Teaching Histology Using Self-Directed Learning Modules (SDLMs) in a Blended Approach

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Abstract

Introduction New technologies like virtual microscopy have revolutionized histology education. However, first-year students often require additional assistance with virtual slides. Online self-directed learning modules (SDLMs) were developed to provide such support to learners by offering them short instructional videos that are uploaded to YouTube and the instructional website. The purpose of this study was to determine the effectiveness of SDLMs and to sample students’ opinions about SDLMs.

Method Over a 3-year time span, SDLMs were used to augment histology lessons, and their effectiveness (on learning outcomes) was measured by using traditional steeple-chase and/or virtual slide assessments. Average percentage scores for both methods of assessment were compared using paired or independent t-tests. Student opinions about SDLMs were collected using an anonymous survey. The survey results were analyzed by average scores and thematic analysis of the narrative responses.

Results Using SDLMs in a blended approach showed significant improvement in students’ academic performance — irrespective of the method of assessment. There was a strong positive correlation with the performance when students were assessed using the virtual slide method. However, a standalone approach using SDLMs did not positively impact learning outcomes. Survey results indicated that most students perceived the videos as helpful for understanding the subject better and as quick review opportunities.

Conclusion The results support the use of SDLMs in a blended instructional approach and as an adjunct resource to conventional microscopy. This use of SDLMs was positively received by learners and significantly improved the learning outcome.

Keywords Self-directed learning modules · Virtual microscopy · Conventional microscopy · Blended approach · Histology

Introduction

Technological innovations and a shift to competency-based curricula have been central reasons for the increasing use of e-learning in medical education. In addition, the current generation of medical students is more tech-savvy and likely to use e-learning over traditional educational resources than previous generations of learners [1, 2]. Many studies have reported that online learning methods are usually as effective, if not superior to traditional didactic approaches in terms of knowledge transfer and student satisfaction [3, 4]. Anatomy education has responded to the technological advances by progressively incorporating online learning resources, virtual simulators, virtual reality, and augmented reality [5–9]. In histology pedagogy, adoption of online learning has evolved from using simple static images to dynamic virtual microscopy — which surpasses conventional microscopy in terms of accessibility, long-term cost-effectiveness, ease of archiving, improved academic performance, and greater student satisfaction [10–14]. Additionally, virtual microscopy also decreases the need for in-person teaching — which has been particularly relevant during the COVID-19 pandemic and in response to curricular changes leaving less time for histology instruction [15–17]. Many medical schools around the world have partially or completely abandoned the use of classical light microscopy in favor of virtual microscopy for the teaching of histology.
In contrast, medical colleges in India continue to rely on conventional microscopy for histology laboratory instruction [22, 23]. One important reason for this resistance to change is that summative assessments (university practical examination) are based on conventional microscopy. Other contributing factors include infrastructure constraints, deep-seated reverence to traditional methods, insufficient faculty development programs, fear — not entirely unfounded — of misuse of the electronic devices, and/or the underuse of online resources by the students [23–25].

Until 2016, histology laboratories instruction at our institution, Sree Gokulam Medical College & Research Foundation in Trivandrum, Kerala, followed the general practice across India and was taught using only conventional light microscopes. Considering the benefits of virtual microscopy and being mindful of the need to expose our students to global practice, a deliberate decision was made in the academic year 2016–2017 to use virtual slides for the first time [22]. However, due to infrastructure limitations at that time, the virtual slides were only used in offline access mode. Nevertheless, students showed improved learning outcomes and positively commented on the use of virtual slides as a supplementary resource. However, this change of incorporating virtual microscopy into our histology curriculum placed additional demands on students and the teaching staff.

As histology instruction is more and more shifting to an online only format [18–21] and often involves the exclusive use of virtual microscopy, new didactic methods are needed to introduce students to the histological slide material. The still ongoing COVID-19 pandemic has greatly accelerated this process and the need for novel didactic approaches [15]. Self-directed learning modules (SDLMs) have emerged as a useful option for the introduction of virtual microscopy and as a component of online histology laboratory instruction without additional burden on students and the teaching staff [26–29]. This study describes a 3-year initiative to teach histology involving online SDLMs at a medical school in India. The purpose of this study was to determine the effectiveness of SDLMs as part of histology laboratory instruction and to gauge students’ opinions about the usefulness of SDLMs to support their learning.

Creation of Self-Directed Learning Modules

Self-directed learning modules (SDLMs) were developed at Sree Gokulam Medical College & Research Foundation where the study was conducted. SDLMs were created using virtual slide images provided by the University of Michigan Medical School in Ann Arbor, MI [30]. These images are available under a Creative Comments License (CC BY-NC-SA 4.0). The SDLMs are short instructional videos that were created by the first author to introduce histology learners to the virtual microscopy slide material and to translate the knowledge learned in the lecture phase to the visual analysis of histology slides/images. The display appropriately magnifies histological images with suitable annotations and narration. They are grounded in contiguity (placing text near the images improves learning), modality (explaining complex images with audio improves learning), and multimedia principles (using both images and instructional message improves learning) and cognitive theory of multimedia learning (learning is better when dual channels are used and the content is systematically organized to allow knowledge construction from the pre-existing knowledge) [31, 32]. To allow student access, individual videos were uploaded to YouTube. Initially, only the modules required for the current study were developed. Subsequently, modules for most of the topics taught in the histology course were added. Before publication, all modules were proofread and reviewed by the
Experimental Procedure

During this study, histology was taught using either conventional microscopy or a blended approach using the online SDLMs supplementing conventional microscopy. To ensure objectivity and to accommodate both methods of teaching, student assessments were performed either using a traditional steeple-chase method with conventional microscopes, and/or involving virtual slides, where the students were asked to identify details in projected virtual slides and to answer relevant questions. Questions using the latter method addressed higher cognitive levels in Bloom’s taxonomy [34]. Following informed consent, only students who attended all the assessments were included and those having difficulty accessing the online learning modules were excluded.

Step I: Study participants were recruited within the cohort of first-year medical students of 2018–2019 batch using convenience sampling (n = 150; 54 men, 96 women, age range 18 y 3 m-22 y 4 m; average age 19.11 ± 0.68 y). Initially, twenty histology slides were taught over 8 weeks using conventional microscopy. At the end of 8 weeks, a pre-intervention assessment was performed using the two assessment methods described above. In the following 8 weeks, students were taught using a second set of twenty slides using a blended approach with addition of the SDLMs (intervention). Students were taught two to three slides each week using conventional microscopy as outlined above. In addition, after the didactic lecture, students were instructed to study the relevant slides using the SDLMs anytime, anywhere, and as often as needed during the week before the laboratory session (Fig. 1). Subsequently, a post-intervention assessment was conducted using the same two assessment methods. Since the SDLMs were being introduced for the first time, opinions of students about these modules were collected using an anonymous survey.

Step II: In the subsequent two academic years (2019–2020 batch: n = 150, 55 men, 95 women, age range 18 y 7 m-23 y, average age 20.01 ± 0.89 y and 2020–2021 batch: n = 150, 49 men, 101 women, age range 18 y 2 m-22 y 9 m, average age 20.62 ± 0.77 y), histology training was influenced by the COVID-19 pandemic. In the initial period, when the students of both the batches were available for the offline classes, histology was taught using conventional microscopy. When COVID-19 pandemic imposed mandatory online classes, inadvertently SDLMs became a mandatory online instruction tools. Each week, the students studied two to three predetermined slides at home using the SDLMs. When students returned to campus, they proceeded with abridged versions of lectures and laboratory sessions using conventional microscopy (time allotted for histology instruction was reduced from 3 h per week to 2 h per week and the number of slides covered in a week increased to 3–5 instead of only 2–3) (Fig. 1). While pre-intervention assessments were done using only the virtual slide method (traditional steeple-chase method was avoided to minimize the risk of COVID-19 infections), post-intervention assessments were performed using both methods.

Step III: For the students of 2020–2021 batch, after the initial conventional microscopy session (followed by pre-intervention assessment), classes had to be converted to online only mode for a period of 8 weeks due to endemic COVID-19 cases. During this period, students were off campus and had only access to SDLMs (that were released each week in a pre-determined sequence) without being able to attend in-person lectures or histology laboratory sessions. When the students returned to the campus at the end of this period, effectiveness of SDLMs in a standalone approach was determined using the virtual slide method of assessment. Following this, the same slides were covered in the

Fig. 1 Flow chart of the experimental procedure. Step I and step II show the order in which the teaching–learning methods were used in a traditional approach and a blended approach using SDLMs. In step III, SDLMs were used in a standalone approach.
abridged lecture and laboratory sessions (as mentioned above). The last set of slides were covered using the blended approach mentioned in step II, which was followed by the post-intervention assessment.

### Data Collection and Analysis

Quantitative data were derived from the scores of the pre- and post-intervention tests. Average percentage scores for both methods of assessment were compared using paired or independent *t*-tests as applicable. The SPSS statistical package, version 22.0 was used for this statistical analysis. The level of significance was set at *p*-values smaller than 0.05.

After step I, an anonymous survey was conducted by administering a face- and content-validated survey tool to the 150 students of 2018–2019 batch (supplementary material). First segment of the survey form consisted of nine statements, where the students were required to select responses on a 5-point Likert scale (strongly disagree to strongly agree). These statements were initially tested on 20 students. Cronbach’s alpha coefficient for all the statements was 0.738, suggesting an acceptable level of internal consistency. Second segment of the survey tool consisted of statements to assess the preferred device to access SDLMS and frequency of internet use, to which frequency distribution was calculated. It also included three open-ended questions, namely, what were the advantages of SDLMS, what were the drawbacks of SDLMS and if they had any suggestions to improve SDLMS.

Semi-quantitative data were generated from the responses to nine statements in the anonymous survey tool. Ordinal values ranging from 1 to 5 were assigned to the responses on a 5-point Likert scale (1 = strongly disagree through 5 = strongly agree). Average scores were calculated for each statement.

Qualitative data stemmed from the narrative responses to the open-ended questions in the anonymous survey tool. A thematic analysis of the narrative comments was performed and percentage responses for each theme were tabulated.

### Results

#### Effectiveness of SDLMS for Teaching Histology

When compared to an exclusive use of conventional microscopy, students performed significantly better when using SDLMS in a blended teaching approach over all the 3 years of this study (Table 1). This improved academic performance when offering SDLMS in a blended approach was seen with both methods of assessment (2018–2019 batch: traditional steeple-chase method: *t* = 3.53, *p* = 0.01; virtual slide method: *t* = 54.339, *p* < 0.001, Table 1). A Pearson correlation was performed to assess the linear relationship between the exposure to SDLMS and academic performance for the two methods of assessment. Although the correlation was weak for traditional steeple-chase method of assessment, *r*(137) = 0.168, *p* = 0.001, there was a strong positive correlation between the two variables with virtual slide method of assessment, *r*(137) = 0.94, *p* < 0.001. Academic performance was significantly better with SDLMS in a blended teaching approach irrespective of the timing of exposure to the SDLMS, whether they were accessed after the didactic lecture (2018–2019 batch: *t* = 54.339, *p* < 0.001) or before the didactic lecture (2019–2020 batch: *t* = 7.107, *p* < 0.001 and 2020–2021 batch: *t* = 2.968, *p* = 0.003) (Table 1, virtual slide method).

When students’ academic performance was compared over a 3-year time span, the results showed opposite trends in the two methods of assessment (Table 1). There was a significant decline in performance from year 1 to year 3 with traditional steeple-chase method of assessment (independent *t*-test: *t* = 3.656, *p* = 0.0001, *d* = 0.44). In contrast, there was a significant improvement in academic performance with the virtual slide assessment method (independent *t*-test: *t* = −1.70, *p* = 0.044, *d* = 0.2). Nonetheless, the effect size was small in both the cases, as indicated by the value of Cohen’s *d*.

However, when SDLMS were offered in a standalone approach, they did not contribute to improved performance.

#### Table 1 A comparison of the academic performance over 3 years between the conventional microscopy (pre-test) and the blended approach using SDLMS (post-test)

| Batch (n)          | Traditional steeple-chase assessment method | Virtual slide assessment method |
|--------------------|---------------------------------------------|---------------------------------|
|                    | Pre-test (Avg. % ± SD) | Post-test (Avg. % ± SD) | *t*-value | *p*-value | Pre-test (Avg. % ± SD) | Post-test (Avg. % ± SD) | *t*-value | *p*-value |
| 2018–2019 (139)    | 63.81 ± 17.86             | 68.42 ± 11.96            | 3.53      | 0.001     | 9.94 ± 5.75            | 63.25 ± 12.08            | 54.339 | <0.001     |
| 2019–2020 (143)    | ^a^ 64.10 ± 17             | ^a^ 61.27 ± 19.60        | ^a^       | ^a^       | 51.55 ± 18.38          | 64.96 ± 13.35          | 7.107  | <0.001     |
| 2020–2021 (136)    | ^a^ 61.27 ± 19.60         | ^a^ 61.27 ± 19.60        | ^a^       | ^a^       | 59.64 ± 21.10         | 66.20 ± 16.42          | 2.968  | 0.003*     |

*n* number of students, *t*-value and *p*-value after paired *t*-test

^a^Significant, level of significance <0.05

^a^Traditional steeple-chase method of testing was not performed due to COVID-19 pandemic restrictions
Perception of Students About the Use of SDLMs

A total of one hundred and forty-three students (49 male and 94 female) returned the survey (95.33% response rate). Most students expressed the opinion that SDLMs were useful not only for understanding the microscopic details, but also helped them in identifying the structures under the microscope (Table 2). They found the self-directed learning modules very useful for a quick review of conventional microscopy (Fig. 2E). Consequently, students have begun to enjoy learning histology due to SDLMs and were using them in addition to textbooks and didactic lectures (Table 2). Since most students were already accessing the internet several times a day (Fig. 2B), mostly using their smartphones (Fig. 2C), most found SDLMs convenient to access (Fig. 2A). Some of the perceived advantages of the modules were that they helped students to better understand histology, review the material as often as needed, easy accessibility anytime and anywhere, and the opportunity to learn at their own pace (Fig. 2D). Almost half of the survey respondents felt that there were no downsides to the modules (Fig. 2E). However, some students were concerned that the modules may cause distractions or device overuse, while others felt that they were too detailed (Fig. 2E). Some students also expressed concerns about eye strains and headaches (Fig. 2E). Almost two-thirds of the class felt that the modules were good as they were, whereas others suggested improvements, like better sound quality, and the addition of quizzes, notes, line diagrams, and animations (Fig. 2F).

Table 2 Responses of students to the nine statements in the survey (n = 143; 49 male, 94 female)

| Survey question no | Item/statement                                                                 | Avg. score ± SD |
|--------------------|--------------------------------------------------------------------------------|-----------------|
| 1                  | I find the histology study modules very useful                                 | 4.29 ± 0.57     |
| 2                  | I find that being able to revise each slide within 5–7 min is the biggest advantage | 4.26 ± 0.69     |
| 3                  | I find it convenient to watch these videos at my own time                      | 4.25 ± 0.68     |
| 4                  | The videos help me to understand the microscopic details better                | 4.06 ± 0.72     |
| 5                  | The videos help me to identify the structures under microscope in the laboratory | 3.93 ± 0.77     |
| 6                  | Because of these videos, I have begun to enjoy learning histology now          | 3.54 ± 0.84     |
| 7                  | The videos do not open quickly putting me off from studying                    | 2.20 ± 0.84     |
| 8                  | I do not have smart phone or convenient internet access hence, I do not get to see the site | 1.93 ± 0.91     |
| 9                  | I find that the textbook and lectures are sufficient, hence, do not feel the necessity to use these videos | 2.04 ± 0.92     |

Scores were calculated from the assigned ordinal values to the responses on a 5-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree.
Fig. 2  Student responses to the survey questions. Ease and mode of access are summarized in A, B, and C. Percentage narrative responses received for the perceived advantages and disadvantages of SDLMS and suggestions to improve the SDLMS are shown in D, E, and F, respectively.
resources follow an asynchronous e-learning approach while minimizing any additional time or manpower burden on learners and teachers [43]. Being an online learning resource, SDLMs support medical students’ transformation into life-long learners. They also meet curricular requirement of students spending less time in the classroom and support a more solitary learning mode [44]. Various types of resources have been reported as SDLMs for teaching histology. These include combinations of PowerPoint files, static images and virtual histology modules [27], virtual lectures and digital slides [45, 46], narration, images, and questions [28], mobile apps [47], case-based asynchronous interactive modules [29, 43], adaptive tutorials [48], and an interactive atlas [49]. Among these available online learning resources, students show a strong preference for instructional videos [50, 51]. Therefore, the SDLMs were designed in the form of short narrative videos using annotated virtual slide images and were published as a YouTube channel. Major advantages of this strategy were that these SDLM resources were free of charge, accessible anytime and anywhere, did not require any additional software, were comprehensive learning packages, made use of virtual microscopy, and were sufficiently short in duration to hold the attention of student learners. Free instructional videos that are not tailored to specific educational needs are often inadequate and of inferior quality [52, 53]. However, our study agrees with Schoenherr et al. that low-cost study modules can be effective when they are made to suit the needs of the local student population and address the objectives of the academic exercises [26]. Similar to our findings, other investigators have also reported that online SDLMs in a blended approach improve academic performance [28, 29, 38, 43, 45, 46, 48, 49, 54–58].

At Indian medical schools, summative assessments for histology still involve the mandated use of conventional microscopy. With the introduction of online SDLMs to supplement the traditional light microscopes, we investigated whether both technologies are equivalent for assessing students’ knowledge of histology. Students were assessed using two methods: (a) by a traditional steeple-chase method to determine if SDLMs influenced the ability to identify the slides under optical microscopes and (b) by a virtual slide method to assess students’ expertise of identifying finer details on virtual slide images and to answer the questions belonging to higher cognitive levels. SDLMs in a blended approach improved the performance in both methods of assessment (Table 1). Although students mentioned that SDLMs helped them to identify structures under a light microscope (Statement 5, Table 2), SDLM-correlated improvements in learning outcome were smaller for the traditional steeple-chase method. In contrast, SDLMs showed a larger effect size and a strong positive correlation with performance in virtual slide assessments. When average scores over the 3 years of the study were compared, academic performance for the traditional steeple-chase assessment method declined, whereas performance for the virtual slide assessment increased. Students of 2018–2019 batch were taught using regular classroom setting for the entire duration of the course, whereas students of 2019–2020 and 2020–2021 batches had regular laboratory sessions only during the initial period before switching to online classes, the latter batch having even shorter exposure to conventional microscopy. This COVID-induced limited exposure to laboratory sessions and light microscopes might be one cause for the observed lower academic performance with the traditional steeple-chase method. Increasing familiarity with SDLMs and virtual microscopy are suspected reasons why students performed increasingly better with the virtual slide method of assessment (Table 1). However, additional data and analysis will be required to verify or reject these hypotheses.

The timing when SDLMs were offered to students differed in various published studies that used a blended approach and is a potential variable that might influence the academic outcome [28]. Learning modules have been offered prior to lectures [58], prior to laboratory sessions [45], during the laboratory sessions [54, 59], or after the lectures/laboratory sessions were completed [28]. All studies reported improvements in academic performance correlating with SDLM availability, except for the last scenario [28]. In the current study, modules were released between the lecture and the laboratory sessions during the first year (step I) and before both lecture and laboratory session in the next 2 years (step II). In both the timelines, SDLMs improved the academic performance (Table 1), indicating that the timing of SDLM release was not a critical factor.

Unlike the positive effect in a blended approach, SDLMs did not improve learning outcomes in our study as a standalone resource. Our result contrasts the findings of Thompson and Lowrie, who reported that academic performance was better with the use of SDLMs in a standalone approach [27]. There are several potential reasons for these contrary findings, one being uneven and infrequent use of the resource. Since frequency and duration of SDLM access were not monitored in our study, especially when students were at home, this may have contributed to infrequent use of the resource. A second reason might be digital burnout due to the prolonged, exclusive e-learning modus for all courses during the COVID-19 pandemic. Students of the 2020–2021 batch began exhibiting signs of digital burnout reflected by a drop in attendance and/or only digital presence in synchronous e-learning sessions, and the avoidance in asynchronous e-learning. This may have also negatively influenced self-regulation and motivation of students in accessing the online learning resources and consequently their academic success [43, 56]. How SDLMs interacted with other course components, specifically the laboratory sessions, may be another important variable influencing their academic impact [3]. In a blended approach, accessing
SDLMs each week was immediately rewarded by a better understanding during the subsequent laboratory sessions hence, the students were enticed to use this resource regularly. However, this context was lost when the same SDLMs were introduced in a standalone approach.

Present-day students belong to a technologically driven generation and are frequently engaged in digital social interactions [1, 2]. Hence, they find the use of online learning resources convenient and acceptable (93.6% in the current study), especially when these resources are perceived as useful and/or interactive [3, 60]. However, introducing SDLMs at a school in a developing country poses several challenges that educators at schools in more affluent regions of the world may not face. Mobility, availability, and affordability make smartphones the most used device by medical students in developing countries (95.1% in the current study) [61, 62]. However, students have commented that the small screen size of smartphones makes them less suitable for studying the finer details of histology images [1, 51]. Notably, only 6.2% of survey respondents in this study mentioned better visuals as an advantage of SDLMs. In the recent study by Finn et al., very few students at a US medical school named smartphone as their favorite learning hardware device with most learners preferring laptop or tablet computers [51]. Therefore, the availability of hardware devices to students, either personal or provided by the school, should be considered before introducing e-learning resources into a medical curriculum.

**Limitations of the Study**

It should be noted that the data in this study were collected over several years at only a single institution. Although we believe these data reflect general trends, care should be applied when transferring conclusions based on this data set to other schools and locations. As students’ survey answers were self-reported and not independently verified, these data may not provide a full reflection of SDLM usage. Specifically, it was not possible to quantify internet access to the modules, setting limits to analyzing the exact role of SDLMs in the observed academic improvements.

**Conclusions**

The introduction of SDLMs for histology laboratory education in a blended approach improved the learning outcome irrespective of the methods of assessment or timing of use. However, SDLMs did not positively influence the learning outcome when offered alone without a corresponding laboratory session. Survey responses revealed a positive attitude by learners towards the use of SDLMs. Hence, the use of SDLMs as an adjunct resource to conventional microscopy in histology laboratory instruction enhanced students’ learning experience and learning outcomes. However, in the context of a medical school in India, several limitations and opportunities became apparent: (a) using online resources in medical education is still in its infancy, limited by the technological infrastructure and the readiness of faculty and students to use them; (b) the implementation of a competency-based medical undergraduate curriculum in India has created an opportunity to adopt self-directed learning approaches; (c) readily available smartphones, although limited in their screen size, have made it easier for students to access learning resources through the internet; and (d) based on the existing practices in India and emerging evidence, online learning resources are more suitable and advantageous when used in a blended approach rather than a complete sudden switch to virtual methods.

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**Declarations**

**Ethics Approval** This study was approved by the Sree Gokulam Medical College & Research Foundation Institutional Ethics Committee (No. IEC/33/420/1/2019/F).

**Conflict of Interest** The authors declare no competing interests.

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