Available online at www.sciencedirect.com

SCIENCE DIRECT®

Medical Engineering & Physics 27 (2005) 633–639

Medical Engineering & Physics

www.elsevier.com/locate/medengphy

Evaluation of the e-Learning material developed by EMERALD and EMIT for diagnostic imaging and radiotherapy

Victoria Aitken [a,*], Slavik Tabakov [b]

[a] Department of Women's Health, KCL-St. Thomas' Hospital, London SE1 7EH, UK
[b] Department of Medical Engineering and Physics, KCL-King's College Hospital, London SE5 9RS, UK

Received 7 December 2004; accepted 23 February 2005

Abstract

Two Leonardo projects, EMERALD and EMIT, have developed in a partnershipof university and hospital departments (the consortia) e-Learning materials in X-ray diagnostic radiology, nuclear medicine, radiotherapy, ultrasound and magnetic resonance imaging for medical physics graduates and other healthcare professionals. These e-Learning materials are described in a separate paper in this issue. To assess the effectiveness and relevance of the e-Learning material, a series of evaluations by student users groups plus experts in medical physics education and training were undertaken.

The students, with backgrounds in physics and clinical ultrasound, reviewed the e-Learning material using an evaluation form developed by the consortia. The student feedback was favourable with students commenting that their level of knowledge had increased having completed the tasks. Areas identified for development were a reduction in text volume and an increase in the time allowed for completion of some tasks. The feedback from the experts was positive with an overall appreciation of the value of the learning material as a resource for students in medical physics field across Europe and identified other disciplines in which the access to the learning material could be useful contribution to their learning. Suggestions made for improvements ranged from grading the tasks into basic and advanced topics to increasing the interactive nature of the material.

These early evaluation of the e-Learning material look promising and provide a framework for further developments in the field. Insight into users and providers views is important if developers are to provide relevant and worthwhile educational learning opportunities.

Keywords: e-Learning; Evaluation; Medical physics training; Ultrasound training

1. Introduction

EMIT and EMERALD are Leonardo projects that have developed e-Learning material to underpin work-linked training in hospitals on ultrasound, magnetic resonance imaging, X-ray diagnostic radiology, radiotherapy and nuclear. The members of project team were drawn from a consortia of universities and hospitals from the UK, Sweden, Italy and Portugal. The EMIT and EMERALD materials consist of series of e-books and educational image databases (IDB) from diagnostic imaging and radiotherapy. The training tasks in the e-Learning material, aim to develop a series of competencies, based on the recommendations of the European Federation of Organizations for Medical Physics (EFOMP) and the UK Institute of Physics and Engineering in Medicine (IPEM) Training Scheme [1]. These materials are described in the paper "Development of Educational Image Databases and e-Books for Medical Physics Training", printed in this issue. As with any new educational tool e-Learning needs to be justified on the grounds of effectiveness and relevance in relation to the students and the professional groups involved in training and education.

This paper presents an outline for conducting an evaluation of e-Learning material using examples from the work of the EMIT and EMERALD projects and commences with a short overview of the background to evaluation. Evaluation has been defined as:

* Corresponding author.

1350-4533/$ – see front matter © 2005 Published by Elsevier Ltd on behalf of IPEM.
doi:10.1016/j.medengphy.2005.02.010

"Evaluation is the collection of, analysis and interpretation of information about any aspect of a programme of education or training as part of a recognised process of judging its effectiveness, its efficiency and any other outcomes it may have." Thorpe [2] (p. 32)

Laurillard [3] states evaluation is an iterative process and should take place at every stage in the design, production and implementation of a new educational intervention. The iterative nature of evaluation should help in making the learning experience more efficient and effective as the feedback is used to improve the material. An evaluation should always be a clear well thought out undertaking as the more effort that goes into the pre-planning of an evaluation the better the outcomes. Before conducting an evaluation it is important to define what is to be investigate and how this going to be achieved. Crompton [4] suggests that having a checklist can be helpful when planning an evaluation as it allows documentation of all aspects of the evaluation procedure to be checked off once completed (see Table 1).

One method to reflect on what can be learned during an evaluation is to use the categories developed by Kirkpatrick [5]. His four-level framework goes from level 1 (the easiest and least resource-intensive) to level 4 (the most difficult and expensive). Moving from level 1 to 4, the evaluation process becomes more difficult and time-consuming, although it provides information of increasingly significant results. The four levels are outlined in Table 2 and described below.

Table 1
Evaluation checklist

Who? (Know your target audience)
Who is the evaluation for?
What? (Understand what is to be evaluated)
Process (efficiency)
Outcome (effectiveness)
Combination of both (relevance)
Purpose (validate, improve or condemn)
Why? (Rational for evaluation)
To improve quality
To determine if aims fulfilled
To prove accountability
When? (Timing—being ready to start)
Have you defined a question?
Will the findings have any effect?
Benefits outweigh costs
How? (Choosing an appropriate technique)
Questionnaires
Interviews
Confidence logs
Observations
Student profiles
Pre-tests and post-tests
Inventory learning checklists

Adapted from Crompton [4].

Table 2
Kirkpatrick's model of evaluation

Level	Measurement focus	Questions addressed
1. Reaction	Students' perceptions	What did trainees think of this training?
2. Learning	Knowledge/skills gained	Was there an increase in knowledge or skill level?
3. Behaviour	Worksite implementation	Is new knowledge/skill being used on the job?
4. Results	Impact on organization	What effect did the training have on the organization?

Adapted from Kirkpatrick [5].

- *Level 1*: Student reactions are the easiest kind of assessment data to gather. This is not to say they are not important. If students do not see value in the learning package, they are not likely to translate the learning objectives into useful knowledge and skills. When students find a course uninteresting, they will be less motivated to learn. While positive student reactions do not ensure that objectives are met, negative reactions guarantee a less successful transfer of knowledge and skills. The questions the evaluation needs to answer and the resources available for the task determine which levels are included.
- *Level 2*: Measurements of learning are used to show whether students' knowledge and/or skills are changed by training. The best way to determine if changes are the result of specific training is to conduct an experiment in which the students are divided into two similar subgroups. Prior to training, both subgroups can be tested on the topics of interest either in writing or through observation. During this pre-test, both groups should perform equally. Then only one of the subgroups is trained. After training, both subgroups are retested. If the trained group now performs better than the untrained group, the training can be identified as the cause of the improvement.
- *Level 3*: Unlike levels 1 and 2, measuring a change in behaviour must be done in the workplace and with sufficient time elapsed for knowledge and skills to have been tried out in the workplace. The most elaborate plan for level 3 evaluation would include an untrained subgroup as described for level 2 and detailed testing of both subgroups in their workplaces before and after the training. This type of evaluation is resource-intensive and is not practical for all training tasks.

  Another strategy is to talk with the students' supervisors about any behavioural changes they have observed since the training was completed. Level 3 evaluation can be difficult because it must be conducted months after the training has been completed. This highlights the importance of planning an evaluation strategy when planning the course.
- *Level 4*: Determining how training affects the organization is the most difficult evaluation to perform. Level 4 evaluation should be conducted when the value of the training or the training program to the overall organization needs to be assessed. A relatively simple example is measuring

changes in sales numbers after training salespeople in a new skill. An increase in sales can be compared to the cost of the training and a bottom-line return on investment calculated. Unfortunately, many topics are not that easy to quantify.

2. Evaluation

The evaluations described in this paper were designed to investigate the views of student users and training experts on e-Learning material developed by the consortia and to evaluate at levels 1 and 2 as identified by Kirkpatrick [5]. There were three structured evaluations based on a questionnaire, two evaluations were undertaken by student groups and the third by experts who provide training for medical physicists. The aim of the evaluation was two-fold: to ask the evaluators to review the content of the material and investigate their opinions on the e-Learning experience.

To evaluate the e-Learning material Kirkpatrick's model of evaluation was used as a framework to build the evaluation questionnaire to look at the effectiveness and relevance of the training method and the learning package. Participants' reactions were gathered via a Likert type survey form after completing the tasks. The questionnaire was designed in two sections (see Table 3). Section I consisted of 11 items scored on a four-point Likert type scale where one was the most negative score and four was the most positive score. The items were divided into five groups with two items on the clarity of the objectives and whether they were met; five items considering the content; one item asking about the overall rating of the material; a further item inquiring whether students would recommend the material to others and finally two items reflecting on the levels of knowledge before and after undertaking the learning tasks. Section II considered what percentage of the student's work required the knowledge plus the level of skills gained from the tasks and whether the student thought they had learnt sufficient to perform the task. The last part of the second section consisted of three open-ended questions that asked what was liked most and least about the learning package and how the material might be improved. Finally, there was a section inviting further comments.

2.1. First evaluation

This was performed by a cohort of 21 international students from a physics background who were attending a 3-week training course on "An Introduction to Medical

Table 3
EMIT student evaluation

Information						
Name:						
Task title:						
Section I						
Objectives	Unclear	1	2	3	4	Clearly stated
	All objectives not met	1	2	3	4	All objectives met
Content	Task sequence poor	1	2	3	4	Sequence appropriate
	Not pertinent to my job	1	2	3	4	Pertinent to my job
	Technically incorrect	1	2	3	4	Technically correct
	Insufficient information	1	2	3	4	Sufficient information
	Excessive detail	1	2	3	4	Detail about right
Overall rating	Poor	1	2	3	4	Excellent
Recommendation						
Would you recommend this learning activity to others?	Never	1	2	3	4	All the time
How would you rate your level of knowledge:						
Before the learning activity?	Low	1	2	3	4	High
After the learning activity?	Low	1	2	3	4	High

Section II

What percentage of your total working time will be spent on tasks that require the skills/knowledge presented in the task?	10 20 30 40 50 60 70 80 90 100%
I learned enough to	
1. Be familiar with terms and concepts covered in the task	☐
2. To perform job tasks with some assistance	☐
3. To perform job tasks without assistance	☐
4. Make decisions and provide advice in the absence of procedural guidance	☐

- What did you like best about this training?
- What did you like least about this training?
- Suggestions for improving this training.

General comments

Physics". All students undertook a single training task related to quality assurance of X-ray fluoroscopy equipment. These students spent a 3 h session reading and acquiring the skills via simulation and 1 week later went to the clinical department to perform the task on X-ray equipment. During this session, the students used their PCs to assess the quality of various X-ray images (digitised in high resolution) and build a contrast-detail curve (using MS Excel). The evaluation was undertaken using section I of the evaluation questionnaire after the simulation exercise and rated the nine items using the Likert type scale. The data from the questionnaires were analysed to look at the descriptive statistics via mean scores and frequencies. The results from the analysis revealed that not all 21 students answered every question with only five questions answered by all. Of the students who responded all rated the objectives for clarity and being met as 3 or 4 (see Fig. 1). One student rated whether the material was technically correct as 1 and one student as 2. The information level, relevance and detail were rated 2 by three students. Otherwise, the first nine items were rated 3 or 4. Only one student reported no increase in their knowledge having completed the task. Comments were also received from the student's supervisors who oversaw the practical element of the task. The supervisors reported that the students were better prepared for the task and required less time than previous years to complete the task (in average 20–40% less time, student dependent).

2.2. Second evaluation

This was performed by 10 first year part-time students registered on the Master of Science (M.Sc.) in Medical Ultrasound at King's College, London, who came to the programme with health related UK Bachelor of Science degrees (B.Sc.). The students undertook clinical tasks based on ultrasound in the first, second and third trimester of pregnancy using the e-Learning material to support the clinical training over a 4-week period and evaluated the material using sections I and II of the questionnaire. This student group was of interest because they were a secondary focus for the EMIT project and it was important to see whether the material would be considered at a level to be relevant to this clinically based group. The data from the questionnaire were analysed to look at the descriptive statistics via mean scores and frequencies. In addition, content analysis of open-ended questions was performed to explore possible emerging themes. The results from the analysis revealed that the e-Learning material was rated highly with all the students scoring the first nine items as either 3 or 4 (see Fig. 2). The majority of the students (six out of eight) rated their knowledge levels as being higher after completing the task. From the second section of the evaluation questionnaire (Table 3), the mean percentage of total working time spent on the tasks undertaken was 55%. This was the percentage of time that the students spent in their workplaces on these examinations. All students felt that they had been able to transfer the learning to their work place with five out of eight students saying they could now perform the task and three out of eight students reporting they were able to adapt the knowledge and skills learnt to novel situations. When asked what the best features were the students highlighted that the material was simple and straightforward to use; it was easy to find information; the design of the material was in a format that was simple to follow; the objectives were clear and the clinical images were very helpful. However, the students identified several areas that needing improvement which were that there was too much text; additional information was required on pathology and less information was wanted on anatomy and physiology. Comments included that the material was good for training and would be useful for a range of healthcare professionals; that there was too much information for a task to be completed in 1 day and that the simple design was easy to follow.

2.3. Comparison between ratings of medical physicist and ultrasound students

When a comparison is made of the two student cohorts (see Table 4), the students rated the learning package very similarly. The mean score for the first nine items in section I for the ultrasound students' evaluation was 3.6 with a range

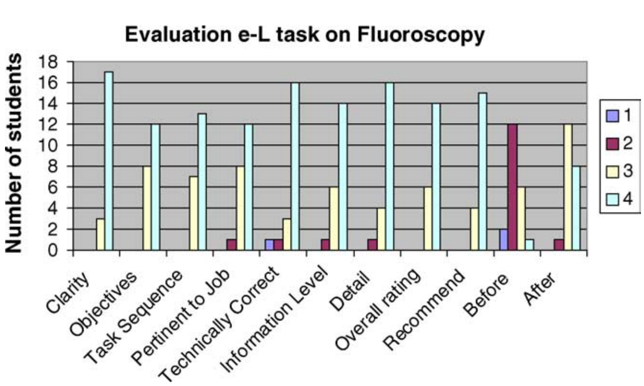

Fig. 1. Graph to show rating scores from the Medical Physicist students' evaluation of 11 items.

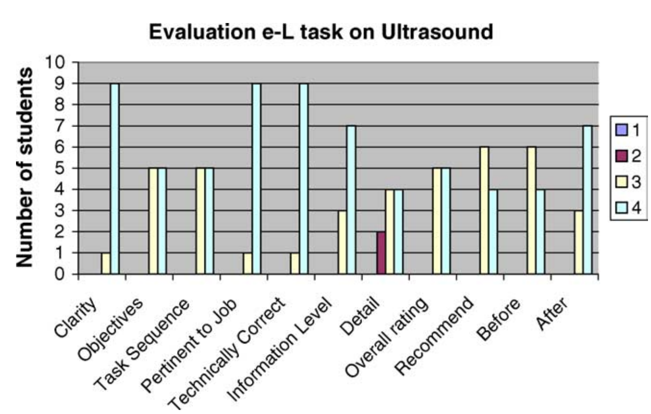

Fig. 2. Graph to show rating scores from the Medical Ultrasound students' evaluation of 12 items.

Table 4
A comparison of rating scores for Medical Physicist students (Evaluation 1) and Medical Ultrasound students (Evaluation 2)

Variable	Medical Physicists students ($n = 21$)					Medical Ultrasound students ($n = 10$)				
	1	2	3	4	Mean	1	2	3	4	Mean
Clarity			3	17	3.9			1	9	3.9
Objectives met			8	12	3.6			3	4	3.6
Task sequence			7	13	3.7			5	4	3.4
Pertinent		1	8	12	3.5			1	8	3.9
Technical accuracy	1	1	3	16	3.6			1	8	3.9
Quantity of information	1	1	6	13	3.5			3	7	3.7
Level of detail		1	4	16	3.7		2	4	4	3.2
Overall rating			6	14	3.7			3	5	3.6
Recommendation			4	15	3.8			6	4	3.4
Level before	2	12	6	1	2.3		1	5	2	3.1
Level after		1	12	8	3.3			3	5	3.6

of scores from 3.2 to 3.9 while the mean score for the medical physics students was 3.7 with a range of 3.5–3.9. The most highly rated item by both the ultrasound and medical physics students was the clarity of the material which had a mean score of 3.9. The lowest mean score for the ultrasound students was 3.2 for level of detail whereas for the medical physics students the lowest mean scores were 3.5 for the pertinence of the material and quantity of material. Both student groups reported an improvement in their knowledge levels after using the learning material from 2.3 to 3.3 for the medical physics students and from a mean score of 3.1 to 3.6 for the ultrasound students.

2.4. Third evaluation

This was undertaken by 10 expert teachers and trainers who attended the International Conference on Medical Physics Training with e-Learning Materials [15] (see Fig. 3). The experts had the opportunity through designated sessions to evaluate the e-Learning package during the conference. The questionnaire for this evaluation consisted of 10 items and related to the MRI and ultrasound tasks. The items were a series of closed questions seven of which used a four-point type Likert scale ranging from very good to inadequate (see Table 5). The responses from the questions were analysed using descriptive statistics via mean scores and frequencies. All participants rated the e-Learning approach to training as very good (4) and the way the tasks were written, the databases, the usefulness of the material and how they would rate the material for e-Learning were scored as either good (3) or very good (4). Nine people answered the question on whether there were sufficient tasks and eight thought there were with one person saying there was room for additional tasks. However, five people did recommend other tasks. The problems identified included the time required to undertake the tasks and the lack of material in the participant's native language. The number of physicists identified as being able to make use of the material in the participant's home country ranged from 5 to 30 with four people commenting that there was a much larger number of other health professionals who could use the material (estimate >300). Finally, suggestions for future developments included that there should be planned updates; that the material is used to train other health professional groups and that regular meetings of training providers are held to discuss and develop the material further. In addition to the evaluation via the questionnaire, the experts were asked in a discussion session what the pros and cons to this form of e-Learning. The positive comments range through the usefulness of the additional features to flexibility and easy to update. The negative comments considered eyestrain, technical requirements of the computer and Internet connection used to the fact that people would miss using books to learn!

Fig. 3. Delegates to the International Conference on Medical Physics Training with e-Learning Materials at ICTP, Trieste, Italy (10–11 October 2003).

Table 5
Evaluation questionnaire used with experts in education and training

1. What do you think of the EMIT and EMRALD approach to training?	1 2 3 4
2. Do you like the way the tasks were written?	1 2 3 4
3. Are there a sufficient number of tasks?	1 2 3 4
4. Would you recommend other tasks?	1 2 3 4
5. How would you rate the image databases?	1 2 3 4
6. Will the learning material be useful for training/education in you country?	1 2 3 4
7. How would you rate the material as tools for e-Learning?	1 2 3 4
8. Do you foresee any problems in the introduction of the learning material?	
9. How many people would use the learning material in your country?	
10. What would be your suggestions about future developments of the material?	

Rating scale: 1, very good; 2, good; 3, acceptable; 4, inadequate.

3. Discussion

The overall results from the evaluation of the EMERALD and EMIT e-Learning material by the three groups was very favourable with the majority of participants (84%) rating the material and its features as good or very good (ratings of 3 or 4). Both student groups reported 25–35% improvements in their knowledge indicating that engaging with the material had been effective. All students rated the pertinence/relevance of the material highly (mean score 3.5). The ultrasound students identified the best features of e-Learning material as being how easy it was to use and the clarity of the material and suggested that the material could be improved by decreasing the amount of text. Comments from the educational providers and trainers centred on that e-Learning is very suitable for medical physics however it is difficult to prepare e-materials which is further compounded by the fact that some universities do not realise the potential of e-Learning and hence do not whole heartedly support development. The questions that were not asked included whether the professions were ready to accept and apply e-Learning and from where resources would be made available to take forward future expansion in this area. Feedback from the evaluations has allowed the consortia to revise the e-Learning package to reflect the comments made. Examples of this include the reduction in the text volume for some tasks; the revision of time allocation for certain tasks; additional images added to illustrate specific points; inclusion of two additional tasks and further consideration has been given to further development of the e-Learning package for professions other than medical physics.

Within higher education (HE), there is a move towards flexible, e-Learning for as it has been recognised to have a number of benefits. For example, by increasing the access via flexible learning, entry to these courses is extended to those geographically isolated, those whose disability prevents them accessing HE and those whose particular social and personal circumstances are not conducive to on campus learning (Wade [6]). Furthermore, it has been reported that traditional lectures are not always rated as the best way to learn (Biggs [7]). Today's students have grown up in a technological age of television, computers and videogames (Frey and Birnbaum [8] and Looms [9]). Some researchers argue that neither students nor teachers regard traditional lectures as effective and students now expect technology to be use effectively as part of their learning experience (Frey and Birnbaum [8], Willcoxson [10], Husbands [11] and Butler [12]). The challenge for lecturers is hold the attention of students from this high-tech generation. Many authors have suggested designing the learning and teaching environment to promote greater student participation and engagement thereby increasing deep learning in the students (Biggs [7] and Hartley [13]). Students find e-Learning appealing and engaging and may therefore be more involved and motivated as a consequence. However, the uptake of e-Learning has been hampered by barriers as identified by the Department for Education and Skills [14]. For example, educational leaders are not yet fully engaged in exploiting e-Learning and e-systems as they need more support to enable them to lead and manage the challenging change processes involved. Against this background of potential problems the framework for expansion and evaluation of e-Learning material becomes one of the highest priorities for developers and researchers.

4. Conclusions

The uptake of the EMERALD and EMIT material on an international scale and its incorporation into the different learning curricula has yet to be evaluated. A long term aim of the consortia is to evaluate, to the third and fourth levels as described by Kirkpatrick [5], when changes in student behaviour occur due to the training process and the effect of the training upon the organization. Nevertheless, the early evaluations outlined here are positive and provide a framework upon which to develop the e-Learning material already produced by the EMERALD and EMIT consortia. The findings from this review suggest that evaluation is a key tool in keeping pace with pace with the technological requirements of the profession and the need for constant updates. To keep up with these demands the consortia is currently considering the addition of the evaluation form as part of the e-Learning package that can be e-mailed back. The use of the e-Learning material can be justified only by its evaluation and it is also the only way to develop its quality.

References

[1] IPEM training scheme prospectus for medical physicists and clinical engineers in health care, IPEM, York (www.ipem.org.uk).
[2] Thorpe M. Handbook of education technology. Ellington, Percival and Race; 1988.
[3] Laurillard DM. Rethinking university teaching: a framework for the effective use of educational technology. London: Routledge; 1993.
[4] Crompton P. Evaluation: a practical guide to methods. In: Learning technology dissemination initiative. Implementing learning technology. 1996. http://www.icbl.hw.ac.uk/ltdi/implementing-it/cont.htm [chapter 12].
[5] Kirkpatrick DL. Evaluating training programs—the four levels. San Francisco: Berret-Koehler Publisher Inc.; 1994.
[6] Wade W. Flexible learning and flexibility in course provision. In: Martin J, Darby J, editors. The CTISS file. Flexible and distance learning, vol. 17. University of Oxford: CTISS Publications; 1994.
[7] Biggs J. Teaching for quality learning at university. Buckingham: Society for Research into Higher Education and Open University Press; 1999.
[8] Frey BA, Birnbaum DJ. Learners' perceptions on the value of powerpoint in lectures. Pennsylvania, USA: EDRS; 2002.
[9] Looms PO. Sailing into uncharted waters—the impact of new media use on education. In: Williamson A, Gunn C, Young A, Clear T, editors. Winds of change in a sea of learning: Proceedings from the 19th annual conference of the Australasian society for computers in learning in tertiary education (ASCILITE), vol. 1. 2002. p. 5–16.
[10] Willcoxson L. The impact of academics' learning and teaching preferences on their teaching practices: a pilot study. Stud Higher Educ 1998;23:59–70.

[11] Husbands CT. Variations in students' evaluations of teachers' lecturing and small-group teaching: a study at the London School of Economics and Political Science. Stud Higher Educ 1996;22:187–206.
[12] Butler JA. Use of teaching methods within the lecture format. Med Teach 1992;14:11–25.
[13] Hartley J. Learning and studying: a research perspective. London: Routledge; 1998.
[14] DFES. Towards a unified e-learning strategy: consultation document. July 2003.
[15] Tabakov S, Roberts C. International conferences in medical physics and engineering—education and training. In: Towards a European framework for education and training in medical physics and biomedical engineering, Studies in health technology and informatics, vol. 82. IOS Press; 2001.