Using online learning modules to fight against antibiotic resistance in Australia

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NPS MedicineWise and the Australian Commission on Safety and Quality in Health Care (ACSQHC) have launched a series of online learning modules designed to help combat antibiotic resistance in hospitals. The aim of the modules is to fill a previously unmet need for an online teaching resource on a common curriculum for hospitals and universities. The modules address specific areas where antibiotic use in hospitals needs improvement. Problem Based Learning has been used as pedagogical approach for the modules. Clinical scenarios are presented with a logical progression of tasks including clinical assessment and diagnosis, investigations, interpretation of results, and antibiotic selection. Expert advice and feedback has been incorporated at each step, helping to improve learning outcomes. Learners can access the modules at their own pace and revisit them upon completion. We report, for the first time, participants' perceptions of the antimicrobial modules as learning resource, usability issues, and possible areas of improvement.

Keywords: Antimicrobial prescribing skills, e-learning in healthcare.

1. Introduction

The widespread use of antibiotics promotes antibiotic resistance. As a consequence, standard treatments become ineffective, and infections persist and may spread to others (Enne et al, 2001). The burden of antibiotic resistance is shared by the community. Infections caused by resistant bacteria need to be treated with costly second- and third-line antibiotics. In emphasising the scale of the problem, the World Health Organization recently warned of a return to the pre-antibiotic era if bacterial resistance to antibiotics continues to develop unabated.

Antibiotic resistance can persist within populations (Sundqvist et al, 2010). In order to preserve the effectiveness of antibiotics, and minimise the prevalence of resistance when it does emerge, prescribers are advised to use an antibiotic: (1) when benefits to the patient are likely to be substantial; (2) of the narrowest spectrum to treat the likely pathogen, as recommended by local guidelines and pathology providers; (3) at the appropriate dose and for the appropriate duration.

Experts at the Antimicrobial Resistance Summit in 2011 agreed that educational initiatives need to define antimicrobial resistance as an urgent public health issue (Gottlieb & Nimmo, 2011). NPS MedicineWise identified online learning as an alternative approach to showcase effective prescribing practices, promote dialogue on critical issues in the field, help students to apply theory to practice, and create enthusiasm and confidence in the learner to implement safe practices. Prescribing is an important part of medical practice, but

may not necessarily be a strong focus in the training of medical students or other health professionals. Safe-prescribing skills and awareness of medication errors is required by all members of the health care team, and should be a core component of undergraduate and postgraduate training programs (Coombes et al., 2008).

The antimicrobial modules are a web-based course founded on the World Health Organization's *Guide to Good Prescribing* (de Vries, 1994). The resource currently comprises four modules covering Surgical Prophylaxis, Catheter-Associated Urinary Tract Infection (CAU-TI), Bacteraemia, and Community Acquired Pneumonia (CAP). The modules have been designed for individual self-paced learning, or can be used as part of small group work. Module content is written by subject-matter experts and undergoes a rigorous peer-review process, similar to that followed by peer-reviewed journals, during its development. Educational designers review the content to ensure that it is appropriate for online delivery, and that the tasks are meaningful and meet the learning outcomes. Evaluators at NPS MedicineWise design formative and summative research to gather the impact of the modules on students' knowledge construction and to find areas of improvement. The main audience for the antimicrobial modules are prescribers (medical graduates) in their first two years post graduation. However, the program is being use by other prescribers such as nurse practitioners as well as hospital pharmacists.

The modules have been designed as a logical progression where learners can engage in their own way with their patients, discuss therapeutic goals with their peers, choose the optimal non-drug and drug therapy, prescribe medicines, and get expert feedback. Additionally, learners can advise the patient how best to use the chosen therapy and finally, test the knowledge gained using review questions built in with experts' feedback at the end of the module. After completion, the learners can revisit the modules and can print My Formulary, which contains the drug classes and prescribed medicines used across the different modules.

The antimicrobial modules' aims: (1) Filling an unmet need for an online teaching resource which is accessible to all prescribers and which forms a common curriculum for hospitals and universities to teach the principles of safe and appropriate antimicrobial prescribing; (2) Providing a teaching resource that is endorsed by experts and addresses problems in the prescribing of antimicrobials known to drive the development of antimicrobial resistance; and (3) Contributing to the overall effort of antimicrobial stewardship in containing and improving the quality of antimicrobial use in Australia.

Problem Based Learning (PBL) was identified as the pedagogical approach for the antimicrobial modules. This approach was considered to be the most suitable to overcome the gap between traditional didactic lecturing and the clinical reality that students would eventually face, so we decided to base their instruction on real-case scenarios. Students will need relevant medical knowledge to solve a clinical problem presented on the module. Since the instructors at McMaster University's Faculty of Medicine developed Problem-Based Learning in 1969 (Albanese and Mitchell, 1993; Vernon and Blake, 1993), this pedagogical approach has proved to be successful in the area of medical education. Currently, 70% of medical faculties in the US use PBL in pre-clinical years (Kinkade, 2005). PBL has been successfully implemented in various disciplines, such business (Stinson and Milter, 1996), education (Duffy, 1994), law (Driessen and Van der Vleuten, 2000), social work (Boud and Feletti, 1991), engineering (Fink,
1999; Woods, 1994) and physics (Williams, 2001).

2. Aims of the study

The aim of this study was to gauge participants' perceptions of module content and usefulness, access to experts' feedback, knowledge construction, and technical issues.

3. Materials and methods

3.1 Learning Design

A typical antimicrobial module has the following logical progression: (1) Introduction to the condition and learning outcomes; (2) a context/case study that defines who and where the learner is for the purpose of the module; (3) a list of short-term therapeutic goals where learners can nominate, vote, and see their peers' votes; (4) expert feedback on therapeutic goals as guidance; (5) consideration of a non-drug treatment and submission of answers followed by expert feedback; (6) choice of the appropriate drug treatment for the condition; (7) verification of the suitability of the treatment; (8) selection of drugs and prescription online followed by expert

feedback; (9) feedback on incorrectly prescribed drugs that may cause adverse reactions; (10) monitoring of patient progress via multiple choice questions and instant expert feedback; (11) provision of information to the patient followed by the expert's ideas; and (12) a multiple choice quiz to give a quick review of the module. Every time learners submit their answers they will get instant expert feedback.

The antimicrobial module follows the three essential characteristics of good learning design according to Britain (2004): (1) learning is active; (2) activities are presented in a logical progression; and (3) the template is reusable. The delivery method is for self-paced learning, but it is flexible enough to be used in face-to-face tutorials. In fact many academics introduce the modules in tutorials at the beginning of the semester and provide the login details to students.

As the antimicrobial modules content is written by content experts with vast clinical experience, the case study presented in each module is authentic. The tasks and the level of interaction promote conceptualisation of the patient, development of critical thinking and problem-solving skills, consideration of different options for treatment, and the meaning of feedback.

3.2 Technical specifications

We have developed our modules using Flash professional and they are hosted on a commercial Flash-based e-learning platform. Each module takes learners approximately one hour to complete. Learners access the modules through a self sign-in process, organised through their universities. The main features of the antimicrobial modules website, where the modules are contained, can be summarised as: (1) self-registration for students; (2) drugs tool; (3) My Formulary tool; (4) prescription writing tool; (5) authoring tool; and (6) monitoring tool.

3.2.1 Self-registration for students
The educational designer at NPS MedicineWise creates a group for each university or organisation on the database. Inside these groups, cohorts are created upon academic request at the beginning of each semester. When a cohort is created and modules are included, the educational designers assign a course key and email sign-up instructions for students to relevant academics. Students of each of these organisations have to self-register into their university and course. The self-registration page can be found at *nps.org.au/antimicrobial modules*.

3.2.2 Drug tool
The drug tool is a database that is organised by clinical condition and is classified into drug classes. A drug class might have many brands of products under it. Each product comes with information such as efficacy issues, safety issues, commentary, and resources. Inside the drug class there are different types of products available, and the database contains details such as drug name, form, strength, directions, quantity, repeats, cost, other issues, and commentary. Links with additional information are placed inside the drug tool. Most of the links comes from the Australian Medicine Handbook (AMH), Therapeutic Guidelines (eTG) and NPS website. This is an example to visualise the structure of the drug tool; *Drug Class> Anti-infectives > antibacterials > aminoglycosides > drug name: Gentamicin.* Each module has a drug tool that allows learners to choose a medicine at the time of prescription.

3.2.3 My Formulary tool
This is a centralised application that takes input from the drug tool. It stores the drug choices from students as well as their notes and which modules they have chosen them from. It also implements a My Formulary page that will display the drugs that the students have added to it (when and by which module they have added them). Additionally, the My Formulary tool provides data for the Write Prescription tool, so the student can choose which drugs they need to prescribe.

3.2.4 Writing prescription tool
This is a tool that allows students to complete and submit an online prescription for the drugs they selected for their patient in a previous step. When they submit this prescription they will get expert feedback. Learners are able to search for drugs in their formulary, select drugs for the prescription, enter doctor, patient and drug details into the prescription, preview and print the prescription (if desired), and get feedback from an expert on the correct prescription. The prescription tools have the same fields as those used in Australian public hospitals and general practice, and look similar.

3.2.5 Authoring tool
This area is exclusively for the educational designer and contains the sequence of activities covered in the learning design part. This section allows the designer to build the series of interactions the module will follow.

3.2.6 Monitoring tools
This section is for academics who want to see their students' progress. The grade book is a functionality that allows gathering of information from the whole cohort and that reports on a spreadsheet the activities of all the students inside the cohort, particularly currently visited and completed modules.

4. Methodology

A cross-sectional questionnaire containing eleven questions was designed and embedded at the end of the modules as an optional activity. The questionnaire captured demographics of participants, content and completion of modules, student's attitude, perception of usefulness, and technical difficulties.

5. Results and discussion

5.1 Demographics of participants

A total of 1291 valid surveys were received. Participants included medical students (67.4%), and hospital doctors (32.4%). Their level of practice was: interns (75.9%), resident medical officers (17.4%), and registrars (5.2%). Ninety-four percent of the participants obtained their medical training in Australia. Table 1 presents the completion of the modules. Note that a fourth module (Community Acquired Pneumonia) was added recently, and no data was yet available during the writing of this paper.

Table 1: Completion of modules

	% (n)
Surgical prophylaxis	37.6% (769)
Catheter-associated urinary tract infection	25.3% (517)
Bacteraemia (line sepsis)	37.1% (757)

5.2 Content of the modules

Almost 96% of participants agreed that the learning objectives of the modules were clear, and 96% agreed that the tasks addressed these learning objectives. Ninety-two percent found these tasks to be engaging, while 90% agreed that the content was clearly presented. Most of the participants (97%) agreed that the modules reflect real life situations (Table 2). This was a remarkable response which may be explained by the fact that the modules were written by subject-matter experts and had undergone a rigorous peer-review process, similar to that followed by peer-reviewed journals, during their development. Additionally, educational designers had a key role in ensuring that the content was appropriate for online delivery, and that the tasks were meaningful and met the learning outcomes.

When participants were asked how difficult the modules were, 81.3% responded that they were just right, 10.8% said they were easy, 0.9% said they were too easy, 6.8% said they were difficult, and only 0.2% said they were too difficult.

Table 2: Participant's perception on content of the antimicrobial modules

	Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
	% (n)			
The learning objectives were clear	1.8% (37)	3.0% (62)	77.8% (1589)	17.4% (355)
The module tasks addressed the learning objectives	1.8% (37)	2.6% (54)	77.5% (1584)	18.0% (368)
The module tasks were engaging	2.1%	6.4%	73.3%	18.3%

	(43)	(130)	(1497)	(373)
The content in the modules was clearly presented	2.8% (58)	7.0% (143)	71.5% (1461)	18.6% (381)
The case study in the module reflects a real life situation	1.9% (39)	1.2% (24)	70.8% (1447)	26.1% (533)

	Medical student	**Hospital doctor**	
	% who agree/strongly agreed		
The learning objectives were clear	95.9% (1326)	93.5% (618)	P=0.016
The module tasks addressed the learning objectives	96.6% (1335)	93.3% (617)	P=0.001
The module tasks were engaging	92.5% (1278)	89.6% (592)	P=0.027
The content in the modules was clearly presented	*No significant difference*		
The case study in the module reflects a real life situation	97.7% (1350)	95.3% (630)	P=0.004

There were no significant differences in the responses to these questions between the different modules.

5.3 Usefulness of the module

Ninety-seven percent of participants found that the antimicrobial modules were relevant to their clinical experience, while 92% thought the module tasks tested their understanding of the topic rather than just their memory. The modules had links to resources such as the Australian Medical Handbook (AMH) and Therapeutic Guidelines (eTG), and 89% of the participants considered them useful. Additionally, ninety percent of participants thought the modules were effective for developing critical thinking skills (Table 3).

Table 3: Participants' perceptions of the usefulness of the antimicrobial modules

	Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
	% (n)			
The module was relevant to my clinical experience	1.3% (26)	2.0% (41)	71.7% (1464)	25.0% (511)
The module tasks tested my understanding of the subject area, rather than just my memory	1.6% (32)	6.5% (132)	74.3% (1518)	17.7% (361)
The module links to other resources were useful	1.6% (32)	9.1% (186)	72.7% (1485)	16.6% (340)
The module was effective for developing my critical thinking skills (e.g. critical analysis, problem solving)	1.7% (35)	8.0% (164)	75.6% (1544)	14.6% (299)

	Medical student	**Hospital doctor**	
	% who agree/strongly agreed		
The module was relevant to my clinical experience	97.5% (1347)	95.0% (628)	P=0.003
The module tasks tested my understanding of the subject area, rather than just my memory	*No significant difference*		
The module links to other resources were useful	87.9%	92.3%	P=0.003
The module was effective for developing my critical thinking skills (e.g. critical analysis, problem solving)	*No significant difference*		

There were no significant differences in the responses to these questions between the different modules.

5.4 Access to feedback

Eighty percent of participants agreed that having access to peers' answers was useful, while 98% agreed that built-in expert feedback was useful. Most (93%) of the participants said that the levels of feedback were adequate to guide the decision-making process during completion of modules (Table 4).

Table 4: Participant's perception on access to expert feedback in the antimicrobial modules

	Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
	% (n)			
Having access to my peers' answers/ideas was useful	3.0% (61)	16.1% (328)	67.8% (1386)	13.1% (268)
Having expert feedback was useful	0.6% (12)	1.2% (25)	50.6% (10.34)	47.6% (972)
There was adequate feedback in the module to guide my decision- making process	1.2% (25)	6.0% (122)	69.5% (1420)	23.3% (476)

Only the attitude to access to peer responses was significantly associated with the learner type and module. Hospital doctors were more likely to agree or strongly agree that access to peer's answers and ideas was useful (88.5%, compared to 77.4% for medical students; P<0.001). Learners who completed the surgical prophylaxis module were less likely to report that they found access to peers' answers was useful (Bacteraemia 83.2% agree/strongly agree, catheter-associated UTI 82.2%, surgical prophylaxis 77.9%; p=0.021)

5.5 Knowledge construction

In regards to knowledge construction, 96% of participants in this study considered that their knowledge of the antimicrobial topic had improved, while 94% agreed that they have a better understanding of the reasons for prescribing particular antibiotics for specific conditions. In contrast, 59% of participants believed they needed more information to better understand the advice given in the modules. Additionally, 87% of participants thought they were now more likely to consider unwanted consequences of antimicrobial prescribing (Table 5).

Table 5: Participants' perception of knowledge construction after completion of antimicrobial modules

	Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
	% (n)			
My knowledge of the antimicrobial topic has improved	0.7% (15)	3.6% (74)	76.3% (1558)	19.4% (394)
I have a better understanding of the reason for prescribing particular antibiotics for specific indications	0.7% (14)	5.4% (110)	73.8% (1570)	20.2% (412)
I needed more information to better understand the advice given in the module	2.7% (55)	38.2% (780)	49.0% (1001)	10.1% (207)
I am more likely to consider unwanted consequences of antibiotic prescribing such as increased antimicrobial resistance	1.3% (27)	11.8% (241)	75.1% (1535)	11.7% (240)

	Medical student	**Hospital doctor**	
	% who agree/strongly agreed		
My knowledge of the antimicrobial topic has improved	96.6% (1335)	93.6% (619)	P=0.002
I have a better understanding of the reason for prescribing particular antibiotics for specific indications	94.9% (1312)	91.8% (607)	P=0.006
I needed more information to better understand the advice given in the module	57.2% (791)	63.1% (417)	P=0.012
I am more likely to consider unwanted consequences of antibiotic prescribing such as increased antimicrobial resistance	*No significant difference*		

	Surgical prophylaxis	Catheter-associated urinary tract infection	Bacteraemia (line sepsis)	
	% who agree/strongly agreed			
My knowledge of the antimicrobial topic has improved	*No significant difference*			
I have a better understanding of the reason for prescribing particular antibiotics for specific indications	*No significant difference*			
I needed more information to better understand the advice given in the module	61.8% (475)	62.1% (321)	54.4% (412)	P=0.004
I am more likely to consider unwanted consequences of antibiotic prescribing such as increased antimicrobial resistance	85.8% (660)	90.1% (466)	85.7% (649)	P=0.04

5.6 Technical/navigation issues

Overall, 88% of participants did not experience technical issues while 12% reported problems. The study did not gauge the type of technical issues on the survey, and this is one of its limitations. Nevertheless, we have a helpdesk at NPS MedicineWise for similar modules (NPC modules), and 70% of the calls are about problems related to the Flash version, 20% are about the Java platform, and 10% about browser compatibility. Ninety percent of participants agreed that the modules were easy to navigate, and 94% thought the instructions in the modules were easy to follow (Table 6).

Table 6: Participants' navigation issues while completing the antimicrobial modules

	Strongly disagree	**Disagree**	**Agree**	**Strongly agree**
	% (n)			
It was easy to navigate through the module	2.5% (25)	8.0% (79)	66.8% (661)	22.7% (225)
The instructions in the module were easy to follow	0.9% (9)	5.2% (52)	70.7% (701)	23.1% (229)

5.7 Antimicrobial modules' uptake by health professionals

The antimicrobial modules were launched to health professionals in October 2012. Participants interested in joining the modules visited the website at www.nps.org.au/npc and followed the instructions to get access to the modules. So far we have good uptake, with 500 users and 394 completions in the first two months. We received several emails from users reviewing the modules. Most of them were positive, as for example:

> *I think the antimicrobial modules are relevant, I like the stepwise progression ... they're very thorough.*
>
> I think that the standard of prescribing both in doctors and medical students needs overall to be improved and I think that the antimicrobial modules are doing an excellent job.
>
> The antimicrobial modules are a very good resource; it presents a logical progression for students to follow when making clinical decisions. I believe it has a lot of interaction that allows students to engage with it in their own way.
>
> I had a look at the surgical prophylaxis and bacteraemia modules and thought that they were pretty good from the perspective of medical students, particularly if aided by a tutor who knows the ins and outs of the prescribing sections and what the voting means.

5.8 Limitations of the antimicrobial modules

There are several limitations of the antimicrobial modules related to functionality, cross-device compatibility, social presence, and multimodal delivery. We are currently working on a strategy to overcome these issues.

The main limitation of the modules is that, for assessment purposes, not all of the interactions are captured on the database. The list of short term therapeutic goals (Step 3 in the sequence), and also the providision of information to the patient (Step 11), are recorded on a database, but this is not accessible to academics on the report. Data on multiple choice questions on considering a non-drug treatment (Step 5), monitoring patient progress (Step 10), and multiple choice quizzes designed to give a quick review of the module (Step 12), cannot be captured. Antibiotics used by participants in different modules can be exported as PDF but academics/supervisors will not have direct access to this information. All of these are technical limitations that need to be addressed in order to promote the modules across healthcare organisations in Australia.

The antimicrobial modules interface is designed in Adobe Flash, which is considered a closed system as Adobe has sole authority as to future enhancement, pricing, etc. Devices running the iOS platform (iPad, iPhones and iPod touch) cannot run Flash content. We are currently investigating the possibility of migrating our modules from Flash to HTML5, CSS3, and JavaScript in the near future. As the level of interactions in the modules is not rich, it is possible to build it with features that are stable and fully supported by modern browsers. With this approach we hope to extend cross-device compatibility, which will help us reach more learners and improve their learning experiences.

It has been confirmed in the literature that one of the major components of student satisfaction in online learning is the level of interaction. High levels of interaction result from highly cooperative learning environments (Simonson et al., 2012). Educators are challenged to seek and implement tools and strategies that recreate face-to-face human elements like cooperation, immediacy, and intimacy, which model physical classroom experiences (Gunawardena & Zittle, 1997). Social presence is the mutual awareness of interacting partners over a communication medium (Short, Williams & Christie, 1976). The modules have a weak social presence and students can only see how their peers replied in the therapeutic goals section (Stage 3) and in considering a non-drug treatment (Stage5). A better way to connect learners may be developing an online learning community promoted by instant messages, where students can create a profile for online discussion and sharing of resources etc. In this space learners can discuss and consider ideas, and learn from each other in a constructive manner. An online learning community of users will help to create social presence, build cohesion, and elevate student's attitudes, performance, satisfaction and student engagement (Ring, 2012).

The antimicrobial modules have been built using a single delivery approach. Learning objects are interactive elements developed in Flash. In recent years, the use of multimedia (videos, podcasts, images etc.) in conjunction with hypermedia, have been successfully applied to many e-learning environments in order to both enhance these environments and to cater for a wider variety of student learning styles (Birch & Gardiner, 2005; Sankey & St Hill, 2009; Sprague & Dahl 2010). Neuroscience research has also revealed that significant increases in learning can be accomplished through the informed use of visual and verbal multimodal learning (Fadel, 2008). In other words, students may feel more comfortable and perform better when learning in environments that cater for their predominant learning style (Cronin, 2009, Omrod, 2008). It has been reported that the use of video cases in PBL scenarios is a valuable stimulus for group discussions by medical students. Students thought the video cases enabled them to create realistic mental pictures of conditions, and provided integrated pictures of patients as people, which challenged them to elaborate the cases seriously and were more memorable than text-based cases (De Leng *et al*., 2007). We are considering including digital video in future modules to describe the case scenarios and possibly the patients concerned. Digital video provides a natural medium for enhancing the sense of context and realism in case studies. It can capture the complexity of real life scenarios and allow students to replay events as many times as they need, and absorb important features that escaped them on first viewing (Reyna, 2010).

6. Conclusion

It has been identified that this technological intervention has good potential to fight antimicrobial resistance. Currently the modules have been rolled out to university students and health professionals. Further studies will be designed in the near future, to gauge the impact of the modules on antimicrobial prescription in hospital settings.

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