AntibioGame® A serious game for teaching medical students about antibiotic use

Rosy Tsopra, Mélanie Courtine, Karima Sedki, David Eap, Manon Cabal, Samuel Cohen, Olivier Bouchaud, Frédéric Mechaï, Jean-Baptiste Lamy

International Journal of Medical Informatics 136 (2020) 104074

Contents lists available at ScienceDirect

International Journal of Medical Informatics

journal homepage: www.elsevier.com/locate/ijmedinf

AntibioGame®: A serious game for teaching medical students about antibiotic use

Rosy Tsopra[a,b,c,d,*], Mélanie Courtine[e], Karima Sedki[e], David Eap[d], Manon Cabal[d], Samuel Cohen[f], Olivier Bouchaud[g], Frédéric Mechaï[g,h], Jean-Baptiste Lamy[e]

[a] INSERM, Centre de Recherche des Cordeliers, UMRS 1138, Université Paris-Descartes, Université Sorbonne Paris Cité, France
[b] Department of Medical Informatics, Hôpital Européen Georges-Pompidou, AP-HP, Paris, France
[c] INSERM, UMR 1099, LTSI Team Health Big Data, Université Rennes 1, Rennes, France
[d] Université Paris 13, SMBH, Bobigny, France
[e] LIMICS, Université Paris 13, Sorbonne Université, Inserm, 93017 Bobigny, France
[f] Sorbonne Université, Paris, France
[g] AP-HP, Hôpital Avicenne, Service de Maladies Infectieuses, F93000 Bobigny, France
[h] IAME - UMR 1137, Paris, France

ARTICLE INFO

Keywords:
Serious games
Antibiotics
Infectious diseases
Primary care
Education
E-learning

ABSTRACT

Introduction: Measures for controlling antimicrobial resistance are urgently required. We describe here AntibioGame®, a serious game for improving the training of medical students in antibiotic use in primary care.
Objective: We aimed to design a serious game for antibiotics teaching and to evaluate its usability and playability by medical students.
Methods: We used various gamification techniques (e.g. use of mascots, avatars, rewards, leader board) and cartoon graphics in the design of AntibioGame®. This game implements clinical case templates built from a list of learning goals defined by a medical team through an analysis of clinical practice guidelines. The game was evaluated by asking medical students to rate their satisfaction and the usability and playability of the game on an electronic form and through group discussions. The electronic form was derived from the MEEGA + scale, a five-point Likert scale including 32 items for assessing both usability and playability.
Results: AntibioGame® is a case-based game in which students play the role of a doctor meeting patients in consultation and helping other health professionals to solve their problems, as in real life. The scenarios are realistic and cover situations frequently encountered in primary care. The 57 medical students enrolled found the game attractive, usable, fun, and appropriate for learning. Game quality was considered "good" (score = 60 on the MEEGA + scale). All the students said they would recommend the game, 96 % liked it and 81 % would use it for revision.
Conclusion: AntibioGame® is a promising tool for improving knowledge in antibiotic prescription that could easily be included in multifaceted programs for training medical students.

1. Introduction

The WHO has warned that *"the world urgently needs to change the way it prescribes and uses antibiotics"* [1]. Indeed, antibiotics are currently widely misused and overused, accelerating the development of bacterial resistance, and leading to complications, death, extended hospital stays and higher medical costs [2].

Most antibiotics are prescribed in primary care. Physicians have to decide "empirically" (i.e. without knowledge of the causal pathogen) whether or not to prescribe antibiotics [3,4]. This requires clinical skill, but also a knowledge of epidemiology, pharmacology, and microbiology [5]. This knowledge is developed during medical training, including lectures on the basics of antibiotic treatment and textbooks on infectious diseases. However, despite this intensive training, many physicians continue to prescribe antibiotics inappropriately [6–8]. One of the reasons for this may be that current teaching approaches and textbooks do not adequately prepare medical students for this task [9–11]. Indeed, these methods have limitations: (i) the learning process is passive and students are not encouraged to develop critical thinking [12]; (ii) students memorize theoretical medical concepts, rather than

* Corresponding author at: INSERM, Centre de Recherche des Cordeliers, UMRS 1138, Université Paris-Descartes, Université Sorbonne Paris Cité, France.
E-mail address: rosy.tsopra@nhs.net (R. Tsopra).

https://doi.org/10.1016/j.ijmedinf.2020.104074
Received 19 July 2019; Received in revised form 7 December 2019; Accepted 2 January 2020

learning to solve the practical problems that arise in medical practice; (iii) students focus on clinical situations encountered in hospitals, but not in primary care; (iv) students focus on a single patient, whereas, in real life, they often have to manage several patients simultaneously; (v) students often miss lectures due to the constraints of their work shifts at the hospital; (vi) students may find the format of current teaching methods unattractive, boring and outdated relative to the new technologies developed in other domains.

Serious games may provide a solution to these issues [13]. These interactive computer applications aim to facilitate "learning through the game" [14]. They propose an entertaining learning environment in which students are exposed to various medical problems, as in real life. Students can formulate hypotheses and suggest solutions, in conditions in which they can make and learn from errors, without fatal consequences for real patients [15]. They are, thus, encouraged to develop analytical and synthetic skills [16]. Serious games also make learning fun, challenging and exciting. Moreover, with their digital format, they allow students to play "anytime anywhere". They are, therefore, much appreciated by students [17], who recommend their use in medical training [18].

A few serious games relating to antibiotic use have already been developed. Some, such as e-Bug games [19,20], aim to educate young children about antibiotic use and resistance. Others, such as Bacteria Combat [21], and Superbugs [22], aim to teach microbiological concepts. A few, such as Septris [23], a case-based online game for teaching sepsis management, or "On call antibiotics" [24], a mobile case-based game for teaching antibiotic prescription, aim to teach medical students about antibiotics. However, these games are based on clinical cases in hospitals, whereas antibiotics are mostly prescribed in primary care. The underlying learning goals of these games are also not always clearly defined, and it may be difficult for medical teachers without specialist computer engineering skills to update the clinical cases. Finally, their graphic design may not have appealed to young people.

We tried to overcome these limitations by designing AntibioGame®, a case-based game for teaching students about antibiotics in primary care. The student plays the role of a doctor meeting patients in consultation and helping other health professionals to solve their problems, as in real life. The scenarios are realistic and cover the learning goals defined by a medical team on the basis of an analysis of clinical practice guidelines. The scenarios are displayed through a graphical interface with a cartoon design.

We describe here the design of AntibioGame® and the evaluation of its usability and playability.

2. Materials and methods

2.1. Design of AntibioGame®

We aimed to design a serious game:

- To teach students how to manage infected patients in primary care. We therefore defined a list of learning goals adapted to primary care;
- That could be easily updated by the medical education team without the need for computer engineers. We therefore chose to create clinical case templates;
- To make the learning process fun, exciting and challenging through a pleasant graphical interface. We therefore used gamification techniques and cartoon design;
- That could be made available on different digital supports, to facilitate its use by students.

2.1.1. Definition of a list of learning goals adapted to primary care

A medical team defined a list of learning goals based on an analysis of three clinical practice guidelines concerning the management of respiratory and urinary infections in primary care.

Table 1
Example of a clinical case written by the medical team based on the template "consultation in the GP's office" (R: Response).

Template	Example of clinical case
Write a clinical case corresponding to the situation "consultation in the GP's office"	Candy, a three-year-old girl, has a cough and has had rhinorrhea for two days. She also has pain in her right ear. She has vomited twice and has eaten very little since yesterday. Your medical examination reveals: - Temperature: 39 °C - Pharynx: erythema - Tonsils: normal - Tympanic membrane: left: normal right: moderate bulging of the tympanic membrane, without otorrhea
Question 1: What is your diagnosis?	
Write the correct response(s)	R: Acute otitis media probably caused by *Streptococcus pneumoniae*
Write a list of wrong responses	R: Pharyngitis probably caused by *virus* R: Acute otitis externa
Question 2: Which paraclinical examinations do you prescribe?	
Write the correct response(s)	R: No paraclinical examination should be performed
Write a list of wrong responses	R: Strep throat test R: Blood tests R: Brain scan
Question 3: What treatment would you prescribe?	
Write the correct response(s)	R: Empiric antibiotic R: Symptomatic treatment
Write a list of wrong responses	R: Antibiotic ear drops R: Corticosteroids R: Referral to an ENT specialist
Question 4: Which antibiotic would you prescribe?	
Write the correct response(s)	R: Amoxicillin, 8090 mg/kg per day for 5 days
Write a list of wrong responses	R: Amoxicillin, 8090 mg/kg per day for 10 days R: Amoxicillin clavulanate, 8090 mg/kg per day for 5 days

2.1.2. Creation of clinical case templates

The medical team built clinical case templates based on the pre-established learning goals. These templates were designed to be (i) generic, to allow adjustment for a large range of medical cases, (ii) realistic, to motivate students, (iii) short, to make it possible for students to play "anywhere anytime", (iv) varied, to ensure that the game did not become monotonous. These templates were then implemented in the game.

When the medical team wishes to add a new clinical case, one of these templates is completed (Table 1), and the clinical case is automatically saved in the game database, without the need for reprogramming.

2.1.3. Use of gamification techniques and cartoon design

Various gamification techniques [25] were used (Table 2): a mascot represented by a superhero called Antibioman appears throughout the game, and helps students if necessary; an avatar with badges personalized according to the student's achievements is displayed in the student's profile; hints and recaps are provided on request; a scoring system, with rewards, points, levels and a leader board, is displayed at the end of each clinical case.

The interface is based on a cartoon design. Some of the characters are reminiscent of well-known cartoon characters. They ask the

Table 2
List of gamification techniques used in AntibioGame® design.

Gamification techniques used [25]	Effects on AntibioGame® design	Anticipated benefits for medical students					
		Learning	Challenge	Confidence	Ease of use	Attractiveness	Fun
Challenge/Quests	Challenges are proposed in the form of various clinical cases that must be solved	x	x		x	x	
Mascot	A mascot, "Antibioman", is symbolized by a superhero appearing throughout the game					x	x
Avatar with badges	An avatar is displayed in the student's profile, associated with badges symbolizing the student's achievements		x			x	x
Hints	Hints are provided on request when the student gives an incorrect answer to a question	x		x		x	
Feedback	Medical knowledge is updated on request at the end of each question	x		x		x	
Rewards	Rewards are given at the end of clinical cases, depending on the accuracy of the answers given by the student		x			x	x
Points	Scores are displayed for experience, knowledge, popularity		x			x	x
Level and progress bar	A level bar is displayed in the form of a syringe that fills up progressively		x			x	
Leader board	A leader board ranks the students according to their scores		x			x	x
Immersion in the real world	The graphical elements include medical decors and cartoon characters. Some of the remarks made by the characters are sarcastic and include references to caricatures of the medical world.			x	x	x	x

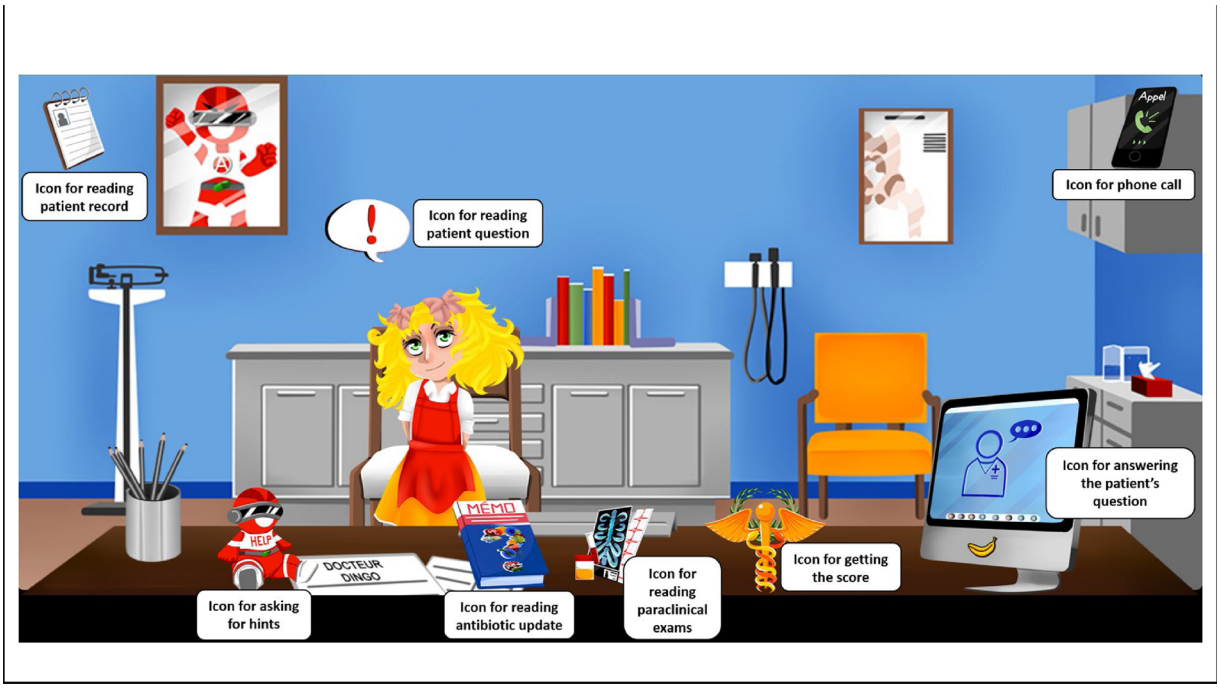

Fig. 1. AntibioGame® interface. Here, a little girl, "Candy", has come to consult her GP. Various interactive and meaningful icons are displayed through the interface.

students questions and respond enthusiastically or sarcastically, depending on the correctness of the answers supplied by the students. The decor corresponds to various medical contexts, and various meaningful icons are used (Fig. 1).

2.1.4. Technical implementation

AntibioGame® is implemented in PHP 7.0 and MySQL 5.7. It is a web application available for personal computers and smartphones. Firefox Mozilla is required for its optimal use.

Various tests were performed during the development process, to check software quality and playability. First, all functions were tested by three students from different backgrounds (video games, computer sciences, and biology). This made it possible to fix 47 problems (e.g. interaction problem with some icons). Second, playability was assessed by seven people from different backgrounds (video games, medical). This made it possible to fix 22 problems (e.g. incomprehensibility of some icons, leading to the addition of information bubbles). Third, medical relevance was assessed by the educational team of the university, including two specialists in antibiotics, the educational director, and the head of a hospital infectious diseases department. This made it possible to fix two problems (e.g. the addition of a "key point" at the end of each clinical case).

2.2. AntibioGame® evaluation

We evaluated student satisfaction and the usability and playability of the game, by organizing several evaluation sessions. Each session began with a presentation of AntibioGame®. The students then played games for three clinical cases on computer tablets, at the end of which, they could compare their results with those of their peers on a leader board. At the end of the evaluation period, we collected their opinions on the game through group discussions and the completion of an electronic form.

Table 3
Clinical cases played in AntibioGame® with their learning goals.

	Diagnosis based on clinical elements	Knowledge of signs of severity	Knowledge of the course of the disease	Knowledge of the most likely causal pathogens	Correct prescription of paraclinical examinations	Correct interpretation of the results of paraclinical examinations	Knowing whether the patient should be managed in hospital	Knowing whether the patient should be treated with antibiotic
Main scenarios								
Patient consultation in the GP's office	x			x	x		x	x
Patient consultation for a second time for the same reason	x		x		x		x	x
Review of paraclinical examinations performed on patient					x	x		
Review of drug prescriptions								
Secondary scenarios								
Call from a pharmacist to check antibiotic dose								
Call from a nurse concerning antibiotic side effects							x	x
Call from a nurse concerning signs of severity for an infection		x	x				x	x
Call from a nurse concerning paraclinical examinations to be performed to monitor antibiotic dose								
Call from a junior doctor concerning the prescription of an antibiotic	x		x				x	x
Call from a microbiologist for pathogen identification				x				

	Choice of the correct antibiotic	Prescription of the correct dose of antibiotic	Knowledge of antibiotic properties	Knowledge of antibiotic side effects	Knowledge of antibiotic contraindica-tions	Knowledge of the drug-drug interactions of antibiotics	Knowledge of the necessary biological monitoring of antibiotic	Knowing how to negotiate with patients
Main scenarios								
Patient consultation in the GP's office	x							
Patient consultation for a second time for the same reason	x							x
Review of paraclinical examinations performed on patient								
Review of drug prescriptions	x		x		x	x		
Secondary scenarios								
Call from a pharmacist to check antibiotic dose		x						
Call from a nurse concerning antibiotic side effects			x	x				
Call from a nurse concerning signs of severity for an infection								
Call from a nurse concerning paraclinical examinations to be performed to monitor antibiotic dose							x	
Call from a junior doctor concerning the prescription of an antibiotic								
Call from a microbiologist for pathogen identification								

2.2.1. Recruitment of medical students

Students were notified of the existence of this study through social networks, the faculty of medicine, and the hospital. For participation, students had to have completed at least two years of a medicine degree and had to sign a consent form. They were not remunerated for their participation, but received a small gift in the form of chocolate at the end of the evaluation.

2.2.2. Electronic form and open discussion

The electronic form included:

- Demographic questions
- 36 questions assessing student satisfaction and the usability and playability of the game. We used the MEEGA + scale [26,27], which assesses 9 items for usability and 23 items for playability on a five-point Likert scale extending from "strongly disagree" to "strongly agree" for each item. The scores for these items yield an overall score for game quality (low quality for scores < 42.5, good quality for scores between 42.5 and 65, and excellent quality for scores > = 65)
- Three questions assessing the students' appreciation of the game, its use for study purposes and areas for improvement
- Additional free comments

At the end of the session, students were encouraged to exchange views concerning their overall opinion of the game during a free discussion.

Quantitative and qualitative analyses of the free comments of the students are presented together in the results section.

3. Results

3.1. AntibioGame® design

3.1.1. Clinical case templates

Ten clinical case templates were created to cover the 16 learning goals defined on the basis of an analysis of clinical practice guidelines (Table 3):

- Four were main scenarios corresponding to GP appointments with patients.
- The other six were secondary scenarios corresponding to phone calls from other health professionals asking for advice. These scenarios were presented only at higher levels in the game and aimed to teach students how to manage two patients simultaneously, as in real life.

3.1.2. Game play

Students first log in with their alias and password. Once logged onto the system, they can see their avatar, personalized with three badges summarizing their achievements in the game.

On the homepage, the mascot asks students to choose a theme for training (e.g. respiratory infections). Once the theme has been chosen, the game starts with a first clinical case (Fig. 2). Students have to read the patient record, and then answer the patient's questions. The student selects the answer from a list of responses proposed by the system and displayed in random order. Once students have validated their answers, they receive a response from the patient, which may be pleasant or sarcastic, depending on the accuracy of their answers. If students answer a question incorrectly they can ask for a hint and try again. They have only two chances to answer the question correctly. Once the question has been completed, the student can choose to read a recap of the medical knowledge related to the question. This recap includes web links to online materials.

At higher levels, the game may involve the student receiving a phone call. These calls occur without warning, briefly interrupting the main clinical case game played by the student. Students are notified by a graphical representation of a phone vibrating and an audio ringtone. They have a short time in which to pick up the phone. The person at the other end of the phone is another health professional asking for some quick advice. Once the students have answered the question posed by the health professional, they receive a reward or a punishment (e.g. a sweet or a bottle of poison) depending on whether they answered the question correctly or not. When they hang up, they return to the main clinical case.

At the end of each main clinical case, a score window is displayed (Fig. 3). It contains (i) an image of the mascot with an encouraging or sarcastic message, depending on the student's achievements, (ii) some "key points to remember" highlighted in yellow, (iii) a syringe, which fills up progressively depending on the student's score, (iv) the learning goals of the medical case played and (v) the three scores assessed:

- The "experience score" increases with the number of clinical case games played and determines the avatar badge "school year" (e.g. at the beginning, the avatar has a badge proclaiming "first year of medicine school").
- The "degree score" is calculated from the number of correct answers provided for main scenarios and determines the "degree" badge of the avatar (e.g. the avatar wears the badge "serial killer" if the student answers incorrectly).
- The "popularity score" is calculated from the number of correct answers provided during phone calls and determines the "popularity with health professionals" badge (e.g. the avatar wears the badge "charming" if the student responds correctly to phone calls).

Each of these scores may increase or decrease as the game progresses. When the students have completed all the clinical cases for a given topic, they can compare themselves with others on the leader board, which ranks students according to their degree score.

3.2. AntibioGame® evaluation

In total, 57 students assessed AntibioGame® (Table 4). They had a mean age of 23 years, and two were "Erasmus students" from other countries. Very few were in the habit of frequently playing video games.

3.2.1. Quality

AntibioGame® was considered to be of "good" quality according to the MEEGA + + scale (score was 60).

3.2.2. Usability (Fig. 4)

Overall, 91 % of the students felt that the AntibioGame® design was attractive. Some described the design as original, captivating and pleasant (Table 5, Ex1), and one felt that it made the discipline of infectious diseases easier to approach. Moreover, 89 % of students found the game easy to play, and 98 % found the rules easy to understand (Table 5, Ex2).

In terms of possible improvements, a few students suggested improving interactions with some icons, or improving readability by the use of other text fonts.

3.2.3. Player experience (Fig. 4)

AntibioGame® provided relevant medical content and made it easier to learn about antibiotic use according to 93 % and 98 % of students, respectively. The game was perceived as "instructive", thanks to the explanations displayed after each question, but also as "professionalizing", thanks to the various realistic clinical cases. AntibioGame® was also seen as promoting competition, cooperation and challenging activities, for 87%–89% of students (Table 5, Ex10). The students saw the phone calls, for example, as an exciting challenge (Table 5, Ex13). 98 % of the students felt that AntibioGame® was fun (Table 5, Ex11-12). Many of the students liked the responses of the game characters to their answers (Table 5, Ex4), but one of the students reported being upset by

Fig. 2. AntibioGame® gameplay. At the beginning of the game, the patient record is displayed on the left. The patient asks the medical student a question, and the student responds by selecting one or more of the responses displayed (upper panel). Once students have validated their answers, they can read the patient's comment, which may be pleasant or sarcastic, depending on the accuracy of the answer. In the lower panel, the patient givens a sarcastic comment because the answer given was incorrect. Students can request hints by clicking on the "help" icon on the left of the desk.

some sentences.

In terms of possible areas for improvement, the game does not currently engage the full attention of students (only 56 % lost track of time when playing). The students also suggested that the clinical cases could be improved by: adding more questions and icons (e.g. imagery), adding questions from other medical specialties, adapting the level of difficulty according to the number of years of medical training already completed by the student, and extending the learning goals to other aspects of antibiotic therapy (e.g. mechanisms of bacteria resistance), and to other medical contexts (e.g. intensive care units).

The students also suggested that the scoring system could be improved by specifying whether each question has one or more answers, adding a correction of each question, providing more hints, and attributing more points for responses that are partially correct.

Finally, some students recommended adding functions such as a multiplayer mode, a timer, daily rewards, and tutorials.

3.2.4. *Use for revision*

All students said they would recommend AntibioGame® to their colleagues; 96 % liked the game, and 81 % said they would play the game for the purposes of revision (Table 5, Ex15-16). All the students said they would like to have training sessions with the game; 79 % said these training sessions should be remote and 78 % said they should include debriefing by a teacher.

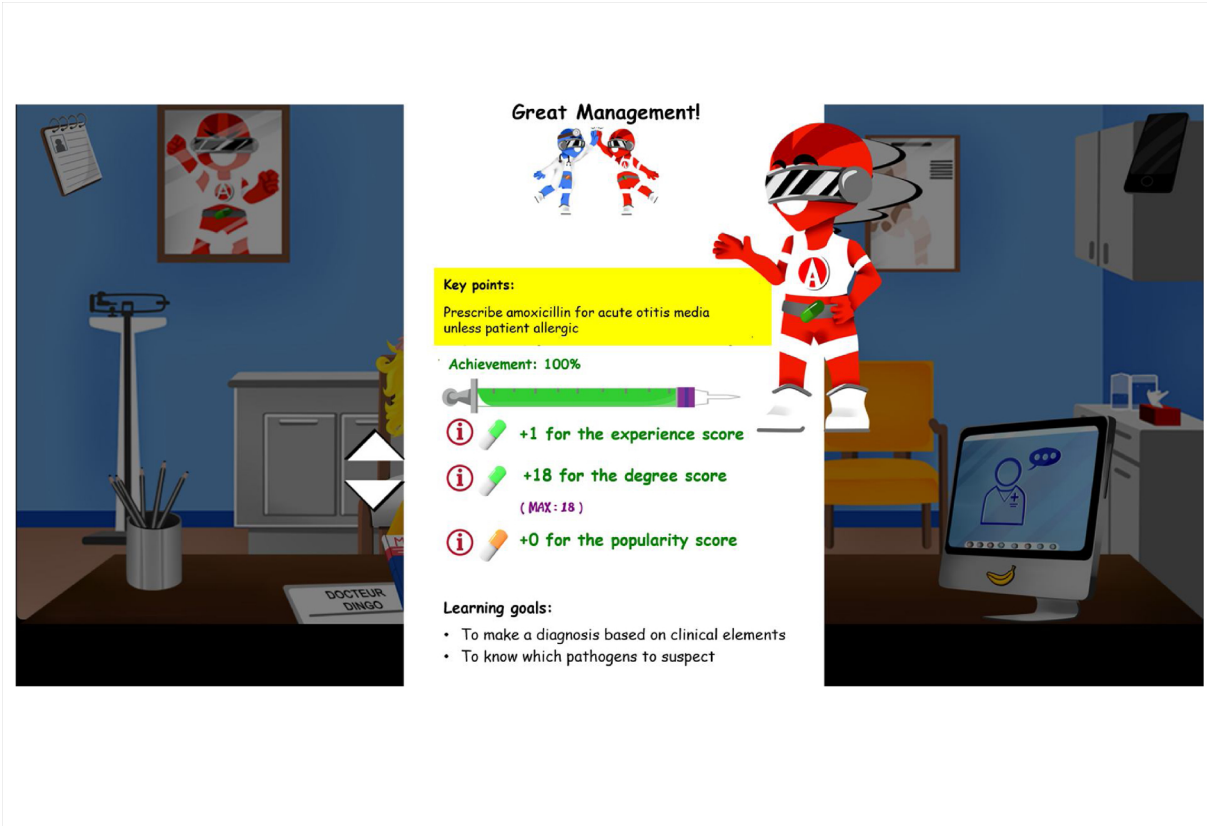

Fig. 3. AntibioGame® Gameplay. At the end of the clinical case, students can see the score window including: (i) the Antibioman mascot, (ii) an amusing picture, depending on student achievement, (iii) the key points highlighted in yellow, (iv) a syringe that gradually fills up as the student's achievements increase, (v) the number of points acquired for each of the three scores and (vi) the learning goals.

4. Discussion

We present here AntibioGame®, a serious game for teaching medical students about the use of antibiotics in primary care. AntibioGame® is a case-based game in which students are asked to manage patients suffering from various infectious diseases and to help other healthcare professionals encountering difficulties with their own patients. The scenarios are realistic and cover the learning goals defined by a medical team based on an analysis of clinical practice guidelines. Gamification techniques and carton design were used in the development of this game, which can easily be updated by the educational team through the use of clinical case templates. The game was found to be of "good" quality. Medical students found AntibioGame® attractive, fun and appropriate for learning about antibiotics. They all said that they would recommend the game to their colleagues, and 81 % said that would use it for revision.

Table 4
Demographic characteristics of medical students.

Characteristics	Percentage (number of students)
Sex	
Female	56 % (32/57)
Male	44 % (25/57)
Age (mean)	23 years
Location of the university of origin of the student	
France	96 % (55/57)
Germany	2 % (1/57)
Romania	2 % (1/57)
School year	
2nd year completed	14 % (8/57)
3rd year completed	21 % (12/57)
4th year completed	25 % (14/57)
5th year completed	33 % (19/57)
6th year completed	7 % (4/57)
Frequency with which the student plays video games	
Never	28 % (16/57)
Rarely/sometimes	37 % (21/57)
At least once a month	11 % (6/57)
At least once a week	18 % (10/57)
Every day	7 % (4/57)

4.1. AntibioGame® design

We chose to design a case-based game, to get as close as possible to medical reality. However, other types of serious games exist [13,28]: (i) adventure games, in which students complete a series of quests [29]; (ii) quizzes, in which students answer series of questions [30]; (iii) board or card games adapted from well-known existing games [21]; (iv) puzzles in which students manipulate visual objects [22]. In the future, we aim to add a mixture of different types of games to AntibioGame®, to increase its chances of adoption by students. Other gamification elements exist but were not used here [25]: time pressure, difficulty adaptation, content unlocking, evolution of performance score, and multiplayer modes. In the future, we aim to add some of these gamification elements to increase student motivation and make the learning process more enjoyable [31]. Finally, we chose to use a 2D frozen cartoon design to reduce cost development. However, other types of design could make the game more realistic, attractive and fun, such as a 3D design with human characters [15], or the adaptation of the interface according to student score [32,33]. In the future, we aim to

Table 5
Extracts from the students' comments (Ex: Extract).

		Students' comments
Usability	Design	*Ex1: "Beautiful design"*
	Use	*Ex2: "It is intuitive and you can rapidly understand how it works"*
Player experience	Satisfaction, Confidence	*Ex3: "I love it!"*
		Ex4: "When the characters make a pleasant comment (e.g. "you are a great doctor"), it makes me more confident"
		Ex5: "I wanted to do more clinical cases and I was disappointed that the evaluation ended"
		Ex6: "I am disappointed that we have to wait to play the game. I hope it will be ready before the end of the medical school"
	Learning, Relevance	*Ex7: "When we learn about classic clinical cases, we don't always have the explanations. Here, I really liked reading the explanations"*
		Ex8: "The hints encourage us to think actively rather than looking directly for the answers"
		Ex9: "With the game, I can learn without feeling that I am studying"
	Interaction, Challenge	*Ex10: "The scoring and the leader board motivate me to study"*
	Fun	*Ex11: "Very good fun; I really like the game play"*
		Ex12: "Great. The game play is fun and helps you to learn in another format"
	Reality	*Ex13: "I really like the phone calls because it makes me feel like a real doctor"*
		Ex14: "There is a gap between what I learn from my books and reality. With the game, I felt like a junior doctor who has to treat the patient"
Use for revision		*Ex15: "When will this game be available?"*
		Ex16: "I will tell all my friends about this game"

Fig. 4. Usability and playability of AntibioGame®. Graphical results. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

improve the design by displaying an interface adapted to student score (e.g. changes in the faces of the characters according to the accuracy of answers).

4.2. AntibioGame® evaluation

We chose to assess AntibioGame® with the MEEGA + method [26]. Other methods exist, but, as pointed out in a systematic literature review, they were developed in an ad-hoc manner, and do not provide an explicit definition of the goal, measurements or data collection methods used [34]. They also differ considerably in terms of the quality factors assessed [34–37]. We chose the MEEGA + method [26] because it is appropriate for evaluations of educational games, it assesses both usability and player experience from the student's perspective, it uses an explicit scale assessing various quality factors, it provides a global score quality, and it is easy to use and free of charge [27]. However, according to the four-level model of training evaluation developed by Kirkpatrick et al. [38], we assessed only the "reaction" level (i.e. the degree to which students find the game beneficial, engaging and relevant to their jobs). Further evaluations are required to assess the other three levels: "learning", "behavior", and "results". To this end, we plan to introduce AntibioGame® into the training program for medical students, and to assess its impact on student learning [15,39].

4.3. Comparison with other teaching methods

We chose to use an approach aiming at "learning through the game" [14]. However, other teaching methods exist. Conventional lecture-based teaching is the most widespread teaching method. It allows students to learn theoretical medical concepts, but also to benefit from the clinical experience of senior doctors. However, this approach may suffer from a lack of practical training, and of attractiveness for new generations of students at ease with technology. MOOCs [40,41] are lecture-based resources available online that allow students to learn remotely, but do not provide practical training. Several MOOCs relating to antibiotic therapy are available for free [41,42]. Manikin-based simulations [43,44] provide students with the opportunity to practice technical gestures, but are difficult to organize. Virtual reality techniques [44–46] provide practical training in which the students are immersed in a real world in which they can interact with characters and objects presented in a 3D virtual environment, but such techniques are expensive and require complex software [47]. A few courses based on virtual techniques have been developed for antibiotic treatment [48]. We decided to develop a serious game to overcome these limitations: this game exposes students to real clinical situations, it is low-cost (estimated cost: 6000 to 10,000 euros), and it is a flexible teaching method that can be associated with other teaching methods.

4.4. Expected potential impact on student learning

Limited evidence is available concerning the efficacy of serious games for promoting knowledge retention [49–52], but we expect AntibioGame® to have a positive impact on student learning. Systematic reviews and meta-analyses [49–52] have concluded that serious games are a viable teaching strategy, but their impact in terms of efficacy has yet to be demonstrated. However, these conclusions are based on only a few randomized controlled trials, because of the limited number of available trials with a methodology of sufficiently high quality for inclusion in such analyses. A few trials have reported that serious games are as effective as traditional methods for promoting student knowledge [53,54], whereas others have reported serious games to be more effective [55]. Further research is required to determine the impact of serious games on the acquisition of knowledge by students. We show here that serious games have the potential to increase enjoyment and motivation in the student's learning process. Students are also encouraged to interact with each other, challenging each other, to obtain higher scores through the gamification elements, such as leader board and awards. We hypothesize that motivated students excited by the game are more likely to spend longer revising, thereby increasing their medical knowledge. In the future, we will perform a randomized control trial to investigate the impact of AntibioGame® on learning outcomes.

4.5. Expected potential impacts on antibiotic resistance

We propose a serious game for improving the training of medical doctors in antibiotic use. We expect to see an impact on the quality of antibiotic prescriptions in primary care, and, consequently, a decrease in antimicrobial resistance. Antimicrobial resistance is a worrying phenomenon that could lead to critical situations in which no effective antibiotic is available for the treatment of common infectious diseases [56,57]. It is becoming urgent to take action against this phenomenon. However, no single action in isolation would be sufficient [58]. The teaching action described here should be incorporated into multifaceted interventions at different levels [58,59,65]. The WHO has proposed a global action plan with five types of intervention [60]: increasing awareness and understanding of antimicrobial resistance (e.g. through educational programs); improving knowledge of antibiotics (e.g. through surveillance and research programs); decreasing the incidence of infections (e.g. through lifestyle habits); optimizing antibiotic use [61] (e.g. through clinical decision support systems [62–64]); and supporting economic investment in the development of new therapies or diagnostic tools. This multifaceted intervention should target not only doctors, but also other healthcare professionals and the general population. Thus, although serious games are a promising tool for improving medical training in antibiotics, other actions are required to achieve a significant impact on antimicrobial resistance.

Authors' contributions

Project leader: RT
Design of the study protocol: RT
Definition of learning goals and clinical templates: RT, DE, SC, FM
AntibioGame® design: RT, DE, MaC
Setting up of the evaluation of AntibioGame®: RT, MaC
Statistical and data analysis: RT, KS
Participation: MeC, OB, FM, JBL
Writing of the manuscript: RT
Agreement with all aspects of the work and approval of the final version for publication: RT, MeC, KS, DE, MaC, SC, OB, FM, JBL

Funding

Funding was obtained from the "*Agence Nationale de Sécurité du Médicament et des Produits de santé (ANSM)*". APP 2016 – RaMiPA Project (Raisonner pour Mieux Prescrire les Antibiotiques or Reasoning for better antibiotic prescription) – Project leader: Dr Rosy TSOPRA.

Summary points

- Antimicrobial resistance is a worrying phenomenon
- Serious games could help to improve antibiotic prescription and, thus, to decrease antimicrobial resistance
- There was no serious game for teaching students about antibiotics in primary care
- AntibioGame® is a case-based game for teaching antibiotics to medical students
- AntibioGame® has the potential to make the learning process more fun, interactive and enjoyable for students
- AntibioGame® is a promising tool that could easily be incorporated into multifaceted programs for medical students

Declaration of Competing Interest

None.

Acknowledgments

We thank all the medical students for taking the time to participate in this study.

We thank Karny BEDIKIAN, Françoise JAUREGUY, Dr Warda KHAMIS, Prof. Bertrand DEGOS and Prof. Jean-Ralph ZAHAR, for encouraging medical students to participate in this study.

We thank Dr Hugues CORDEL and Thomas PLANQUES for their advice.

We thank Bernard VIRGINIE for his technical support.

We thank Giani PETRI for his advice regarding the use of the MEEGA + scale.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijmedinf.2020.104074.

References

[1] World Health Organization, Antibiotic Resistance, (2018) (Accessed December 31, 2018), https://www.who.int/news-room/fact-sheets/detail/antibiotic-resistance.
[2] P.G. Davey, C. Marwick, Appropriate vs. inappropriate antimicrobial therapy, Clin. Microbiol. Infect. 14 (Suppl 3) (2008) 15–21, https://doi.org/10.1111/j.1469-0691.2008.01959.x.
[3] K. Gupta, T.M. Hooton, K.G. Naber, B. Wullt, R. Colgan, L.G. Miller, et al., International clinical practice guidelines for the treatment of acute uncomplicated cystitis and pyelonephritis in women: A 2010 update by the Infectious Diseases Society of America and the European Society for Microbiology and Infectious Diseases, Clin. Infect. Dis. 52 (2011) e103–e120.
[4] M. Woodhead, F. Blasi, S. Ewig, J. Garau, G. Huchon, M. Ieven, et al., Guidelines for the management of adult lower respiratory tract infections–full version, Clin. Microbiol. Infect. 17 (Suppl 6) (2011) E1–59.
[5] S. Leekha, C.L. Terrell, R.S. Edson, General principles of antimicrobial therapy, Mayo Clin. Proc. 86 (2011) 156–167, https://doi.org/10.4065/mcp.2010.0639.
[6] J. van den Broek d'Obrenan, T.J.M. Verheij, M.E. Numans, V.D. Velden, A.W, Antibiotic use in Dutch primary care: relation between diagnosis, consultation and treatment, J. Antimicrob. Chemother. 69 (2014) 1701–1707, https://doi.org/10.1093/jac/dku005.
[7] M.A. Steinman, C. Landefeld, R. Gonzales, PRedictors of broad-spectrum antibiotic prescribing for acute respiratory tract infections in adult primary care, JAMA 289 (2003) 719–725, https://doi.org/10.1001/jama.289.6.719.
[8] J.A. Linder, R.S. Stafford, Antibiotic treatment of adults with sore throat by community primary care physicians: a national survey, 1989-1999, JAMA 286 (2001) 1181–1186, https://doi.org/10.1001/jama.286.10.1181.
[9] S. Miles, J. Kellett, S.J. Leinster, Medical graduates' preparedness to practice: a comparison of undergraduate medical school training, BMC Med. Educ. 17 (2017), https://doi.org/10.1186/s12909-017-0859-6.
[10] J.C. Illing, G.M. Morrow, C.R. Rothwell nee Kergon, B.C. Burford, B.K. Baldauf, C.L. Davies, E.B. Peile, J.A. Spencer, N. Johnson, M. Allen, J. Morrison, Perceptions of UK medical graduates' preparedness for practice: a multi-centre qualitative study reflecting the importance of learning on the job, BMC Med. Educ. 13 (2013) 34, https://doi.org/10.1186/1472-6920-13-34.
[11] L.V. Monrouxe, L. Grundy, M. Mann, Z. John, E. Panagoulas, A. Bullock, K. Mattick, How prepared are UK medical graduates for practice? A rapid review of the literature 2009-2014, BMJ Open 7 (2017) e013656, , https://doi.org/10.1136/bmjopen-2016-013656.
[12] H.G. Schmidt, S.L. Wagener, G.A.C.M. Smeets, L.M. Keemink, H.T. van der Molen, On the use and misuse of lectures in higher education, Health Prof. Educ. 1 (2015) 12–18, https://doi.org/10.1016/j.hpe.2015.11.010.
[13] R. Wang, S. DeMaria, A. Goldberg, D. Katz, A systematic review of serious games in training health care professionals, Simul. Healthc. 11 (2016) 41–51, https://doi.org/10.1097/SIH.0000000000000118.
[14] B. Bergeron, Developing Serious Games, Charles River Media, Hingham, Mass., Etats-Unis d'Amérique, 2006.
[15] F. Buttussi, T. Pellis, A. Cabas Vidani, D. Pausler, E. Carchietti, L. Chittaro, Evaluation of a 3D serious game for advanced life support retraining, Int. J. Med. Inform. 82 (2013) 798–809, https://doi.org/10.1016/j.ijmedinf.2013.05.007.
[16] C.C. Bonwell, J.A. Eison, Active Learning: Creating Excitement in the Classroom, ASHE-ERIC Higher Education Reports, ERIC Clearinghouse on Higher Education, The George Washington University, One Dupont Circle, Suite 630, Washington, DC, 1991 20036-1183 ($17, 1991. https://eric.ed.gov/?id=ED336049 (Accessed February 23, 2019).
[17] F.W. Kron, C.L. Gjerde, A. Sen, M.D. Fetters, Medical student attitudes toward video games and related new media technologies in medical education, BMC Med. Educ. 10 (2010) 50, https://doi.org/10.1186/1472-6920-10-50.
[18] M. Jeffres, L. Biehle, A study assessing the educational value of serious games in infectious diseases – going beyond memorization, Open Forum Infect. Dis. 4 (2017) S444, https://doi.org/10.1093/ofid/ofx163.1127.
[19] D. Farrell, P. Kostkova, L. Lazareck, D. Weerasinghe, J. Weinberg, D.M. Lecky, N. Adriaenssens, T. Koprivová Herotová, J. Holt, P. Touboul, K. Merakou, R. Koncan, A. Olczak-Pienkowska, A. Brito Avô, J. Campos, C.A.M. McNulty, Developing e-Bug web games to teach microbiology, J. Antimicrob. Chemother. 66 (2011) v33–v38, https://doi.org/10.1093/jac/dkr121.
[20] A.R. Hale, V.L. Young, A. Grand, C.A.M. McNulty, Can gaming increase antibiotic awareness in children? A mixed-methods approach, JMIR Serious Games 5 (2017), https://doi.org/10.2196/games.6420.
[21] Bacteria Combat, (n.d.). http://www.e-bug.eu/young_sub.aspx?cc=eng&ss=11&t=Bacteria%20Combat (accessed January 6, 2019).
[22] Superbugs | Longitude Prize, (n.d.). https://longitudeprize.org/antimicrobial-resistance/superbugs (accessed February 16, 2019).
[23] K.H. Evans, W. Daines, J. Tsui, M. Strehlow, P. Maggio, L. Shieh, Septris: a novel, mobile, online, simulation game that improves sepsis recognition and management, Acad. Med. 90 (2015) 180–184, https://doi.org/10.1097/ACM.0000000000000611.
[24] E. Castro-Sánchez, E. Charani, L. Moore, M. Gharbi, A. Holmes, "On call: antibiotics"- development and evaluation of a serious antimicrobial prescribing game for hospital care, in: B. Schouten, S. Fedtke, M. Schijven, M. Vosmeer, A. Gekker (Eds.), Games for Health 2014, Springer Fachmedien Wiesbaden, 2014, pp. 1–7.
[25] M.-A. Maheu-Cadotte, S. Cossette, V. Dubé, G. Fontaine, T. Mailhot, P. Lavoie, A. Cournoyer, F. Balli, G. Mathieu-Dupuis, Effectiveness of serious games and impact of design elements on engagement and educational outcomes in healthcare professionals and students: a systematic review and meta-analysis protocol, BMJ Open 8 (2018) e019871, , https://doi.org/10.1136/bmjopen-2017-019871.
[26] G. Petri, MEEGA+: A Method for the Evaluation of Educational Games for Computing Education, (2018), p. 47.
[27] MEEGA+ Team, MEEGA+ a Model for Evaluating Educational Games – GQS – Software Quality Group, (2019) (n.d.). http://www.gqs.ufsc.br/meega-a-model-for-evaluating-educational-games/ (Accessed February 22, 2019).
[28] I. Gorbanev, S. Agudelo-Londoño, R.A. González, A. Cortes, A. Pomares, V. Delgadillo, F.J. Yepes, Ó. Muñoz, A systematic review of serious games in medical education: quality of evidence and pedagogical strategy, Med. Educ. Online 23 (2018), https://doi.org/10.1080/10872981.2018.1438718.
[29] ElderQuest: Adventures in Geriatrics!, ElderQuest: Adventures in Geriatrics!, (2019) (n.d.). http://eqhome.org/ (Accessed February 16, 2019).
[30] T. Jirasevijinda, L.C. Brown, Jeopardy!: an innovative approach to teach psychosocial aspects of pediatrics, Patient Educ. Couns. 80 (2010) 333–336, https://doi.org/10.1016/j.pec.2010.06.002.
[31] W.J. Boendermaker, M. Boffo, R.W. Wiers, Exploring elements of fun to motivate youth to do cognitive Bias modification, Games Health J. 4 (2015) 434–443, https://doi.org/10.1089/g4h.2015.0053.
[32] somalley, Back Quack |, University of Michigan 3D Lab, 2019 (n.d.). http://um3d.dc.umich.edu/learning/back-quack/ (Accessed February 16, 2019).
[33] M. Brown, J. Pinchin, R. Valand, C. Larkin, J. Pattinson, K. Benning, NightShift Simulation to Train Newly Qualified Doctors in Non-technical Skills: a Feasibility Study, (2019), p. 5 (n.d.).
[34] G. Petri, C.G. von Wangenheim, How to Evaluate Educational Games: a Systematic Literature Review, (2019) (n.d.). http://www.jucs.org/jucs_22_7/how_to_evaluate_educational (Accessed February 22, 2019).
[35] E.A. Akl, R. Mustafa, T. Slomka, A. Alawneh, A. Vedavalli, H.J. Schünemann, An educational game for teaching clinical practice guidelines to Internal Medicine residents: development, feasibility and acceptability, BMC Med. Educ. 8 (2008) 50, https://doi.org/10.1186/1472-6920-8-50.
[36] G. Duque, S. Fung, L. Mallet, N. Posel, D. Fleiszer, Learning while having fun: the use of video gaming to teach geriatric house calls to medical students, J. Am. Geriatr. Soc. 56 (2008) 1328–1332, https://doi.org/10.1111/j.1532-5415.2008.01759.x.
[37] V. Vallejo, P. Wyss, L. Rampa, A.V. Mitache, R.M. Müri, U.P. Mosimann, T. Nef, Evaluation of a novel Serious Game based assessment tool for patients with Alzheimer's disease, PLoS One 12 (2017) e0175999, , https://doi.org/10.1371/journal.pone.0175999.
[38] D.L. Kirkpatrick, J.D. Kirkpatrick, Evaluating Training Programs: the Four Levels, 3 ed., Berrett-Koehler Publishers, USA, 2006.
[39] D. Telner, M. Bujas-Bobanovic, D. Chan, B. Chester, B. Marlow, J. Meuser, A. Rothman, B. Harvey, Game-based versus traditional case-based learning: comparing effectiveness in stroke continuing medical education, Can. Fam. Phys. 56 (2010) e345–351.
[40] N. Rocha-Pereira, N. Lafferty, D. Nathwani, Educating healthcare professionals in antimicrobial stewardship: can online-learning solutions help? J. Antimicrob. Chemother. 70 (2015) 3175–3177, https://doi.org/10.1093/jac/dkv336.
[41] J. Sneddon, G. Barlow, S. Bradley, A. Brink, S.J. Chandy, D. Nathwani, Development and impact of a massive open online course (MOOC) for antimicrobial stewardship, J. Antimicrob. Chemother. 73 (2018) 1091–1097, https://doi.org/10.1093/jac/dkx493.
[42] WHO, Massive Online Open Course (MOOC) on Antimicrobial Stewardship, (2014) (Accessed February 16, 2019), http://www.euro.who.int/en/health-topics/disease-prevention/antimicrobial-resistance/news/news/2014/05/massive-online-open-course-mooc-on-antimicrobial-stewardship.
[43] F. Lateef, Simulation-based learning: just like the real thing, J. Emerg. Trauma

Shock 3 (2010) 348–352, https://doi.org/10.4103/0974-2700.70743.
[44] S.Y. Liaw, S.W.-C. Chan, F.-G. Chen, S.C. Hooi, C. Siau, Comparison of virtual patient simulation with mannequin-based simulation for improving clinical performances in assessing and managing clinical deterioration: randomized controlled trial, J. Med. Internet Res. 16 (2014), https://doi.org/10.2196/jmir.3322.
[45] L. Li, F. Yu, D. Shi, J. Shi, Z. Tian, J. Yang, X. Wang, Q. Jiang, Application of virtual reality technology in clinical medicine, Am. J. Transl. Res. 9 (2017) 3867–3880.
[46] P. Youngblood, P.M. Harter, S. Srivastava, S. Moffett, W.L. Heinrichs, P. Dev, Design, development, and evaluation of an online virtual emergency department for training trauma teams, Simul. Healthc. 3 (2008) 146–153, https://doi.org/10.1097/SIH.0b013e31817bedf7.
[47] M. Samadbeik, D. Yaaghobi, P. Bastani, S. Abhari, R. Rezaee, A. Garavand, The applications of virtual reality technology in medical groups teaching, J. Adv. Med. Educ. Prof. 6 (2018) 123–129.
[48] X. Pan, M. Slater, A. Beacco, X. Navarro, A.I.B. Rivas, D. Swapp, J. Hale, P.A.G. Forbes, C. Denvir, A.F. de, C. Hamilton, S. Delacroix, The responses of medical general practitioners to unreasonable patient demand for antibiotics - a study of medical ethics using immersive virtual reality, PLoS One 11 (2016) e0146837, https://doi.org/10.1371/journal.pone.0146837.
[49] E.A. Akl, K.M. Sackett, W.S. Erdley, R.A. Mustafa, M. Fiander, C. Gabriel, H. Schünemann, Educational Games for Health Professionals, Cochrane Database Syst Rev., 2013, p. CD006411, https://doi.org/10.1002/14651858.CD006411.pub3.
[50] P.S. Bhoopathi, R. Sheoran, Educational Games for Mental Health Professionals, Cochrane Database Syst Rev., 2006, p. CD001471, https://doi.org/10.1002/14651858.CD001471.pub2.
[51] G. Blakely, H. Skirton, S. Cooper, P. Allum, P. Nelmes, Educational gaming in the health sciences: systematic review, J. Adv. Nurs. 65 (2009) 259–269, https://doi.org/10.1111/j.1365-2648.2008.04843.x.
[52] E.A. Akl, R.W. Pretorius, K. Sackett, W.S. Erdley, P.S. Bhoopathi, Z. Alfarah, H.J. Schünemann, The effect of educational games on medical students' learning outcomes: a systematic review: BEME Guide No 14, Med. Teach. 32 (2010) 16–27, https://doi.org/10.3109/01421590903473969.
[53] M.E.W. Dankbaar, O. Richters, C.J. Kalkman, G. Prins, O.T.J. ten Cate, J.J.G. van Merrienboer, S.C.E. Schuit, Comparative effectiveness of a serious game and an e-module to support patient safety knowledge and awareness, BMC Med. Educ. 17 (2017), https://doi.org/10.1186/s12909-016-0836-5.
[54] R.A. Tubelo, F.F. Portella, M.A. Gelain, M.M.C. de Oliveira, A.E.F. de Oliveira, A. Dahmer, M.E.B. Pinto, Serious game is an effective learning method for primary health care education of medical students: a randomized controlled trial, Int. J. Med. Inform. 130 (2019) 103944, , https://doi.org/10.1016/j.ijmedinf.2019.08.004.
[55] M. Boeker, P. Andel, W. Vach, A. Frankenschmidt, Game-based e-learning is more effective than a conventional instructional method: a randomized controlled trial with third-year medical students, PLoS One 8 (2013) e82328, , https://doi.org/10.1371/journal.pone.0082328.
[56] S. Harbarth, M.H. Samore, Antimicrobial resistance determinants and future control, Emerg. Infect. Dis. 11 (2005) 794–801, https://doi.org/10.3201/eid1106.050167.
[57] J. Carlet, C. Rambaud, C. Pulcini, Save antibiotics: a call for action of the world alliance against antibiotic resistance (WAAAR), BMC Infect. Dis. 14 (2014), https://doi.org/10.1186/1471-2334-14-436.
[58] S.R. Arnold, S.E. Straus, Interventions to Improve Antibiotic Prescribing Practices in Ambulatory Care, Cochrane Database Syst Rev., 2005, p. CD003539, https://doi.org/10.1002/14651858.CD003539.pub2.
[59] P. Davey, E. Brown, E. Charani, L. Fenelon, I.M. Gould, A. Holmes, C.R. Ramsay, P.J. Wiffen, M. Wilcox, Interventions to Improve Antibiotic Prescribing Practices for Hospital Inpatients, Cochrane Database Syst Rev., 2013, p. CD003543, https://doi.org/10.1002/14651858.CD003543.pub3.
[60] WHO, Global Action Plan on AMR, WHO, 2019 (n.d.). http://www.who.int/antimicrobial-resistance/global-action-plan/en/ (Accessed February 23, 2019).
[61] T.F. Barlam, S.E. Cosgrove, L.M. Abbo, C. MacDougall, A.N. Schuetz, E.J. Septimus, A. Srinivasan, T.H. Dellit, Y.T. Falck-Ytter, N.O. Fishman, C.W. Hamilton, T.C. Jenkins, P.A. Lipsett, P.N. Malani, L.S. May, G.J. Moran, M.M. Neuhauser, J.G. Newland, C.A. Ohl, M.H. Samore, S.K. Seo, K.K. Trivedi, Implementing an antibiotic stewardship program: guidelines by the infectious diseases society of america and the society for healthcare epidemiology of america, Clin. Infect. Dis. 62 (2016) e51–e77, https://doi.org/10.1093/cid/ciw118.
[62] R. Tsopra, J.-P. Jais, A. Venot, C. Duclos, Comparison of two kinds of interface, based on guided navigation or usability principles, for improving the adoption of computerized decision support systems: application to the prescription of antibiotics, J. Am. Med. Inform. Assoc. 21 (2014) e107–116, https://doi.org/10.1136/amiajnl-2013-002042.
[63] R. Tsopra, J.-B. Lamy, K. Sedki, Using preference learning for detecting inconsistencies in clinical practice guidelines: methods and application to antibiotherapy, Artif. Intell. Med. 89 (2018) 24–33, https://doi.org/10.1016/j.artmed.2018.04.013.
[64] R. Tsopra, K. Sedki, M. Courtine, H. Falcoff, A. De Beco, R. Madar, et al., Helping GPs to extrapolate guideline recommendations to patients for whom there are no explicit recommendations, through the visualization of drug properties. The example of AntibioHelp® in bacterial diseases, J. Am. Med. Inform. Assoc. 26 (2019) 1010–1019.
[65] J. Krishnakumar, R. Tsopra, What rationale do GPs use to choose a particular antibiotic for a specific clinical situation? BMC Fam. Pract. 20 (2019) 178.