Time for change? Feasibility of introducing micromodules into medical student education: a randomised controlled trial

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A B S T R A C T

Introduction: Didactic lectures have been the foundation of learning for many medical students. However, in recent years, the flipped classroom model has become increasingly popular in medical education. This approach enhances pre-class learning, allowing the limited contact time between clinicians and medical students to be focused on practical issues. This study evaluated the effectiveness and non-inferiority of online micromodule teaching in terms of knowledge transfer concerning specific urology topics.

Methods: Medical students without prior exposure to the urology subspecialty were enrolled in the study, then randomised to a traditional didactic lecture group or an online micromodule group. Knowledge transfer was assessed by pre-intervention and post-intervention multiple-choice questions and objective structured clinical examinations that involved the acquisition of medical histories from real patients.

Results: In total, 45 medical students were enrolled (22 in the traditional didactic group and 23 in the online micromodule group). In terms of knowledge transfer (assessed by objective structured clinical examinations), the efficacy of online micromodules was comparable to traditional didactic lectures, although the difference was not statistically significant (P=0.823). There were no significant differences in terms of knowledge acquisition, retention, or clinical application between the two groups.

Conclusion: In terms of acquiring, retaining, and applying foundational urological knowledge, online micromodules can help medical students to achieve outcomes comparable with the outcomes of didactic lectures. Online micromodules may be a viable alternative to traditional didactic lectures in urology education.

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New knowledge added by this study

- Compared with traditional didactic lectures, online micromodules have similar knowledge transfer efficacy in medical student education.
- The flipped classroom model may help to allow the limited contact time between clinicians and medical students to focus on practical training and experience sharing.

Implications for clinical practice or policy

- Large-group didactic lectures will likely decline in the future.
- There is an urgent need to develop teaching methods appropriate for the modern era.
- Micromodules may be regarded as a flipped classroom component that can facilitate learning and knowledge transfer.

Introduction

The coronavirus disease 2019 pandemic dramatically changed modern life. Traditional didactic lecture methods suddenly became impossible,[1] and there was a need to maintain social distancing. A shift to online didactic lectures was the most common solution. However, there is evidence that information acquisition becomes inefficient beyond the first 10 to 15 minutes of a lecture.[2] It may be even more difficult to concentrate in online lectures that lack interaction between the speaker and audience. Notably, videos longer than 10 minutes are less likely to be viewed.[3,4] Short online video lectures (ie, micromodules), with or without interactive elements, offer an attractive alternative. Such micromodules can be incorporated into the flipped classroom (FC) model, which is a pedagogical paradigm shift that rearranges how time is spent in and out of the classroom.[5]

是時候改變了嗎？在醫學生教育引入微模塊的可行性：隨機對照試驗

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簡介：教學講課一直是許多醫學生學習的基礎。然而，近年翻轉課堂法在醫學教育中逐漸流行。這種方法增強了課前學習，使臨床醫生和醫學生之間有限的接觸時間可以集中在實際問題上。本研究評估在線微模塊教學在涉及特定泌尿外科主題的知識轉移方面的有效性和非劣效性。

方法：未接觸過泌尿外科亞專業的醫學生被納入研究，然後隨機分配到傳統教學講課組或在線微模塊組。知識轉移通過學習前和學習後的多項選擇題和客觀的結構化臨床考試進行評估，包括從真實患者獲取病史。

結果：本研究共招收了45名醫學生（傳統教學組22名，在線微模塊組23名）。在知識轉移方面（通過評估客觀的結構化臨床考試），在線微模塊的效果與傳統的教學講課相似（P=0.823）。兩組之間在知識獲取、保留或臨床應用方面沒有顯著差異。

結論：在獲取、保留和應用基礎泌尿外科知識方面，在線微模塊可以幫助醫學生取得與教學講課相近的結果。在泌尿外科教育中，在線微模塊可能是替代傳統教學講課的可行方案。

The FC model is becoming increasingly popular in medical education. It is attractive to the current generation of students who are accustomed to utilising digital media; on average, 70% of students prefer this learning model.[6] Students can learn pre-class materials at their own pace; they can also enjoy more in-class active learning and interaction. Moreover, they can negotiate the FC platform at their preferred time and in their preferred place. Instead of passively delivering information in class, educators can devote valuable contact time to interactions with students, exploration of their needs, and discussions of more nuanced and challenging topics.[6] The acquisition of foundational information becomes an active self-directed process, outside of the classroom.

Considering the continuous growth of medical literature, today's medical students must acquire an expanded field of knowledge before graduation. A modern urology clerkship should alleviate the intense time pressures placed on students by helping them to effectively and efficiently develop diagnostic and procedural core competencies. Where possible, students should be allowed to learn by active participation, rather than listening and reading, during the limited available contact time. The FC model holds great promise in achieving this goal.[7]

The success of the FC model requires an efficacious online platform that facilitates self-directed learning; stringent evaluation of the online platform is necessary. However, methodologically rigorous qualitative and quantitative studies and evidence-based recommendations are scarce.[8] Most published works quote practical wisdom, anecdotes, and principles of educational theory as the basis for their recommendations.[9]

This pilot study was conducted to compare our institution's online micromodule platform with traditional didactic lectures in facilitating the acquisition of foundational urological knowledge by medical students.

Methods

This prospective, single-centre, single-blind randomised controlled trial, performed at a tertiary academic hospital, investigated whether online micromodules are non-inferior to traditional didactic lectures as an instructional medium; this trial is a component of a larger movement towards the FC approach in clinical training.

Urology curriculum

The urology clerkship is a surgical subspecialty in our faculty curriculum. All medical students have 1 week of clinical attachment in their final year of medical clerkship training (Year 6). The standard curriculum consists of lectures, bedside tutorials, and clinical shadowing. Traditionally, lectures are delivered to the whole class at the beginning of the academic year. Students then shadow our team in small groups on the wards, in clinics, and in the operating theatre. Teaching is opportunistic, based on symptoms, signs, investigations, diseases, and procedures encountered in the clinical setting. Formal knowledge assessment is conducted during end-of-year examinations in the form of written examinations (multiple-choice questions [MCQs] and short-answer questions), objective structured clinical examinations (OSCEs), and clinical short case examinations.

Study intervention

In this study, we selectively assessed knowledge transfer with regard to two urology topics: approaches to lower urinary tract symptoms (LUTS) and haematuria. First, a didactic lecture on the management of LUTS and haematuria, along with other topics, was recorded during its delivery in our routine lecture series for final-year students. Subsequently, two micromodules were prepared concerning the management of LUTS and haematuria; the micromodule content was similar to the didactic lecture content. The study participants continued with their scheduled urology training in Year 6; therefore, the study intervention was regarded as supplemental curriculum. Because the participants' overall learning opportunities were not affected, we decided to obtain only verbal consent for inclusion in the study.

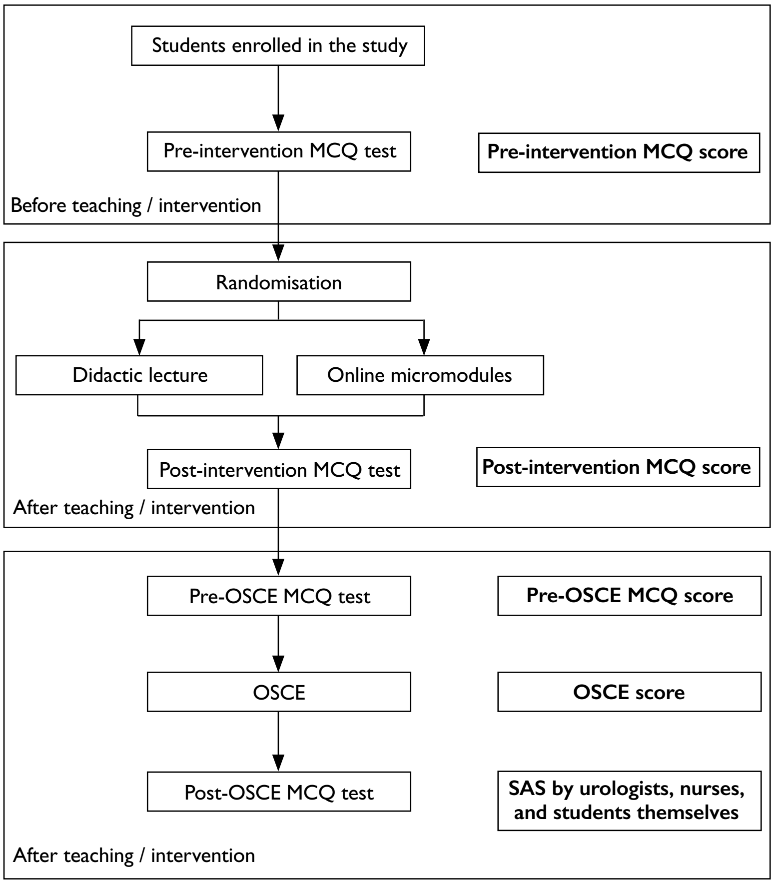

FIG. Flow of pre-intervention assessment, randomisation, intervention, and post-intervention assessment
Abbreviations: MCQ = multiple-choice question; OSCE = objective structured clinical examination; SAS = subjective assessment score

Randomisation, allocation concealment, and blinding of participants

Medical students in Years 4 to 6 with no exposure to the urology subspecialty rotation were voluntarily recruited for the study. Participants were randomly allocated to either traditional didactic lectures or online micromodules; rigorous proctored tests were administered in accordance with the schedule shown in the Figure. Permuted block randomisation was conducted using a computer program. Random allocation sequences were placed into identical sealed and numbered envelopes. Designated research staff members were responsible for allocating consecutively numbered envelopes to the participants.

Students randomised to the traditional didactic lecture were grouped into a class, which watched the pre-recorded 45-minute didactic lecture in the lecture theatre (as if the students were attending a standard lecture). Students randomised to the online micromodule group viewed the micromodules on separate computers at their own pace. The total runtime of these micromodules was 10 minutes each, and students were expected to explore the content in its entirety within 45 minutes. The breadth and depth of topics covered in both interventions were identical to each other and similar to past lectures; the only difference was the delivery medium. The students could not be blinded; however, all outcome assessors (including content creators) were blinded to intervention allocation because the didactic lecture was not delivered live or in person.

Assessment

We used the Kirkpatrick's four-level training evaluation model as the basis for evaluations of instructional effectiveness. In the context of online learning, Level 1 (reaction) refers to the student's affective responses to training quality or relevance, usually measured by surveys; Level 2 (learning) refers to knowledge directly obtained from the online lecture, usually measured by knowledge tests such as MCQs and true-false questions; Level 3 (behaviour outcomes/transfer of learning) refers to improvements in the outcomes of tasks not directly taught in the instructional content, typically measured through practical or standardised examinations; and Level 4 (results) refers to the impact of training on organisational goals (ie, actual benefit to patients).

Prior to randomisation, a pre-intervention MCQ test was used to determine participant baseline knowledge. Immediately after randomisation and completion of training, participants repeated the MCQ test to determine the degree of knowledge acquisition (ie, Kirkpatrick Level 2). Their confidence in the subject matter was also measured using a 10-point scale (ie, Kirkpatrick Level 1).

After 3 weeks of teaching, each participant underwent individual assessments in outpatient clinics. The MCQ test was administered again to test knowledge retention. Then, an OSCE was administered to assess the participant's approach to a real patient with either LUTS or haematuria. A nurse was present as a chaperone and third-party assessor, who gave a subjective assessment score, measured using a 10-point scale. The participant then presented the case to a urologist, who assessed the collected information using a structured marking scheme. Additionally, the urologist gave a subjective assessment score, similar to the nursing assessment. All student assessors were blinded to the allocated teaching approach. The scores from the nurses and urologists were used to assess student performance in the OSCE (ie, Kirkpatrick Level 3); they also were used to assess the overall effectiveness and safety of the micromodule teaching approach. Due to the study design, the impact of training on organisational goals (ie, Kirkpatrick Level 4) was not assessed.

Statistical analysis

Statistical analysis was performed using SPSS (Windows version 23.0; IBM Corp, Armonk [NY], United States). There was no crossover between treatment arms. Data were analysed using an intention-to-treat approach. Descriptive statistics (means, standard deviations, and ranges) were used for demographic data. Independent samples *t* tests or one-way multivariate analysis of variance were used for parametric continuous variables; the Mann–Whitney *U* test was used for non-parametric continuous variables; and the Chi squared test was used for categorical variables. P values <0.05 were considered statistically significant.

Results

Between 4 December 2017 and 22 January 2018, 45 medical students voluntarily enrolled in this study at our hospital; 22 students were randomised to the didactic lecture group and 23 students were randomised to the online micromodule group. Most participants (77% and 74%, respectively) were in their final year of medical education. There were no significant differences in demographic composition between the two groups (Table 1). The difference in pre-intervention MCQ scores also was not statistically significant (P=0.471), indicating that the participants had similar baseline knowledge (Table 2).

In this study, the primary outcome was the difference in OSCE scores between the didactic lecture and online micromodule groups, as assessed by the urologists. This outcome corresponds to Level 3 of the Kirkpatrick model. Three-quarters of participants assessed real patients with LUTS; the remaining participants assessed patients with haematuria. There was no difference in OSCE score between the groups (13.09 ± 1.59 vs 12.98 ± 1.75, P=0.823) [Table 2].

The secondary outcome was the difference in knowledge acquisition and retention between interventions. Knowledge acquisition was defined as the difference between pre-intervention and post-intervention MCQ scores. Knowledge retention was defined as the difference between pre-intervention MCQ score and pre-OSCE MCQ score (taken 3 weeks after the intervention). Both of these outcomes correspond to Level 2 of the Kirkpatrick model. There were improvements in MCQ scores after teaching in both groups, although not statistically significant. However, there was no difference in the degree of improvement between the groups. Therefore, knowledge acquisition for the two groups were similar. For the assessment of knowledge retention, one-way multivariate analysis of variance with adjustment for pre-intervention MCQ scores revealed no statistically significant difference between post-intervention MCQ score and pre-OSCE MCQ score (Wilks' Lambda=0.894, P=0.101, partial η^2=0.106).

Finally, subjective assessment of confidence and competence was conducted; this assessment corresponds to Kirkpatrick Level 1. There was a significant improvement in post-intervention self-rated confidence, but there was no difference in the degree of improvement between the groups (Table 2). In terms of clinical performance (Kirkpatrick Level 3), there were no differences between the groups in terms of subjective assessment score by the urologists (7.89 ± 0.91 vs 7.70 ± 0.91, P=0.487) or nurses (8.05 ± 0.72 vs 8.04 ± 0.71, P=0.993).

TABLE 1. Baseline participant characteristics*

	Didactic lecture group (n=22)	Online micromodule group (n=23)	P value
Male	9 (40.9%)	11 (47.8%)	0.641
Female	13 (59.1%)	12 (52.2%)	
Year 4	4 (18.2%)	5 (21.7%)	1.000
Year 5	1 (4.5%)	1 (4.3%)	
Year 6 (final year)	17 (77.3%)	17 (73.9%)	

* Data are shown as No. (%), unless otherwise specified

TABLE 2. Assessment result of the students during different phases of the study*

	Didactic lecture group (n=22)	Online micromodule group (n=23)	P value
Pre-intervention MCQ score†	50.18 ± 3.59	51.13 ± 5.01	0.471
Post-intervention MCQ score†	57.32 ± 3.63	55.91 ± 6.52	0.375
Pre-OSCE MCQ score†	54.45 ± 6.10	52.22 ± 6.58	0.244
OSCE score assessed by urologists‡	13.09 ± 1.59	12.98 ± 1.75	0.823
Pre-intervention self-marking by students§	4.59 ± 1.18	5.04 ± 1.64	0.295
Post-intervention self-marking by students§	5.80 ± 0.83	5.87 ± 1.14	0.805

Abbreviations: MCQ = multiple-choice question; OSCE = objective structured clinical examination

* Data are shown as mean ± standard deviation, unless otherwise specified

† Total marks=75

‡ Total marks=15

§ Total marks=10

Discussion

Our results show that both didactic lectures and online micromodules can help medical students achieve comparable outcomes in terms of acquiring, retaining, and applying foundational urological knowledge. Thus, online learning platforms may be viable substitutes for didactic lectures in the broader context of a move towards the FC approach.

In a systematic review of literature concerning the use of online lectures in undergraduate medical education,[6] 45 studies were identified; only 21 (47%) of those studies had clearly established control and intervention groups. Among the 21 studies, only six (29%) assessed learning using an OSCE or equivalent practical examinations; the remaining studies used MCQ tests. There was considerable heterogeneity in the manner by which online lectures were integrated into existing surgical curricula, which hindered meta-analysis. However, online lectures generally tended to be non-inferior to traditional lectures.

Online learning offers many benefits to educators and students. First, it ensures round-the-clock access to learning materials. Second, it allows students to revisit these materials throughout the curriculum. Third, online learning platforms can track and verify that students have accessed and completed specific materials. Fourth, electronic content can be updated in a convenient manner; distribution is instantaneous and universal. Fifth, students have autonomy over the sequence and pace of learning, as well as the allocation of time; these aspects allow them to tailor their learning experience to meet personal objectives. Sixth, although a higher initial investment may be required, online learning platforms can be reused, exchanged, and collaborated on; they offer new economies of scale.[10,11] Finally, the coronavirus disease 2019 pandemic led to concerns about the spread of infection, such that online micromodules became an attractive option for medical student education that permitted social distancing. Notably, online micromodules represent easily accessible media that can be used for continuing medical education, and interactive teaching can be added to enhance learning experience.

An important limitation of online learning is that educators may utilise the scheduling freedom offered by online platforms to overburden students with learning materials; they may not consider the large amount of non-classroom time that may be allocated to other tasks. To avoid this phenomenon, we established 'bite-sized' modules (ie, micromodules) and ensured that all topics covered are highly relevant to future clinical practice. Such short modules also match the students' attention spans.[2-4] However, we acknowledge that educators may initially expend greater effort in the preparation of online modules.[4]

Although there were some improvements in MCQ scores after the lecture or micromodules, they were weaker than expected, potentially because the post-intervention MCQ test occurred immediately after the lecture and there was insufficient time for participants to process the lecture content. Another limitation of the study design was that there were no tutorials or in-class interactions after the lectures. Thus, the acquired knowledge may not have been consolidated, resulting in suboptimal knowledge retention. Nevertheless, this study was designed to demonstrate non-inferiority between pedagogical approaches. Educators should remember that online learning is one component of the overall FC model. An overhaul of the broader teaching mentality and existing curriculum is required to realise the paradigm shift offered by the FC model. Thus, simple conversion of existing lecture notes to an electronic format will not effectively facilitate learning. There is a need for full utilisation of software/technologies to prepare multimedia/truly interactive micromodules; this approach is more likely to enhance student learning experiences. It is also challenging to develop effective methods for assessment of student competencies. Educators should support and collaborate with clinicians in this regard, thereby complementing each other's efforts.[4,12-15]

In addition to video lectures, online platforms can be used to deliver diverse educational content, including interactive multimedia learning modules, discussion forums, polling, and virtual patients. We deliberately excluded these materials for the duration of this study because they represent distinct instructional configurations in terms of content and interactivity. The combination of interactive elements and lecture into a single intervention group would have confounded and invalidated the results.[6,8] Thus, the video lectures solely consisted of slide decks, narration, and video. More studies are needed to determine how to best incorporate these teaching approaches into the instructional design of future curricula.[11]

The present study focused on the transfer of clinical knowledge and management of common urological symptoms via micromodules. Future research should examine whether online lectures can also effectively transfer practical procedural skills. Because of time constraints and the curriculum system, exposure during the clerkship period is extremely limited. Therefore, the current instructional approach for physical examination and basic clinical procedures (eg, insertion of urethral and central venous catheters) is often informal, opportunistic, and unstructured. Further studies may clarify the role of online education in procedural training.

Conclusion

Online micromodules were non-inferior to a traditional didactic lecture in terms of knowledge transfer focused on urology topics. Further enhancement of the interactive elements of the instructional medium will improve learning experience. Micromodule utilisation can be optimised during the development of the FC model of teaching. In times such as the recent pandemic era, where social distancing must be maintained throughout the educational process, there is an urgent need for curriculum reform that maximises the use of technology to enhance medical student learning.

Author contributions

Concept or design: CF Ng.
Acquisition of data: CH Yee, PKF Chiu, JYC Teoh, FPT Lai.
Analysis or interpretation of data: K Lim.
Drafting of the manuscript: K Lim, CF Ng.
Critical revision of the manuscript for important intellectual content: All authors.

All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of interest

As editors of the journal, CF Ng and JYC Teoh were not involved in the peer review process. Other authors have disclosed no conflicts of interest.

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Ethics approval

This research aimed to improve instruction through the use of educational tests administered to the participants. All participants provided informed consent without the collection of personal or sensitive data.

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