Abstract
Usability testing is widely used in the commercial world during the process of developing new products, especially software and websites. However, it appears to be rarely used in the development of e-learning in medical education. The focus of usability testing is the user of the particular product and it informs product development by using a systematic process to identify usability problems at an early stage during product development so that these problems can be rectified. Usability testing of e-learning considers the characteristics of the learner, the technological aspects, the interaction and instructional design and finally the context. Testing under the conditions that the e-learning intervention will typically be used is the preferred method but more extreme situations can provide useful information. Product development should be iterative and rapid cycles of testing and refinement are essential to produce an effective e-learning intervention.

Introduction
The use of technology for teaching and learning (e-learning) is almost universal in medical education, including undergraduate and postgraduate. There are many approaches to e-learning, from the use of virtual worlds to highly sophisticated virtual patients to online discussions to the use of mobile devices. The intention of all of these approaches is that e-learning will be an effective educational intervention but recent research has highlighted that there is a wide variation in the effect between different studies (Cook et al. 2008).

An e-learning intervention is complex, and the learner is immediately affected by its usability as they interact with both the educational content and the technology that is used to deliver this content. All of this occurs within a wider educational context. A usability testing perspective can provide a useful approach to understanding and overcoming the barriers to effective learning for an e-learning intervention. Fisher and Wright (2010) highlight that there is a lack of research into usability testing in education. Our personal experience of e-learning in medical education is that usability testing is not commonly employed except as an evaluation of the final product. This may be too late to ensure that an e-learning intervention can achieve its intended outcomes and it can also prove costly if substantial redevelopment is necessary. We have used the term e-learning intervention in this article to include both the use of a specific and independent e-learning resource, such as an online module or learning sequence, a podcast or web site, and a more structured intervention, such as an online course or online learning environment.

Practice points
- Usability testing has a focus on the user and requires a systematic process.
- The aim of usability testing is to inform product development by the early identification and rectification of usability problems during product development.
- Usability testing of e-learning considers the characteristics of the learner, the technological aspects, the instructional design and the context.
- Testing under the conditions that the e-learning intervention will typically be used is the preferred method but more extreme situations can provide useful information.
- Product development should be iterative and rapid cycles of testing and refinement are essential.
- Wider dissemination of the evaluation findings would help developers avoid common pitfalls.

The principles of user-centred design
User-centred design is widely and routinely used in the commercial world for the development of new products, especially software and websites, but also in healthcare informatics. However, it appears to be rarely used in medical education for the development of e-learning interventions. The basic principles of this design process are an early focus on the needs of users and an iterative approach that is based on early and repeated usability testing so that the product can be constantly refined (Dumas & Redish 1999). The needs of users...
may be initially identified but several assumptions are usually made by the developers of the new product, such as how users will actually put the new product into action. However, an intensive analysis of the needs of the user can produce a variety of different and conflicting needs and this may not help the decisions that developers have to make. User-centred design takes a more pragmatic initial approach to the product development process and recognises that only by usability testing of the new product will the needs of the user be identified. Usability testing at an early stage of product development allows the needs of the user to influence the development of a new product before it is more advanced in its development.

The principles of usability testing

The central focus of usability testing is always the needs of the user (Chisnell & Rubin 2008). A user has to interact with a tool to produce an intended action and this tool can be simple, such as a hammer, or more complicated in the case of technology, such as a microwave oven. Our own personal experiences with using technology can be extremely frustrating. The door of the oven may open the wrong way so that it obscures the controls or the timer has a bleep that is identical to the doorbell. In this example, the product designer is fully trained to use design principles but the product is not usable and does not meet the needs of the user. Usability testing is a systematic process that evaluates the ease with which users can use the tool to achieve their goals.

Usability and usability testing in e-learning

There is a long history of considering usability and usability testing in software development and recently these principles have been applied to e-learning (Zaharias & Poylymenakou 2009). The intrinsic motivation of the user to learn can be considered to be central to the usability of e-learning and this is dependent on the interaction between the technology (such as the screen size), interaction design (which is how the user interacts with the content) and the instructional design (which is how the educational content is presented to produce the maximum impact on learning). Usability also includes the context within which the e-learning is being used, such as on campus with a virtual learning environment (VLE) or in the busy clinical workplace.

Zaharias and Poylymenakou (2009) highlight the importance of usability testing at an early stage of the development of any new e-learning intervention so that the needs of the user can influence product development and produce maximum impact on learning. Effective e-learning requires a complex alignment of learner characteristics, the technology being used, the instructional design and the context. All of these factors must be considered in usability testing for e-learning. The educational content is important but it is even more important that the content is delivered in such a way that effective learning can occur.

Fisher and Wright (2010) outline how usability testing could be used to develop a model for online courses. Its application may help to increase student satisfaction but also reduce the time staff have to deal with problems associated with online course. E-learning development can be costly and human resource intensive. Not adopting a usability testing approach could increase the development costs if the end product has significant usability problems and subsequently requires significant re-development.

**Tip 1: Always maintain a user and learner focus**

The needs of the user of an e-learning intervention should always be considered. It is easy to be complacent and feel reassured that the intervention has had the combined input of a technical and an educational expert in its development but it is still no guarantee that it will engage the learner and produce the desired impact on learning. The development of a new e-learning intervention is often constrained by numerous factors. New e-learning interventions are often developed in institutions which may have a specific delivery approach, such as a VLE, and there may also be excellent onsite broadband internet connectivity. However, these conditions may not be readily available to the intended user who lives in a rural setting or works in a busy clinical environment. The designers may have high familiarity with particular software packages that only produce a specific format of presentation, such as a wiki or discussion board, and they do not appreciate that the learner may have never previously seen anything like it before in their life.

The basic message is that no effective learning will result from all the hard work and money that has been put into designing the e-learning intervention if the learner does not use the intervention.

**Tip 2: Ensure that usability testing is systematic**

Intrinsic motivation is essential for effective learning and there is increasing recognition of the importance of affective and emotional aspects of usability. Learners will not be motivated if they find the e-learning intervention visually unappealing, boring or frustrating to navigate and difficult to use and work their way through. Usability testing is more than a simple satisfaction survey and requires a systematic approach to identify the various factors that interplay to produce effective e-learning.

The goal of usability testing is to identify and rectify problems with usability. This testing does not prove that the e-learning intervention is effective but without usability testing it is unlikely that the intervention will achieve its intended impact on learning. Usability testing is always an artificial situation and the participants are rarely fully representative of the target population. An important aspect of usability testing is to ensure that testing occurs in a variety of situations and with an appropriate selection of users.
Tip 3: Decide on whether to test in real life situations

The ideal situation is to perform usability testing in the conditions under which the e-learning intervention will be used by the learner. This may be easy to achieve, such as in a university computer cluster or classroom, but can be difficult if the intervention is used at home. Usability testing under more controlled test conditions, such as in a purpose built room, have the advantage of being able to exclude extraneous distractions and to ease the work of the tester.

A useful approach is to consider under what conditions the majority of learners will use the e-learning intervention and to identify if there are any circumstances in which some learners may be significantly different. This is particularly important since one of the advantages of e-learning is that it can be used ‘anytime and anywhere’. For example, images that can be easily viewed on a full size computer screen may prove impossible to view on the screen of a small mobile device.

Tip 4: Decide on the most appropriate method to collect usability test data

Questionnaires, interviews and focus groups are common methods for usability testing and will be familiar to most medical educators. The development of questions and their administration require appropriate expertise. A validated questionnaire about the usability of e-learning has recently been developed from a range of items identified in a variety of the published guidelines and studies (Zaharias & Poylymenakou 2009). The advantage of these methods is that they can be used to survey a large number of learners but they rely on self-report and usually require some predetermined view of the needs of the user.

Experts in usability testing prefer to study the live interaction of the user with the product and consider that the increased time and resources required are essential to obtain an understanding from the perspective of the user. A commonly used method is a think aloud protocol in which the user verbalises their thought processes as they perform a task or series of tasks. The interaction can also be filmed and reviewed by the tester at a later date. Usability testing software packages are also available which digitally record the testers’ key strokes and interaction with the computer. This software can also record comments and reactions to the e-learning intervention and enable observers to connect and observe testing sessions and comment simultaneously (Fisher & Wright 2010). These approaches can be particularly useful for e-learning usability testing but are rarely used at present.

The e-learning delivery system often provides important quantitative process data that can be easily collected, such as the overall extent of use of certain resources or repeated access to a resource by a single user.

The sample size for usability testing is usually small and is based on the finding that 95% of usability problems can be discovered with just five to six people that are chosen from a cross-section of users (Nielsen 1994). It is important to remember that the intention of usability testing is to quickly identify and rectify problems with usability during the development of the product.

Tip 5: Consider the characteristics of the learner who will use the e-learning intervention

It is a naïve assumption that an e-learning intervention will be effective for all learners. Each learner will bring a wide variety of attributes to the learning experience, such as age, gender, cultural background, confidence and competence of using a computer or other technology, preferred learning style, previous experience of e-learning and the use of technology, previous knowledge of the learning content and motivation. However, it is usual to have a ‘typical’ learner for a particular e-learning intervention, such as young technological savvy medical students or older doctors using e-learning for continuing medical education. The usability testing should try and test a sample from this specific learner population.

The ‘typical’ learner is important but also the ‘least competent user’ (LCU) should be considered, even if they are not a significant part of the eventual target group of learners. The assumption is that if the LCU can muddle their way through the e-learning intervention then other more competent users will find it easier to successfully complete the intervention. The concept of the LCU does not only refer to computer and technical skills but also to the other factors that will influence their learning, such as their level of content knowledge.

There is a statutory and legal requirement in most countries to consider the learner with disabilities, such as visual impairment or limb motor dysfunction, and many of the aspects are related to the use of technology and will be further discussed in Tip 7.

Tip 6: Consider the context within which the e-learning intervention will be used

Usability testing should ideally be performed in the same circumstances that the ‘typical’ learner will use the e-learning intervention, including the workplace. Mobile devices are commonly used in clinical settings and usability problems can arise due to poor internet or wireless connections. Similar factors also need to be considered in low resource settings, such as many countries in the developing world where connectivity may be intermittent, especially in rural areas. Alternative e-learning delivery systems, such as CD ROMS/DVDs may be required in these settings and care must be taken to ensure these are updated to ensure the content is current. Consideration should also be given to the accessibility of external resources the e-learning intervention may link to or where the intervention is a content mashup combining data and resources from several sources. For example, a workplace based learner may encounter ‘internet denial’ or ‘denial of service’ and be unable to access the resources due to local firewall and security issues (Prince et al. 2010).

There is increasing interest in ‘blended learning’ in which there is a combination of face-to-face instruction and an
e-learning intervention, such as a seminar that is supported by several podcasts or online modules that students are expected to use as self-directed learning resources. Usability testing of the podcast or module may be erroneous if the tester was not aware of the associated face to face intervention.

**Tip 7: Consider the technological approach being used to deliver the e-learning intervention**

The main areas to consider for usability testing of the technological approach are navigation, learnability, accessibility, consistency and visual design. It is also important to ensure that content is compatible across a wide variety of operating systems, different browsers and versions of browsers.

**Navigation.** Learners should be able to decide on the order and pace of interacting with the learning content. This requires tools, such as menus or indexes, that allow learners to find specific items of content and to identify where they are in a sequence of instruction or commands.

**Learnability.** The layout should allow learners to easily accomplish basic tasks the first time that they encounter the intervention. This requires consideration of how learners ‘intuitively’ begin to use technology, such as reading a screen from the top of a page to the bottom. Appropriate formatting, such as clear headings and bulleted lists, should be applied to support readability of the content.

**Accessibility.** Any learner, irrespective of their disability, should be able to use the intervention. The range of potential disabilities is wide and includes cognitive, visual, hearing and motor impairments. Screen design is important, such as avoidance of certain colours in colour blindness, and software design should also consider these disability issues, such as the opportunity to use keystrokes instead of mouse clicks for navigation. Full details are beyond the scope of this article and will usually have been addressed in the software development process, especially if provided by a standard commercial supplier.

**Consistency.** The terminology of the functions, colours and font sizes should be used consistently.

**Visual design.** The most important information for the learner should be clear and easily read. An essential aspect is the overall aesthetic appeal since this can immediately produce a strong affective and emotional reaction in the learner and this will significantly influence motivation and engagement with the learning content.

Further details on this aspect are included in the book by Chisnall and Rubin (2008).

**Tip 8: Consider the instructional design for the e-learning intervention**

Instructional design is the process by which the content is presented to the learner so that it can produce the maximum impact on learning. The main areas to consider are interactivity, content and resources, media use, design of learning activities and learner guidance and support.

**Interactivity.** Long sections of text or audio do not effectively engage learners and some form of meaningful interaction should be included to encourage active learning, such as games and quizzes or activities which require decision making or reflection.

**Content and resources.** The breadth and depth of the learning content should be sufficient to enable to learner to meet the intended learning outcomes of the e-learning intervention.

**Media use.** Multimedia, either visual or audio, should only be used to assist learners to focus on the main learning points. Providing simultaneous information in different media can overload and confuse the learner.

**Design of learning activities.** The overall e-learning intervention should be based on good principles of design of learning activities, such as an initial statement on what the learner is expected to learn, a logical sequence of instruction and some form of assessment, either self reflection or a quiz (Gagne & Driscoll 1988).

**Tip 9: Use rapid cycles of e-learning intervention development and evaluation**

An iterative approach to product development is an essential feature of user-centred design and requires several cycles that include product development, usability testing and progressive refinement of the product. The aim of this process is that users will find the final product to be highly usable. An important aspect of this development process is that each cycle is achieved in a short period of time so that the findings can quickly influence the design of the product.

A compromise always has to occur that balances the available resources for testing and the amount of information required to inform important decisions on the design of the product. Usability testing typically involves small numbers of users in situations that are identical to that in which the product will eventually be used.

The concept of rapid short cycle product development and evaluation does not appear to be characteristic of the development of most e-learning interventions in medical education. There is often a tendency to produce an e-learning intervention with little input from the intended users and then a final evaluation usually only occurs after it has been widely implemented and used by many learners, often in a variety of contexts. This approach may be too late to influence further refinement of the e-learning intervention since substantial time and money has already been spent on its development.

**Tip 10: Decide on the use of a participatory approach for usability testing**

Participatory product design is more of an underlying philosophical approach than a specific technique (Baskerville & Wood-Harper 1996). This approach involves users in all stages of the design process, including usability testing. Typically several potential users join the product development team and
they contribute their own unique perspective in all cycles, from initial design of the product, planning of usability testing and the iterative refinement of the product.

The main advantage of the participatory approach is that users are at the heart of product development and its usefulness in the development of information systems has been clearly demonstrated. The approach has also been recommended for e-learning intervention development but it appears to be less widely used in practice.

**Tip 11: Widely disseminate the results of the evaluation of the usability of the e-learning intervention**

Most medical education journals report studies that evaluate e-learning interventions but these are mostly related to the final product. Some useful insights to guide further development by other e-learning providers may be obtained but there is rarely a description of the iterative development process. This could be due to the lack of reporting of the important usability testing process that was used to inform the final product or (more likely) that this process did not occur. There are also issues about the degree to which the evaluation is regarded as research and the quality of the approaches to data collection and analysis.

Important lessons that have been obtained through painful experience can be highly relevant to other developers of e-learning interventions and alternative ways to widely disseminate the findings from usability testing should be considered. Word-of-mouth between colleagues still continues to be the main approach but presentations at conferences and uploading to personal web sites or blogs could be considered so that they can be readily identified on the World Wide Web.

**Tip 12: Reflect on the overall development process to inform the next e-learning project**

There is often a ‘steep learning curve’ when developing a new e-learning intervention. The various pitfalls and attempts at recovery, such as recruitment of users or working with learning technologists, should be used to inform future projects. These insights are essential to consider if any e-learning intervention is to be developed in the future, especially if using a rapid cycle approach with its tight time constraints. Often there is little explicit discussion of these issues by the product design project team yet they can make or break a project.

**Conclusion**

Usability testing can be applied to e-learning interventions to ensure that they achieve their intended educational impact. The aim of usability testing is to inform product development by the early identification and rectification of usability problems during product development. Usability testing of an e-learning intervention is a user-centred and systematic process that considers the characteristics of the learner, the technological aspects, the interaction and instructional learning design as well as the context within which the e-learning will be used. The testing should produce a more effective intervention, especially when the development is iterative and in rapid cycles.

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**Notes on contributors**

JOHN SANDARS, MD MSc FRCGP MRCP Cert Ed, is a Senior Lecturer in Community Based Education and academic lead for e-learning in the Medical Education Unit, Leeds Institute of Medical Education, The University of Leeds.

NATALIE LAFFERTY, BSc (Hons), is a Lecturer (E Learning) in the School of Medicine at The University of Dundee.

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