Assessing the impact of Medical Microbiology classes using active strategies on short- and long-term retention on medical students: an innovative study

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Abstract

One of teachers' concerns, with students in general and medical students in particular, is to ensure as much as possible that information goes from students' short-term memories to their long-term memories. The present study focuses on knowledge retention in Medical Microbiology and assesses the effectiveness of some strategies implemented for short- and long-term retention. A pre- and post-test was used to assess student's learning. This study involved students of Porto University (test group). Test group participants were all attending the third year of the Medicine Degree Program. The results of post-test 1 were considered very positive and support the importance of these applied active activities and/or methodologies in Medical Microbiology for short-term retention. However, the results obtained in post-test 2 showed that knowledge retention after 9 months, despite substantial, decreases.

Keywords Teachers · Medical students · Microbiology

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Introduction

The human memory is complex demanding periodic reviews for short- and long-term preservation of knowledge or skills. Conventionally, the human memory has been divided into two stages such as (a) short-term memory which represents storage of a limited amount of information (six to eight bits) for a limited time (usually less than 15 s) and (b) long-term memory defined as a memory of a longer duration [1]. Nonetheless, forgetting occurs regardless of both the skills or the material being taught, and the age or the background of the students. This phenomenon occurs at different time scales, from 1 week to the next and from one semester to the following.

For obvious reasons, the process of learning and retention of basic science information has crucial relevance in medical education. Recent studies revealed that medical students forget roughly 25–35% of the basic science knowledge after 1 year, more than 50% by the next year [2] and 80–85% after 25 years [3]. Thus, strategies used in basic medical science learning have been criticized since they are very theoretical. The magnitude of factual material, the lack of clinical relevance, and the inadequate connection between practical application of basic sciences to clinical conditions and the teaching methods used are just some of the points raised [4–6].

In our understanding, it is crucial to define effective learning strategies to promote long-term retention of knowledge and/or skills, although the effectiveness of most learning strategies remains unknown [7]. According to Pasher (2006), educational failures often reflect problems in retaining information over time, rather than in acquiring the information in the first place [8]. In this regard, it has been proposed that curricular strategies emphasizing content review are more effective when compared with the ones that strengthen initial learning [9]. Additionally, it was suggested that assessment has an impressive positive effect on future retention. Roediger and coworkers revealed that students which were assessed on material and successfully recall or recognize it kept that material in their memories longer than those who were not evaluated [10].

Conversely, active learning strategies can promote long-term retention, and these have been shown to yield better outcomes than traditional learning [11, 12]. According to Kvam, long-term memory is enhanced by using active learning where the student is familiarized with the material through real examples [13]. Active learning techniques could include demonstrations/simulations, peer review, discussion, problem-solving using real data, “just in time” teaching, laboratory work under guidance, and team-based learning (TBL). In a previous work, it was referred that the inclusion of laboratory work and hands-on activities in Science Educational programs were of strong value in Science Education [14]. A meta-analyze study developed by Freeman and coworkers indicated that students in classes with traditional lecturing were 1.5 times more likely to fail than students in classes applying active learning methodology [15]. This study

demonstrated that active learning increases examination performance in STEM. Wieman deepened the work of Freeman concluding that active learning methodology achieves better educational outcomes compare to traditional methods [16]. During active learning, students are spending a substantial part of the class time making activities that require them to be actively processing and applying information, such as answering questions using electronic clickers, completing worksheet exercises, and discussing and solving problems with colleagues [16].

It was described that incorporating an active learning strategy in a Pharmacology course concerning antimicrobial compounds leads to a significant increase in long-term performance comparatively to traditional lectures [17]. A study performed by Nelson and coworkers also demonstrates that an active curriculum implemented in pediatric residents was effective in teaching evidence-based medicine and promote long-term retention [18].

Demonstrations help students understand and remember new concepts, mainly when teachers try to explain complex topics such as those that can occur in sequential steps [19]. Sheakley and collaborators demonstrate that the combination of simulation and lecture increase short-term understanding [20]. The application of TBL in health education was reviewed by Ofstad and Brunner and the conclusion was that the use of TBL improves students’ engagement, communication, and knowledge retention [21]. A recent work also showed that TBL can be an effective method for teaching applied pharmacokinetics [22].

Several departments in the Portuguese University system have reformulated their undergraduate curricula to provide more hands-on research activities for their students, while several other units are pursuing technological approaches to improve teaching and learning. The faculty of “Land and Food Systems” has created a web-based simulation program called “Green Genes,” to aid students the understanding of in genetics understanding [23], which according to a recent oriented research laboratory work seems to be valuable in Science Education [24].

An educational program developed by O’Connel and collaborators 1992 assessed short- and long-term retention concerning a metered-dose inhaler technique. The study demonstrated that after 2 months, the scores were lower than immediately after the program test, ranging from 0 to 92 points in verbalization and 10–80 points in what concerns demonstration. The authors concluded that this educational program significantly improved the use of the metered-dose inhaler. These authors also recommended that the program should be recurrent to maintain the levels of retention [25].

In summary, medical students are continuously reminded to build a concrete basis in a certain subject and learn how to apply this knowledge in their clinical practice. The present study focuses on knowledge retention in Medical Microbiology and assesses the effectiveness of some strategies implemented by Portuguese Microbiology teachers for short- and long-term retention.

The goals of the current study were (i) to evaluate the knowledge on Medical Microbiology contents before the Medical Microbiology classes start, (ii) to investigate to which extent medical microbiology students retain basic knowledge after medical microbiology classes, (iii) to infer the effectiveness of the applied strategies, and (iv) to conclude about knowledge retention along time.

A pre- and post-test questionnaire covering several Medical Microbiology topics was used to assess student's learning. The pre-test was applied in the begin of the semester and a post-test was applied twice: post-test 1 at the semester's end (after 4 months) and post-test 2, 5 months later at the end of the following semester (Fig. 1).

- The initial background knowledge (T0) of the students in Medical Microbiology is acceptable;
- Students' short-term (T1) and long-term (T2) retention in the test group is considerably higher than the initial background (T0);
- The knowledge acquired is progressive along the study T1 vs T2;
- In the test group, student's short-term (T1) and long-term retention (T2) is considerably higher than students of the control group.

Methods

Research questions

The research questions addressed in this study try to confirm the following hypotheses:

Participants

The study took place between October 2014 and June 2015 and involved students from two Portuguese universities: University 1—second year of Environmental Sciences Degree Program (control group; $n = 30$) and University 2—third year of Medicine Degree Program (test group; $n = 127$). The students from the control group only attend the discipline of Microbiology in the third year.

Fig. 1 Outline of the study, goals, contents, strategies, and competencies

Test group participants were all attending the third year of Medicine Degree Program (Table 1).

The control group corresponds to about 95% of the total students of the second year of Environmental Sciences Degree Program (Table 1). The large percentage of adherence to the questionnaire in the control group was likely due to the fact that this control test was implemented by the Director of Environmental Science Degree. We choose the control group based on the fact that this group attended the same subjects in Secondary School as the test group and at this moment in the university they have not contacted yet with the subject of Microbiology. The control group did not receive any treatment.

Ethical approval for the study was obtained from both universities. The student's participation was voluntary and anonymous. Participants were informed about the study and it was assured that the anonymity was respected. There were no refusals to participate.

Data collection and analysis

The quantitative results of this study were obtained through three-time application of a questionnaire during regular classes of Medical Microbiology. We measured the questionnaire validity by means of a pilot study with 10 medical students from the same scholar level. The questionnaire was revised based on the recommendations of these students prior to administration. The pre-test was applied in the first class of the semester (October), and the two post-tests, the first at the end of the semester (February) and the second after 5 months (July-Second Semester) (Fig. 1). Figure 1 shows the outline of this study, goals, contents, strategies, and competencies.

The questionnaire contained 26 questions covering several topics (Fig. 2). Questions were constructed by the authors involved in this study and was answered during a regular class of Medical Microbiology course, within 20 min.

Questions QA-B were personal (gender, age), and the remaining questions are depicted in Supplementary Tables 2 and 3 and include the following topics: examination by light microscopy [1], selection of biological samples to be taken and how to be harvested [2, 9], distinction between Gram-negative

and Gram-positive bacteria [3], culture media composition and sterilization methods [4, 5, 21], microbial identification techniques, methods of direct diagnosis and antimicrobial susceptibility testing [6, 8, 20], criteria for antimicrobial therapeutic selection [7], agents related to gastroenteritis [10], microbial agents related to sexually transmissible infections [11], etiological agent of stomach cancer [12], microbial agent transmitted through air conditioning ducts [13], Gram-positive bacteria characterization [14, 22], etiology of *Vibrio cholera* infection [15], *Escherichia coli* phenotypic characterization [16], tuberculosis in Portugal [17], fungi characterization [18], virus characteristics [19], definition of metabolism [23], kinetics of microbial growth [24], transmission of genetic material in bacteria [25], and microbial genomes [26].

The issues addressed in the questionnaire do not possess equal clinical practice relevance. We consider that the answers to questions 2, 3, 6–10, 12–15, 17, 19, 20, and 22 are crucial for the clinical practice of all the general medical practitioners. Answers to questions 1, 5, 16, 18, 21, 24, 25, and 26 are more specific, and are more relevant for Pathologists or Medical Researchers. For this reason, we gave particular emphasis to the first group of questions [2, 3, 6–10, 12–15, 17, 19, 20, 22].

The variables distribution was assessed by histogram evaluation. Since variable distribution was not asymmetric, non-parametric tests were used. Friedman test was performed for the comparison between T0, T1, and T2 in both control and test groups. Wilcoxon Signed Ranks Test was used for the comparison between T0 and T1, and T1 and T2. For the comparison of the test and control groups for T0, T1, and T2, the Mann-Whitney *U* test was used. All statistical analysis were performed using the SPSS statistical software (v. 23.0).

Intervention

In Medical Microbiology classes, the teaching/learning strategies used are diversified. They are mainly student-centered (active learning), which is in accordance with the Bologna Declaration. This model provides the students to develop different specific skills defined to obtain a degree in Medicine, and also to gain a set of generic skills related to study design, biostatistics, teamwork, technology use, and autonomous and responsible performance of experimental work. Microbiology teachers of this faculty implemented frequently several active activities such as video films, PowerPoint presentations with analysis and discussion, guided laboratorial work, presentation and discussion of scientific publications, usually known as Journal-clubs, teamwork with the help of informatics tools, demonstrations/simulations, student presentations, and problem-solving situations in order to carefully explore the contents covered. All the experimental protocols implemented are previously discussed. The theoretical and practical classes of Microbiology were structured around the themes focused in the pre-test, requiring an active participation of students, a

Table 1 Characterization of the test and control groups

Class	No. of students	Age
Test group		
Students from Medicine (3rd year) Faculty of Medicine, University of Porto	127	19–24
Control group		
Environmental Sciences students (2nd year) University of Minho	30	19–23
Total	157	19–24

Fig. 2 **a** Radar map showing the variation in the percentage of correct answers in the study group between the pre-test, post-test 1, and post-test 2 (Results for crucial questions). **b** Radar map showing the variation in the percentage of correct answers in the study group between the pre-test, post-test 1, and post-test 2 (Results for all the questions)

continuous self-learning approach, and an encouraged teamwork. The theoretical approach is complemented with practical lectures, where students should acquire important skills such as teamwork, scientific experimental design, as well as analysis and interpretation of data. During the semester students performed intercalary evaluations since they answered three quizzes.

Results

Control group

In general, the initial background of the control group is limited (Supplementary Table 2, Fig. 3). In the control group, no significant improvements were detected between the pre-test and post-test 1 ($p = 0.849$), with the exception of the Q17 (Supplementary Table 2, Fig. 3). The comparison between

post-test 1 and post-test 2 did not reveal statistically significant differences ($p = 0.315$), although there was an increase in the percentage of correct answers for the questions Q1, Q6, Q9, Q14, Q16, Q18, and Q20 (Supplementary Table 2, Fig. 3).

Test group/control group

There are significant differences between the scores obtained by the students in test group and the students in control group concerning the initial background (T0) ($p = 0.002$) and short-term (T1) ($p < 0.001$) and long-term knowledge retention (T2) ($p < 0.001$) (Supplementary Tables 2 and 3).

Test group

For most questions, the initial background of medical students in terms of percentage of correct answers was greater than 40%, with exception of questions Q1, Q5, Q6, Q17, Q21,

Fig. 3 Radar map showing the variation in the percentage of correct answers in the control group between the pre-test, post-test 1, and post-test 2 (Results for all the questions)

Q22, and Q26 (Fig. 2a, b, Supplementary Table 3). The data collected in post-test 1 showed a significant improvement for all crucial questions ($p < 0.001$) (Supplementary Table 3, Fig. 2a).

Regarding post-test 1, the data collected showed an improvement in the percentage of correct answers for all the questions $p < 0.001$ (Supplementary Table 3, Fig. 2b). Statistically significant differences between post-tests 1 and 2 were found ($p < 0.001$). However, a decrease in the number of correct answers was observed for questions Q1, Q5, Q7, Q8, Q14, Q19, Q20, Q22, Q24, Q25, and Q26, between post-tests 1 and 2 (Fig. 2a, b, Supplementary Table 3).

Regarding questions Q2, Q3, Q6, Q8, and Q9 considered of extreme importance, the initial student's background was high, (except for Q6), which maintained a low number of correct answers both in post-tests 1 and 2 (Supplementary Table 3). Concerning the results observed for Q10, Q12, and Q13 was quite satisfactory (Supplementary Table 3, Fig. 2a, b). However, was observed a high score in the Q13 in the pre-test (Supplementary Table 3). On the topic of tuberculosis (Q17), only 9% of the Medical students in the pre-test answered correctly, and a small increase was detected in post-tests 1 and 2 (23% of correct answers) (Supplementary Table 3, Fig. 2a, b). Relatively to Q19 "Virus features," the initial background was apparently high (83%), the percentage of correct answers increased in post-test 1, but decreased in post-test 2 (Supplementary Table 3). Conversely, the initial background on the topic addressed in Q20 was moderate, with a significant increase in post-test 1. However, a decrease in the number of correct answers was detected in post-test 2 (Supplementary Table 3). Q22, displayed quite satisfactory results in post-test 1. Once again, the percentage of correct answers in post-test 2 decreased significantly comparatively to post-test 1 (Supplementary Table 3, Fig. 2a, b). Relatively to Q1, Q5, Q16, Q18, Q21, and Q25, the results obtained in

the pre-test were significantly improved in post-tests 1 and 2 (Supplementary Table 3, Fig. 2a, b).

Discussion

Fundamental science is crucial for the society; however, applied science such as medical science developments are indispensable, to provide the translation of science in health and consequently in economic improvements. The quality of the medical education in Portugal is considered excellent, and the Portuguese medical doctors are recognized worldwide for their quality and competency (World Certificate ASPIRE, Award Corino de Andrade). In order to analyze the profile of Medical students in Microbiology contents, we design a study in one Faculty of Medicine (Portugal).

We investigated the initial background of Medical students in Medical Microbiology contents and the role of the active learning strategies implemented in the promotion of short- and long-term retention. We used a convenience sample of students which enabled a rapid collection of data in short amount of time with limited resources. Information on socio-economic and intellectual level of the participants was not collected.

There are significant differences between the scores of the students in the test group and the students in the control group concerning the initial background (T0) ($p = 0.002$) and short-term (T1) ($p < 0.001$) and long-term knowledge retention (T2) ($p < 0.001$). Although the initial background of the test group is higher than the control group, these contents were not yet addressed at the university, this is likely due to the fact that test group students entered the University with very high marks and some of these contents were explored in the secondary school.

In general, the initial background of the Medical students is acceptable. For most questions, the percentage of correct answers was greater than 40%, with exception of questions Q1, Q5, Q6, Q17, Q21, Q22, and Q26. This percentage of correct answers in the pre-test was not such a big surprise since these students in order to be accepted in such Degree Program did undergo through a demanding Secondary School Education (the average rating for admission into Medical Schools in Portugal is very high, around 18.5 points in 20). The percentage of correct answers to the questions Q1, Q5, Q6, Q17, Q21, Q22, and Q26 was below 40%, which is understandable since most of these issues are out of the Biology program taught in the secondary school. The data collected in post-test 1 showed a significant improvement for all crucial questions ($p < 0.001$) (Supplementary Table 3, Fig. 2A). As mentioned before, we consider the questions 2, 3, 6–10, 12–15, 17, 19, 20, and 22 crucial for all Medical doctors in their clinical practice and for this reason, we will discuss them with particular emphasis of the answers. Regarding post-test 1, the data collected showed

an improvement for all the questions $p < 0.001$ (Supplementary Table 3, Fig. 2b). Statistically significant differences between post-tests 1 and 2 were found ($p < 0.001$); however, a decrease in the number of correct answers was observed for questions Q1, Q5, Q7, Q8, Q14, Q19, Q20, Q22, Q24, Q25, Q26, between post-tests 1 and 2 (Fig. 2a, b, Supplementary Table 3). Since post-test 1 was applied at the end of the semester, on the assessment day, the results obtained were very positive. Medical students studied these subjects carefully to do the exam and carried out the questionnaire immediately afterwards. After studying the subjects, the students should know the contents better which reflected the short-term memory.

Questions Q2, Q3, Q6, Q8, and Q9 may be crucial for correct diagnosis and applied therapeutics. Regarding these aspects, the initial student's background was high, except for Q6, which maintained a low number of correct answers both in post-tests 1 and 2. The relevance of this question for medical practice is clear; doctors need to know which methodology should be used for microbial identification. In this regard, we suggest that this content should be considerably reinforced in the future. On the other hand, Q7 is of extreme relevance in order to prevent microbial resistances, and despite the satisfactory results obtained in pre-test 1, post-test 2 showed a significant decrease in the number of correct answers. Data from the literature revealed that antibiotics are among the most commonly prescribed medications; however, they are very often misused [26, 27], and the indiscriminate use of antibiotics has contributed to the progressive loss of bacterial susceptibility and spreading of bacterial resistant strains [28]. In the UK, 30% of adults believe that antibiotics can be effectively used to treat coughs and colds [29, 30], and a more embracing study revealed that 60% of the Europeans do not know that antibiotics are ineffective against viruses [31]. In Portugal, studies performed in schools at different educational levels had also shown a limited of knowledge about antibiotics and their correct use [32], which may be attributed to insufficient formal education on this topic [32]. In Europe, the lowest levels of bacterial resistance have been verified in Scandinavian countries, Great Britain, and Netherlands, probably due to the strict guidelines [33, 34]. With this in mind, it is imperative to reinforce the active strategies used in Medicine Degree Programs, mainly the discussion of clinical cases and laboratory work. A research work developed by Bonwell and Eison 1991 defined active learning as “instructional activities involving students in doing things and thinking about what they are doing” [35]. Active learning has been shown to yield better outcomes than traditional learning [11, 12]. On the other hand, lectures using PowerPoint presentations, notes, and multiple-choice tests seems to encourage short-term retention [36]. Furthermore, much has been written about the benefits generated by active participation in collaborative work compared with traditional lecturing

[37]. This association can be summarized as a more real development of high-level thinking processes, a more effective learning, a greater knowledge/skills retention, a higher degree of student's satisfaction, and/or higher self-esteem [28, 38–42]. According to recent studies, the benefits of active learning were consistent across the STEM disciplines [15, 16]. The results that emerge from these studies have important implications for the future of STEM teaching and STEM education research [15, 16]. The results observed for Q10, Q12, and Q13 were quite satisfactory in all tests. We observed a high score in Q13 in the pre-test, and we attributed this result to a recent episode of Legionellosis in Portugal, which has been broadcasted by daily media.

On the topic of tuberculosis, a notifiable disease in Portugal, only 9% of the Medical students in the pre-test answered correctly, and a small increase was detected in post-tests 1 and 2 (23% of correct answers). Tuberculosis is one of the most damaging infectious diseases and has resurged during the last decade in many industrialized countries. New strains of *Mycobacterium tuberculosis* that are resistant to one or more antibacterial compounds are emerging [43]. This disease induces high mortality rates in the world, killing 2 to 3 million patients each year [44]. After the analysis of the obtained scores, it is an intention of all the microbiology teachers of this faculty to revise and reinforce this subject, because resistant strains are also emerging in Portugal. Q19, addressing “Virus features,” revealed that the initial background on this topic was apparently high (83%). The percentage of correct answers increased in post-test 1, but decreased in post-test 2. Conversely, the initial background of the students in the topic addressed by Q20 was moderate, with a significant increase in post-test 1. This was probably due to the persistence of the teachers to apply active methodologies. However, a decrease in the number of correct answers was detected in post-test 2. Q22 displayed quite satisfactory results in post-test 1. The majority of the students realized the importance of looking for *Streptococcus agalactiae* in the third trimester of pregnancy to avoid infections in newborn. Once again, the percentage of correct answers in post-test 2 decreased significantly comparatively to post-test 1.

In general, the scores obtained in post-test 1 were higher than the obtained in post-test 2, since post-test 1 was applied on the assessment day. After studying the subjects, the students should know the contents better; these results reflected the importance of testing. According to the literature, testing as an active element of learning is more effective than studying the factual knowledge repeatedly [45]. The worst results obtained for several questions in post-test 2 are in agreement with the literature. A short training course in Pharmacotherapy was administered to 219 undergraduate medical students in Netherlands, Nepal, Nigeria, Australia, India, the USA, and Indonesia. The impact of this course measured in three stages showed that both the transfer and the retention effect were

maintained at least 6 months after the training session in all of the seven medical schools, enlightening continuous education as a powerful tool for teaching antibiotics [46]. Another study conducted by Custers 2010 provides an excellent review on basic science knowledge retention in general and in medical education in particular [2]. The examination of these types of knowledge retention studies yields controversial results, with some indicating a great deal of knowledge retention and others reveals significant loss of knowledge over time [2]. Naturally, people forget much of what they have learned; therefore, it is crucial that students are challenged by learning strategies that yield long-term knowledge. Thus, it is crucial to define new and better learning strategies that can promote long-term retention. Specht and Sandlin also emphasized the importance of active learning in student's retention of the concepts over the time [47].

Questions Q1, Q5, Q16, Q18, Q21, and Q25 are very specific and especially relevant to future Pathologists or Medical researchers. The results obtained in the pre-test were significantly improved in post-tests 1 and 2, which is tempting to associate to the used active methodologies.

In general, we may classify the initial background of the control group as frail. In the control group, no significant improvements were detected between pre-test and post-test 1 ($p = 0.849$), with the exception of Q17. The comparison between post-test 1 and post-test 2 did not reveal statistically significant differences ($p = 0.315$), although there was an increase in the percentage of correct answers for questions Q1, Q6, Q9, Q14, Q16, Q18, and Q20. The outcomes of this study regarding the control group are in agreement with the ones reported by Nemati, which indicated that the performance of the experimental groups was higher than that of the control groups due to the strategy applied [5].

This study has some limitations such as the choice of the control group (is the possible), and not the most appropriate in terms of participants' number and background. Since the sample size of the control group was limited, comparisons between control and test group may be underpowered. In a follow-up study, the use of higher samples for the control group is recommended.

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