Contents lists available at ScienceDirect

Academic Pathology 11/2 (2024) 100114

Academic Pathology

journal homepage: www.journals.elsevier.com/academic-pathology

Regular Article

Enhancing hematopathology peripheral blood smear education through asynchronous video material: A pilot report

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A B S T R A C T

This study explores the effectiveness of asynchronous video material as a supplementary educational tool for trainees in hematopathology. Traditional pedagogical methods often rely heavily on faculty involvement, potentially limiting the breadth of information trainees receive due to constraints in faculty time and the variety of cases covered in a limited time interval/rotation. Asynchronous video-based learning presents a potential solution to these challenges. This concept has been utilized effectively in various fields of medical education. In this study, we describe our implementation of an educational program utilizing asynchronous video material to supplement traditional learning methods for peripheral blood smear interpretation for learners on a hematopathology clerkship. Following a pre-test/post-test assessment with 13 trainees, we analyzed the correlation between video viewing percentage and changes in test scores. The results indicate an improvement in test scores following exposure to video content, supporting the positive impact of asynchronous video material on hematopathology education. Trainees had positive feedback regarding this new educational tool. This study suggests that such self-directed learning could enhance traditional teaching methods, ensuring broader and more consistent coverage of hematopathology concepts.

Keywords: Asynchronous learning, Digital education, E-Learning, Educational outcomes, Hematopathology education, Instructional technology, Learning resources, Medical education, Medical trainees, Online learning, Pedagogical methods, Pathology training, Self-directed learning, Teaching strategies, Video-based learning

Introduction

Teaching pathology in an academic institution relies heavily on faculty involvement. Traditional hematopathology training primarily depends on one-on-one sign-out sessions with faculty utilizing a double-headed microscope. Despite being essential to learning, the effectiveness of this method can be compromised due to various limitations in faculty time and the range of cases to which trainees are exposed during their relatively short time on the clerkship. Another important consideration is that some individuals' learning styles may require an alternative asynchronous learning component to effectively master microscopy. The asynchronous video materials in this study were designed to supplement the traditional teaching methods in hematopathology.

At the University of Minnesota's Hematopathology Division of the Department of Laboratory Medicine and Pathology, we educate a variety of trainees, including medical students, pathology residents, and hematology/oncology fellows, on introductory hematopathology concepts. Typically, the trainees will go through a self-directed digital introduction to blood smear cytomorphology with the objective of discriminating peripheral blood and bone marrow elements with minimal interpretation of findings. Once the trainees have completed this digital introduction, they will go through a few patients' blood smears with our physician extender, a medical technologist with morphologic expertise, with an explanation of how to write up the blood smear report in the electronic medical record. After this review with the physician extender, the trainees are assigned two blood smears per day from the patient schedules, triaged, and assigned by the physician extender. The trainees enter the core lab automated differential as well as perform their own manual differential; in addition, they draft a preliminary report. These blood smears are reviewed daily via a double-headed microscope with the attending hematopathologist. The trainees are also exposed to weekly scheduled hematopathology didactics with unknowns and a scheduled daily consensus conference where complex and interesting cases are discussed to gain consensus among the hematopathology faculty prior to case sign-out.

In response to the COVID-19 pandemic, additional teaching modalities needed to be developed to ensure excellent and equitable education for trainees. Another consequence of COVID that we observed at our institution was an increased number of blood and bone marrow cases and an increase in the complexity of cases. As clinical faculty faced the ever-growing problem of finite time and increased workload, we elected to try innovative educational methods in our division to continue excellent education, but to also allow flexibility for the learner and the faculty member. The asynchronous video materials utilized in this study were

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https://doi.org/10.1016/j.acpath.2024.100114

Received 17 August 2023; Received in revised form 22 December 2023; Accepted 3 February 2024; Available online 27 March 2024

designed to supplement the traditional teaching methods in peripheral blood smears, allowing exposure to several distinct diagnoses and interpretations in the peripheral blood. Asynchronous video learning in medical education, although not new, is lacking in published studies within hematopathology. This study aims to measure the impact of these videos on trainee learning outcomes in hematopathology, hypothesizing that increased engagement with video materials would correlate with test scores.

Materials and methods

A group of benign, reactive, and neoplastic diagnoses were created with the help of the hematopathology division faculty, and slides were identified from historical collections of peripheral blood smears corresponding to the listed diagnoses. Our study's focus on a spectrum of benign, reactive, and neoplastic diagnoses directly aligns with key ACGME milestones in pathology education. This includes AP/CP milestones: Medical Knowledge 1: Diagnostic Knowledge, and Patient Care 4: Interpretation and Diagnosis, as well as hematopathology-specific milestones like Medical Knowledge 4: Morphologic Interpretation and Diagnosis, and Medical Knowledge 6: Clinical Reasoning in Hematopathology and Hematology. This alignment underscores the practical relevance and applicability of our findings in advancing pathology training and practice. The asynchronous video materials were recorded using Zoom (sharing live video microscopy while reviewing the slide with simultaneous narration by the hematopathologist, C.A.) and involved showcasing a collection of slides that have been accumulated over many years by several pathologists. These slides, which lacked any patient-identifying information and were organized by a labeling number, represented a broad range of hematopathology cases (Table 1). The recording setup involved an Olympus DP74 camera attached to an Olympus BX45 microscope, which was integral for generating clear and detailed images. The images from the microscope were captured and streamed using cellSens, a digital camera software, ensuring high-quality video output for the trainees. Videos were recorded/generated using the Zoom platform, and the electronic files were kept on a server that was accessible to the participants. The videos are currently hosted on the University of Minnesota Laboratory Medicine and Pathology YouTube channel with a Playlist entitled “Hematopathology,” which can be accessed publicly.[1]

An IRB was created for this study at the University of Minnesota (IRB ID: STUDY00012796), and trainees who participated in this study comprised medical students, pathology residents, and hematology oncology fellows who were part of a hematopathology rotation from July 2021 to May 2022. The trainees consented to be a part of this research study.

A pre- and post-test format was adopted, designed to resemble the end-of-rotation assessment typically given to pathology residents at the end of their 3-month rotation in hematopathology. The tests comprise diverse topics, including red blood cell morphologic changes and interpretation, white blood cell differential and morphology with interpretation, and other miscellaneous topics from classic hematology and infectious diseases (Table 2). The videos were optional for the trainees involved, and trainees were also asked to self-report the percentage of videos they watched on the post-test. After the post-test was submitted, the trainees went over the pre-test and post-test slides and questions with the hematopathology fellow at the time (C.A.), the designer of the supplemental educational material. A survey was designed and sent to participants to gather qualitative feedback from trainees regarding their experience with the asynchronous videos.

The correlation between the percentage of videos viewed and test scores was assessed as part of the study's key objectives. Our hypothesis was that trainees who engaged more with the video material would demonstrate improvements in test scores.

Table 1
List of videos by title, sorted by thematic topic.

Red Cell	Myeloid	Lymphoid
Normal peripheral blood smear	Acute myeloid leukemia (AML)	Acute lymphoblastic leukemia (ALL)
B12 deficiency	Anaplasmosis	Chronic lymphocytic leukemia/small lymphocytic lymphoma (CLL/SLL)
Filariasis	Acute promyelocytic leukemia (APML)	Follicular lymphoma
Iron deficiency	Chronic myelogenous leukemia (CML)	Hairy cell leukemia
Malaria and babesia	Congenital anomalies (Pelger Huet, May–Hegglin, Alder–Reilly, Chediak Higashi)	Reactive lymphocytosis
Agglutination and rouleaux	Eosinophilia	Neoplastic lymphocytosis
Poikilocytosis including hemolysis	Granulocyte colony-stimulating factor (GCSF)	Richter's transformation of CLL
Sickle cell anemia	Hypogranular neutrophils	Sezary syndrome
	Leukoerythroblastic blood reaction (LEBR)	
	Lysosomal storage disorders	
	Toxic neutrophils	

Results

Thirteen trainees were enrolled in this study, including four medical students, four pathology residents, and five hematology/oncology fellows (both adult and pediatric) (Table 3). Data analysis revealed improved test scores post-video exposure overall (Fig. 1). The average pre-test score was 5.7 (median score: 5), increasing to an average post-test score of 7.7 (median score: 8). Trainees reported viewing between 50% and 75% of the videos on average. Further analysis revealed a slight positive correlation between the percentage of videos watched and the post-test score, indicating the potential effectiveness of this teaching approach (Fig. 2). The strongest positive correlation between the percentage of videos watched and the change in test score and in posttest score was in the medical school students.

Qualitative data was also gathered from participants (Table 4). The survey data collected on the usefulness of the videos in analyzing peripheral blood smears was highly positive. A total of 100% of the respondents found the videos helpful, and all of them would recommend that future trainees utilize these videos. The strengths of the peripheral blood smear videos were highlighted by the participants. They appreciated that the videos provided a detailed real-time analysis of blood smears, emphasizing the importance of a systematic approach to slide analysis and ensuring the identification of key morphologic features. Unlike still images or high-power perspectives, the videos demonstrated how one would analyze a slide in person, reinforcing proper analytical technique. The participants also found the provided details incredibly helpful, as the videos went beyond morphologic details and included relevant clinical contexts and conditions associated with various morphologic features. Additionally, the brevity of the videos was appreciated, as they were easy to pick up and review.

In terms of improvements, one suggestion was to include more captions or graphics highlighting important key features or concepts. However, overall, the participants did not identify additional areas that needed improvement. They believed that the videos worked well for reviewing topics, especially the shorter ones.

General feedback on the peripheral blood smear videos was overwhelmingly positive. Participants described the videos as detailed and helpful resources that resembled narrated, real-time textbook images of various cases. The videos were particularly beneficial for audio/visual learners. Moreover, participants found the videos useful regardless of their experience level in analyzing peripheral smears, as they served as an instructional guide for addressing questions about the findings in a case. It was also noted that the videos were most effective when reviewed early in a rotation, further emphasizing their value as a learning resource.

Table 2
List of questions pre and post assessment.

PRE TEST	POST TEST
Q1: The morphologic findings and CBC data are most consistent with which of the following: RBC: 3.00 Hgb: 7.7 MCV: 59 MCHC: 27.8 WBC: wnl Platelets: wnl A. Autoimmune hemolytic anemia B. Thalassemia C. Iron deficiency anemia D. Hyposplenism	Q1: The morphologic findings and CBC data are most consistent with which of the following: RBC: 6.20 Hgb: 9.0 MCV: 67 MCHC: 34.8 WBC: wnl Platelets: wnl A. Autoimmune hemolytic anemia B. Thalassemia C. Iron deficiency anemia D. Hyposplenism
Q2: The morphologic findings are most consistent with the following: A. Hyposplenism B. Liver Failure C. Thalassemia D. DIC	Q2: The morphologic findings are most consistent with the following: A. Hyposplenism B. Liver failure C. Thalassemia D. Disseminated Intravascular Coagulation (DIC)
Q3: Based on the morphologic findings, which of the following infectious processes is most likely? A. Infectious mononucleosis B. Malaria C. Babesia D. Anaplasmosis	Q3: Based on the morphologic findings, which of the following infectious processes is most likely? A. Infectious mononucleosis B. Malaria C. Ehrlichiosis D. Anaplasmosis
Q4: Which of the following etiologies is LEAST likely for the peripheral blood smear findings: A. Extensive burns requiring ICU admission B. Infection C. Myeloproliferative neoplasm D. Chronic inflammation	Q4: Which of the following etiologies is MOST likely for the peripheral blood smear findings: A. Plasma cell myeloma B. Infection C. Myeloproliferative neoplasm D. Myelodysplastic syndrome
Q5: A 70-year-old male has a white cell count of 175 and the peripheral smear morphology. What is the most likely diagnosis: RBC: 2.3 Hgb: 6.4 MCV: 87 WBC: 174.8 Platelets: 225 A. Reactive neutrophilia B. Chronic myeloid leukemia (CML) C. Chronic myelomonocytic leukemia (CMML) D. Parasitic infection	Q5: A 70-year-old male has a CBC and this peripheral smear morphology. What is the most likely diagnosis: RBC: 3.1 Hgb: 7.3 MCV: 77 WBC: 62.5 Platelets: 813 A. Reactive neutrophilia B. Chronic myeloid leukemia (CML) C. Acute myeloid leukemia (AML) D. Essential thrombocythemia (ET)
Q6: The patient is a young adult. The Complete Blood Count (CBC) is remarkable for a hemoglobin of 9.8 and a white cell count of 18, and a platelet count of 19. Based on the morphologic features, which diagnosis is most likely: RBC: 3.23 Hgb: 9.8 MCV: 86 WBC: 18 Platelets: 19 A. Acute promyelocytic leukemia B. Acute lymphoblastic leukemia C. Acute myeloid leukemia with t (8; 21) D. Acute myeloid leukemia with inv (16)	Q6: The patient is a young adult. The patient was found to have >20% blasts in the marrow. Based on the morphologic features of this peripheral blood sample, which diagnosis is most likely: A. Acute promyelocytic leukemia B. Acute lymphoblastic leukemia C. Acute myeloid leukemia with t (8; 21) D. Acute myeloid leukemia with inv (16)
Q7: A 5-year-old male presents with joint pain and fatigue. Based on the morphologic features, which of the following diagnoses is most likely A. Acute promyelocytic leukemia B. Myelodysplastic syndrome C. Acute lymphoblastic leukemia D. Prominent hematogone population in a child	Q7: A 10-year-old male presents with joint pain and fatigue. Based on the morphologic features, which of the following diagnoses is most likely A. Acute promyelocytic leukemia B. Myelodysplastic syndrome C. Acute lymphoblastic leukemia D. Prominent hematogone population in a child
Q8: A 70-year-old male presents with fatigue. He is found to have anemia and a white cell count of 15, with the represented morphologic findings. Which of the following diagnoses is most likely: Hgb: 9.8 MCV: 92 WBC: 15 Platelets: 160 A. Infectious mononucleosis B. Hairy cell leukemia C. Chronic lymphocytic leukemia D. Follicular lymphoma	Q8: A 70-year-old male presents with fatigue. He is found to have anemia and a white cell count of 15, with the represented morphologic findings. Which of the following diagnoses is most likely: RBC: 2.9 Hgb: 8.5 MCV: 99 WBC: 112 Platelets: 25 A. Infectious mononucleosis B. Hairy cell leukemia C. Chronic lymphocytic leukemia D. Follicular lymphoma
Q9: The morphologic findings and CBC data are most consistent with which of the following: RBC: 5.28 Hgb: 10.9 MCV: 65 MCHC: 31.7 WBC: wnl Platelets: wnl A. Oxidant hemolysis B. Iron deficiency anemia C. Thrombotic Thrombocytopenic Purpura (TTP) D. Thalassemia	Q9: The morphologic findings and CBC data are most consistent with which of the following: RBC: 1.7 Hgb: 6.9 MCV: 110 WBC: 3.7 Platelets: 183 A. G6PD deficiency B. Iron deficiency anemia C. TTP D. Thalassemia
Q10: Which of the following medications is the patient likely taking based on the morphologic findings: Tacrolimus Ceftriaxone Dapsone Hydroxyurea	Q10: Which of the following medications is the patient likely taking based on the morphologic findings: Tacrolimus Ceftriaxone Dapsone Hydroxyurea (HgB SS) Q11: Approximately what percentage of the blood smear videos did you watch? (circle one) 0–25% 25–50% 50% 50–75% 75–100%

Discussion

The COVID-19 pandemic impacted all aspects of medical education, including a shift in pedagogy and a shift in perspective on how to use the new technologies for medical education.[2–4] There continues to be a rising importance of virtual resources like asynchronous videos.[2–6] Our findings suggest that self-directed learning via asynchronous videos can enhance traditional sign-out sessions in hematopathology education, providing trainees access to a broader range of cases and interpretations. This study could potentially inspire other institutions to develop asynchronous educational materials that can enhance understanding of pathology concepts, making sign-out sessions more productive. Asynchronous learning offers flexibility, convenience, and the capacity to facilitate both self-directed and group learning. This aligns with findings from previous research.[2,4–8] Asynchronous learning also faces challenges such as sub-optimal internet connections and a lack of hands-on activities.

The study has its limitations, including potential self-selection bias and the absence of a control group, making it difficult to attribute improvements solely to the video material. Future research should address these limitations with larger sample sizes. Future studies should also explore long-term knowledge retention, compare the effectiveness of asynchronous video material with other educational interventions, and investigate faculty members' perceptions regarding the integration of video-based learning into their teaching practices.

This study indicates a significant improvement in post-test scores, suggesting the effectiveness of asynchronous video material in enhancing

Table 3
Participants results.

Participant	Training level	Pre-test	Post-test	Self-reported % of videos watched	Numeral (1 = 0–25%, 2 = 25–50%, 3 = 50%, 4 = 50–75%, 5 = 75–100%)	Change in score
1	Medical student MS4	6	8	50	3	2
2	Heme/Onc fellow	8	5	50–75	4	−3
3	Heme/Onc fellow	3	6	25–50	2	3
4	Pathology resident PGY1	7	9	75–100	5	2
5	Heme/Onc fellow	5	5	75–100	5	0
6	Pathology resident PGY1	4	6	75–100	5	2
7	Heme/Onc Fellow	7	8	50	3	1
8	Pathology resident PGY1	6	9	50–75	4	3
9	Heme/Onc fellow	5	8	0–25	1	3
10	Medical student MS4	5	9	75–100	5	4
11	Pathology resident PGY1	8	9	75–100	5	1
12	Medical student MS4	5	10	75–100	5	5
13	Medical student MS1	5	8	50	3	3
	Average	5.7	7.7		3.8	2

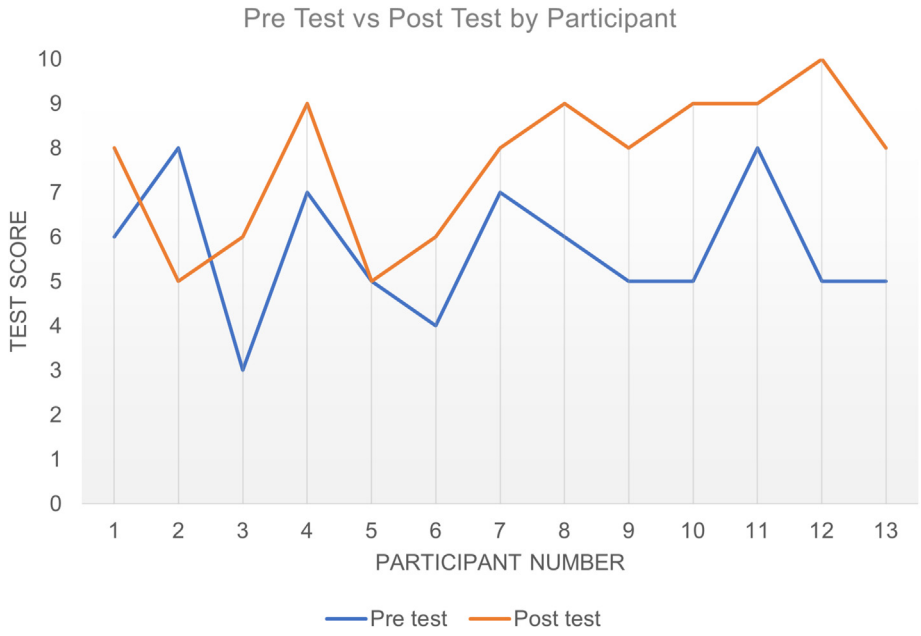

Fig. 1. Each participant is graphed along the X-axis and their pre- and post-test scores are graphed along the Y-axis, showing that almost every participant improved their scores following their viewing of the asynchronous learning videos.

the learning experience for hematopathology trainees. Asynchronous video-based learning offers a promising method for enhancing trainee education in hematopathology by providing structured, self-directed learning that supplements traditional teaching methods, ensuring broader coverage of pathology concepts for all rotating trainees.

Asynchronous video materials can slow down the conversation, prompting more thoughtful responses and helping overcome cultural and language barriers. This has been seen in prior studies investigating asynchronous video in problem-based learning.[3,6] This research fills a gap in the field of hematopathology and could guide other institutions in developing similar resources for their trainees, thereby enhancing the overall quality of education in this field. A recently published study showed how e-learning in hematopathology education can be an effective strategy in graduate medical education.[9] Although further studies are needed, our study supports initial evidence of the positive impact of video-based learning on trainee understanding and knowledge in hematopathology, like results obtained in previous studies.[7–9]

The implications for practice from this study extend beyond the field of hematopathology. The novel approach of using asynchronous video material for education can be adapted to various other fields within medical education and beyond. The flexibility, convenience, and self-directed nature of this learning style can greatly benefit learners who can engage with the material at their own pace, thereby reducing the potential for gaps in their understanding of complex topics. Additionally, asynchronous video material can serve as a valuable resource that can be accessed multiple times by learners over time, facilitating a deeper understanding of the subject matter.[10] Such materials can also provide a standardized baseline of information for all learners, thereby promoting uniformity and equity in the knowledge acquisition process.

The potential limitations and challenges associated with this learning style should also be acknowledged and addressed in future practice. Ensuring that learners have reliable internet connections and supplementing video material with hands-on activities can further enhance learning outcomes. Additionally, recorded materials will need to be updated periodically based on changes in the field.

We acknowledge the limitations of a small and heterogeneous participant group in our study. The variation in backgrounds, ranging from medical students to hematology/oncology fellows, may influence the learning outcomes. This diversity, while enriching the study's scope, also introduces complexity in interpreting the results. Particularly, the varying levels of prior training among participants were not explicitly analyzed as a variable, which could have impacted the

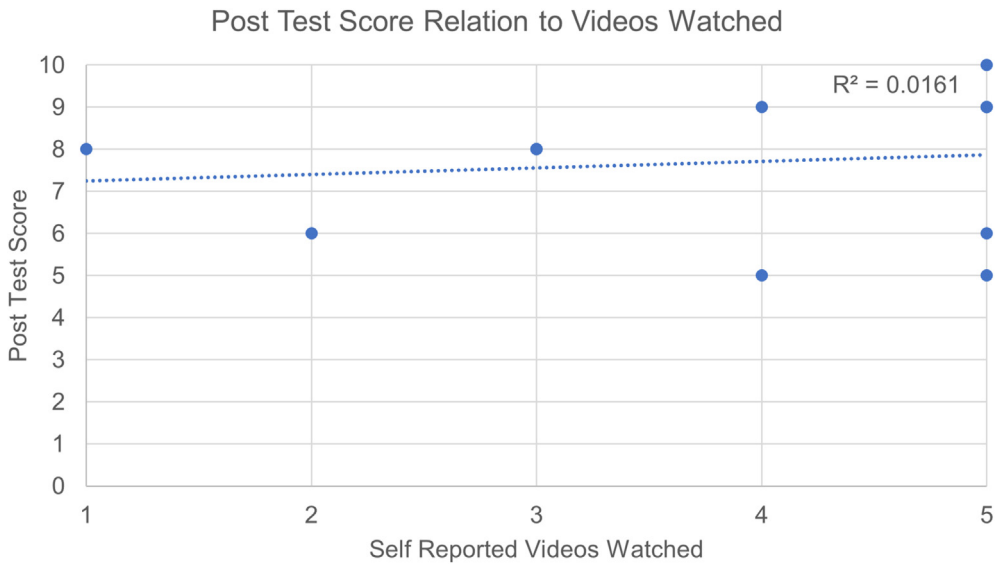

Fig. 2. The self-reported number of videos watched is graphed along the X-axis (1 = 0–25%, 2 = 25–50%, 3 = 50%, 4 = 50–75%, and 5 = 75–100% of videos watched). The post test scores are graphed along the Y-axis, and using the statistical analysis of R^2 on Excel, we show a modest but positive correlation between the post-test score and the number of videos watched.

Table 4
Qualitative feedback.

Survey Question	Response
Did you find the videos helpful?	100% answered Yes
Would you recommend future trainees use these videos?	100% answered Yes
Strengths of the peripheral blood smear videos	"They were short. They were easy to pick up and easy to review." "The videos go through in great detail the approach to analyzing a blood smear in real-time. Instead of showcasing still images or high-power views of definitive features, many of the videos show how one would actually analyze a slide in person, which not only reinforces proper analytical technique but also emphasizes (whether directly or indirectly) the importance of having a routine approach to slide analysis to ensure key morphologic features are not missed." "Of course, the details provided in the videos are also incredibly helpful, as more than morphologic details are conveyed, including key clinical contexts and conditions associated with various morphologic features and what pathophysiologic processes cause the morphologic features to arise."
What could be improved about the peripheral blood smear videos?	"Perhaps including more captions or graphics with the text of important key features or concepts would be helpful." "I think overall they work well for reviewing topics, especially the shorter ones." "I cannot identify many suggestions for improvements."
Other general feedback regarding the peripheral blood smear videos	"The peripheral smear videos are detailed and helpful resources, like narrated, real-time textbook images of various cases." "They work best when reviewed early in a rotation." "They are also particularly helpful for audio/visual learners." "Additionally, regardless of the watchers' experience (whether they have looked at peripheral smears before or are newcomers to peripheral smear analysis), the videos serve as a helpful instructional guide whenever one has questions regarding the findings in a case."

learning efficacy. The lower post-intervention outcome observed in an experienced hematology-oncology fellow underscores the need for further investigation into individual learning trajectories and prior knowledge. In this case, the lower score is thought to be related to a highly stressful day on the day of the post-test. These findings point to the necessity of a more nuanced approach in future studies to account for the diverse educational backgrounds and experience levels of participants. While this preliminary study primarily focuses on immediate educational impacts, we acknowledge the potential for broader benefits, such as changes in learner behavior and, possibly, enhanced patient outcomes. These aspects, though not explored in this pilot study, are crucial for a comprehensive understanding of the intervention's efficacy and are recommended for future research to fully encapsulate its impact.

Our findings reinforce the importance of ongoing innovation in educational strategies in the field of pathology and in medical education. Incorporating technology into teaching practices and leveraging it to improve learning outcomes is becoming increasingly crucial in the ever-evolving landscape of medical education.

Conclusions

While more research is required to further evaluate the long-term effectiveness and impact of asynchronous video learning, this study provides encouraging preliminary evidence supporting its potential as a valuable tool in enhancing medical education. It is our hope that our work will inspire further development and application of such educational resources, thereby improving trainee education and ultimately patient care outcomes.

Funding

The article processing fee for this article was funded by an Open Access Award given by the Society of '67, which supports the mission of the Association of Pathology Chairs to produce the next generation of outstanding investigators and educational scholars in the field of pathology. This award helps to promote the publication of high-quality original scholarship in *Academic Pathology* by authors at an early stage of academic development.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to extend our gratitude to the trainees who participated in this study. Their commitment to learning and professional development has been invaluable to the success of this research. Additionally, we would like to thank our colleagues and faculty members who have provided support and feedback throughout the development and implementation of this project.

Additionally, we acknowledge the University of Minnesota which supported this research, fostering an environment that values innovation and continuous improvement in medical education.

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