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Review article

# Impact of COVID-19 pandemic on ophthalmology medical student teaching: educational innovations, challenges, and future directions

*Tony Succar, PhD, MScMed(OphthSc)*[a,b,*], *Hilary A. Beaver, MD*[c,e,f,g,h,i,j,k], *Andrew G. Lee, MD*[c,d,e,f,g,h,i,j,k]

[a] *Massachusetts Eye and Ear, Harvard Medical School, Boston, Massachusetts, USA*
[b] *University of Sydney, Discipline of Ophthalmology, Save Sight Institute, Sydney, Australia*
[c] *Blanton Eye Institute, Houston Methodist Hospital, Department of Ophthalmology, Houston, Texas, USA*
[d] *Departments of Ophthalmology, Neurology, and Neurosurgery, Weill Cornell Medicine, New York, New York, USA*
[e] *Department of Ophthalmology, University of Texas Medical Branch, Galveston, Texas, USA*
[f] *University of Texas MD Anderson Cancer Center, Houston, Texas, USA*
[g] *Department of Ophthalmology, The University of Iowa Hospitals and Clinics, Iowa City, Iowa, USA*
[h] *Departments of Neurology and Neurological Surgery, Weill Cornell Medical College, New York, New York, USA*
[i] *Department of Ophthalmology, Baylor College of Medicine (Adjunct Professor), Houston, Texas, USA*
[j] *The UT MD Anderson Cancer Center, Houston, Texas, USA*
[k] *The University of Iowa Hospitals and Clinics (Adjunct Professor), Iowa City, Iowa, USA*

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ABSTRACT

Graduate medical education (GME) in ophthalmology has faced and overcome many challenges over the past years, and 2020 has been a game-changer. Although the severe acute respiratory syndrome coronavirus pandemic disrupted medical education globally, ophthalmic educators rapidly transformed their curricula to novel and effective virtual learning formats. Thus, while the COVID-19 outbreak has been one of the most significant challenges faced in the history of medical education, it has also provided an impetus to develop innovative teaching practices, bringing with it unprecedented success in allowing medical students to continue their education in ophthalmology despite these challenges. We review and appraise novel educational interventions implemented by various institutions in response to the COVID-19 pandemic, highlighting their effectiveness, challenges and proposing future directions beyond the pandemic. Many of these innovations will persist even after the end of the pandemic because they have proven that face-to-face learning is not required for all aspects of the ophthalmic GME curriculum. As ophthalmic educators harness the power of educational technology it is critical that their novel educational

* Corresponding author: Tony Succar, PhD, MScMed(OphthSc), Massachusetts Eye and Ear, Harvard Medical School, Boston, Massachusetts, USA.
*E-mail address:* tony_succar@meei.harvard.edu (T. Succar).


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initiatives are incorporated into competency-based curricula with assessments mapped to the competencies. Future research should focus on evaluating the impact of this transformation to virtual learning environments on student performances as well as implementing longitudinal assessment strategies for clinical competence in workplace-based practice.


## 1. Introduction

An ophthalmic evaluation is a core clinical skill, and ophthalmic medical student education is a cornerstone to improving eye health care globally. Graduate medical education (GME) in ophthalmology has faced and overcome many challenges over the past years[1,2,4,5,8,10,14,15,18,21,23-28] and 2020 has been a game-changer.[3,7,9,16,17,22,30,32] Although the severe acute respiratory syndrome coronavirus pandemic disrupted education globally, ophthalmic educators rapidly transformed their curricula to novel and effective virtual formats.[3,6,12,16,22,30,32] While the COVID-19 outbreak has been one of the most significant challenges faced by educators, it has also provided an impetus to develop innovative teaching practices, bringing with it unprecedented success in allowing medical students to continue their education in ophthalmology despite these challenges. These innovations may persist even after the end of the COVID-19 pandemic and may offer medical students' opportunities inaccessible previously due to higher costs of travel and accommodation.'

Competency-based medical education is an outcome-based model that has become the new standard of medical education internationally. Ophthalmology competency-based GME curricula have shown to be more effective than content-based curricula alone.[13,14,23] As ophthalmic educators harness the power of educational technology, it is critical that their novel educational initiatives are incorporated into competency-based curricula with assessments mapped to the competencies. Current global GME competencies that all medical students should demonstrate are outlined in Table 1.

We review and appraise novel educational interventions implemented by various institutions in response to the COVID-19 pandemic, highlighting their effectiveness, challenges, and proposing future directions beyond the pandemic. Novel interventions from the following institutions (Table 2) will be discussed: American Academy of Ophthalmology (AAO), Association of University Professors of Ophthalmology (AUPO), Houston Methodist Hospital Blanton Eye Institute, Emory University School of Medicine, University of Illinois, UCLA Stein Eye Institute, Ohio State University (OSU), Johns Hopkins University School of Medicine, Queen's University, University of Hong Kong, Christian Medical College, Kalpana Chawla Government Medical College and Hospital, and the University of Edinburgh.

## 2. The American Academy of Ophthalmology (AAO) and Association of University Professors of Ophthalmology (AUPO)

The AAO has an international impact on medical education with its mission "*to protect sight and empower lives by serving as an advocate for patients and the public, leading ophthalmic education, and advancing the profession of ophthalmology.*"[17]

The mission of the AUPO is to "*serve, strengthen, and represent departments of ophthalmology; to provide support, information, and leadership opportunities to department chairs, program directors, and other faculty members; to promote excellence in ophthalmic education; to foster vision research and to promote ethical practice and excellence in eye care in order to ensure the best possible vision for the public.*" (AUPO Website)

Together they have provided leadership and ophthalmic educational resources in response to the effects that the COVID-19 pandemic has had on medical student education and proposed the creation of online curricula, virtual clerkships and electives. The AUPO Medical Student Educator Council meets regularly to guide national education in ophthalmology.[9] AUPO has developed a series of recommendations to mitigate the impact of the COVID-19 pandemic for the 2020-2021 ophthalmology match cycle to ensure a successful residency application process by focusing on four guiding principles: safety, equity, fairness, and transparency (AUPO website: https://aupo.org/programs-services/medical-students). In addition, the AAO website contains a medical student portal that includes interactive medical student cases, a guide to the bedside ophthalmic examination, and ophthalmology residency application guidelines (AAO website: https://www.aao.org/medical-students).

## 3. Houston Methodist Hospital Blanton Eye Institute

At the Houston Methodist Hospital Blanton Eye Institute a novel virtual neuro-ophthalmology elective (Fig. 1) was developed to provide medical students quality exposure to ophthalmology despite challenges posed by COVID-19. The elective included a virtual curriculum which taught the core anatomy, diseases and concepts of neuro-ophthalmology; opportunities to study unique cases through morning reports, research opportunities, and grand rounds presentations; clinical experience via patient encounters; and assessments in the form of oral and written examinations.[32]

Although the curriculum focuses on a neuro-ophthalmology elective, the core components can be used as a template for other ophthalmic subspecialties in the future. An oral examination is administered virtually during the last week of the elective by the course director. The examination format is modeled after the American Board of Ophthalmology's oral examination for graduated ophthalmology residents seeking board certification.[32]

Beyond the pandemic the video-based morning reports and conferences could be used in the future. The virtual nature of these conferences allows for increased medical student

**Table 1 – List of international GME competencies and objectives for ophthalmology.**

| Institution | Competencies and objectives |
|---|---|
| Association of University Professors of Ophthalmology (AUPO).[11] | Medical Student Objectives[11]:<br>(1) Describe the anatomy of the eye and the visual system<br>(2) Perform a basic eye examination<br>(3) Evaluate a patient with acute painless vision loss<br>(4) Evaluate a patient with chronic vision loss<br>(5) Evaluate a patient with a red or painful eye<br>(6) Evaluate a patient with eye trauma<br>(7) Evaluate a patient with an eye movement abnormality or diplopia<br>(8) Describe the important causes of vision loss in children<br>(9) Describe the ocular manifestations of systemic disease<br>(10) List the most important ocular side effects of systemic drugs<br>(11) List the common ocular medications that can have systemic side effects<br>(12) Describe when it is necessary to refer a patient urgently to ophthalmology |
| HYPERLINK "http://www.icoph.org/resources/15/Principles-and-Guidelines-of-a-Curriculum-for-Ophthalmic-Education-of-Medical-Students.html" International Council of Ophthalmology : Principles and Guidelines of a Curriculum For Ophthalmic Education 0f Medical Students (icoph.org) Webpage: http://www.icoph.org/resources/15/Principles-and-Guidelines-of-a-Curriculum-for-Ophthalmic-Education-of-Medical-Students.html Accessed March 26, 2021 | All medical students should demonstrate competency in these areas:<br>(1) Measurement of near visual acuity with and without correction.<br>(2) Determination of visual fields by confrontation technique.<br>(3) Assessment of extraocular motility in the 6 cardinal positions of gaze and primary position.<br>(4) Measurement and interpretation of pupillary size and reaction to light.<br>(5) Penlight examination of the anterior segment, including upper lid eversion.<br>(6) Examination of the optic nerve and posterior pole with direct ophthalmoscopy.<br>(7) Removal of superficial corneal or conjunctival foreign body. |
| 2020 Royal College of Ophthalmologists Curriculum for Undergraduates and Foundation Doctors. Webpage: https://www.rcophth.ac.uk/training/ophthalmology-for-medical-students-and-foundation-doctors/ Accessed March 26, 2021 | Students should be able to perform the following in adults and interpret common abnormalities as appropriate:<br>(1) Take an ophthalmic history<br>(2) Measure Snellen visual acuity (unaided and best corrected)<br>(3) Examine pupil reactions<br>(4) Examine extraocular movements<br>(5) Direct ophthalmoscopy to examine the red reflex, anterior segment and fundus<br>(6) Examine visual fields by confrontation<br>(7) Use slit lamp to view the eyelids, conjunctiva, cornea, iris and lens h.<br>guide someone who has visual impairment.<br>Students should be able to: recognize the following conditions, describe their risk factors and causes, provide basic advice on management for:<br>The red eye<br>Gradual deterioration of vision<br>Sudden or subacute loss of vision<br>Diplopia<br>Transient visual symptoms (migraine, amaurosis fugax, and papilledema)<br>Other diagnoses (blepharitis, dry eye, meibomian cyst, basal cell carcinoma, herpes zoster ophthalmicus, subconjunctival hemorrhage, posterior vitreous detachment, choroidal nevus / melanoma. |

**Table 2 – Summary of COVID-19 interventions developed at each institution.**

| Institution | Intervention |
|---|---|
| American Academy of Ophthalmology (AAO) | Medical student resources: https://www.aao.org/medical-students |
| American University of Professors of Ophthalmology (AUPO) | Medical student resources: https://aupo.org/programs-services/medical-students |
| Houston Methodist Hospital Blanton Eye Institute | A novel virtual neuro-ophthalmology elective was developed which included a virtual curriculum encompassing the core anatomy, diseases and concepts of neuro-ophthalmology and opportunities to study unique cases through morning reports, research opportunities, and grand rounds presentations; clinical experience via patient encounters; and assessments in the form of oral and written examinations. |
| Emory University School of Medicine | A 4-week novel teleophthalmology curriculum for medical students was developed via the video-conference software Zoom (San Jose, CA). |
| University of Illinois | The department devised a new curriculum, titled "Ophthalmology Online", which was a 4-week sequential educational curriculum that built upon itself to provide a well-rounded educational experience for all medical students. |
| UCLA and OSU | A virtual ophthalmology shadowing clerkship elective for fourth year medical students was implemented which was composed of four sections: patient workup with technicians/imaging specialists, patient interview and general exam with an attending ophthalmologist, the slit lamp exam with attending ophthalmologist, and didactics. Medical students observed all aspects of the patient encounter, using a smartphone, a videoconferencing app such as FaceTime or Zoom, and a tabletop stand. |
| Johns Hopkins | A 1-week, online elective for medical students was developed which included lectures from ophthalmology attendings, cataract surgery narration exercises with an anterior segment surgeon, and short presentations by the medical students on a topic of their choice. |
| Queens University, Canada | A virtual pedagogical approach for teaching ophthalmology to medical students was developed, it was found that interactive webinars and modules can successfully recreate clinically immersive learning environments while maintaining social distancing. |
| The University of Hong Kong | As a necessary replacement for traditional face-to-face small group clinical demonstrations during the COVID-19 pandemic, video-based and written materials to precede and complement Zoom™ (Zoom Video Communications Inc., San Jose, CA, USA) were developed and included platform-based small group tutorials. |
| Christian Medical College, India | Audio visual modules for teaching direct ophthalmoscopy and torchlight examinations were developed. The AV teaching module included torchlight examinations of the eye; swinging flashlight test, ROPLAS (Regurgitation on Pressure over the Lacrimal Sac) test, Anterior Chamber Depth (ACD) assessment, examination of the cornea, lens and Direct Ophthalmoscopy (DO) along with the evaluation of the optic disk margin, neuro-retinal rim, cup disk ratio using the prescribed techniques. |
| Kalpana Chawla Government Medical College, India | Ophthalmology lectures were uploaded in PowerPoint format on an education management system (EMS). While making the presentation, salient points were highlighted and included clinical scenarios and photographs to encourage students to read further on that particular topic. In addition, a WhatsApp group consisting of the full class of students along with the ophthalmology faculty was created. |
| University of Edinburgh, UK | Implemented an e-learning tool to reduce extraneous cognitive overload for teaching ophthalmology to medical students. Eight goal-free ophthalmic disease-specific factsheets were created, integrating basic and clinical sciences teaching across 30+ information sources. Key facts were thematically arranged in comparative statements underscoring variations between differential diagnoses, and hyperlinked to online content. |

attendance due to decreased travel constraints and the ability for students at a different institution to attend. Additionally, students are assigned virtual topics to review on their own time from a YouTube website (neuro-ophthalmology with Dr. Andrew Lee (NODAL) at https://www.youtube.com/channel/UC5HcfsELV0W9AqtvJvpQQSg) to prepare for the next day debrief and study sessions about various neuro-ophthalmology topics.[32]

## 4. Emory University School of Medicine

Devaro and colleagues developed a 4-week novel teleophthalmology curriculum for medical students at the Emory University School of Medicine via the video-conference software Zoom (San Jose, CA). The elective was offered during COVID-19 to mitigate educational interruption and explored the integration of students into telemedicine platforms. The first component of the course was online self-directed learning that consisted of prerecorded lectures and interactive online activities. The first week provided an introduction to the eye and covered topics on red eye and acute vision loss. The second week focused on chronic vision loss, systemic disease, glaucoma, and retinal diseases. The third week concentrated on orbital trauma and oculoplastic surgery. The final week was devoted to pediatric ophthalmology, neuro-ophthalmology, and ocular oncology. Students were required to submit proof of completion of interactive online activities.[7]

The second component was student presentations held twice a week. Each student gave a 15-minute case-based ses-


**Fig. 1 – The virtual neuro-ophthalmology setting at the Houston Methodist Hospital (photos courtesy of Andrew G. Lee, MD) demonstrating: virtual clinical teaching only, virtual white board teaching, and the integration of both virtual and live audience teaching.**

sion to teach fellow students about an ophthalmic disease. The third component was case-based discussions led by department faculty. There were eight discussions: acute vision loss, red eye, chronic vision loss, oculoplastic surgery, ocular trauma, neuro-ophthalmology, pediatric ophthalmology, and ocular oncology. Each session was 1 hour. The fourth component was optional telehealth observations at Emory Eye Center, offered in the fourth week. The fifth component was chart review activities. All students with access to the electronic medical record platform engaged in remote chart review projects aimed at helping the residents working at the Grady Eye Center during the COVID-19 outbreak.[7]

The authors found a significant increase in self-reported knowledge. In addition, self-reported interest in ophthalmology increased significantly. The class performed significantly higher in ophthalmology questions than UWorld Step 2 CK question bank users. Their study suggests remote electives may have great potential to enhance student education, knowledge, and interest in ophthalmology.[7] This curriculum may be helpful to educators worldwide, as the entire curriculum can be conducted remotely, it can aid students without ophthalmology programs at their home institution or integrate an online curriculum with a clinical ophthalmology course. It can also provide mentorship and career development opportunities to faculty, who wish to train the next generation of ophthalmologists. As COVID-19 continues to transform medical education, studies of telehealth experience and objective assessment are needed to explore further the potential of remote learning in ophthalmology.[7]

## 5. University of Illinois

The University of Illinois at Chicago College of Medicine (UIC COM) is one of the largest medical schools in the country with over 300 medical students each year across three campuses. Medical students from UIC COM and other programs across the country frequently perform clinical ophthalmology electives in the department throughout the year.

With guidelines developed by UIC COM during the pandemic, all medical student education moved from in person to web-based learning. The department devised a new curriculum titled “Ophthalmology Online”, a 4-week sequential educational curriculum that built upon itself to provide a well-rounded educational experience for all medical students.[20]

Ophthalmology Online consisted of a weekly ophthalmology subspecialty theme with designated reading from e-textbooks in the initial part of each week, viewing of online videos, solving clinical vignettes mid-week, and culminating into e-lectures specifically designed for medical students by subspecialty faculty. The e-lectures were a mix of lecture and case-based learning with opportunity for discussion of the weekly reading and viewing assignments. The students were expected to craft a summary of their weekly e-learning, a final oral presentation via Zoom or WebEx, and a final exam administered via SurveyMonkey (San Mateo, CA). The department now offers students from other medical schools the opportunity to participate in electives that provide online ophthalmology education that includes web-based patient evalu-

ations using slit-lamp camera systems that can be projected via Zoom or WebEx, with opportunities for students to participate in patient exams and clinical decision-making. Overall, the changes to medical education necessitated by the coronavirus crisis enabled educators to utilize new strategies that can be implemented in medical education moving forward.[20]

## 6. UCLA and OSU

At the UCLA Stein Eye Institute and the OSU, Tsui and colleagues implemented a virtual ophthalmology shadowing clerkship elective for fourth year medical students composed of patient workup with technicians/imaging specialists, patient interview and general exam and the slit lamp exam with an attending ophthalmologist, and didactics. Medical students observed all aspects of the patient encounter using a smartphone, a videoconferencing app such as FaceTime or Zoom, and a tabletop stand.[30]

Advantages for the use of virtual slit lamp examinations included providing a unique opportunity for students to view clinical encounters, which could be useful for teaching rounds. Slit lamp adapters were more affordable than slit lamp cameras, and there may be a wider availability of video or photographs of clinical findings for teaching purposes. Ultimately, virtual rotations in the future may also offer medical students opportunities that may have been inaccessible because of the costs of travel, accommodations, and scheduling.[30]

Challenges to using teleconferencing software for clinical rotations include that neither Zoom nor FaceTime have manual focusing capabilities, therefore dynamic adjustment of the slit lamp may be needed to focus the image for the student observer. These educators anticipate that the use of FaceTime for a virtual rotation will transition to a HIPAA-compliant application such as Microsoft Teams.[30]

## 7. Johns Hopkins University

At Johns Hopkins University the Office of Faculty Education developed an educational series that offered several courses to faculty to enhance their online teaching. The faculty were supported by courses on how to use video-conferencing platforms, create a supportive learning environment, and conduct virtual clinical teaching and precepting. The School of Medicine's Ophthalmology Department developed a 1-week, online elective for medical students that included lectures from ophthalmology attendings, cataract surgery narration exercises with an anterior segment surgeon, and short presentations by the medical students on a topic of their choice. They hope to continue offering the course to augment exposure of medical students to ophthalmology when clinical rotations resume.[16]

Medical students considering ophthalmology are encouraged to attend the Department's virtual grand rounds, resident didactics, and journal clubs – all conducted using online conferencing platform. Students may learn about direct ophthalmoscopy and refraction via online modules. Ophthalmology interest groups can still meet online with guest lecturers to provide advice on career and residency application planning.[16]

## 8. Queen's University, Canada

He and colleagues developed a virtual pedagogical approach for teaching ophthalmology to medical students and conducted a survey study to assess the programs feasibility and efficacy. Their study found that interactive webinars and modules can successfully recreate clinically immersive learning environments while maintaining social distancing. Furthermore, it was found that such open-access virtual platforms may mitigate inequities in accessing high-quality medical education.[12] Medskl.com, a free online learning resource, conducted an ophthalmology program for medical students that comprised four synchronous webinars held weekly and six asynchronous video modules that could be completed independently.[12]

Students who reported that the webinars and modules were effective for learning were more likely to agree that this format helped supplement in-person clinical teaching. In addition, students reported that the modules were more effective than webinars for learning ($P = 0.04$). Unlike webinars ($P = 0.04$), however, students did not believe that modules were effective in increasing their knowledge and confidence in ophthalmology. Unfortunately, 68% of medical student respondents believed that COVID-19 hindered their exposure to ophthalmology. When assessing the characteristics of an effective virtual learning environment, 74% preferred virtual (synchronous or asynchronous) modalities over didactic in-class learning. Students found webinars to be most helpful for receiving immediate feedback from experienced clinician educators (79%) and participating anonymously in clinical cases (79%). The greatest utility of modules was scheduling flexibility (92%) and individualization to learning needs (77%). Participants also reported that access to virtual ophthalmology learning increased equitability and inclusion to medical education, and those who attended more webinar sessions were less likely to feel socially isolated.[12]

## 9. The University of Hong Kong

With COVID-19, face-to-face small group tutorials at the University of Hong Kong were not advisable. This was especially true of ophthalmic clinical skills that require close contact between the examiner and the patient. Shih and colleagues introduced video-based and written materials to precede and complement Zoom platform-based small group tutorials.[22]

These educators taught ophthalmic clinical skills to second-year medical students that included visual acuity assessment with near Snellen chart, pupil examination, visual field testing by confrontation, extraocular movement examination, and direct ophthalmoscopy. In order to replace face-to-face group tutorials, they devised a three-pronged approach to provide an effective learning experience. First, for each examination technique, they included written information regarding: (a) technique; (b) physical signs demonstrated; (c)

common mistakes by medical students, and (d) clinical relevance. Second, they recorded a video of a clinical teacher demonstrating the techniques on a surrogate patient. Both written material and videos on the e-learning platform were uploaded. Third, after going through the online materials, the students were split into groups of 30 students for a single 60-minute tutorial with a clinical teacher on the Zoom cloud-based video conference platform. During the tutorial, the teacher went through each key ophthalmic clinical skill and highlighted important points, pitfalls, and clinical knowledge. The last 10 minutes were reserved for questions from students. Using the private message function, students were able to pose anonymous live questions. Assessment was conducted at the end of the block in the form of objective structured clinical examination (OSCE) stations.[22]

Their approach was designed both to enhance knowledge acquisition and to increase competency attainment in ophthalmic clinical skills. By introducing an element of self-directed learning to precede tutorials, the students took a proactive role. The tutorials themselves further served as an opportunity for critical reinforcement of self-directed learning. It was noted that the students were able to better follow the online clinical demonstration with the help of pretutorial materials.[22]

Benefits resulting from the introduction of Zoom tutorials included the ability for students to send live questions to the clinical tutor anonymously via private message. It allowed the tutor to address questions for the entire group's benefit without students having to reveal their identity. This is important in countries where social, cultural, and hierarchical norms may preclude asking questions comfortably in a public or virtual setting.[22] Participants preferred instead to email their teachers later to address their questions. Furthermore, another advantage was that recordings of the Zoom tutorials were made available to students to rewatch later at their own pace.[22]

A major challenge encountered was difficulty teaching direct ophthalmoscopy online. To learn this technique, students needed access to simulated patients. Furthermore, much of the difficulty in this particular skill is in understanding the correct angle of approach and the necessary adjustments to be made when examining the fundus. The authors concluded that face-to-face tutorials are still a more effective means of teaching direct ophthalmoscopy.[22]

## 10. Christian Medical College, Vellore, India

Given the challenges of teaching direct ophthalmoscopy, it may be well suited for video-based instruction, particularly if videos enable the student to see what the examiner sees when performing direct ophthalmoscopy. Rose and colleagues developed audiovisual modules for teaching direct ophthalmoscopy and penlight examinations. They created this module specifically to benefit medical students posted in various peripheral hospitals after competition of their MBBS, as well for those who plan to be general practitioners. These skills can help them pick up a relative afferent pupillary defect, blocked tear ducts -with regurgitation on pressure over the lacrimal sac shallow anterior chamber (primary angle-closure glaucoma suspects), corneal ulcer, mature cataract, papilledema, glaucomatous discs, and white pupillary reflex in in a child–all of which need prompt referral to an ophthalmologist.[19]

The authors found significant improvement in ophthalmology knowledge and skills. The feedback on the Likert scale indicated more than 80% agreement in themes ranging from the clarity of understanding, holistic coverage, confidence in performance and interpretive abilities of the students. There was good agreement on the ideal duration of the module and the interest it stimulated.[19]

The authors reported several benefits to their model: (1) standardization; (2) reduced staff teaching time, equipment, and space requirements; and (3) less dependence on live patients. They concluded that their system might be durable and sustainable and in conjunction with the teaching practices that existed prior to COVID-19.[19]

One potential drawback, however, is the cost involved in creating videos; however, the one-time cost could lead to a return on investment from savings in time and staffing. They concluded that other validated modules could also have powerful translational implications in the post-COVID-19 GME environment and might be useful in sustaining competence in clinical skills among medical students and physicians.[19]

## 11. Kalpana Chawla Government Medical College, Karnal, India

In response to the COVID-19 pandemic, Sud and colleagues reported a shift to online teaching of medical students. The GME ophthalmology lectures were uploaded in PowerPoint format on an education management system. While making the presentation, salient points were highlighted and included clinical scenarios and photographs to encourage students to read further on that particular topic. In addition, a WhatsApp group consisting of the students and ophthalmology faculty was created. Reference material and related videos of clinical examination and surgical procedures were shared in this group, and the students were encouraged to ask questions on this platform. Simultaneously, a Google form of 10 multiple-choice questions on the topic was shared on the WhatsApp group that was to be completed within 1 day. This served a dual purpose of ensuring that the students were reading the study material provided in a timely manner and also as formative assessment to gauge their understanding.[29]

Feedback was taken regarding their perception of online classes, and students felt that online classes were a viable alternative to classroom lectures. The main advantages as perceived by the students were: ease of access anytime from anywhere, the material could be read at any pace as many times as necessary, with access to reference material simultaneously. In this study, 17.6% students felt that the MCQs helped them in self-assessment. The students felt the main disadvantage was that this mode of teaching was not as interactive as classroom lectures. The challenges faced by the students were poor Internet connectivity and availability of devices used to access the study material.[29]

## 12. The University of Edinburgh, UK

Tzoumas and colleagues designed and implemented an e-learning tool to reduce cognitive overload in teaching ophthalmology to medical students. Eight goal-free ophthalmic disease-specific factsheets were created, integrating basic and clinical sciences teaching across 30+ information sources. Other strategies employed included coherence (exclusion of extraneous words), spatiotemporal contiguity (presenting corresponding words and pictures in close proximity and simultaneously), signaling (highlighting important words), and personalization (employing a conversational style).[31] Key facts were thematically arranged in comparative statements underscoring variations between differential diagnoses, and hyperlinked to online content. A nonrandomized pretest/posttest study was conducted to evaluate the resource and, compared to existing resources for ophthalmology teaching, the intervention received improved ratings for quality, utility, reliability and overall satisfaction.[31]

## 13. Future directions

In summary, we believe that the COVID-19 pandemic is a motivator for disruptive innovation for ophthalmic GME. Ophthalmic educators from across the globe responded to the GME crisis with creativity, energy, and timely countermeasures. Many programs rapidly transformed their GME curricula and culture to leverage effectively virtual formats and digital platforms. Many of these innovations will persist even after the end of the pandemic because they have proven that face-to-face learning is not required for all aspects of the ophthalmic GME curriculum. We have highlighted research, challenges and adaptations implemented by various institutions that have shown that virtual teaching methods can be employed successfully. The challenges posed have provided opportunities to explore new and innovative teaching-learning practices that could further shape ophthalmic medical student education in the future. It is critical that any new innovations should be competency-based, which is shown to be more effective than content-based curricula. Future research should focus on evaluating the impact of this curricular transformation to virtual learning environments on student performances, as well as implementing longitudinal assessment strategies for clinical competence in workplace-based practice.

## 14. Methods of literature search

The literature search was conducted through the MEDLINE/PubMed and Google Scholar databases to review the educational impact of COVID-19 on medical student teaching. While articles from all years were included, the review focused mostly on articles published from January 2020 to December 2020 during the COVID-19 pandemic. The search was conducted using various combinations of the following search terms: ophthalmology medical student teaching, medical student education, ophthalmology medical curricula, COVID-19, Coronavirus. Articles were reviewed and included if the information therein was pertinent to medical student education during the COVID-19 pandemic. Articles were excluded if they focused solely on postgraduate education and continuing medical education. English language abstracts were screened for relevance and the full texts of articles that met the inclusion criteria were obtained. A further hand search of reference lists for articles were reviewed for other publications of significance. English abstracts for articles written in another language were reviewed and included if the inclusion criteria were met.

## Conflicts of interest

The authors Tony Succar, Hilary Beaver, and Andrew Lee, all report no conflicts of interest.

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