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Research article

Therapeutic drug monitoring: an e-learning resource

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The main aim of this project was to produce an interactive e-learning resource explaining the pharmacokinetic principles related to therapeutic drug monitoring (TDM). The target audience for the resource were scientists at Manchester Royal Infirmary and the intended learning outcome for the users was to improve their understanding of the pharmacology behind the results they generate. The null hypothesis stated that the resource would not cause a significant improvement in the users' understanding of pharmacokinetics. The ADDIE Instructional Design Model was applied to the learning situation. A pre-project questionnaire allowed for a needs analysis to be conducted, determining the current level of knowledge. Design and development involved production of project plans and storyboards and the entire resource was produced using Opus Professional. The resource was distributed via compact discs, along with pre- and post-resource questionnaires to permit analysis. Knowledge was compared before and after using the resource to establish the effectiveness of the resource, and the functionality of the resource was evaluated. The needs questionnaire results outlined the existing level of knowledge as being varied and provided suggestions for possible concepts to include in the resource. A more precise and accurate definition of TDM, why it is carried out, and the pharmacokinetic parameters were apparent in the post-resource questionnaire results. Confidence in the understanding and interpretation of data produce was not significantly improved (Wilcoxon matched pairs signed ranks test, $n = 14$, $P = 0.13$), while confidence in the understanding of pharmacokinetic parameters was significantly improved (Wilcoxon matched pairs signed ranks test, $n = 16$, $P = 0.01$). About 81% of the audience found the resource very helpful to understanding TDM and all of the users found it either easy to use or very easy to use. The post-resource results showed that confidence in the understanding of pharmacokinetics was improved, indicating that the learning outcomes of the user were achieved thus allowing the null hypothesis to be rejected. However, confidence in understanding the data generated was not improved, suggesting a possible aspect to be developed if the project was to be repeated. Functionality of the resource was successful as users found the resource easy to use and navigate.

Key words: therapeutic drug monitoring, e-learning resource, pharmacokinetics.

Introduction

Therapeutic drug monitoring (TDM) utilizes the principle that the clinical response of a drug is directly related to its concentration in blood and hence monitoring is carried out to support the management of patients receiving certain drugs.[1, 2] The central goal of TDM is to use drug concentration to manage drug regimens to optimize therapy.[3] The target group consisted of about 30 scientists who work in the Biochemistry, Toxicology and Microbiology laboratories at the Manchester Royal Infirmary, and who carry out TDM on a regular basis. Their key responsibility is to monitor blood samples received from patients to determine the concentration of a given drug. This concentration can then be used by a clinician to determine the success of treatment and whether sub-optimal, optimal or toxic drug concentrations are being achieved.

It was considered that the target audience needed improved grounding in pharmacokinetics to strengthen their comprehension of the reasoning behind the data that they generated. A resource was designed to support the users' understanding of the potential sources of pharmacokinetic variation, which can result in the varying drug concentrations they monitor in patients' samples.[4]

The resource followed the concept of a clinical audit for the Central Manchester and Manchester Children's University Hospitals NHS Trust (CMMC)[5] with the purpose of improving patient care and outcomes following a systematic review of the TDM process through implementing the change of improving knowledge.[6] The process of resource development referred to the stages of clinical audit to improve their awareness and, therefore, enhance their understanding of the results which they generate.

The majority of information relating to TDM can be found either in textbooks[7–9] or journals.[10] However, content is often too textual and few pharmacology textbooks describe TDM specifically, presenting more complex information than is necessary. Therefore, there was a need for a specific resource. The resource was based around the concept of enquiry-based learning,[11] which describes an environment that is driven by active learning.[12] Active learning encourages effective learning and permits the opportunity for the user to reason, enabling the acquisition of knowledge.[13] The resource was developed as e-learning to provide interactivity for the user and the advantage that the user could pursue their studies at their own pace.[14] The latter was useful as the target audience consisted of professionals who work in a busy environment and are under pressure to maintain their knowledge but are often faced with restrictions due to time or other factors.[15] The resource had to cater for varied levels of knowledge present in multidisciplinary teams.[16] The range of learning styles present in the target audience, such as visual, auditory and kinaesthetic learning styles,[17] had to be taken into consideration. Therefore, diagrams, keywords and a 'hands-on' approach were implemented in the resource to cater for this range of learning styles.

Overall, the main aim was to produce an interactive e-learning resource to explain the main pharmacokinetic principles related to TDM. The learning outcome for the user was to improve their understanding of the pharmacology behind the results that they produce. The null hypothesis was that the resource did not cause a significant improvement of the users' understanding of pharmacokinetics with respect to TDM.

Materials and Methods

ADDIE Instructional Design Model

The ADDIE instructional design model[18] was used as the framework for the structuring and development of the resource. The phases of analysis, design, development, implementation and evaluation were applied to the learning situation.

Analysis

The need for the resource and the feasibility of the project were analysed through a pre-project (needs) questionnaire shown in Figure 1. The survey was conducted with scientists who carry out TDM as well as other biochemical tests in the Biochemistry, Toxicology and Microbiology laboratories at Manchester Royal Infirmary. Pre-project questionnaires were distributed to 25 out of the 29 staff used for the needs questionnaire on the 3 December 2007. Staff were given two weeks to complete and return them to Dr. Gwen Ayers (co-supervisor at the hospital). The questionnaire aimed to determine the background, current level of understanding and requirements of the target group and whether there was a need to produce an e-learning resource on TDM.

Design

Development of Project Plan

A detailed plan (Figure 2) was produced detailing the various components of the resource and demonstrating the links between them, allowing for a thorough visualization of the format and layout and how to represent the content. The design strategy ensured that the resource was interactive and included audience participation to facilitate learning through active learning. Presentation took into account the potential range of learning styles of the audience.

Storyboard of Content

An extensive storyboard was devised to delineate the full content and layout of the resource (Figure 3). The content was kept to the essential points relating to pharmacokinetics, as the resource was designed to take approximately 30–45 min to complete in order to retain the attention of the user.

A quiz section was included to test the knowledge gained while using the resource. The selection of an incorrect answer presented the option to return to the relevant page to revise the content, ensuring that the learning outcomes of the user were achieved. Positive feedback was given for correct answers and negative feedback for incorrect answers.

Scientific Content Included

The key scientific points to be included in the resource were a basic introduction of TDM and indications for monitoring, and also a precise, yet thorough explanation of the pharmacokinetic parameters affecting drug concentration. The terms therapeutic objective and therapeutic window were defined to allow the user to relate the pharmacology to terminology that they may encounter while performing TDM. Absorption was defined with reference to bioavailability, first pass metabolism and the kinetics of absorption, outlining the potential sources of variation in drug absorption. Distribution was described in terms of the apparent volume of distribution and potential sources of variation. Metabolism was explained using diagrams to

Therapeutic Drug Monitoring: Pre-Final Year Project Questionnaire

I am a final year undergraduate studying Pharmacology at the University of Manchester. My final year project is entitled 'Therapeutic Drug Monitoring' and I aim to produce an e-learning resource for Clinical Scientists and Biomedical Scientists based at the Manchester Royal Infirmary to outline the background underlying Therapeutic Drug Monitoring and the basis of interpretation of the data generated. I would be very grateful if you could take a few minutes to fill in this questionnaire to allow me to determine the needs and requirements of my learning resource.

Many Thanks,
Krupa Samani.

Question 1: What is your name?
……

Question 2: What is your degree or highest qualification?
……

Question 3: What do you consider to be the definition of 'Therapeutic Drug Monitoring'?

Question 4: Why do you think it is necessary to carry out Therapeutic Drug Monitoring on the drugs which you test?

Question 5: How long have you been carrying out Therapeutic Drug Monitoring?
……

Question 6: How often do you carry out Therapeutic Drug Monitoring? Please tick the most appropriate response.

- ☐ Daily
- ☐ Two or three times a week
- ☐ Weekly
- ☐ Two or three times a month
- ☐ Monthly
- ☐ Other (please specify) ……

Question 7: From the following list of drugs, which have you carried out Therapeutic Drug Monitoring on in the last 3 months? Please tick all that apply.

- ☐ Cyclosporin
- ☐ Sirolimus
- ☐ Tacrolimus
- ☐ Lithium
- ☐ Digoxin
- ☐ Phenytoin
- ☐ Carbamazepine
- ☐ Phenobarbital
- ☐ Methotrexate
- ☐ Gentamicin
- ☐ Tricyclic antdepressants
- ☐ Other (please specify)……..

Question 8: How confident do you feel about your ability to understand and interpret the data which you produce?

- ☐ Not confident at all
- ☐ Slightly confident
- ☐ Confident
- ☐ Very confident

Question 9: What topics would you like included in an e-learning resource on Therapeutic Drug Monitoring?

Figure 1. Pre-project (needs) questionnaire distributed to allow for the analysis phase of resource production.

represent the phases of metabolism and the factors that may affect drug metabolism. Excretion of drugs was shown with reference to clearance, the elimination rate constant and half-life.

Choice of Software and Resource Distribution

The software was produced in Opus Professional,[19] which allowed for the production of an interactive resource.

Development

Layout and presentation were kept simple yet eye-catching to preserve the attention of the user while remaining easy to read and understand. Aspects of interaction were introduced to allow the user to relate participation to motivation and instructions were clear and easy to follow where required.

The colour scheme of the resource was consistent throughout to provide continuity and avoid the resource becoming difficult to read and understand. Diagrams and flow charts were introduced to break-up large blocks of text and to make the content easier to understand and animation was used wherever appropriate.

Implementation

The completed resource was delivered on compact discs (CDs) as the target group was fairly small and to avoid problems with firewalls at the Manchester Royal Infirmary, which may have prevented viewing the resource as a webpage.

Distribution of the Resource

The resource was handed out individually to the target audience of the same 29 scientists on the 15 April 2008 and staff

Topic Area: Therapeutic Drug Monitoring (TDM)

Aims: To facilitate the learning of pharmacological parameters underlying the process of TDM **by promoting enquiry into** pharmacokinetics **or by a problem-solving activity on** drug disposition **by using an enquiry based activity**

Outcomes: After working through this resource you should:

Know about The basis of TDM, the pharmacology underlying the interpretation of results generated in the laboratory

Understand The definition of TDM and why it is carried out, pharmacokinetic parameters – Absorption, Distribution, Metabolism, Elimination, etc.

Appreciate The reasoning for why results may vary and why it is necessary to know the background information to allow for a suitable dose to be tailored for the individual patient concerned

Develop skills of Correct and efficient interpretation of results based on genuine understanding of drug disposition rather than simply relating to a published drug level

Scenario/problem (200 words+)

Think of a situation that will encourage participants to explore the information.

Based on the outcomes of the pre-project questionnaire, start with basic introduction page outlining what TDM is, why it is carried out and indications for TDM.

Follow through using links/animations/diagrams/flow charts to show various aspects of drug disposition which underlie how the blood sample is used to tailor a dose to suit the patient. Describe and explain pharmacokinetic parameters to allow the user to understand the basic principles of pharmacology. Interactive/spider diagram style with sample as central focus allows the user to explore all the information independently. Include specific drug examples based on results of questionnaire which outline the drugs monitored regularly. Also add quizzes at the end of each section to test the knowledge that has been learned.

Definitions:

In this box list the terminology that you want to introduce to the users

Word from scenario/problem	definition
TDM	The use of drug measurements to assist the management of patients receiving certain drug treatments
Specific drug eg.	Based on results of questionnaire, include examples of drugs and why they are tested
Drug disposition	Overview of Absorption, Distribution Metabolism, Excretion

Figure 2. Developed e-learning project plan including specific content, initial ideas and a preliminary storyboard of content.

were given time until 18 April 2008 to return the questionnaires to Dr. Gwen Ayers.

Evaluation

To determine the effectiveness of the resource, a set of questionnaires were also handed out with the CD (Figures 4 and 5). The questionnaires consisted of a pre- and post-resource questionnaire to allow for a before and after evaluation to be performed. They contained questions related to knowledge of the audience before and after using the resource to allow for the effect of the resource on knowledge to be analysed and also questions relating to functionality to assess the usability of the resource.

Descriptive and analytical methods were used to evaluate the data received from the pre- and post-resource questionnaires. Keywords were extracted from the answers to open questions to identify similar responses, which were grouped together, and to allow for comparisons to be made between before and after using the resource. In relation to the questions regarding confidence levels of the users, SPSS 14.0 for Windows was used to carry out a Wilcoxon matched pairs signed rank test on responses given before and after using the resource. This test was selected since the data was non-parametric and the difference in the responses to categories, before and after, were being examined.[20]

Results

The Resource

The completed resource can be accessed at: http://www.ls.manchester.ac.uk/undergraduate/courses/modules/elearning/elearningprojects/

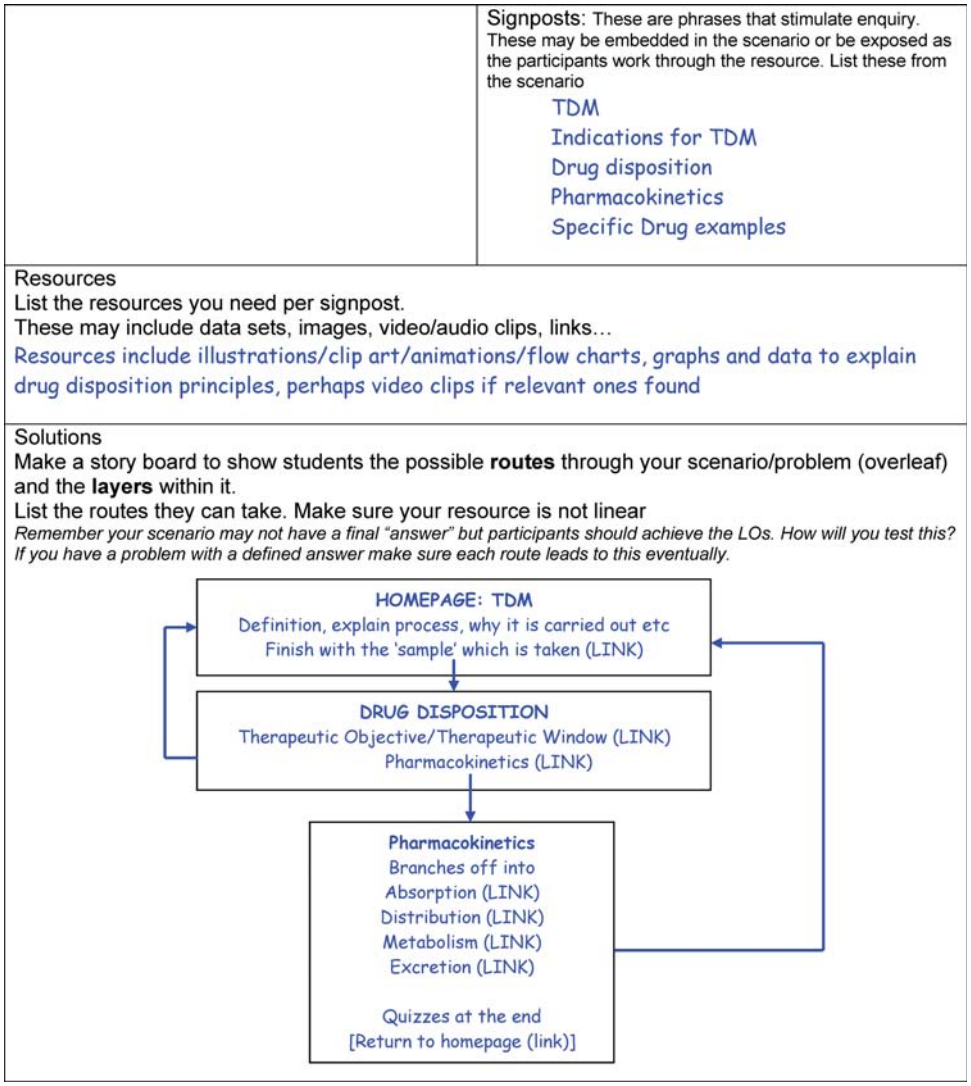

Figure 2. Continued.

Pre-Project (needs) Questionnaire

Of the 29 pre-project questionnaires handed out, 17 were returned, providing a 59% return. The results helped to define the main aim of the resource, which was to enhance the awareness of the basic pharmacokinetic principles underlying the interpretation of the results generated by TDM through the production of an e-learning resource. The learning outcomes of the target audience were to have a greater understanding of the pharmacology behind TDM on completion of the resource.

Target Audience

The majority of the audience had at least a BSc qualification, though a wide range of qualifications were held from A-Level to PhD and MBChB. Of the target group, 70% had been carrying out TDM for up to 5 years, and only two people had performed the process from 22 to 25 years. Out of 17, 10 people carried out TDM on a daily basis though one-third of the people did perform TDM only occasionally. A wide range of drugs were tested by the target audience, though lithium, phenytoin and digoxin were the drugs that were frequently monitored.

Current Knowledge of TDM

The popular definition of TDM (10/17 respondents) was 'Measuring the concentration of drugs'. There was a wider variety of answers to the open question 'Why is TDM carried out' with 'Avoid toxicity' as the most favoured but also 'Monitor patient compliance', 'Ensure efficacy' and 'Optimize dosing' given.

The results from Question 9 and summary of the aspects of TDM the target group would like to be included in the e-learning resource are shown in Table 1. Responses were

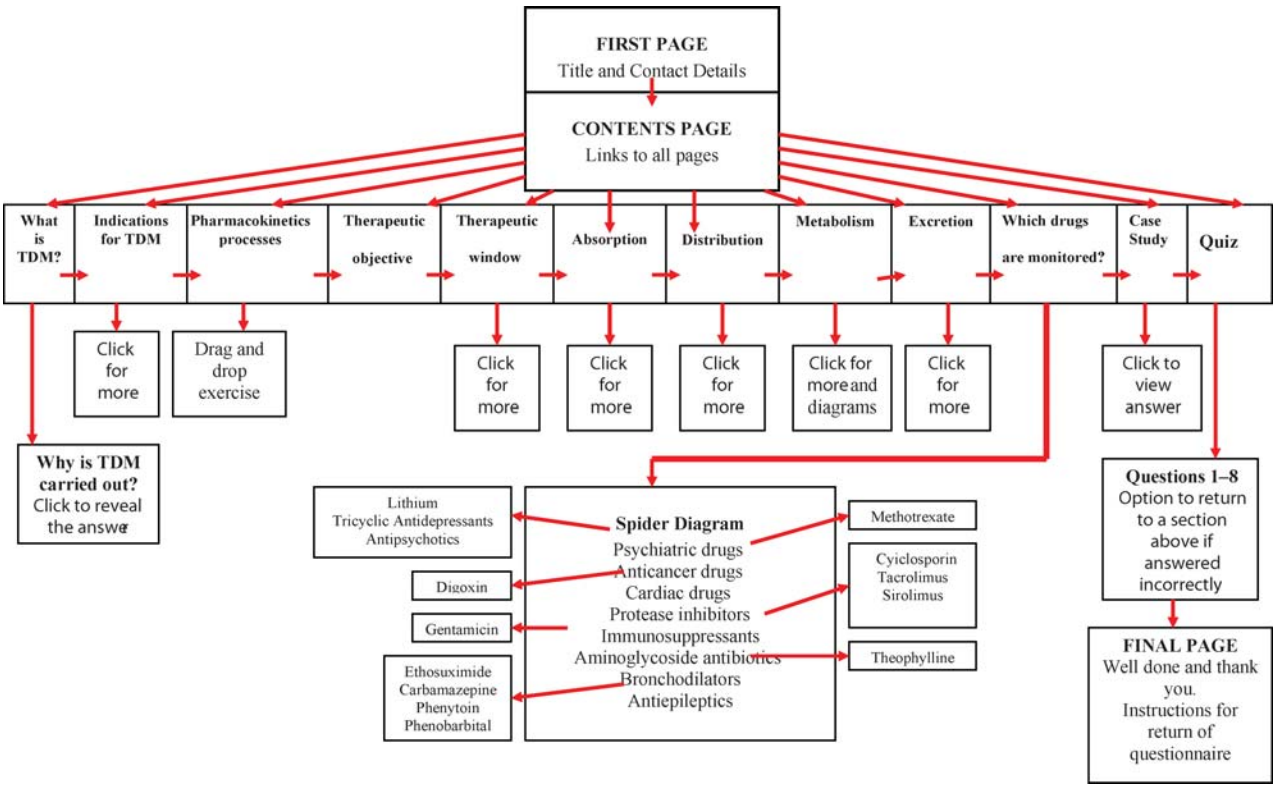

Figure 3. Detailed storyboard outlining the final content and layout of the resource.

varied, with suggestions ranging from specific drug examples to including 'everything' relating to TDM.

Pre- and Post-Resource Testing Questionnaires

Out of the 25 questionnaire and resource packs distributed, a total of 16 were returned, a 64% return.

Effects on Knowledge

Using the resource widened and clarified the perceptions among the audience as to the definition and purposes of TDM (Table 2).

Tables 3–6 show understanding in relation to each pharmacokinetic parameter. Again, answers to all questions were more focused and relevant following the use of the resource. Many responses closely matched the definitions given in the resource, though a range of responses was still present.

Effects on Confidence of Knowledge

For the question relating to confidence in understanding and interpreting the data produced, no significant improvement was seen after using the resource (Wilcoxon matched pairs signed rank test, $n = 14$, $P = 0.13$; Figure 6).

However, a significant improvement was seen regarding confidence in the understanding of pharmacokinetic parameters following the use of the resource (Wilcoxon matched pair signed rank test, $n = 16$, $P = 0.01$; Figure 7).

Eighty-one percent of the audience found the resource very helpful to understanding TDM (Figure 8). All of the users found the resource either easy to use or very easy to use (Figure 9).

Further Comments of the Audience on the Resource

The final question on the post-resource questionnaire allowed the target audience to express their views on the e-learning resource. Comments received included 'Well presented and easy to use' ($n = 7$) and 'Very informative' ($n = 4$).

Discussion

Potential Bias in the Data

It is necessary to be aware of potential bias resulting from the methodology employed. Although the return rates for the needs and the pre-/post-resource questionnaires were high, 59% and 64%, respectively, biased samples could have resulted. The level of educational achievement was varied, which could have confounded the ability to detect resource-induced increases in confidence in understanding TDM data and pharmacokinetic parameters. In handling

Therapeutic Drug Monitoring: An e-learning resource
Pre-resource Questionnaire

I am a final year undergraduate studying Pharmacology at the University of Manchester. My final year project is entitled 'Therapeutic Drug Monitoring' and I have produced an e-learning resource for Clinical Scientists and Biomedical Scientists based at the Manchester Royal Infirmary to outline the background underlying Therapeutic Drug Monitoring and the pharmacokinetic basis of interpretation of the data generated. I would be very grateful if you could take a few minutes to fill in this questionnaire before using my resource and the second questionnaire, which is attached, after using the resource. The resource takes approximately 30 minutes to work through and provides a basic introduction to the pharmacokinetic parameters which can indicate a need for Therapeutic Drug Monitoring. Please provide your name and contact details as there will be a prize draw to win £25 of Love to Shop vouchers for all participants who complete and return both questionnaires to Gwen Ayers by 18th April 2008.

Many Thanks,
Krupa Samani.

Question 1: What is your name?
……

Question 2: What is your email address or alternative contact details?
……

Question 3: What do you consider to be the definition of 'Therapeutic Drug Monitoring'?

Question 4: Why do you think it is necessary to carry out Therapeutic Drug Monitoring on the drugs which you test?

Question 5: How confident do you feel about your ability to understand and interpret the data which you produce?
Not confident at all
Slightly confident
Confident
Very confident

Question 6: How confident do you feel about your understanding of pharmacokinetic parameters which can affect drug therapy and therefore indicate the need for Therapeutic Drug Monitoring?
Not confident at all
Slightly confident
Confident
Very confident

Question 7: Please write beside each term below what you feel is the correct definition for that specific pharmacokinetic parameter.

ABSORPTION……
……
……
DISTRIBUTION……
……
……
METABOLISM……
……
……
EXCRETION……
……
……

Please use the e-learning resource on the CD provided now.

Figure 4. Pre-resource questionnaire distributed with the resource to allow for initial knowledge and understanding of the target audience to be evaluated.

responses to open questions, similar words/phrases were grouped together and care was taken by the researcher not to introduce bias. Notwithstanding these qualifications, some conclusions can be drawn.

Suitability of the Resource for the Target Audience

Target Audience

There was a wide range of qualifications present in the audience suggesting that the resource needed to cater for varying levels of previous knowledge. Similarly, although the majority of the scientists had been carrying out TDM for several years, they said that would benefit them by gaining more information on a process which they carry out regularly. They listed the drugs they tested, which suggested possible drug examples to be included in the resource.

Current Knowledge of TDM

It was apparent that the audience had a general idea that TDM involved 'measuring the concentration of drugs', but many varied responses were also received. Similarly, it was evident that the majority of the scientists felt that TDM was carried out to 'avoid toxicity,' which is an incomplete answer.

Therapeutic Drug Monitoring: An e-learning resource
Post-resource Questionnaire

Question 1: What do you consider to be the definition of 'Therapeutic Drug Monitoring'?

Question 2: Why do you think it is necessary to carry out Therapeutic Drug Monitoring on the drugs which you test?

Question 3: How confident do you feel about your ability to understand and interpret the data which you produce?

Not confident at all
Slightly confident
Confident
Very confident

Question 4: How confident do you feel about your understanding of pharmacokinetic parameters which can affect drug therapy and therefore indicate the need for Therapeutic Drug Monitoring?

Not confident at all
Slightly confident
Confident

Question 5: Please write beside each term below what you feel is the correct definition for that specific pharmacokinetic parameter.

ABSORPTION.....
.....
.....
DISTRIBUTION.....
.....
.....
METABOLISM.....
.....
.....
EXCRETION.....
.....
.....

Question 6: How helpful did you find the resource to understanding therapeutic drug monitoring?

Very unhelpful
Somewhat unhelpful
Slightly helpful
Very helpful

Question 7: How was the usability of the resource?

Very difficult to use
Difficult to use
Easy to use
Very easy to use

Question 8: Do you have any further comments on the e-learning resource?

Thank you for giving your time to complete these questionnaires and use this e-learning resource. Please return this questionnaire pack to Gwen Ayers by 18th April 2008.

Figure 5. Post-resource questionnaire to be completed following the use of the resource to allow for evaluation of the resource.

Design of the Resource to Suit the Target Audience

Following from the pre-project needs analysis, it was possible to infer that a clear definition and explanation of the indications for TDM were necessary to be included in the resource. In addition, it was decided that a clear guide to pharmacokinetics would allow the user to understand many of the other concepts.

Effectiveness of the Resource

Effects on Knowledge

Prior to use of the resource, there was a general understanding of the concept behind TDM but some incorrect responses, such as 'measurement of levels of toxicity in the blood', were also received. Post-resource responses (Tables 2–6) were more precise and focused, with many relating specifically to content from the resource. These observations supported the conclusion that the resource improved the knowledge of the user.

Similarly, from Table 2, it is clear that the use of the resource widened the knowledge of the user with regards to the reasons behind TDM. The pre-resource responses showed wide-ranging responses, though the majority of people answered that TDM is carried out to 'avoid toxicity.' After using the resource, more keywords from the content appeared in the answers and there was more breadth of knowledge; suggesting that the resource had improved understanding.

Concerning drug absorption, pre-resource responses portrayed misconceptions of absorption and some thought it was defined as 'the entry of drug into the organism' (Table 3). This error was corrected following the use of the resource, indicating that the resource had improved the users' understanding. Similarly, there was improved

Table 1. Responses showing what aspects of therapeutic drug monitoring (TDM) the target group would like to be included in the e-learning resource

Topic	Number of responses
Guide to pharmacokinetics	3
Time of sampling	4
Drug–drug interactions	2
Drug examples	
Aminoglycosides	1
Glycopeptides	1
Flucytosine	1
Vancomycin	1
Gentamycin	1
Everything	1
Therapeutic ranges	3
Alternate names for drugs	1
Alternate drugs to treat patients	2
Toxicity	3
Interpretation of test results	2
Importance of TDM	2
Reasons for TDM	4
Multiple therapies	1

Similar words/phrases were grouped together

knowledge and understanding of the concepts of distribution, metabolism and excretion (Tables 4–6).

Effects on Confidence of Knowledge

There was no improvement in confidence and in their ability to interpret results after using the resource (Figure 6). There was already a high level of confidence present in the audience and that could be a possible reason why an improvement could not be detected. Conversely, the confidence in understanding pharmacokinetic parameters increased significantly, suggesting that the resource improved knowledge (Figure 7).

Functionality of the Resource

The majority of the users found the resource helpful and easy to use (Figures 8 and 9). The majority of feedback received was positive. These results suggest that all of the factors taken into consideration in the design and development phases were essential and successful in creating a useful and easy-to-use resource.

Effectiveness of the Utilization of Active Learning

Concerning the use of e-learning and active learning in the resource, it is apparent that many of the users found this a very effective way to learn. Following responses received in the post-resource questionnaire and a discussion with the audience, it became apparent that they found that the use of a computer facilitated their interaction during the learning process[15] and mentioned the advantage of being able to pursue their studies in their own way, own time and places of choice. This has been found to be the single biggest advantage of self-instructional e-learning materials as it allows participants to study when and where it suits them.[16]

Implications for the Use of the Resource

Subsequent to a discussion with the users of the resource, it became apparent that the resource could be integrated into a number of training programmes at Manchester Royal Infirmary. The e-learning resource could be used as part of 'Continuing Professional Development' to widen and test the knowledge of staff who carry out TDM. The resource could be 'of use to junior laboratory staff or as part of nurse education.' To avoid problems with firewalls at the hospital, the resource could be uploaded onto the hospital intranet to allow all users to access it.

Table 2. Responses regarding the definition and purposes of therapeutic drug monitoring (TDM) before and after using the resource

Answer	Number of responses pre-resource	Number of responses post-resource
Avoid toxicity	16	5
Determine if dose is ineffective	5	0
Manage a patients dose	5	4
Measurement of drug concentration in blood	3	12
Monitoring to allow for optimal dosage	3	4
Measurement of levels of toxicity in the blood	1	0
Provide maximal clinical outcome	0	7
Narrow therapeutic window	0	6
Monitoring of special populations	0	4
Inpatients with hepatic or renal insufficiency	0	3

Similar words/phrases were grouped together.

Table 3. Responses regarding the definition of drug absorption before and after using the resource

Answer	Number of responses pre-resource	Number of responses post-resource
Uptake of drug by the body	4	1
How much of the administered dose is absorbed into the circulation or target organs	3	0
The movement of drug into the body	3	1
The rate at which the drug is absorbed into the bloodstream	3	0
The entry of drug into the organism	1	0
The process by which unchanged drug proceeds from the site of administration to the site of measurement within the blood	0	11

Similar words/phrases were grouped together.

Table 4. Responses regarding the definition of drug distribution before and after using the resource. Similar words/phrases were grouped together.

Answer	Number of responses pre-resource	Number of responses post-resource
The spread to all the internal parts of the body	5	0
Transport to the correct area of the body	3	3
Process of partitioning into different compartments	3	2
The area of cells or tissues in which the drug is found	2	0
Binding to plasma proteins	1	0
The process of reversible transfer of a drug between the blood and tissues	0	5

Similar words/phrases were grouped together.

Table 5. Responses regarding the definition of drug metabolism before and after using the resource

Answer	Number of responses pre-resource	Number of responses post-resource
Breakdown by the body	4	1
A process of conversion of drug using enzymes	3	2
Process for detoxification and inactivation or activation of the parent drug	3	2
How the body changes it	3	0
The enzyme-mediated conversion of a lipophilic compound into a more water-soluble one	0	7
Takes place on the smooth endoplasmic reticulum of the liver	0	5

Similar words/phrases were grouped together.

Table 6. Responses regarding the definition of drug elimination before and after using the resource

Answer	Number of responses pre-resource	Number of responses post-resource
The main route of elimination of metabolites and unchanged drug	15	0
Irreversible process	1	6
The irreversible loss of drug from the body	0	6
Elimination of waste product	0	6
Elimination of drug in either a changed or unchanged form	0	2

Similar words/phrases were grouped together.

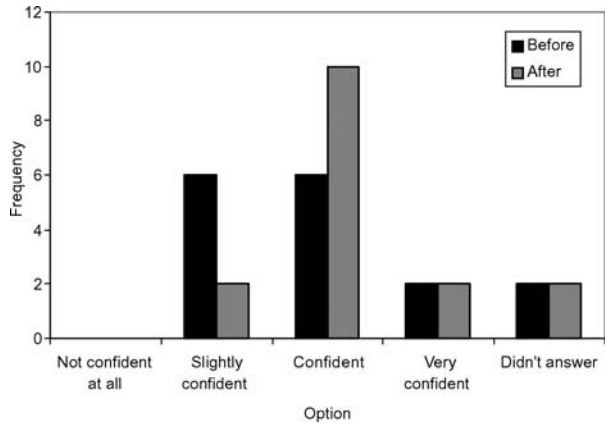

Figure 6. A bar chart representing the responses relating to confidence in understanding and interpreting the results the audience generates before and after using the resource.

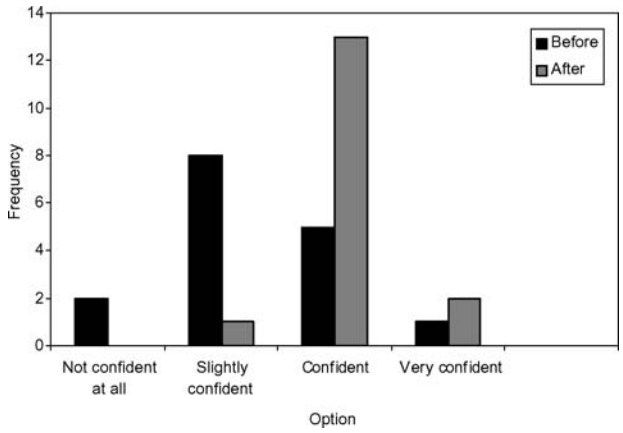

Figure 7. A bar chart representing the responses relating to confidence in understanding pharmacokinetic parameters before and after using the resource.

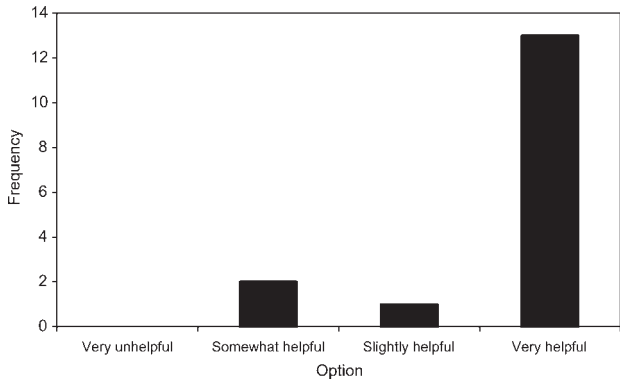

Figure 8. A bar chart representing the results relating to how helpful the target audience found the resource to understanding TDM.

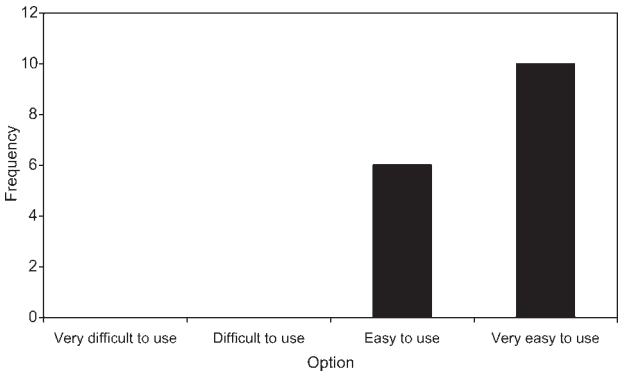

Figure 9. A bar chart representing how easy the audience found the resource to use.

Conclusions

The resource met the initial aims and the learning outcomes of the target audience by providing an interactive e-learning resource to explain and widen the understanding of the pharmacokinetic principles related to TDM. The significant improvement in confidence of understanding pharmacokinetic parameters allow the null hypothesis to be rejected.

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Author Biography

Krupa Samani recently graduated from the University of Manchester with a Pharmacology BSc Honours degree. This article originates from her final year project, and shows her keen interest in pharmacokinetics and the basic drug disposition concepts underlying drug discovery, development and subsequent therapy. Throughout my degree course, Krupa gained an insight into the basic principles which are fundamental to successful drug development. She also carried out both *in vitro* and *in vivo* research which has allowed her to appreciate the effects of drugs in whole organisms. Krupa has a particular interest in research into new drugs: she hopes to build a career in research, in particular within the pharmaceutical industry.

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