Greater interaction between research, industry, community, and policy will improve the relevance and adoption of public health tools. This is crucial for the all-important scale-up of new strategies. Rather than simple provision of a guidebook, policy makers and innovators might better serve communities by considering strategies that are co-designed and co-produced. That dynamic and contextual process can explicitly address local and regional priorities around ecosystems, climate change, health risks, and economics.

The vector-control management agenda is formidable, and despite substantial research efforts, control programs remain little changed. Meanwhile, the global burden of vector-borne disease continues to increase. The global community is ill-equipped to face that threat and unsure of what to do given the long lead-in times for the evaluation of new public health tools. Perhaps it is time that, rather than relying solely on vertically communicated guidelines, governments and communities mobilize to develop their own pragmatic action plans, as was achieved in an integrated approach with community involvement [10], in full acknowledgement of their inevitable shortcomings but in recognition that the status quo cannot deliver. These action plans are bound to be integrated and based on the evidence base as it exists, however flimsy and however much it has to be based on entomological rather than epidemiological proofs. This surely must be an immediate consideration whilst waiting for the vector-control panacea.

Acknowledgments

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[ii]www.who.int/heli/risks/vectors/malariacontrol/en/

[iii]www.who.int/vector-control/vcag/vcag-may2018-sustainability-improvement.pdf?ua=1

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Science & Society

Adaptive e-Learning: Emerging Digital Tools for Teaching Parasitology

Caitlin N. Pfeiffer[1,*] and Abdul Jabbar[1,*]

Adaptive learning activities can respond to a learner's needs in real time, facilitating the development of higher-level skills including bringing together knowledge from different disciplines to solve real-world problems. Here we discuss the use of online adaptive learning activities designed to help veterinary students apply their knowledge to work through parasite case studies.

Why Do We Need Adaptive Learning?

Consider an ideal face-to-face learning experience. You might imagine a classroom where individual instructor's attention is freely available to the learner; where the learner progresses at their own pace, asking questions as they arise; where an extra explanation is given as needed, and the learning task is adapted to the learner's needs 'on the fly'.

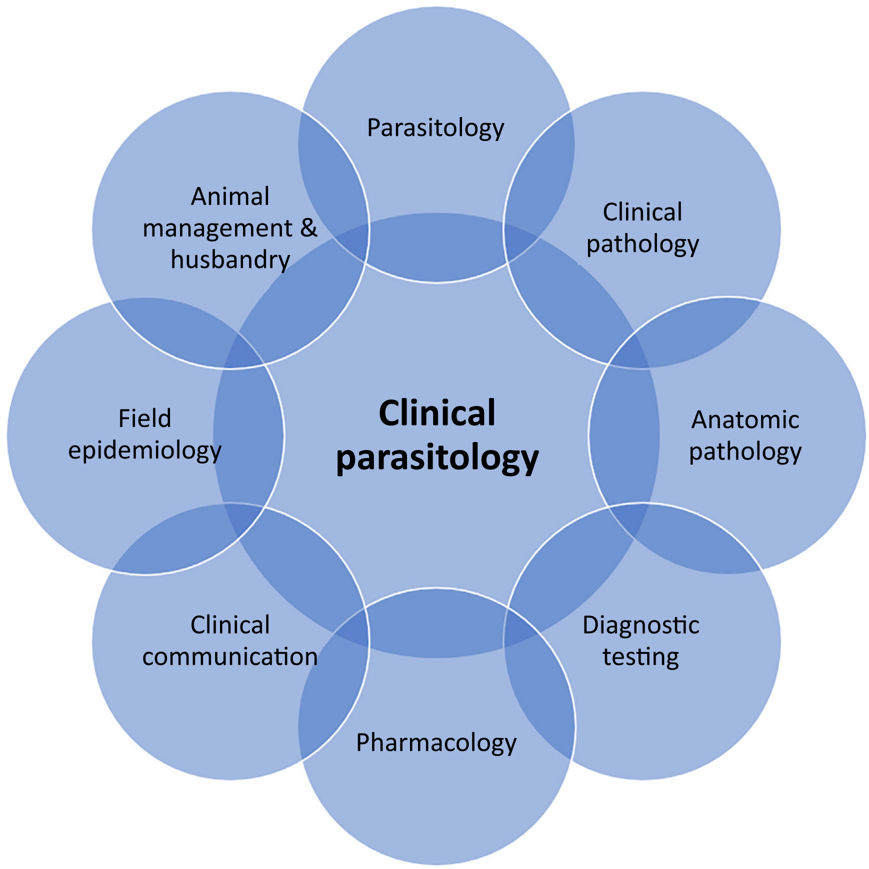
These ideal learning experiences are difficult to create, including in tertiary education where instructors must manage the needs of several hundred learners simultaneously. But the principle of adapting activities to learners' needs remains valid – and technology increasingly offers a way to help bridge that gap.

Adaptive learning activities deliver custom experiences that adapt to each unique learner, through just-in-time feedback, multiple pathways through the material, and access to additional resources, based on the student's performance or preferences [1]. Adaptive learning activities delivered through online platforms can simulate a one-on-one learning experience while accommodating the resource constraints of university teaching. In this article, we demonstrate how adaptive learning can help students to integrate knowledge from multiple disciplines to solve real-world problems in parasitology.

How Can Adaptive Learning Activities Help to Integrate Multidisciplinary Knowledge?

As tertiary students progress toward employment, they require both adequate knowledge of relevant disciplines and the skills to integrate that knowledge to address real-world problems. For example, to effectively treat and manage parasitic diseases veterinarians must use knowledge from many areas, including understanding the parasite, the host's response to infestation, relevant diagnostic tests and pharmacological treatments, animal management, epidemiology, and effective clinical communication (Figure 1). Therefore, veterinary students should be taught how to bring these areas of knowledge together, and parasitology teaching activities are useful examples to demonstrate how technology can support students to do so [2].

When teaching complex problem-solving skills (such as 'clinical reasoning', a 'Day One Competence' required by graduate veterinarians [3]) the provision of specific and timely feedback can help students to understand their thought processes and is easily facilitated through online adaptive learning activities. Traditionally, clinical reasoning has been taught through student observation of competent clinicians who share their thought processes by 'thinking-out-loud' and coaching students to an appropriate diagnosis or treatment plan [4]. This approach is highly valuable but is also time-consuming and very inefficient. Adaptive learning activities that provide real-time feedback and commentary on students' underlying thought processes offer a new and effective way to build preliminary skills in this area, to maximize the benefit of clinical teaching programs.



Trends in Parasitology

Figure 1. Core Components of Cross-Disciplinary Knowledge to Solve Real-World Veterinary Parasitology Problems. The schematic diagram shows the different subdisciplines of veterinary science (outer circles) that must be brought together for a veterinarian to manage a real-world clinical parasitology problem.

Considerations for Designing Adaptive Learning Activities

When using new technology for teaching, including adaptive e-learning platforms such as Smart Sparrow Adaptive eLearning Platform [i] or Articulate Storyline 360 [ii], it is tempting to allow the possibilities offered by the platform to distract from your pedagogical goals. Asking some key questions (Box 1) can help to focus your learning design and avoiding being derailed by novelty. Regardless of the platform, the essential principles of learning design still apply: learning objectives should be identified, specifying both the knowledge and generic skills the student should attain

Box 1. Key Questions to Address When Designing Adaptive Learning Activities

1. What do you want your learners to take away (intended learning objectives)?
2. What domain knowledge do your learners already have?
3. What level of cognitive engagement are you trying to achieve?
4. What level of reasoning do you expect from your learners?
5. How long should the activity take? What can be covered in that time?

by the end of the activity. Returning often to the learning objectives throughout activity design helps to ensure that the final activity is fit for purpose.

The desired level of cognitive engagement should reflect the learning objectives. Bloom's taxonomy [5] remains useful to consider the cognitive process used to complete the task, with six levels: remembering, understanding, applying, analyzing, evaluating, and creating. Different activity types can be used to encourage these different categories of cognitive engagement. For example, ranking differential diagnoses from most- to least-likely, based on the clinical information provided, requires greater cognitive engagement than simply selecting appropriate differential diagnoses from a list. The expected level of cognitive involvement relevant to the students' progression through the curriculum should be reflected in the question or activity types that are included in the adaptive learning activity.

Considering the whole curriculum, students' anticipated knowledge and clinical reasoning skills should also be considered, especially for clinical case studies. For example, if they have received instruction on parasitology, but not pharmacology, it makes sense to focus on the diagnosis rather than treatment recommendations for a parasitic condition. The student's cognitive load should be also taken into account. For inexperienced students, beginning with 'typical' cases, avoiding excessive unrelated clinical information, and providing a more linear path through the content can allow them to work from case presentation to clinical solution without becoming overwhelmed [6]. As students progress through the course and build their clinical reasoning skills, cases can be increasingly authentic, with additional information provided and a less linear structure.

In addition, it is important to consider how the activity relates to other learning tasks in the curriculum. Adaptive learning activities have been previously offered as a stand-alone task [7], preparatory material for other tasks (a 'flipped classroom' approach) [8], or as optional additional content to support core learning activities [9]. How the activity relates to other course contents influences what information can be assumed as prior knowledge. An advantage of adaptive learning is the ability to include remediation for students who require it without forcing all students to review material unnecessarily. These remedial activities can be either offered to students to complete voluntarily or linked to 'screening' questions included in the activity, where an incorrect response indicates that a student may benefit from clarification.

Finally, the task should be constrained to an appropriate duration and volume of content. Presenting an entire clinical case, recreated from initial presentation to long-term prevention recommendations, may not be the best approach to achieve the intended learning objective(s). Active learning is cognitively demanding, and students may become tired or lose interest during extended activities. A balance between how closely the activity simulates a real clinical problem and the desired learning objectives, as well as between the level of detail presented and the duration of the task, should be found. Restricting the duration (ideally 15–30 min) may make students more likely to complete the entire task as it has been designed. Overall, the challenge is to scaffold the activity to achieve your objectives, encouraging students to engage deeply with the material and supporting them to approach a real-world situation with their current knowledge and reasoning skills.

An Example Using a Real Case: Tony's Weaner Woes

At the Melbourne Veterinary School (University of Melbourne), several online adaptive tutorials were implemented in 2018 using Smart Sparrow. This platform has a simple 'point-and-click' author interface, allowing tutorials to be created by subject-matter staff without extensive technical support or code-based software programming. A single tutorial can include a variety of question types, each with its own 'rules' for either adaptive feedback or adaptive pathways through the content that respond to student actions. The Smart Sparrow platform also has extensive inbuilt analytics, allowing instructors to review student performance, including time-to-completion and responses to individual questions, both summarized for a group of learners as well as individually for each student. This feature allows evaluation of the tutorial for ongoing improvement, including identifying topics or concepts that the students find problematic (i.e., where they continue to make errors despite the feedback and remediation provided).

A tutorial was created based on a real case of anthelmintic resistance in gastrointestinal nematodes infesting a mob of weaner (immature) sheep seen by the sheep consultancy service at the Melbourne Veterinary School. The case study's objective was to help students revise relevant knowledge from different disciplines and to integrate it to (i) make a diagnosis, and (ii) explain the epidemiology of the clinical problem. The activity walked students through a clinical approach to the problem, including taking a history, performing a clinical examination, developing and ranking a list of differential diagnoses, selecting relevant diagnostic tests (based on the pros and cons of the available tests), interpreting test results, and finally returning to the clinical history to make a diagnosis and describe the epidemiology of the case. Adaptive feedback was provided to students at each step, to support their understanding of the clinical approach and highlight any knowledge deficits or misconceptions. Links to relevant external resources produced by the sheep industry were provided as optional supplementary material. Students could work through the case study at their own pace, allowing them to reflect on their thinking as they progressed.

Voluntary access to the case study was given to veterinary students in their penultimate and final year of the Doctor of Veterinary Medicine program at the Melbourne Veterinary School in October 2018, in the weeks preceding their final exams for the year. Students were not required to complete the case study as part of their course requirements, and the activity was not assessed. The case study was available for 3 weeks and was accessed via a web link distributed by email to the students. For evaluation purposes, pre- and postcompletion self-evaluation questions were integrated into the case study, each using a Likert scale (Figure 2). Free-text qualitative feedback questions were also included at the end of the case study. In total, 25 students completed the module, of which 23 responded to the postcompletion evaluation questions. The median time to complete the module was 25 min (range 8.5–47 min).

All students who responded to the evaluation questions reported an increase in both their understanding of the diagnostic approach to diarrhea in weaner sheep and their confidence in knowing how to reach a diagnosis. The proportion of students agreeing or strongly agreeing that they understood and had confidence in the diagnostic approach to this topic increased following tutorial completion from 43% to 96% and from 39% to 83%, respectively. Students particularly appreciated the feedback they received when they selected an incorrect response, reporting that they 'like how everything has a detailed explanation' and finding the explanations for why they were incorrect 'really informative, helping me understand my thought process'. Aligning with previous studies [7,9], student feedback for the tutorial was

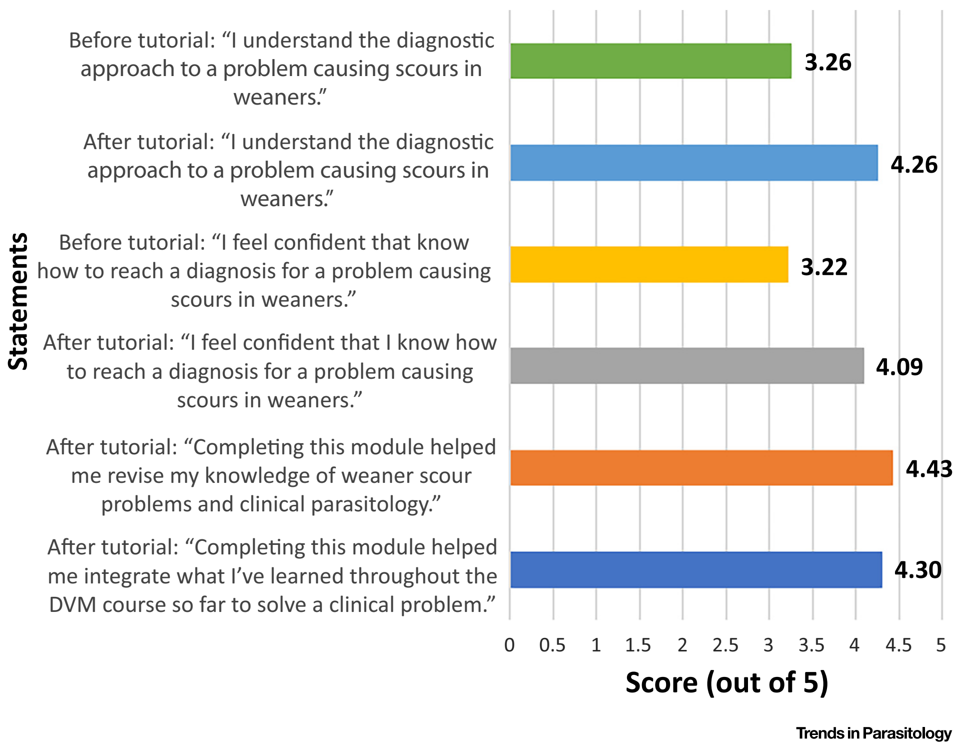


Figure 2. Student Feedback for the Online Adaptive Parasitology Tutorial 'Tony's Weaner Woes'. The students were given two statements prior to, and four questions after, tutorial completion and asked to rate them using the following criteria: (1) strongly disagree; (2) disagree; (3) neither agree nor disagree; (4) agree; (5) strongly agree. The data indicate the mean score for 23 students who completed all six questions, who were DVM3 and DVM4 students at the Melbourne Veterinary School.

overwhelmingly positive. Indeed, one student simply gave the feedback: 'More of these, please!'.

Future Potential of Adaptive e-Learning in Parasitology

The use of online adaptive learning as described in this article has been very successful in the training of veterinary students, supporting their growing clinical reasoning skills as they construct approaches to solving clinical problems. Further, we believe that these types of activities need not be restricted to clinical teaching programs. Skills that enable students to bring different types of knowledge and understanding together to solve real-world problems are needed throughout parasitology teaching programs, including in evolutionary biology, ecology, and molecular biology. The design considerations presented in this article aim to encourage further development of active and engaging online adaptive learning activities that can support students to achieve meaningful learning outcomes.

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Resources

[i]www.smartsparrow.com/

[ii]https://articulate.com/360/storyline

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Forum

Sensing What's Out There – Kinetoplastid Parasites

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Kinetoplastid parasites such as trypanosomes and *Leishmania* must adapt to their environments to survive within their hosts, yet they do not express many of the well established families of signal transduction receptors. Evidence suggests that other membrane proteins, including transporters and channels, play central roles in environmental sensing in these parasites.

Kinetoplastid parasites live in a variety of distinct environments in their mammalian hosts; *Trypanosoma brucei* is an extracellular parasite of the adipose tissue, skin, blood, and brain, whereas *Trypanosoma cruzi* lives in the cytosol of host cells in a variety of tissues, and *Leishmania* species live inside macrophage phagolysosomes. In both the vertebrate host and insect vector, and when transiting between them, parasites are exposed to dynamic physiological conditions, such as fluctuating nutrient levels, and they must sense the external environment to thrive within a hostile landscape. However, the signaling pathways that these evolutionarily ancient parasites employ to sense 'what's out there' are largely an enigma. Genome sequences for each of these parasites revealed that many of the classes of membrane proteins that mediate sensation (G-protein-coupled receptors, heterodimeric G-proteins, receptor tyrosine kinases) of the environment in most other eukaryotes are completely absent from these unicellular eukaryotes. How then is it that these pathogens sense and respond to pronounced environmental changes to support successful parasitism?

Sensing of environmental changes in kinetoplastid parasites doubtless engages both intracellular and cell-surface sensors, as is the case with many biological systems. In this Forum article, we focus primarily on surface membrane sensing, although reference is made to how membrane proteins may be critical for the functioning of internal sensing systems. Indeed, probable roles for several membrane proteins have been suggested by recent research (Box 1). In particular, transporters and channels are likely to serve central functions in environmental sensing, perhaps to a significantly greater degree than in organisms that express a wide range of signal transduction receptors.

Some permeases or channels likely mediate sensing by allowing influx of metabolites or other solutes, thus enabling the activity of internal sensors by making their ligands available, even though the carriers are probably not sensors themselves. One such example is the PAD (proteins associated with differentiation) transporters [1]