Adaptive Tutorials Versus Web-Based Resources in Radiology: A Mixed Methods Comparison of Efficacy and Student Engagement

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Rationale and Objectives: Diagnostic imaging is under-represented in medical curricula globally. Adaptive tutorials, online intelligent tutoring systems that provide a personalized learning experience, have the potential to bridge this gap. However, there is limited evidence of their effectiveness for learning about diagnostic imaging.

Materials and Methods: We performed a randomized mixed methods crossover trial to determine the impact of adaptive tutorials on perceived engagement and understanding of the appropriate use and interpretation of common diagnostic imaging investigations. Although concurrently engaged in disparate blocks of study, 99 volunteer medical students (from years 1–4 of the 6-year program) were randomly allocated to one of two groups. In the first arm of the trial on chest X-rays, one group received access to an adaptive tutorial, whereas the other received links to an existing peer-reviewed Web resource. These two groups crossed over in the second arm of the trial, which focused on computed tomography scans of the head, chest, and abdomen. At the conclusion of each arm of the trial, both groups completed an examination-style assessment, comprising questions both related and unrelated to the topics covered by the relevant adaptive tutorial. Online questionnaires were used to evaluate student perceptions of both learning resources.

Results: In both arms of the trial, the group using adaptive tutorials obtained significantly higher assessment scores than controls. This was because of higher assessment scores by senior students in the adaptive tutorial group when answering questions related to topics covered in those tutorials. Furthermore, students indicated significantly better engagement with adaptive tutorials than the Web resource and rated the tutorials as a significantly more valuable tool for learning.

Conclusions: Medical students overwhelmingly accept adaptive tutorials for diagnostic imaging. The tutorials significantly improve the understanding of diagnostic imaging by senior students.

Key Words: eLearning; adaptive tutorials; radiology; diagnostic imaging; medical education; engagement.

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A basic understanding of diagnostic imaging is vital for undergraduate medical students (1,2). In fact, application of this knowledge is often expected from students in their first postgraduate year (3). Medical imaging both requires and informs knowledge of anatomy, physiology, and pathology and allows students to develop an understanding of the role of radiology in diagnostic medicine (4,5). Failure to develop basic radiology skills also has significant health care and economic implications. In the United States, up to 30% of imaging studies are reported to be ordered inappropriately (6). This places a huge burden on the health budget and often results in unnecessary harm to patients (7,8).

Despite its clear importance, radiology is visited only briefly in many medical curricula (9). Indeed, many medical students believe that there is insufficient teaching of diagnostic imaging (1,10). This situation is exacerbated by the lack of accepted standard guidelines and curriculum in radiology for medical students at our institution, throughout Australia, and in many other countries, including the United States. As an image-centric specialty, radiology is well placed to use digital and online teaching solutions as a means of increasing student exposure to the core elements of the discipline (5,11).

It is only by reviewing many images that students can begin to understand radiologic interpretation and diagnosis, and therefore, its use in clinical care (12). Online educational resources best support this requirement for access to large image sets. In a study conducted in the United Kingdom, students reported

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high levels of satisfaction and increased confidence in image interpretation after implementation of an online radiology module (11). Thus, creation of high-quality digital imaging resources that allow flexible and interactive learning in radiology could potentially improve health care, reduce unnecessary tests, prevent harm to patients, and increase equity in resource distribution (9).

Self-directed learning is an undeniably important attribute for medical graduates. However, cognitive load theory suggests that students can only learn efficiently once they possess sufficient knowledge to guide their own study (13). Otherwise, the excessive amount of information being processed in working memory will cause cognitive overload. As a result, students may have incomplete or disorganized knowledge, and may develop misconceptions. This is particularly the case if students attempt to learn independently via the Internet: Web sites contain medical information of variable quality and veracity, and many simply do not meet basic publication standards (12). In contrast, guided instruction allows working memory to focus on the construction of schemata that are required to integrate new information with the student's existing knowledge (13).

Hence, a potentially helpful form of e-learning for diagnostic imaging is the use of guided instruction by adaptive tutorials. These are a type of online intelligent tutoring system, which can provide immediate feedback on misconceptions, as well as offering self-paced, personalized learning, based on students' interactions with the system. A number of intelligent tutoring systems have contributed to improvements in student academic performance superior to that of classroom instruction, and close to that which can be achieved with a human tutor (14). One example is *Co*llaborative *Me*dical *T*utor (COMET), a collaborative intelligent tutoring system used to facilitate medical problem-based learning (15). Students who used COMET achieved significantly greater improvements in clinical reasoning skills, compared with those who participated in human-tutored sessions. We have previously shown that adaptive tutorials in histopathology were superior to traditional methods of learning (16).

To determine whether adaptive tutorials are an acceptable and effective method of learning diagnostic imaging for medical students, we conducted a randomized mixed methods crossover study to evaluate their impact on the perceived engagement and efficacy of learning of students, when compared with an existing peer-reviewed online resource. The adaptive tutorials focused on the use and interpretation of two common diagnostic imaging investigations (chest X-rays and computed tomography [CT] scans).

MATERIALS AND METHODS

Development of Adaptive Tutorials

The Adaptive eLearning Platform (AeLP) developed by Smart Sparrow (http://www.smartsparrow.com) was used to create two novel adaptive tutorials that introduced participants to the use and interpretation of chest X-rays and CT scans of the head, chest, and abdomen. Each adaptive tutorial was divided into two sections. The first section related to basic principles of the imaging technique, appropriate use, radiation safety, risks, and interpretation of normal structures. The second section covered examples of abnormal imaging in a variety of common, classical, and critical conditions relevant to junior medical students. The intended learning outcomes of our adaptive tutorials align with the Alliance of Medical Student Educators in Radiology National Medical Student Curriculum (17).

In the adaptive tutorials, which were deliberately targeted at an introductory level, static screens providing information were interspersed with rich interactive elements such as multiple-choice questions and drag-and-drop questions (Fig 1). The tutorials provided immediate feedback that was adapted to individual student responses.

In collaboration with a radiologist, as well as senior academic staff of the Department of Pathology, the adaptive tutorials were revised and edited before the crossover trial. For the purposes of the trial, the adaptive tutorials were made available as extracurricular resources only to the appropriate study groups. Subsequent integration of these resources into the curriculum was predicated on the results of the trial.

Public versions of the adaptive tutorials used in the trial are available to view via the following links (recent browser version required, Flash enabled):

Chest X-rays: https://aelp.smartsparrow.com/learn/open/g6rwfde5.

CT scans: https://aelp.smartsparrow.com/learn/open/s4293ex3.

Participants

Medical students enrolled in phase 1 (years 1 and 2) and phase 2 (years 3 and 4) of a 6-year undergraduate medicine program were recruited by broadcast e-mail for a randomized crossover trial of the adaptive tutorials. In phase 1, students are primarily taught at the main campus, with a focus on scenario-based learning that integrates biomedical, social, and clinical sciences. In phase 2, which aims to encourage practice-based learning, students balance their time between clinical attachments and campus-based teaching of the relevant biomedical and social sciences. We recruited students only from phase 1 and phase 2 of the program, for two reasons:

1. The adaptive tutorials for diagnostic imaging were pitched at an introductory level, suitable for junior students. Further, our phase 1 students have clinical exposure from the outset of the program, enabling them to understand the potential relevance of common imaging abnormalities;
2. Phase 3 students (years 5 and 6 of the Medicine program) are exposed to face-to-face diagnostic imaging seminars and hospital-based radiology education, so inclusion of these students would have been a potential source of bias.

Ninety-nine medical students volunteered for the study. A power calculation had determined that a minimum of 18 students per study group was necessary to detect a 20% difference between the groups with 99% statistical power.

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