

## Technical Note

## Cytopathology whole slide images and virtual microscopy adaptive tutorials: A software pilot

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Received: 03 July 2015

Accepted: 12 August 2015

Published: 28 September 2015

### Abstract

**Background:** The constant growth in the body of knowledge in medicine requires pathologists and pathology trainees to engage in continuing education. Providing them with equitable access to efficient and effective forms of education in pathology (especially in remote and rural settings) is important, but challenging. **Methods:** We developed three pilot cytopathology virtual microscopy adaptive tutorials (VMATs) to explore a novel adaptive E-learning platform (AeLP) which can incorporate whole slide images for pathology education. We collected user feedback to further develop this educational material and to subsequently deploy randomized trials in both pathology specialist trainee and also medical student cohorts. Cytopathology whole slide images were first acquired then novel VMATs teaching cytopathology were created using the AeLP, an intelligent tutoring system developed by Smart Sparrow. The pilot was run for Australian pathologists and trainees through the education section of Royal College of Pathologists of Australasia website over a period of 9 months. Feedback on the usability, impact on learning and any technical issues was obtained using 5-point Likert scale items and open-ended feedback in online questionnaires. **Results:** A total of 181 pathologists and pathology trainees anonymously attempted the three adaptive tutorials, a smaller proportion of whom went on to provide feedback at the end of each tutorial. VMATs were perceived as effective and efficient E-learning tools for pathology education. User feedback was positive. There were no significant technical issues. **Conclusion:** During this pilot, the user feedback on the educational content and interface and the lack of technical issues were helpful. Large scale trials of similar online cytopathology adaptive tutorials were planned for the future.

**Key words:** Cytopathology, digital microscopy, pathology education, software, virtual microscopy, virtual microscopy adaptive tutorials, virtual slides, whole slide images, whole slide image

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Van Es SL, Pryor WM, Belinson Z, Salisbury EL, Velan GM. Cytopathology whole slide images and virtual microscopy adaptive tutorials: A software pilot. J Pathol Inform 2015;6:54.

Available FREE in open access from: <http://www.jpathinformatics.org/text.asp?2015/6/1/54/166016>

### INTRODUCTION

The constant growth in the body of knowledge in medicine requires pathology specialists, pathology specialist trainees as well as medical students to engage in continuing education.

Providing these groups with equitable access to an efficient and effective form of education is important (especially in remote and rural settings), but challenging. Virtual microscopy is just beginning to play a role in specialist pathology training, in pathology proficiency testing,<sup>[1-4]</sup> and has been shown to be a very useful learning tool.<sup>[5-8]</sup> However, provision of whole slide images (WSI) or virtual slides (vslides) alone for teaching may not be sufficient to convey salient diagnostic features, suggesting that additional support is needed to maximize the acquisition of information in pathology education.<sup>[7]</sup> Microscopic pathology, which is image-based, translates easily into an interactive E-learning environment.<sup>[9]</sup> Interactive virtual modules teaching pathology have been shown to result in better engagement, improved pattern recognition,<sup>[10]</sup> and improved performance in examinations.<sup>[11]</sup>

When considering the implementation of learning interactivity, feedback and flexibility are essential for engagement and learning impact.<sup>[12,13]</sup> Self-paced guided learning has also been shown to improve the accumulation of knowledge.<sup>[14,15]</sup> Virtual microscopy adaptive tutorials (VMATs) are a type of online adaptive tutorial system. They are self-guided, emphasize learning by interaction and exploration of WSI, focus on remediation of misconceptions and adaptive sequencing of questions, and activities for individual learners.<sup>[15,16]</sup> VMATs are created with the adaptive E-learning platform (AeLP), an intelligent tutoring system, which has already made significant differences to successful learning for a number of undergraduate university courses.<sup>[15,17]</sup> However, the use of VMATs to teach the difficult area of cytopathology to Australian cohorts has not been described. Consequently, prior to planning and implementation of randomized crossover studies of cytopathology WSI and VMATs in two separate cohorts (anatomical pathology trainees and also senior medical students), we developed three cytopathology VMATs to serve as a pilot study. During the pilot, we collected user feedback on the educational content, the interface, and any technical issues. This information was used in developing online cytopathology adaptive tutorials for larger scale trials.

## METHODS

### Implementation

We developed three cytopathology pilot VMATs and open access was given to all Royal College of Pathologists of Australasia (RCPA) fellows and trainees over a period of 9 months for use, feedback, and comment.

This pilot study was developed to gauge acceptance of virtual cytopathology slides and associated VMATs by trainees and specialists in pathology.

### Virtual Slide Image Acquisition

Digital cytopathology images were acquired at  $\times 40$  magnification with an Aperio Scanscope XT (Leica

Biosystems, Vista, CA, USA). Additional focal points were manually inserted to maximize the in-focus areas on the final WSI. Hundreds of individual adjacent high power images from each glass microscope slide were created in JPEG format and fused, “stitched” or “tiled” together, compressed into multi-resolution file format (.svs) to create one almost seamless image. Slides were scanned in two dimensions (X- and Y- axis) and the zoom was possible through the multiple magnifications that had been captured.

The virtual cytopathology slides were stored in a biomedical image database and delivered using a custom-built whole slide viewer. The image database, Slice, incorporates a server and an innovative WSI viewer developed by the BEST network (<http://www.best.edu.au>). It is supported by recent versions of all major web browsers and later.

Tiling script converted the digitized microscope slide into JPEG files that could be stored in the database for use with annotating (the authoring tool). The script generated sets of tiles for each “zoom level” or “magnification level” in the viewer. Image file size ranged from 800 MB to just over 2 GB. Those slides whose file size was  $>2$  GB were reassessed and any nondiagnostic areas including those areas on the peripheral aspects of the slide were cropped manually to improve interaction with the interface.

### Development of Virtual Microscopy Adaptive Tutorials

VMATs were created using the AeLP, an intelligent tutoring system developed by Smart Sparrow (<https://www.smartsparrow.com/>).

The VMAT user interface is intuitive. However, information to the side of the WSI on the first pages of each lesson provides instructions on how to navigate the adaptive tutorial and to quickly orientate the user. Continual functions include forward and back options and a “restart” button to return to the main menu button on each screen [Figures 1 and 2].

The VMAT interface [Figures 1 and 2] can be accessed through the following links:

Adaptive Tutorial for Pilot Cytopathology Case 1:

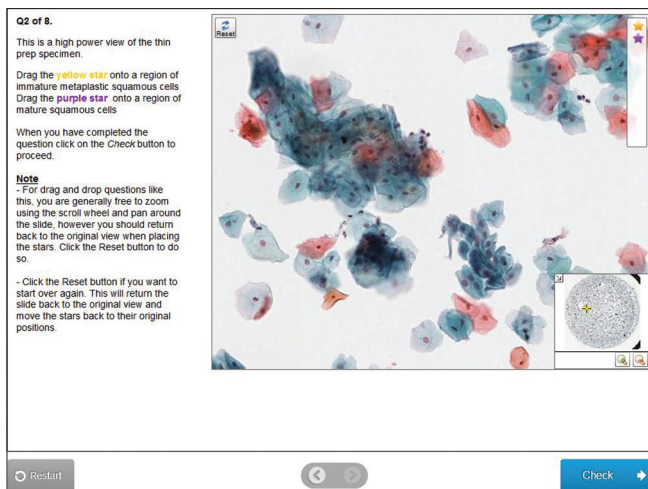
<https://aelp.smartsparrow.com/learn/open/5e8865181678420688b52345849916c3>.

Adaptive Tutorial for Pilot Cytopathology Case 2:

<https://aelp.smartsparrow.com/learn/open/51b61dd4c4f64527bb6c32ad7dd8143>.

Adaptive Tutorial for Pilot Cytopathology Case 3:

<https://aelp.smartsparrow.com/learn/open/d7e9ba6c954b41bfb48908df869f5e2d>.



**Figure 1: Virtual microscopy adaptive tutorials interface. An example of a drag-and-drop question**

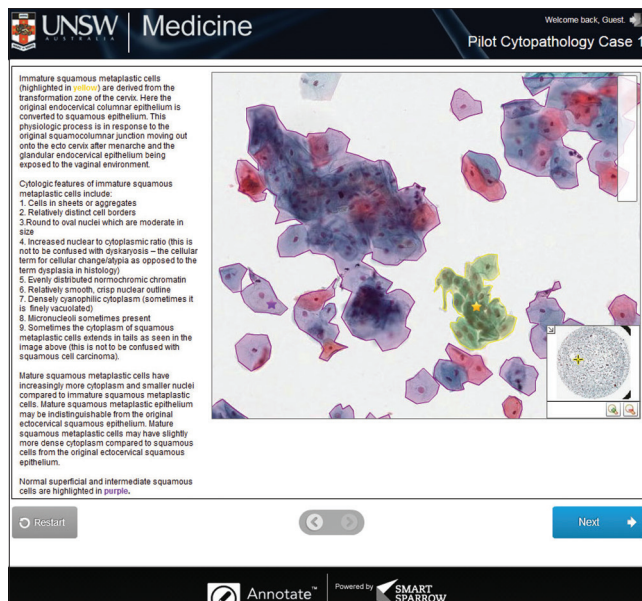
### Interactive Features of Virtual Microscopy Adaptive Tutorials

Engagement and interactivity are promoted within the adaptive tutorials by utilizing a variety of question formats (e.g., multiple-choice, drop-down lists, drag and drop type questions, fill-in-the-blank). An example of a drag and drop the question and associated feedback is seen in Figures 1 and 2]. Immediate feedback is provided following the user's/learner's submission of responses. Feedback may contain useful educational information about the area on the slide, sometimes with the appropriate area being highlighted with different shading or arrows on the feedback screen. The screens generally do not permit progress until the question has been attempted. The author can limit the number of attempts for a question. The screen is programmed to reset after feedback is given on an incorrect answer. These tutorials allow participants to engage with the content at their individual pace.

An evaluation questionnaire can also be programmed into the conclusion of the adaptive tutorial. Immediate visual and written feedback can be provided to the individual user/learner based on their response [Figures 1 and 2]. The AeLP also allows the author to monitor patterns emerging in users' learning via analytical data available in real-time via the AeLP's web interface. The VMAT author can track the spectrum of errors related to participants' underlying misconceptions and consequently adapt the content and remedial feedback states of the tutorial.

### Deployment and Evaluation

In order to gauge user experience and engagement, three pilot cytopathology VMATS and their associated WSI were placed on the RCPA website, in 2013 prior to the deployment of a randomized trial in this population.<sup>[18]</sup> The WSI and VMAT links were advertised through the monthly RCPA newsletter, *Pathology Today*.



**Figure 2: Virtual microscopy adaptive tutorials feedback. Individualized visual and written feedback provides immediate reinforcement of correct responses**

The educational material was password-accessible to RCPA members (pathology trainees and specialist pathologists). Users were asked to complete feedback questionnaires on completion of each VMAT. The questionnaire comprised 5-point Likert scale items and enabled users to evaluate perceived impact on learning and engagement resulting from the VMATs. The items were as follows:

1. The interactive questions using virtual slides were helpful
2. The interactive questions using virtual slides improved my understanding
3. I clearly understood what was required of me in performing the tasks
4. I would like to see more interactive questions using virtual slides in other practical classes
5. I learned more from interactive questions using virtual slides than from exploring virtual slides independently
6. I learned more from interactive questions using virtual slides than from exploring glass slides independently.

A comment box was provided for written responses. All VMATs and questionnaires were completed anonymously.

## RESULTS

### Pilot Cases 1, 2 and 3

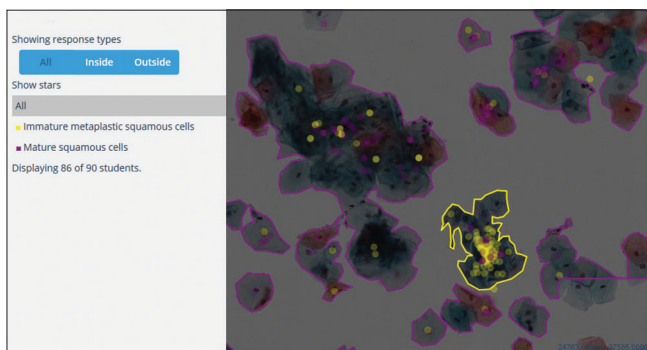
Usage figures were automatically provided by the platform, along with the information about the average time users spent on each VMAT, and whether individual users completed the lesson. The majority of users spent

a small amount of time (median 5 min) engaging with the adaptive tutorial. Thirty-one percentage of 119 users ( $n = 37$ ) completed pilot Case 1, including the questionnaire. Forty-one percentage of 32 users ( $n = 13$ ) completed pilot Case 2, whereas 40% of 30 users ( $n = 12$ ) completed pilot Case 3. The overall completion rate was 62 out of 181 users at the point in time when the analytics page was accessed. The completion of the VMAT was contingent on submission of the survey at the end of the lesson. As the responses were anonymous, there was no indication whether the respondents were specialist pathologists or pathology trainees. Correspondingly, there was no indication as to which participants completed all three cases. Medical students were not involved in this pilot, as only fellows or trainees of the RCPA could access these tutorials. In addition, the main aim of the pilot was to gather feedback from specialist trainees and their pathologist supervisors in preparation for a larger randomized crossover trial in the specialist trainee cohort.

An analysis tab is accessible to the lesson author. It displays lesson usage, completion rates, grades, and the proportion of adaptive feedback in use. This analysis gives direction to the level of complexity of the lesson for the user/learner cohort and whether the adaptive feedback is adequate to effectively remediate errors. The average grade for each lesson is provided, which also may be an indicator of whether the complexity level needs to be modified. The analytics page also enables a heat map analysis [Figure 3] for drag and drop questions, thereby facilitating a quick visual analysis of learners' areas of weakness and strength, as well as common misconceptions.

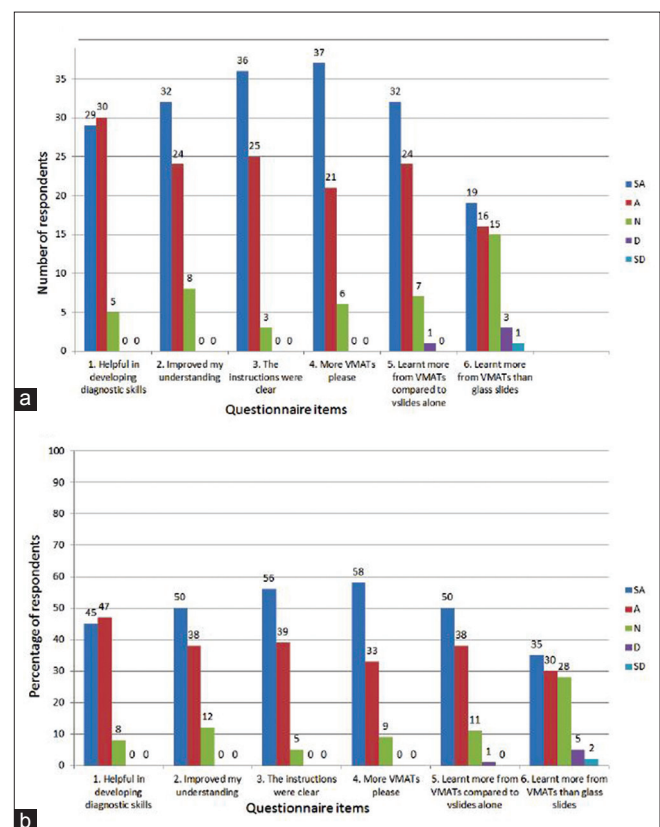
### Evaluation Questionnaires

Anonymous responses to an online questionnaire, which could be incorporated into the lesson, were available to participants upon the completion of each pilot VMAT. Automated graphed analysis of the percentage and number of responses to each survey question for each category of strongly agree to strongly disagree was



**Figure 3: Heat map.** A heat map showing responses to a drag and drop question, enabling detection of learners' strengths and weaknesses, as well as common misconceptions

provided by the AeLP for each VMAT. It should be noted that the analytics are automatically updated on a regular basis and the responses to the survey were accessed by us from the platform at a slightly later point in time to the overview analytics. The response numbers for each category from each question were combined from all three pilot surveys. These numbers were exported into an excel document, and the results are displayed [Figure 4a and b]. There was a consistently positive perception of the VMATs [Figure 4]. Ninety-two percentage (59 out of 64) agreed that VMATs were helpful in developing diagnostic skills in cytopathology; 88% (56 out of 64) agreed that VMATs improved their understanding of cytopathology; 95% (61 out of 64) agreed that the instructions in the VMATs were clear; 91% (58 out of 64) agreed that they would like to use more VMATs; 88% (56 out of 64) agreed that they learned more from VMATs as compared to virtual slides alone; 65% (35 out of 54) agreed that they learned more from VMATs than they would have done from a glass slide alone.



**Figure 4: Likert-scaled responses to the feedback questionnaires expressed as (a) number and (b) percentage of respondents, respectively.** There was strong overall agreement from users that Virtual microscopy adaptive tutorials helped understanding and development of skills. There was also broad agreement that users learned more from Virtual microscopy adaptive tutorials than traditional glass slides or virtual slides alone (virtual microscopy adaptive tutorials, virtual microscopy adaptive tutorial; vslide, virtual slides; SA: Strongly agree; A: Agree; N: Neutral; D: Disagree; SD: Strongly disagree

## User Perception of Virtual Microscopy Adaptive Tutorials

Open-ended feedback included positive comments on the layout of the VMATs, flexibility, usability, benefits for learning, for example, “good basic material for those starting out in cytopathology,” and enjoyment reflected in comments such as “fun to do.” Users also offered helpful suggestions to improve the layout and functionality of future VMATs.

## DISCUSSION

With technology constantly and rapidly advancing, pathology specialist trainees and specialists will have increasingly higher expectations about how they should be able to engage with learning and continuing educational resources. The modes of engagement in digital learning are rapidly morphing to accommodate these expectations.<sup>[19]</sup> Others have already shown that learning from an interactive and remediating E-learning environment is perceived to be at least as helpful as learning in a real-life laboratory.<sup>[14]</sup>

Preliminary findings from scaled and written anonymous feedback from this small pilot on learning with cytopathology VMATs indicated that users perceived them as useful to improve understanding of cytopathology, particularly when compared to virtual slides, or even glass slides, alone. The majority of participants were also interested in seeing more VMATs becoming available. In response to user comments during the pilot, we were subsequently clearer in our instructions in future lessons. Comments from users on the content of the tutorial also allowed improvement and correction of errors.

VMATs are novel in that they are specifically designed to “adapt” to the user’s decision making process through remediation of misconceptions. Furthermore, analytics provided by the AeLP provides teachers with evidence of the effectiveness, or lack thereof, of the adaptive feedback used in the tutorial. A modest proportion of users completed any of the three VMATs. These are novel learning tools for learning histopathology and cytopathology, and interest in them from pathologists and trainees might be expected to be high. However, VMATs are quite intensive and there was no incentive offered for completion. Therefore, in this time-poor cohort, it is unsurprising that there was a substantial drop out rate.

From an educational perspective, the advantages of virtual microscopy via a large cloud-based image repository, such as the one described in this paper, are numerous. These include: (a) Rapid access; (b) relative permanence as compared to glass slides, which are prone to fading and breakage; (c) ability to provide ideal teaching cases to large and/or dispersed audiences simultaneously; (d) multi-site consultation and/or education, including using

annotation<sup>[6,8]</sup> or incorporation into online tutorials;<sup>[17]</sup> (e) straightforward incorporation into formative and/or summative online assessments.<sup>[20]</sup> Educational slides are available for teaching from the repository described in this paper, <https://www.best.edu.au/>.

The AeLP itself is straightforward to use. However, the preparation of educational content to accompany each virtual slide within the VMAT requires diagnostic expertise and understanding of potential misconceptions and storyboarding of the proposed content and adaptive feedback contained within the lesson. The VMAT itself can be built by a nonspecialist trained in using the platform providing that they are supplied with an adequate storyboard of the proposed content. The average development time for each VMAT is between 15 and 20 h, depending on the complexity of both the educational content and the layering of interaction within the VMATs. The cost is dependent on the availability of prescanned virtual slides, or availability of local image acquisition services, and licence agreement for authoring and using the AeLP. Other VMATs developed with this software can be explored at <https://www.best.edu.au/courseware/Pathology>.

## CONCLUSIONS

Access to large sets of instructive virtual cytopathology and histology VMATs has the potential to guarantee equity and standardization of good teaching material, as well as to promote networking and collaborative study, including for pathologists and trainees in rural or remote locations. Cytopathology VMATs developed for this preliminary pilot were well received through anonymous feedback. This highlights the importance of the development of further VMATs and subsequent organization of randomized trials comparing this education method to traditional techniques.<sup>[18]</sup>

### Availability and Requirements for Virtual Microscopy Adaptive Tutorials

- Project name: Cytopathology whole slide images and VMATs for postgraduate and undergraduate pathology education
- Project home page: [http://web.med.unsw.edu.au/Pathology/Cytopathology\\_Pilot\\_VMATs.htm](http://web.med.unsw.edu.au/Pathology/Cytopathology_Pilot_VMATs.htm)
- Operating system: The AeLP is a SaaS (Software-as-a Service) cloud-based platform, accessed via the web, with support for all major operating systems, browsers software, and/or devices
- Programming language: VMATs have been created by educators using the AeLP authoring environment; an online tool programmed using Adobe Flex/Flash/AS3 technology, for the creation of adaptive, personalized, and interactive learning experiences. The AeLP can publish to the web in either Flash or HTML5 formats.

VMATs have been authored using a specialized authoring environment plugin, annotate, enabling the creation of interactive questions and screens, using high resolution virtual slides, hosted on Slice, an image repository created by BEST (<https://www.best.edu.au>), maintained by Smart Sparrow (<https://www.smartsparrow.com>)

- Other requirements: Published annotate learning experiences include a flash component (.swf file) in the webpage. As a consequence, Adobe Flash Player must be installed on the browser the learner is using to access the online activity
- The above implies that published learning experiences authored using Annotate, cannot be accessed via an Apple tablet device, such as an iPad, as Apple does not permit the Flash Player to be installed on its tablet browsers
- Other requirements: The user requires a launch link to access an AeLP learning experience. The link is automatically created upon the author publishing an activity. Links are often delivered to the user/learner via E-mail or an institution learning management system course page
- Licence: The creation, deployment, analysis and sharing of adaptive content using the AeLP requires a licence, which only applies to educators and institutions, not to learners/users. Further, BEST resources such as slice and annotate can be freely used by BEST community members. Any restrictions to use by nonacademic: None

### Acknowledgments

Image acquisition: Dr. Maria Sarris (Histology and Microscopy Unit, UNSW); Technical Support: Mr. Jake Surman (UNSW), Mr. Peter Zarzour (UNSW), Mr. Gary Goldie (Smart Sparrow), the BEST Network, Glass Cytopathology slides: Ms. Joanne La Malfa (Anatomical Pathology Department, Prince of Wales Hospital, Sydney).

### Financial Support and Sponsorship

This project was supported in part by the Royal College of Pathologists of Australasia (RCPA) which has received Australian Government funding under the Specialist Training Program (#247).

### Conflicts of Interest

ZB is co-founder of Smart Sparrow and Director of Instructional Solutions, Smart Sparrow, Surry Hills, NSW 2010 Sydney, Australia.

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