reflection and problem solving and stimulating independent learning and self-discipline.[5]

The emergence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) significantly disrupted medical education and required the intensive, prompt attention of medical educators. In response to the coronavirus disease (COVID-19), the Faculty of Medicine quickly transferred the theoretical parts of the curriculum to an online format. Small groups convened online in virtual team settings, and clinical skills sessions either occurred online or were deferred.[6] Most small group seminars and tutorials had to become live remote courses. This often added to the workload of doctors and faculty already burdened with the large influx of COVID-19 patients.

The main drawbacks of online learning are potential technical issues and student isolation.[7] Whether online learning improves knowledge retention and improves exam performance remains debatable.[8] Two recent systematic reviews found that distance education was not different from traditional education in terms of effectiveness.[9, 10] There are considerable controversies about the real impact and potential benefits of using e-learning to improve clinical skills, mainly due to the heterogeneity of the subjects studied.[11, 12] Few studies have evaluated correlations between knowledge acquisition, the retention of clinical skills, and the teaching methods used. Lastly, a rarely considered factor is e-learning's true financial cost.[13]

Recent studies suggest that combining face-to-face training with e-learning is more flexible than other educational methods.[14, 15] The challenge will be to identify optimal ways of using e-learning as part of a blended approach to learning in clinical settings.[12] Comparing virtual and traditional education can provide evidence to identify best teaching practices.

The present research was carried out to compare the effects of e-learning and traditional seminar-based training on medical students' reasoning and how they applied their knowledge to clinical skills by evaluating their performance in a written pediatrics exam. Our secondary aims were to evaluate medical students' satisfaction with these two different learning methods, and to assess the factors associated with e-learning that might influence exam scores.

Methods:

Study design and subjects

This was a prospective observational study involving two cohorts participating in an eight-week pediatric clerkship rotation (2016–17 and 2017–18 intakes) of about 30 fourth-year medical students at the

University of Geneva's Faculty of Medicine, Switzerland.

According to a 2009 decision by the cantonal Ethics Committee of Geneva and the Teaching Committee Office of the University of Geneva's Faculty of Medicine, research projects in the field of medical education, dealing with existing anonymized data, and designed to evaluate the quality of undergraduate or postgraduate educational programs, are exempt from the need for a full review process by the cantonal Ethics Committee of Geneva. All the data were completely anonymized after merging and consolidation. All files and records were stored in local institutional data servers.

Learning activities

Traditional learning

Medical students participate in several supervised clinical activities during their pediatrics clerkship and attend a standardized program of traditional case-based seminars held for each clerkship rotation.

Online e-learning course format

Geneva Children's Hospital has set up an educational website that allows medical students to achieve various learning objectives in pediatrics through individual learning using case-based scenarios. These deal with the most common situations faced in general pediatrics, neonatology, pediatric orthopedics, and pediatric surgery. Most of the learning objectives are covered exclusively in e-learning modules available on the educational website, which is available 24/7.

E-learning modules use the Moodle™ (Moodle Pty Ltd, West Perth WA 6872, Australia) platform. Each learning activity is structured as follows:

- An introduction including statements about specific learning objectives;
- A topic covered using a step-by-step approach, including one or several case-based vignettes; question–answer–feedback sections alternate with theoretical learning content;
- A quiz section enabling students to review the learning content; key features of diagnosis and management skills are tested using multiple-choice questions; several attempts per quiz are allowed, and students can review their attempts throughout their clerkship; quiz settings also allow students to see the correct answers, their scores, and get some feedback immediately after their attempt.

Pediatric exam evaluation method

Students take a written exam once, after they have completed their clerkship: students who did their clerkship between January and April (two groups) take the May exam; those who did their clerkship between June and December (three groups) take the January exam. The latter students thus have a more extensive overall clinical and theoretical background since they have completed clerkships in other fields in the meantime.

Exams are online and use either the CAMPUS (for computers) or tEXAM (for tablets) software provided by the Umbrella Consortium for Assessment Networks (UCAN, Heidelberg, Germany). Exam content is

designed to test clinical reasoning skills and theoretical knowledge. Students must deal with the step-by-step management of several clinical situations presenting different common pediatric complaints. Supplemental patient information, given sequentially, allows them to move towards case resolution.[16]

Experimental questions were identical in both the May and January exam sessions in order to have a reasonable means of comparing the students. A retrospective study showed that our students were more likely to get higher scores in exams taken in the second session (January) than in the first (May). This difference may be explained by the fact that medical students taking the exam in May have less overall clinical experience.[17]

Comparing e-learning and traditional seminars

To compare the e-learning and lecture formats, two e-learning modules (on constipation and gastroesophageal reflux) were taught exclusively using traditional seminars (the 2016–17 academic intake) and exclusively using e-learning modules (the 2017–18 academic intake). Seminars were given by the authors of the e-learning modules so as to maximize similarities between the learning content in the seminars and e-learning modules. Students from the 2016–17 academic intake could not access any parts of the constipation and gastroesophageal reflux e-learning modules (introduction section, case-based vignette, or quiz) (Figure 1). We named the questions relating to the two subjects the *teaching format experiment questions* (TFEQ), and we analyzed and compared the TFEQ scores for these two academic intake groups.

Factors influencing scores in subjects taught using e-learning

Questions on subjects taught exclusively using e-learning (seven modules; Figure 1) were named the e-learning experiment questions (EEQs). The following factors were considered: exam scores (excluding TFEQs and EEQs), the number of quizzes taken, quiz scores, sex, and the cohort effect.

Access to every e-learning module made by individual students using their institutional login was documented. We considered the number of attempts each individual made with each quiz, as well as the highest score they obtained on each quiz.

Each exam session also included 34–36 other items (i.e., non-experimental) covering a range of related topics. These items were different in each exam session. The topics tested using these items were taught in seminars, Problem-based learning tutorials, and/or e-learning chapters. Thus, corresponding scores could be used as controlling factors for estimating each student's level.

Evaluation of student satisfaction

All the students were invited to evaluate teaching activities (on knowledge acquisition, the clarity of learning objectives, achieving learning objectives, curriculum adequacy, teacher preparedness, e-learning, and traditional lecture or tutorial learning activities) at the end of their eight-week pediatrics clerkship. Four-point Likert scale items were used in all our institutional surveys.

Analysis

Scores (0 to 100) were given as the percentage of points scored divided by the maximum points achievable. Data were summarized using mean, median, and inter-quartile range (IQR), and Student's t-tests were used to compare the two different groups' scores.

We used multivariate linear regressions to investigate associations between EEQ scores and all the exam's other item scores, numbers of quizzes taken, mean scores obtained for the different quizzes (if a quiz was attempted several times, we considered the highest score), sex, and a cohort effect. All the analyses were made using R software, version 3.6.3 (R Foundation for Statistical Computing, Vienna, Austria).

Results:

Study group

The study group included 299 (43.5% males; 56.5% females) fourth-year medical students from the 2016–17 and 2017–18 academic intakes; median age on the exam date was 24.1 years old (IQR 23.4–24.9).

Comparing e-learning with traditional seminars

Students exposed to interactive e-learning modules had almost the same TFEQ scores as students exposed to traditional seminars (mean 79%, median 80%, IQR 67–100% vs. mean 80.3%, median 80%, IQR 67–100%; $p = 0.975$) (Figure 2).

Factors influencing exam scores in subject areas taught using e-learning

A linear regression model showed that EEQ scores were associated with both the number of quizzes taken and sex, irrespective of the scores on non-experiment items (Table 1).

Table 1
Linear regression model of exam scores for items associated with e-learning subjects (EEQ) (R2 = 0.1814)

	Univariate analysis			Multivariate analysis		
Predictor	Coefficient	Standard error	*p*	Coefficient	Standard error	*p*
Control score (non-experiment items)	0.564	0.113	< 0.0001	0.568	0.114	< 0.0001
Number of quizzes taken	0.715	0.289	0.0142	0.717	0.289	0.0140
Quiz score	3.029	1.788	0.0921	-0.213	1.778	0.9048
Cohort effect°	-0.120	2.026	0.9530	-2.691	1.927	0.1645
Sex§	-3.735	2.017	0.0658	-4.140	1.880	0.0290
§ Males compared with females.						
° Second cohort (2016–17 academic intake) compared with first cohort (2017–18 academic intake).						

Survey regarding the two learning methods

Table 2 compares students' evaluation questionnaire responses regarding e-learning and traditional seminars. Even though overall evaluations were almost identical, students reported learning more during e-learning modules than in traditional seminars and that their learning objectives were better explained in the e-learning modules. They felt, however, that traditional seminars were better integrated into the curriculum.

Table 2
Satisfaction questionnaire comparing e-learning and traditional seminars (N = 201 respondents)

	E-learning	Traditional seminars	
	Mean ± SD	Mean ± SD	*P*
I learned a lot during this activity	**3.70 ± 0.46**	**3.37 ± 0.56**	**< 0.0001**
The learning objectives are clearly explained	**3.34 ± 0.73**	**3.21 ± 0.65**	**0.0259**
I was able to achieve the learning goals	3.22 ± 0.61	3.30 ± 0.57	0.2166
The activity is well integrated into the curriculum	**3.16 ± 0.79**	**3.40 ± 0.59**	**0.0002**
The teachers are well prepared	3.54 ± 0.62	3.65 ± 0.48	0.0522
Overall mean score	3.38 ± 0.49	3.38 ± 0.48	0.69074
SD = standard deviation			

Discussion:

E-learning vs. traditional seminars

By using the studies found on Nosignificantdifference.org as indicators of the overall effectiveness of distance and online learning, the present study provided evidence to suggest that online learning is at least as effective as traditional teaching formats, but that evidence is by no means conclusive. Given the issues of selection bias that later studies pointed out and the lack of rigorous methodologies in earlier studies, it is difficult to say how meaningful these results really are.[18]

This study found no differences in clinical knowledge and the acquisition of reasoning skills (subject-related exam scores in questions based on case resolution and key features) when comparing e-learning and traditional lecture-based methods. A Cochrane review has also shown that when compared to traditional learning, e-learning makes little or no difference to health professionals' skills and knowledge. Even if e-learning were more successful than traditional learning in particular medical education settings, general claims that it is inherently more effective than traditional learning may be misleading.[10] This suggests that distance learning, e.g., by transforming seminars into e-learning modules, could be a long-term solution for freeing up tutors' and students' time without losing quality. However, knowing that this would lead to fewer contacts and interactions among students, it might be wise to encourage them to follow their e-learning modules in groups so as to enhance the exchanges between them.

The COVID-19 pandemic has caused unprecedented disruption to medical education and healthcare systems worldwide. One study showed that only 27.7% of medical students had participated in online medical education programs during the COVID-19 pandemic, whereas 65% reported using the internet for participating in study groups and discussions.[19] The current pandemic context led us to start discussing potential new ways of replacing traditional learning that would have minimal effects on the progression of students' overall medical training. We moved our institution's pediatric teaching from face-to-face seminars and tutorials to synchronous videoconferences and asynchronous e-learning modules on Moodle.

The option of covering several learning objectives using interactive e-learning modules, carried out by students autonomously and independently, freed tutors to spend valuable teaching time dealing with COVID-19 patients. It also gave more freedom to the students voluntarily engaged in caring for COVID-19 patients, who could then complete the e-learning modules at more appropriate times. Further studies should evaluate how to integrate e-learning—and the new opportunities it offers for learning and teaching—within traditional methods.

Factors influencing exam scores

As expected, exam scores for the items associated with e-learning subjects depended on student's intrinsic capacities and skills. This was illustrated by the fact that the TFEQ and EEQ scores were

associated with the non-experiment item scores. TFEQ scores were also associated with the number of quizzes taken and sex.

The positive impact of completing quizzes (doing more quizzes led to better scores) was one interesting result of our study. It illustrates the importance of completing quizzes that put students into situations that mimic practice through real-life, case-based scenarios. It also shows the importance of giving students the opportunity to self-assess after having completed a stand-alone e-module. Several publications, supported by neuroscience, have shown that giving students frequent formative tests an effective method of learning.[20] During interactive face-to-face courses, tutors give constant feedback based on discussions with the students and the repetition of key points. During an e-learning module, done independently, an end-of-module quiz in some way fulfils the same role (repeating key points and enabling students to check whether they have understood them). This is about students creating an intellectual process based on theoretical clinical skills and knowledge—training for later implementation in their practice.

In a study based on semi-structured interviews and seeking to reveal the factors that medical students believe affect their academic performance, three core themes were identified: engagement with learning, reflections on learning methods, and experiences and the application of learning to future practice.[21] A study to evaluate factors influencing the National License Examination step 1 score in preclinical medical students showed that students with high motivation to study medicine had higher scores; daily preparation time (h/day) and internet for academic use and achievement of study targets were also higher in the excellent group (scores ≥ 80%).[22]

Our study found some evidence that female students got higher EEQ scores. However, we found little evidence in the literature of sex-related differences regarding assessment performance and the use of e-learning. Previous studies have indicated that there are generally no significant differences in average participation, grades, motivation, and satisfaction between males and females. However, some differences have been found regarding the use of certain Moodle resources, the perception by men that e-learning activities interfere with their social life, and a greater sense of duty among women.[23] A meta-analysis of sex differences in general knowledge concluded that previous research had likely overestimated them.[24]

We observed no evidence of any transmission of information about questions from the 2016–17 intake students to the 2017–18 intake students, since there was no difference in the success rates for the items used in both their exams.

Student satisfaction and evaluation questionnaire

Traditional learning and e-learning were given similar overall evaluations, and students were satisfied with both learning methods. However, they claimed that they learned more during e-learning than in traditional seminars, perhaps because important information is repeated several times in the e-learning

modules, initially in the specific subject question format, then in the theoretical explanations that follow the question, and afterwards in the quiz associated with the module.

Students thought that traditional seminars were better integrated into the curriculum because they occur at set times in set places, whereas with e-learning, students must decide for themselves when to study. However, students subjectively experienced this as "better quality" learning because they had to study independently at a time that felt good for them; this is another reason to encourage the development of more stand-alone e-learning modules to cover learning objectives. Nevertheless, there should also be dedicated time slots in their timetables reserved for autonomous learning. Links should be developed between planned, timetabled activities and e-learning modules to better integrate the latter into the curriculum.

Many students do part-time work during their studies, which can sometimes make it difficult to attend every seminar or small group tutorial. Another interesting feature of e-learning is the ability to externalize learning activities. Teaching and learning could even be done in a shared way with other centers, universities, and hospitals. Thanks to technology, more flexible solutions are now readily available.

In a survey of 92 medical students (mean age = 20.5 years old) multiple regression analysis showed that sex (student socio-demographic characteristics), performance expectations (cognitive factors), and the learning climate (social environment) were predictors of learners' perceived satisfaction.[25] A systematic review of factors influencing student ratings in undergraduate medical education course evaluations indicated that overall course ratings are mainly influenced by student satisfaction with teaching and exam difficulty, rather than high quality teaching objective standards derived from the literature of (qualitative research). Quantitative research studies have also pointed out factors such as students' demographic characteristics, exposure to teaching, satisfaction with evaluations, and evaluation processes themselves. Sex (being female), greater initial interest in course content, higher exam scores, and greater satisfaction with exams were all associated with more positive overall course ratings.[26]

Study limitations

Our study had some limitations. It was carried out in a single faculty and the results might not be generalizable to others. However, we included all the students, hence avoiding the selection bias of studies conducted among volunteers. It did not evaluate costs or other economic aspects linked to the two teaching methods, but this was really beyond the study's scope. We did not evaluate the duration of the online access to modules because students' access is not continuous: interruptions cannot be easily measured, preventing a reliable quantification of time online. We did not make a pre-assessment of students' baseline knowledge and later assess how their knowledge had developed. Finally, there was a very small number of experimental items. Further studies might examine the issue of students' feelings of isolation during e-learning, and its consequences, which this study was unable to.

Conclusions:

We found no evidence of differences in medical students' reasoning or how they applied their knowledge to clinical skills between cohorts using e-learning and traditional lecture-based methods. E-learning could be used as a supplement or an alternative to traditional face-to-face medical teaching methods without compromising teaching quality. The number of quizzes taken and sex were the two factors associated with better exam scores, which underscores the importance of self-assessment. Students were satisfied with both learning methods, but they claimed that they learned more through e-learning. We should find better ways to integrate e-learning modules into the medical student curriculum, especially if there were to be a repeat of the COVID-19 context.

List Of Abbreviations:

SARS-CoV-2: respiratory syndrome coronavirus 2.

COVID-19: coronavirus disease.

TFEQ: teaching format experiment questions.

EEQs: e-learning experiment questions.

IQR: interquartile range.

Declarations:

Ethics approval and consent to participate: The study protocol was presented to the president of the Ethics Committee of Geneva. Following a 2009 decision by the Ethics Committee of Geneva and the University of Geneva's Faculty of Medicine Teaching Committee Office, research projects in the field of medical education, dealing with existing anonymous data, and designed to evaluate the quality of undergraduate or postgraduate educational programs, are exempt from the need for a complete review by the Ethics Committee.

Consent for publication: Participants gave consent for direct quotes from their interviews to be published in this manuscript.

Availability of data and materials: The dataset used and analyzed during the present study are available from the corresponding author upon reasonable requests.

Competing interests: The authors report no conflicts of interest.

Funding: Not applicable.

Authors' contributions: All the authors contributed to the study design. FS wrote the paper. SA supervised data collection and was responsible for data integrity. BC analyzed the data in its entirety and ensured

analytical accuracy. DS, MN, and AG revised the manuscript for intellectual content, readability, and suitability. All the authors read and approved the manuscript's final version.

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Figures

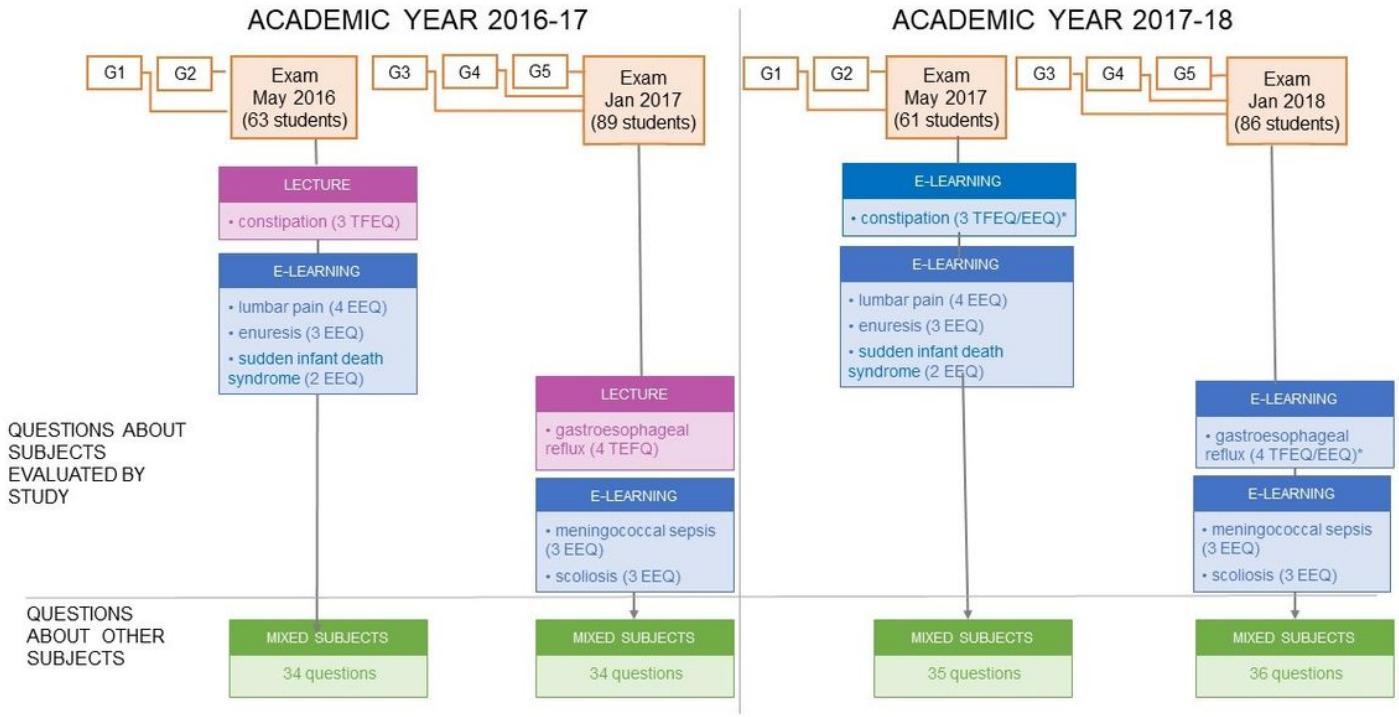

Figure 1

Title: Subjects of questions by teaching format. Legend: Definitions: Mixed subjects: Different subjects and different questions used for each exam, these subjects were taught by lectures, PBL- vignettes and/or e-learning chapters. Teaching format experimental questions (TFEQ) the CBWE questions related to the constipation and gastro-esophageal reflux , the two subjects taught either by traditional lectures in 2016/2017 or by e-learning in 2017/2018. E-learning experimental questions (EEQ) the CBWE questions on the seven subjects taught exclusively by e-learning. All experimental questions were kept identical during both May sessions as well as during both January sessions, to compare students with the same background. * These questions were both analyzed as TFEQ and EEQ

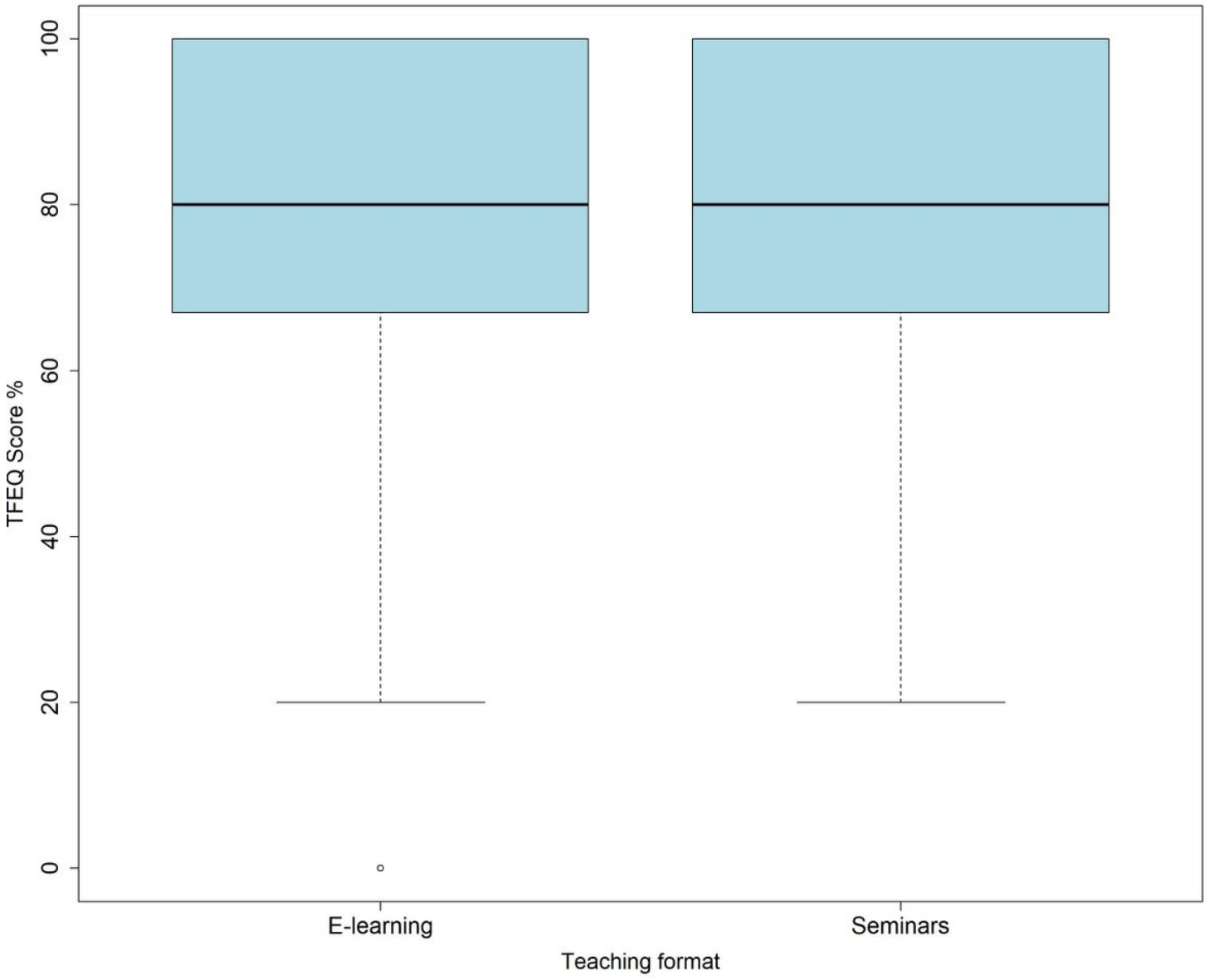

Figure 2

Title: Total combined scores from tests on gastroesophageal reflux and constipation by teaching format.