Gamified e-learning course: A way to prudent use of antibiotics

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Abstract

The increase in antimicrobial resistance combined with the misuse of antimicrobials calls for antimicrobial stewardship programs to promote prudent use of antimicrobials. Education of prescribers can complement other antimicrobial stewardship activities.

We report the successful development of a gamified e-learning course simulating the daily clinical work based on three virtual patients. We evaluated the course using a 16-item questionnaire, in which 125 doctors reported to have completed the course. Seventy-six percent (N 123) reported to have a wider knowledge of rational use of antibiotics after the course, and this was regardless of their self-estimated prior knowledge. The course was assessed by 74 % (N 119) to have a high professional level and by 67 % (N 119) to have motivated them to rational use of antimicrobials. The game-inspired design of the course was reported to have a positive influence on the learners’ motivation for completing the course (64 %, N 114), helped maintain interest during the course (66 %, N 115), and enhanced the perceived educational benefit of the course (71 %, N 112). The interactive elements of the course were generally evaluated to be more educational than the passive elements.

In conclusion, an interactive and gamified e-learning course based on virtual patients can be used as a strong educational tool in an antimicrobial program.

Keywords: E-learning, Antimicrobial Stewardship, Survey, Gamification
Introduction

The increase in antimicrobial resistance is a global problem. It is estimated that by 2050 ten million lives a year will be at risk due to increased antimicrobial resistance as only a few new antimicrobial drugs are in the pipeline (O’Neill J 2016). In addition, studies at European hospitals have estimated that 37-64%, of antimicrobial treatments prescribed in hospitals are inappropriate or unnecessary (Cusini A et al. 2010, Pulcini C et al. 2007, Willemsen I et al. 2007). Therefore, it is highly necessary that we address both the increase in antimicrobial resistance and the misuse of antibiotics (Norrby R et al. 2009, Villanueva T. 2012).

One of the reasons for inappropriate antimicrobial prescribing could be lack of education (Charani E et al. 2013, Cusini A et al. 2010) and difficulties in maintaining an education program (Pulcini C et al. 2013). Antimicrobial stewardship programs aim at optimizing the use of antimicrobials and reducing the adverse effects of antimicrobials. Education can be included in antimicrobial stewardship programs (Barlam TF et al. 2016, Dellit TH et al. 2007, Pollack LA et al. 2014) and in addition, education is considered a valuable tool in obtaining a change in prescription behaviour (Pulcini C et al. 2011).

Education using e-learning offers a great number of advantages, being available at all times and easily accessible. Furthermore, the use of virtual patients offers a safe learning environment (Ellaway R et al. 2008, McCarthy D et al. 2013). While e-learning using virtual patients offers a risk-free experimental learning environment, gamification offers educators a framework to structure and convey the subject matter. Gamification is a relatively recent term, and so a widely accepted definition has yet to be found. Even so, it is generally understood as a set of principles, tools and techniques which are born in video games but spill over into several other contexts, including education (Perrota C et al. 2013). Or put more simply; gamification is the use of game mechanics and rules in non-gaming contexts (Pesare E et al. 2016). Usage of actual games and simulation in education has been found to be promising in delivering significant learning gains and promoting commitment (McCoy L et al. 2015). However, only a few efforts have been made in researching the effectiveness of a gamified approach (Perrota C et al. 2013, Pesare E et al. 2016).

The aim of our study was to develop a gamified e-learning tool to promote prudent use of antibiotics with an appeal to both senior and junior physicians, and thereby to raise the awareness and knowledge of the correct use of antibiotics and the consequences of misuse of antibiotics. In addition, we wanted, by a survey, to investigate the potential educational benefits and overall usefulness of our gamified e-learning program.

Methods

Participants

The participants in this study were doctors employed at two regional hospitals (hospital A and hospital B) in Central Denmark Region.

We introduced the e-learning course at hospital A 8th February 2016, and it was mandatory from 1st March 2016 for all doctors working at the clinical departments, excluding the department of paediatrics. We introduced the e-learning course at hospital B 25th August 2016.

Hospital A and hospital B are tertiary hospitals located in the Central Denmark Region with 81.771 and 92.900 bed-days respectively in 2015. The e-learning course was developed as a part of an antimicrobial stewardship program.
based on audits, guidelines, an antimicrobial organisation, and finally on education including training sessions as well as the e-learning course.

Learning objectives

After completing the course the learners will have gained knowledge about: antibiotics and basic microbiology including knowledge about the relatedness between specific microorganisms and specific infectious diseases and the indications for prescribing antibiotics, which microbiological samples should be collected in certain clinical situations and the consequences of untimely collection, the importance of sufficient documentation of indication and speculation regarding antimicrobial treatment, the microbiological side-effects of antibiotics including selection of resistant microorganisms, the consequences of antibiotic over-use including the increase of antimicrobial resistance and the frequency of antimicrobial resistance both locally and globally, and finally when and how to ask for advice and support.

Development

To ensure that the final product would meet the mentioned learning objectives, as well as be understandable for our future users, we chose to follow an agile, iterative participatory design strategy. We did this by constantly cycling between proposing a new design, evaluating the design and proposing a new design, based on our findings from the previous evaluation. To heighten product usability and align intended knowledge transfer of the products to actual user needs, design and evaluation were done in close collaboration and dialog with both potential users and domain experts.

The final product

After approximately ten months of working through this iterative process of incremental refinement, we had our final product: A gamified simulation-based e-learning course based on three virtual patients.
After choosing one of the virtual patients (Figure 1), the learner had a number of opportunities. They could read the patient history, ask a colleague for advice, order paraclinical tests (biochemical, serological, microbiological, and/or radiodiagnostical), and finally choose an antibiotic treatment and an indication for the treatment. However, once an antibiotic treatment was chosen, sampling of microbiological tests for culture was no longer an option. The remaining choices remained open throughout the game.

After choosing an indication and treatment the learner received the first line of feedback followed by a status of the patient's condition, the microbiological test results and the opportunity to re-evaluate his or her choices.

The outcome of each of the three virtual patients was determined on the basis of the chosen treatment, the chosen indication, and which tests (if any) the learner had ordered. Based on these decisions, feedback was algorithmically generated after each virtual patient was completed. In this way, the learners had the opportunity to reflect upon each of their previous decisions. Finally, each virtual patient was concluded with a short video addressing the dilemmas presented in the patient case in a broader context.

Each individual feedback was accompanied by points, which were calculated based on the learner's choices of paraclinical investigations, antibiotic treatment, and indication. The learner must obtain at least 50 of a possible 100 points for each virtual patient to pass the course. To obtain 100 points the learner would have to choose the correct indication, the appropriate antibiotic treatment, and the relevant paraclinical investigations. If the learner changed his or her choice of antibiotic treatment and indication after the first feedback, the points were adjusted accordingly. Each virtual patient could be reset and repeated any number of times. The learner must have completed all the virtual patients to pass the course. When the learner passed the course, she or he had the opportunity to enter their
name into a course-wide high score list. In this way the learner could compete with themselves and colleagues.

Data collection

From the system hosting the course (the LMS) we pulled place of employment and completion status. Data were collected shortly before the survey was sent out.

Survey instrument

We developed the questionnaire on the e-learning course in conjunction with a questionnaire on rational use of antibiotics, which was part of an antimicrobial stewardship program. We developed the questionnaire in consultation with a group of experts on questionnaire design.

The 16-item questionnaire regarding the e-learning course collected information on the quality, the educational level of eight elements, the gamified structure, the obtained knowledge, and the usefulness of the e-learning course. We also collected data about the respondents' current speciality and employment.

To validate the questionnaire, it was submitted a pilot test to check comprehension and clarity of the questions. We performed two rounds of interviews: first round with five junior doctors, one staff specialists, and one consultant, and second round with two junior doctors, two staff specialists, and two consultants.

The questionnaire used a seven-point likert scale where the respondents specified their level of agreement or disagreement (Alwin DF et al. 1991).

Survey administration

We distributed the questionnaire in November 2016. The doctors were asked to complete the questionnaire at the daily meeting. Those who were not present received both an e-mail and a letter with the questionnaire. Questionnaires not returned within two weeks triggered an e-mail. A tracking number was used for each participant to ensure confidentiality.

Data analysis

We analysed data using Stata/SE 13.1 for Windows (College Station, Texas, USA). Comparisons between responses were analysed by odds ratios (OR) with 95% confidence intervals (95%CI).

For the calculations score five to seven were grouped as positive and one to four were grouped as negative.

For analysis of representativeness the Chi-square test were used.

Ethics

The Danish Data Protection Agency (record number: 1-16-02-84-15) and the Central Denmark Region approved the project. The Scientific Ethics Committees for Central Denmark Region deemed the project exempt from approval, because the project was not covered by the definition of a scientific research project according to the Danish law no. 593 Act on scientific ethical treatment of health science research projects.
Results

A total of 134 doctors employed at hospital A, Central Region Denmark had by the 31st of October 2016 completed the e-learning course. At hospital B, Central Region Denmark the corresponding number was 19 by the same date.

Three-hundred-and-one respondents completed the questionnaire on rational use of antibiotics, which corresponds to a response rate of 74%. Ninety-five percent of the doctors found it relevant to gain more knowledge on the subject (N 237). Of those nearly fifty percent found it highly relevant to obtain more knowledge on the subject.

One-hundred-and-twenty-five of 301 respondents reported having completed the e-learning course and therefore up to 125 could answer the questionnaire evaluating the e-learning course. Of this group 66 were junior doctors, 14 staff specialists, and 66 consultants. Three respondents had not stated their title.

Figure 2: Questionnaire results from 125 medical doctors at two regional hospitals in the Central Denmark Region, November 2016.

Ninety-three out of 124 (75%) of the respondents estimated that they had extensive knowledge (score five to seven) about the topic rational use of antibiotics before they completed the e-learning course. Ninety-four out of 123 (76%)
respondents reported that they had gained a wider knowledge about rational use of antibiotics after completing the course. In addition, there was no difference between the group of doctors with a self-estimated high knowledge about rational use of antimicrobial agents compared with the group with self-estimated low knowledge about the topic (OR 0.39 95 % CI 0.09-1.31).

In general, the e-learning course was evaluated as having a high professional level (74 %, N 119). This assessment was independent of the respondents' reported prior knowledge of the topic (OR 1.51 95 % CI 0.54-4.02). The fact that the e-learning course was gamified had a positive influence on the learners' motivation for going through with the course (64 %, N 114), for maintaining interest during the course (66 %, N 115), and finally for the educational benefit of the course (71 %, N 112). In general, the junior doctors were more positive compared with staff specialists and consultants, however; we only observed a statistically significant difference between the groups regarding maintaining interest during the course (OR 3.09 95 % CI 1.28-7.54).

During the e-learning course the learners had to make decisions simulating their daily clinical work. This was assessed to be positive by most of the learners (83 %, N 97) with no difference comparing junior doctors with staff specialists and consultants (OR 2.63 95 % CI 0.78-9.52).

As seen in figure 2 the active elements in the e-learning course, such as feedback based on the learners' decisions and decision-making similar to real clinical situations, were evaluated more positively than the passive elements in the e-learning course, such as video or text.

While only 56 % (N 120) of the respondents replied that they use knowledge obtained during the course, 67 % (N 119) reported that the e-learning course had motivated them to rational use of antibiotics.

Discussion

We have managed to create an e-learning course simulating the daily clinical work and to evaluate the educational potential of the course. We observed, in accordance with Doherty & McKimm (2010) that e-learning provides opportunities when face-to-face learning is difficult.

Despite the fact that the learners were both junior and senior doctors, we managed to create a course with an educational benefit for both groups. In addition, our data suggest that the e-learning course offered educational potential for learners with both high and low self-estimated prior knowledge about the subject, suggesting that we have managed to create an educational program with a broad appeal which can be used independently of the learners' prior knowledge of the topic. Although, the data suggest that those with self-estimated high knowledge of the topic rational use of antibiotics gained less from the e-learning-program compared with those with self-estimated low knowledge of the topic, we find it reasonably to conclude that both groups did learn from the course.

The fact that the course simulated the daily clinical work was evaluated positively, which is in line with the work by de Araujo Guerra Grangeia et al (2016). They showed that an educational program based on the real world is a strong educational tool.

Interactive course-elements (e.g. algorithmically-generated feedback based on the users' choices) being more positively rated than passive knowledge transfer methods (e.g. video) aligns well with the well-known 'learning-by-doing' principle popularized by John Dewey (Reese HW 2011), which has been expanded upon by David Kolb (1984), who argues that effective learning must be rooted in a concrete experience. The student must then reflect upon this experience and subsequently act to create a new experience. Research into the use of e-learning in the
medical field further substantiates this finding: It has been suggested that interactivity can improve satisfaction and motivation for learning (de Araujo Guerra Grangeia T et al. 2016) and that virtual patients help to heighten commitment and short-term as well as long-term memory retention (McCarthy D et al. 2013).

Only 55 % of the respondents (N 123) answered that they use knowledge obtained from the course when they prescribe antimicrobial agents. One could speculate that the reason could be that it is difficult to state from where you have your knowledge and unlike the work by Gordon et al (2011) we did not perform tests of the learners, but based our evaluation on self-reported change in motivation and practice. Boeker et al (2013) evaluated both the cognitive learning outcome and students’ attitude towards gamified e-learning, and like us they observed a positive attitude towards gamified e-learning. The e-learning course has inspired 68 % to rational use of antimicrobial agents. Also Walsh et al (2011) estimated self-reported changes in motivation and practice and found that on-line modules had triggered a change.

We created the e-learning course with little need for continuing support. In addition, it is designed to be easily updatable with more virtual patients, providing a simple way to add new learning objectives. The e-learning course is accessible from any device connected to the Internet, which gives the maximal flexibility of time and space as described by Dawson et al (2011). To achieve the same learning goals in our project using lectures, it would have required lectures in all twelve departments more than once in order to reach all doctors. This, of course, must be compared to the time spent by the two clinical microbiologists and one infectious diseases specialist in the process of developing the e-learning course. It could have been valuable to perform a comparative study of the two teaching modalities.

Our study has several strengths. We designed the course using an agile, participatory design strategy, thereby securing a high usability of our course. We distributed our survey to a large cohort at two different hospitals, thus increasing the robustness of our data. Furthermore, the response rate was high and the undercoverage was low, which heightens the generalizability of our findings.

This study does have limitations. Although the course was mandatory, not everybody completed the course thus presenting an initial bias. Participating in the questionnaire was voluntarily thereby presenting a selection bias. The questionnaire used in our study has not been used before. It was, though, validated by an expert in questionnaire design. Finally, our data is based on self-reported data which means that we do not have the possibility of controlling the learners’ responses, however, the questionnaire was anonymised and there was no motivation for answering incorrectly.

**Conclusion**

In conclusion, we have created an e-learning course with a broad appeal. We evaluated the educational value of the program and found that the game-based approach positively influenced the learners’ motivation for completing the course, helped maintain interest during the course and enhanced the perceived educational benefit of the course. Furthermore, we found that the interactive course elements had a higher perceived educational benefit compared with the more passive elements. Simulating the learners’ daily clinical work was also found to have a positive influence on the educational benefit of the course. Finally, we found that the e-learning course heightened the learners’ motivation for rational use of antibiotics.
Take Home Messages

- The successful development of a gamified e-learning course simulating the daily clinical work based on virtual patients
- An interactive and gamified e-learning course based on virtual patients can be used as a strong educational tool in an antimicrobial program
- Simulating the learners' daily clinical work has a positive influence on the educational benefit of learning

Notes On Contributors

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Appendices

Declaration of Interest

The author has declared that there are no conflicts of interest.