OMARC: An Online Multimedia Application for Training Health Care Providers in the Assessment of Respiratory Conditions

Oscar Meruvia-Pastor[1,5§], Pranjal Patra[1], Karen Andres[2], Creina Twomey[3], Lourdes Peña-Castillo[1,4]

[1] Department of Computer Science, Faculty of Science, Memorial University of Newfoundland, St John's, NL, Canada
[2] GI/Hepatology South Health Campus, Calgary, AB, Canada
[3] School of Nursing, Memorial University of Newfoundland, St John's, NL, Canada
[4] Department of Biology, Faculty of Science, Memorial University of Newfoundland, St John's, NL, Canada
[5] Office of the Dean of Science, Faculty of Science, Memorial University of Newfoundland, St John's, NL, Canada

[§]Corresponding author:
Dr. Oscar Meruvia-Pastor
Assistant Professor
Department of Computer Science,
Office of the Dean of Science,
Faculty of Science,
Memorial University of Newfoundland

E-mail: Oscar-at-mun-dot-ca

Accepted Manuscript License: Creative Commons CC BY NC ND
Final Version available at: http://dx.doi.org/10.1016/j.ijmedinf.2016.02.007

ABSTRACT

Objectives

OMARC, a multimedia application designed to support the training of health care providers for the identification of common lung sounds heard in a patient's thorax as part of a health assessment, is described and its positive contribution to user learning is assessed. The main goal of OMARC is to effectively help health-care students become familiar with lung sounds as part of the assessment of respiratory conditions. In addition, the application must be easy to use and accessible to students and practitioners over the internet.

System Description

OMARC was developed using an online platform to facilitate access to users in remote locations. OMARC's unique contribution as an educational software tool is that it presents a narrative about normal and abnormal lung sounds using interactive multimedia and sample case studies designed by professional health-care providers and educators. Its interface consists of two distinct components: a sounds glossary and a rich multimedia interface which presents clinical case studies and provides access to lung sounds placed on a model of a human torso. OMARC's contents can be extended through the addition of sounds and case studies designed by health-care educators and professionals.

Validation and Results

To validate OMARC and determine its efficacy in improving learning and capture user perceptions about it, we performed a pilot study with ten nursing students. Participants' performance was measured through an evaluation of their ability to identify several normal and adventitious/abnormal sounds prior and after exposure to OMARC. Results indicate that participants are able to better identify different lung sounds, going from an average of 63% (S.D. 18.3%) in the pre-test evaluation to an average of 90% (S.D. of 11.5%) after practising with OMARC. Furthermore, participants indicated in a user satisfaction questionnaire that they found the application helpful, easy to use and that they would recommend it to other persons in their field.

Conclusions

OMARC is an online multimedia application for training health care students in the assessment of respiratory conditions. The software integrates multimedia technology and health-care education concepts to facilitate learning, while being useful and easy to use. Results from a pilot study indicate that OMARC significantly helps to improve the capacity of the users to correctly identify lung sounds for different respiratory conditions. In addition, participants' opinions about OMARC were quite positive: users were likely to recommend the application to other persons in their field and found the application easy to use and helpful to better identify lung sounds.

KEYWORDS

Online Multimedia Applications; Respiratory Health Assessment; Education and Training towards Lung Sounds Assessment, Usability and User Satisfaction Questionnaire

1. INTRODUCTION

As part of a patient's physical assessment, health care providers such as nurses and physicians are often faced with the problem of correctly characterizing sounds from the chest/thorax, typically using a stethoscope. Most of the currently available training resources associated with health assessment come from traditional learning resources, such as textbooks. Sometimes these textbooks also have sounds and videos provided in audio CDs or DVD-ROMs [1,2,3,8,9]. These are valuable resources; however, often the sounds are presented in isolation of a clinical scenario which would enhance comprehension of the materials to be learned. In some higher education institutions, students may have access to life-size training computer-operated mannequins which may cost from several hundreds to thousands of dollars [4,5,6,7]. The price of these training mannequins and the complexity of setting them up limit their accessibility. In many cases, students have opportunity to use these resources only a couple of times during a course. On the other hand, educational tools such as mobile apps have been shown to be similarly effective to a high-fidelity human patient simulator with regards to retaining new knowledge and teaching cardiopulmonary assessment skills, as indicated by Yoo and Lee [34]. In this work we introduce OMARC, an online multimedia application designed to support the training of health care professionals to identify and assimilate lung sounds. OMARC stands for Online Multimedia Application for the Assessment of Respiratory Conditions. By developing OMARC, this research explores the use of multimedia applications for training health care providers to identify sounds from a patient's thorax (i.e. the chest region). Since practicing health care professionals may also need to refresh these same skills from time to time, they are also a target audience for OMARC and we certainly expect that they would also benefit from it.

In addition to addressing the limitations of existing training material, a major consideration that this research aims to address is the possibility of offering a training application that is available to people who might be at a remote location, a rural setting, or studying online, and might not have ready access to the facilities and resources of higher education institutions such as universities or colleges. Our proposed solution for these circumstances is to make the multimedia training application available over the internet by using a widely available multimedia platform to present web-based applications. From a remote location, any smartphone, tablet or other internet-enabled computer or device with a web browser and the Flash Player installed, would allow users online access to OMARC.

The prototype developed during this research project integrated lung sounds with interactive multimedia elements in the context of a clinical setting describing two case studies. These case studies described the change in the patient's condition through multiple visits to the health-care provider. The prototype has been developed in Adobe's Flash Builder and ActionScript [17] and has a database back-end which is accessed through Apache [18], MySQL [19] and PHP [20]. There are numerous applications currently available for accessing lung (and heart) sounds, including some that can be used in multiple platforms and are free to download [10,11,12,13,14,15,16]. However, pulmonary auscultation findings must be interpreted carefully and put into context with other clinical findings [42]. What makes OMARC unique is that it presents a narrative about abnormal lung sounds, using interactive media showing the locations in the chest where these sounds are usually found, and describing the patient conditions that are associated with these sounds via sample case studies designed by professional nursing practitioners and educators, whereas other software simply presents the sounds in isolation without any additional information.

OMARC offers a truly interactive multimedia experience that integrates educational technology a way that is affordable and easy to use but most importantly, facilitates learning. OMARC has been used to perform a pilot study to find out whether it actually addresses the limitations of traditional learning resources, while avoiding the costs and accessibility limitations of high-cost training solutions such as mannequins. The participants in the study were ten first year nursing students at Memorial University of Newfoundland. The case studies presented to the participants were fictional case studies developed by Dr. Karen Andres and Dr. Creina Twomey, and the sounds used were licensed for research and academic use from the audio CD of "Auscultation Skills: Breath and Heart Sounds" by Wolters Kluwer Health [2]. The application was designed and implemented by Mr. Pranjal Patra and Dr. Oscar Meruvia and the statistical analysis of the results of the study was done by Dr. Lourdes Peña-Castillo. The user study was reviewed and approved by Memorial University Interdisciplinary Committee in Ethics in Human Research ICEHR # 20141133-SC.

In the pilot study we found that the multimedia software application is associated with an improvement in the user's ability to identify the different types of lung sounds, when compared to the use of a sounds glossary. Not only did the results of the pilot study show a statistically significant improvement in the trainees' ability to identify lung sounds, but feedback from the participants was overwhelmingly positive. For instance, 70% of participants stated that the application helped them learn the sounds or that they would recommend the application to other persons in their field.

This research project started out as a vision to improve the current learning resources available for nursing students to gain expertise in health assessment in a way that is innovative, accessible and affordable. As noted by Ribbons [31], in an environment of increasing economic constraint, it is necessary for nurse educators to design and implement cost-effective teaching and learning strategies. We found lung sounds assessment is one of the most important elements to teach students learning health assessment [42,43]. Different approaches to solve the problem were considered and initially it was devised that something in the format of a serious game could be attempted [21,22,23,24,25,26,27]. However, there are several existing serious games for health professionals and serious games development requires more human and material resources than the ones available for this project. Hence, we chose to develop a multimedia application to support lung sounds assessment. Multimedia computer-based learning tools have been previously created for pulmonary auscultation, and there is evidence that multimedia training improves learning and performance skills [36,37,38]. For example, Sestini et al.[36] found that medical students who attended a multimedia seminar on lung sounds during which digitized lung sounds were played and the corresponding time-expanded waveform and frequency spectrum were commented on and displayed on a computer, had significantly lower inaccuracy score than those students who did not attend the multimedia seminar. However, none of these multimedia tools present lung sounds within the context of case studies in the way OMARC does.

As we worked through the design of the software, it became evident from early on that we could not just simply introduce a new application to the community but that it had to be shown that the application enhanced student learning related to health assessment. Based on a review of the state of the art, it is clear that that there are many websites and mobile apps focused on health assessment and student learning [10,11,12,13,14,15,16]. However, few of these tools have been shown to enhance student learning. This shortcoming has already been pointed out by Yoo and Lee [34]. In their study, students using a mobile app retained their knowledge of lung assessment longer than students using a high-fidelity human patient simulator. A contribution similar to OMARC is that presented by Hou et al. [35], where a computer-aided learning system for assisting teachers and nursing students in auscultation techniques was developed. It allows teachers to record lung sounds and to provide these sounds with additional figures and videos, allowing nursing students to self-study auscultation techniques. Their results from a user study with 15 nursing students show that auscultation abilities of the students were significantly improved by using the computer-aided learning system. Compared to their system, OMARC is designed to work online and additionally enriches the learning experience through the introduction of case studies, which provide contextual information about the circumstances that might be present when the sounds are heard. An important outcome of this work is the objective evaluation of the benefit to student learning and the objective demonstration that this is an application that actually works for health-care students.

Since the main motivation for the development of OMARC is to improve the learner's abilities to assess the health of their patients, we provide evidence that the software developed serves the purpose for which it was designed.

The primary hypothesis of this pilot study (H1) is that OMARC helps users become better at assessing lung sounds after exposure to the application, compared to exposing the students just with a glossary of sounds which allows them to hear the sounds and read a description of each of them. This glossary represents a traditional companion resource provided with some textbooks.

From a multimedia application design perspective, it is important to establish the quality of the different elements of the multimedia application and their success in connecting the academic goals with the goals of ease of use and usability in one application, so we generated a set of secondary hypotheses to understand more precisely the participants' perception of the application:

Hypothesis 2.1 (H2.1): Users will prefer the case studies with an interactive thorax model over the sounds glossary.

Hypothesis 2.2 (H2.2): Users will find the multimedia application easy to use.

Hypothesis 2.3 (H2.3): Users will find that the multimedia application helped them better understand lung sounds compared to the written glossary.

Hypothesis 2.4 (H2.4): Users are likely to recommend the multimedia application to other persons in their field.

To test the main hypotheses (H1) we first evaluated the participants' understanding of lung sounds after going through the sounds glossary, which presents sounds and their description in a list format where they can hear the sounds and read their descriptions as provided by a textbook publisher, without case studies and without an interactive thorax model. After exposure to the sounds glossary and participants' skills evaluation, we asked participants to complete a series of steps by which they went through the other elements of the multimedia application, which included the case studies and the interactive thorax model. Participants were asked to go through two fictional case studies which depicted scenarios where a patient makes several visits to a health-care provider and the participants are asked to listen to different sounds placed on the chest and lung regions. After exposure to the application, participants were evaluated once again to measure if there has been an improvement from using OMARC.

To test the second set of hypotheses (H2.1 – H2.4) participants were asked to provide answers to several interface-related questions in the Likert scale. Once participants completed the questionnaire, they were asked to provide unstructured feedback.

2. System Description

2.1 Interface Design

The interface has been designed with the goal of providing an interactive experience for the users as they learn about lung sounds, with special consideration of being intuitive and easy to use, as the target audience is not expected to be made of expert computer users. The interface of the application contains two main types of components: the sounds glossary and case studies. There is only one sounds glossary, but there can be multiple cases studies. Case studies contain interactive chest diagrams with playable sounds that can be placed in different regions of the thorax and descriptions of the interactions between a patient and the health care provider as the patient is assessed over several visits (or interactions). Case studies integrate both textual information and interactive chest diagrams in such a way that the user or trainee can go through the evolution of a patient's history as he or she meets the health care provider and at the same time, the trainee can go to the chest diagram of the patient and listen to the sounds which are associated with the case study being described. The chest diagram can be explored both in anterior and posterior views and different sounds can be heard for either view at different locations, depending on the condition illustrated.

2.2. Implementation

The system was implemented using Adobe Flash Builder for the front end and communicates with a MySQL database at the back end through the WAMP server. An important reason to use Flash was its high market penetration of 99% on personal computers [29] and rapidly growing adaptation on the mobile smartphone/tablets arena [30]. When designing the front end we aimed at creating an interface that was intuitive for an audience with a widely varying level of familiarity when it comes to using computer programs. The primary roles of the back-end side of OMARC were to provide a means of storing details about the specifics such as users, sounds, case studies (or scenarios) and evaluations, and a way to serve the pages quickly, securely and consistently with acceptable serving times. In the next sections we describe the main components of the interface in more detail.

2.3. Sounds Glossary

The sounds glossary contains textual descriptions of normal and abnormal/adventitious sounds and the actual sound files. The goal of the glossary is to present a central location where all the sounds in the application are listed and can be studied individually, similar to what is provided as companion material in some textbooks. Figure 1 shows a snapshot of the Sounds Glossary, which is the component shown by default when the user accesses the interface for the first time. For each sound in the glossary there are two sound files. The first contains the actual sound that corresponds to the condition, and the second sound file is the publisher's audio explanation for the sound. When the user clicks on any of the sound names or descriptions the system plays the sound.

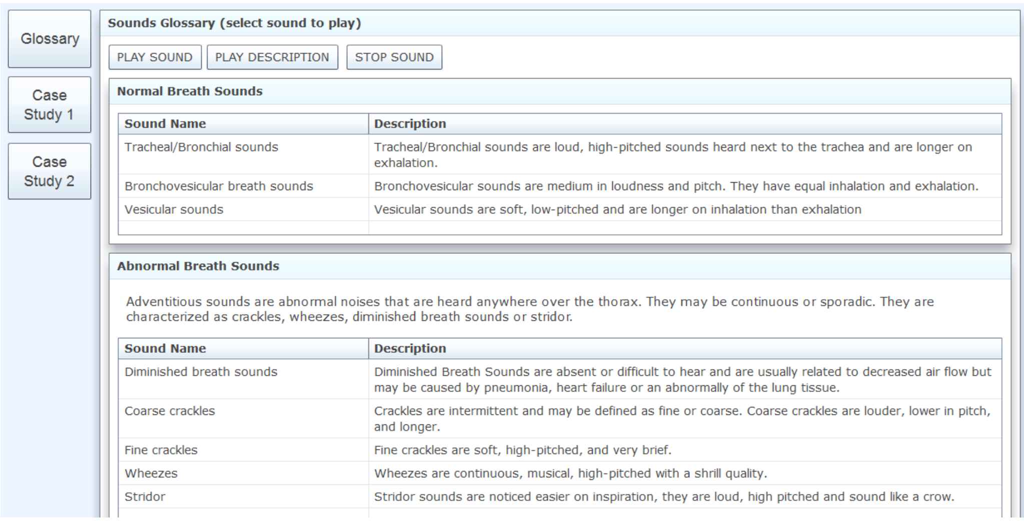


Figure 1: The Sounds Glossary Component. It lists a series of playable sounds by name with a textual description on the right side.

2.4. Case Studies

The case studies component presents a more realistic experience illustrating some important aspects of the process that a health care provider is expected to go through as a patient arrives, is assessed and treated, all the way through his or her discharge. Figure 2 shows a snapshot of the case studies component.

Case studies illustrate multiple visits of a patient to a health care provider. The number of visits is decided by the designer of the case study. Each of the visits in the case study is accessed through the tabs at the top of the component. Each tab is labelled according to the type of visit, such as “regular check-up” or “Emergency room visit”. For each visit, the case study contains a textual description of a patient’s history and condition, along with any relevant information for that particular visit that the designer of the case study determines. Under the textual description of the visit, an illustrated model of the patient’s chest is presented where the user can explore in more detail the sounds resulting from the auscultation of the patient’s chest. This sound exploration component is at the heart of the multimedia experience and it is where the user gets to hear the sounds described in the visit at the correct anatomical location, set by the designer of the case study. The number and arrangement of these buttons can be chosen from a set of standard auscultation regions typical of a lung health assessment, shown in Figure 4, but it is also possible to show buttons for only a handful of these locations at the anterior or posterior views, as illustrated in Figures 2 and 3.

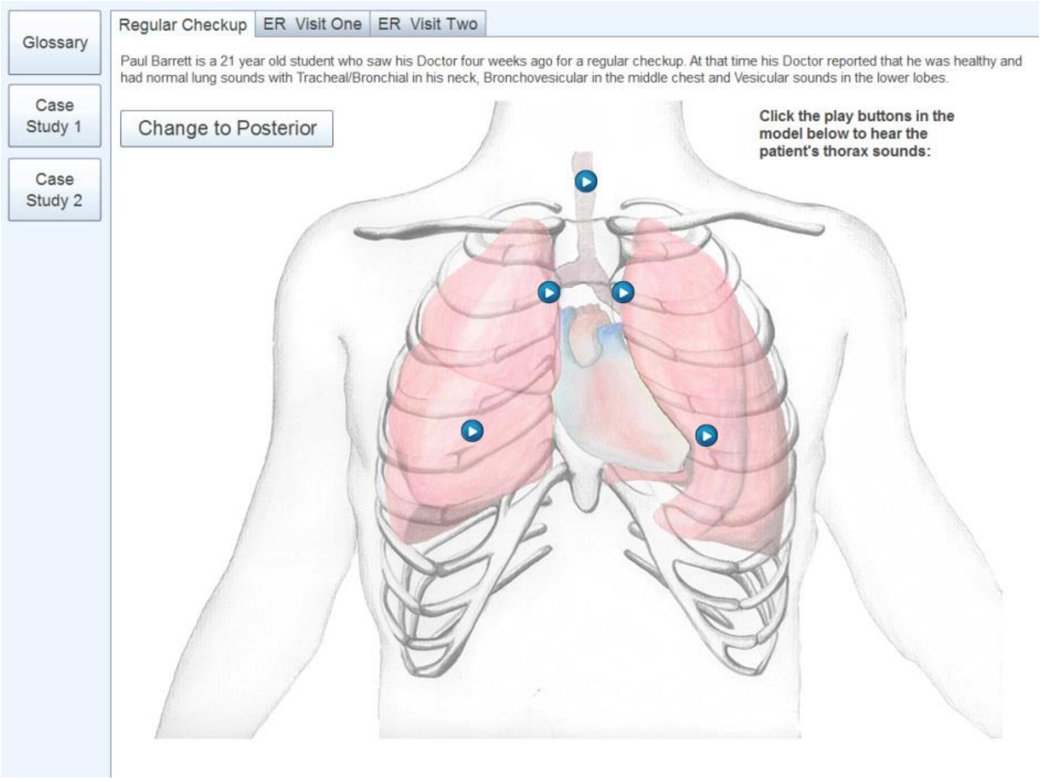


Figure 2: Snapshot of a case study

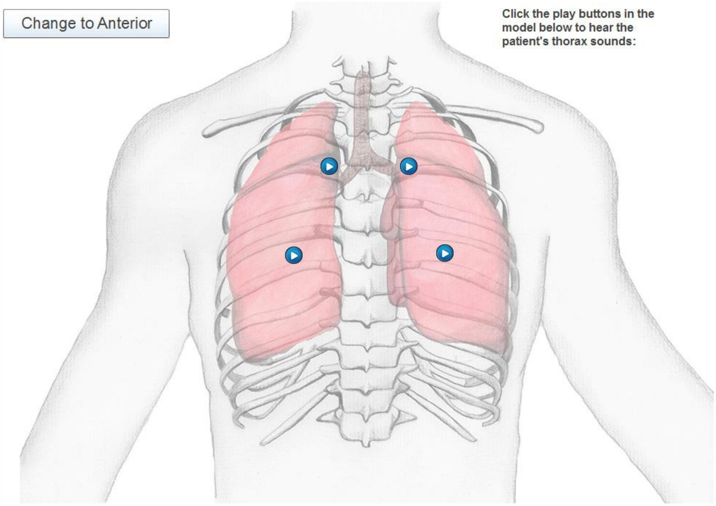


Figure 3: Interactive chest exploration, posterior view

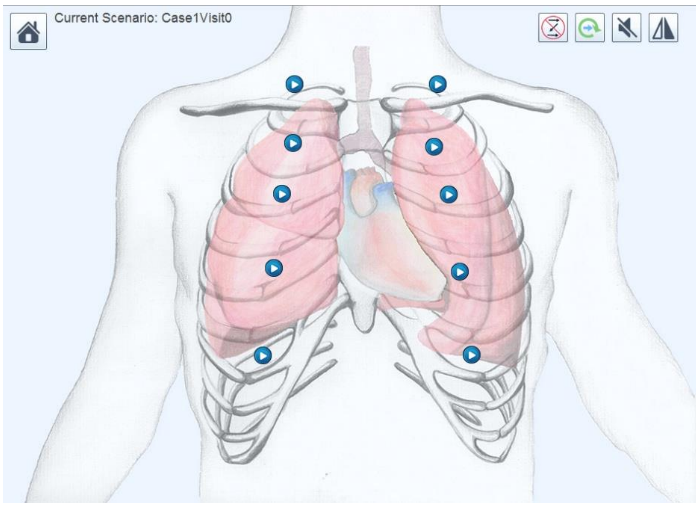
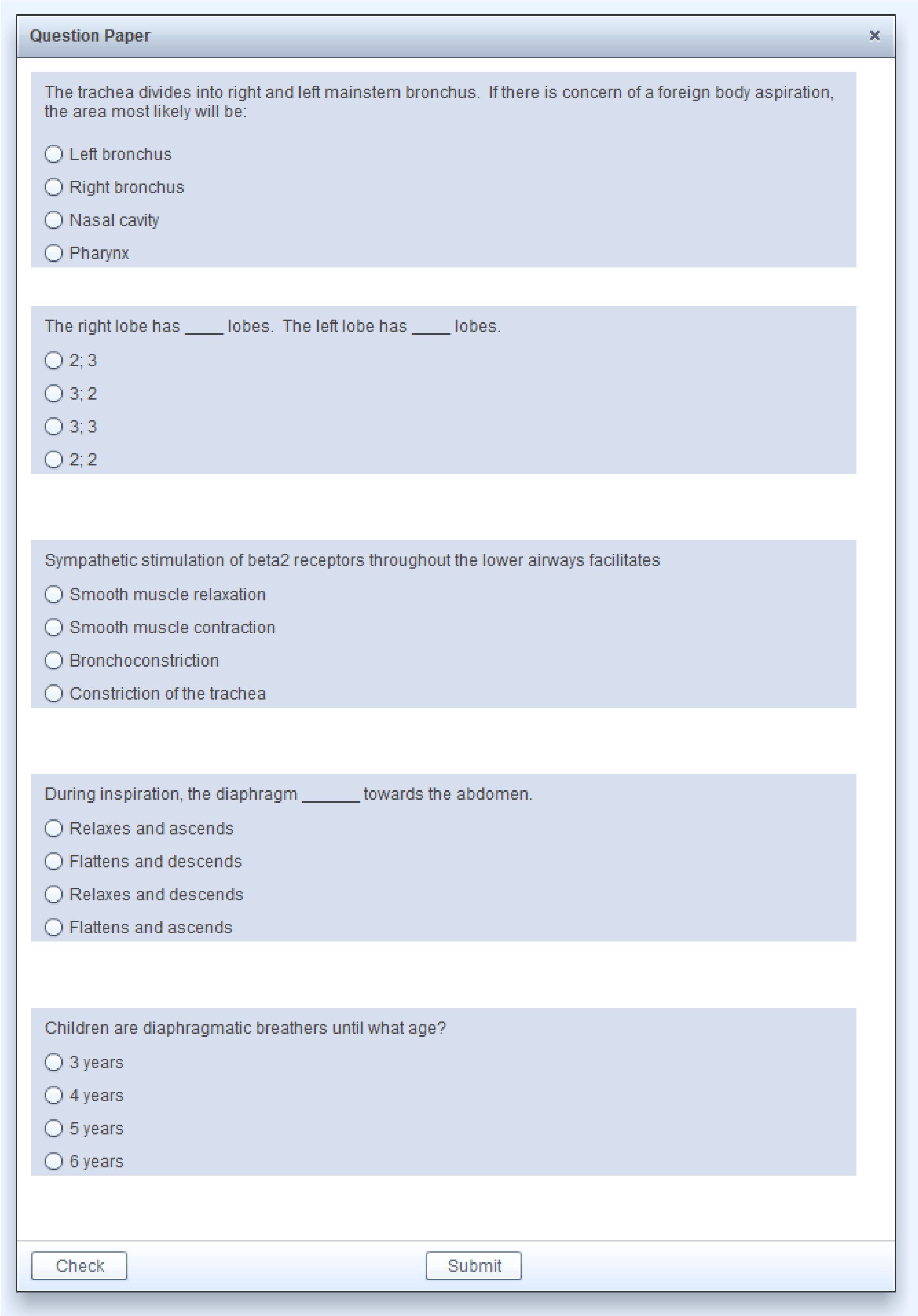


Figure 4: Standard auscultation regions, anterior view

2.5 Additional Modules

There are two additional modules in the application that were not tested with the user study but are part of this software. The first module is the evaluation module. The evaluation module allows professors and educators to setup multiple choice examinations and users to take these examinations. Accordingly, there are two interfaces for this module, the interface for the users who take the examinations and the other is the interface for educators to create and setup the examinations. A new version of the software will focus on improving the multimedia testing module to place questions for the participants which include text, pictures and sounds. This testing module could be used instead of the quiz functionality available in D2L [41], which was used for the pilot study.

The second module is the account management system. This is a small module to manage access to the software and establish the role of the users. It includes registration components to create user and administrator accounts for the system. The user account corresponds to the role of the persons making use of the case studies and the administrator account corresponds to the instructors or account holders allowed to setup evaluation questionnaires and case studies for the users of the system. Figure 5 shows a snapshot of the evaluation interface.



Question Paper

The trachea divides into right and left mainstem bronchus. If there is concern of a foreign body aspiration, the area most likely will be:

- ◯ Left bronchus
- ◯ Right bronchus
- ◯ Nasal cavity
- ◯ Pharynx

The right lobe has _____ lobes. The left lobe has _____ lobes.

- ◯ 2; 3
- ◯ 3; 2
- ◯ 3; 3
- ◯ 2; 2

Sympathetic stimulation of beta2 receptors throughout the lower airways facilitates

- ◯ Smooth muscle relaxation
- ◯ Smooth muscle contraction
- ◯ Bronchoconstriction
- ◯ Constriction of the trachea

During inspiration, the diaphragm _______ towards the abdomen.

- ◯ Relaxes and ascends
- ◯ Flattens and descends
- ◯ Relaxes and descends
- ◯ Flattens and ascends

Children are diaphragmatic breathers until what age?

- ◯ 3 years
- ◯ 4 years
- ◯ 5 years
- ◯ 6 years

Check Submit

Figure 5: Sample evaluation after training.

3. EXPERIMENTAL VALIDATION AND RESULTS

Ten persons participated in the pilot study. Although ten is a small sample size, it is a sample size that has previously been used to assess learning tools in this field [32,33]. Participants were recruited from a first year health assessment nursing course. All students in the course were invited to participate, but participation was entirely voluntary. No monetary compensation was offered for participation and participants were assured that their participation would not have an effect on their academic evaluation. All the participants in the study provided informed consent. Prior to the study, participants were provided with the consent forms and a printed copy of a sounds glossary containing the sounds in the applications glossary component, similar to glossaries found in related textbooks for health assessment. Figure 6 shows the design of the pilot study, which will be described in more detail in the next sections.

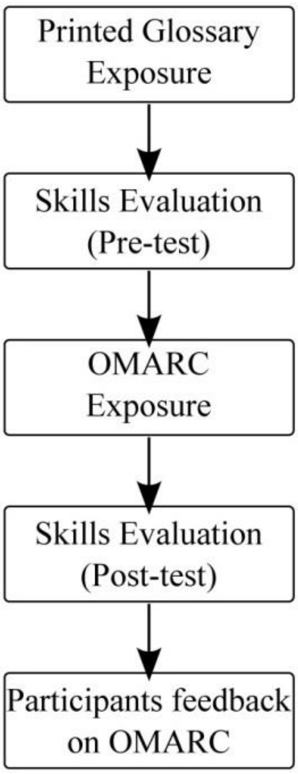


Figure 6. Design of the pilot study

3.1 Performance evaluation

The experimental design used to evaluate OMARC is similar to that used by Hou et al. [35]. There, fifteen nursing students who had received traditional auscultation instruction participated in a pilot study where they took an auscultation test before using a computer-aided auscultation learning system, and another after. This within-subject design was chosen because we didn't know beforehand how many participants were going to attend and within-subject designs need fewer participants [40].

To test the main hypothesis (H1) we first evaluated the participants' understanding of lung sounds prior to any exposure to OMARC by doing a pre-test evaluation of their skills. For the pre-tests participants were allowed to use only the information provided to them in the printed copy of the glossary, which is what most first year students are expected to have been exposed to, i.e. no multimedia or real-life exposure to normal and adventitious lung sounds.

After the pre-test, participants went through OMARC's playable sounds glossary, which presents sounds and their description in a list format where they can hear the sounds and read their descriptions as provided by the sounds publisher (ear-bud headsets were provided). After that, participants went through the multimedia cases studies, which involve two fictional case studies describing scenarios where a patient makes several visits to a health-care provider. Here, participants listened to different sounds placed on the chest and lung regions. After exposure to the application, participants were evaluated once again (Post-test) to measure if there had been an improvement after using the application.

Table 1. Performance scores

	Average	Standard Deviation
Pre-Test Score	63%	18.3%
Post-Test Results	90%	11.5%

Table 1 shows the percentage of correct answers obtained on average by the students before using OMARC (pre-test score) and after being exposed to OMARC (post-test results). We tested whether the post-test scores of the ten participants were statistically significant higher than their pre-test scores using paired Student t-test (a parametric test) and paired Wilcoxon signed rank test (a non-parametric test) available in R (version 3.0.2). Both statistical tests found the post-test scores to be significantly higher than the pre-test scores, p-value = 0.000722 and p-value = 0.004335 for the t-test and the Wilcoxon test, respectively. These results suggest that using OMARC improved the participants' capacity to correctly identify lung sounds for different conditions. Figure 7 shows the box plot for the overall test scores.

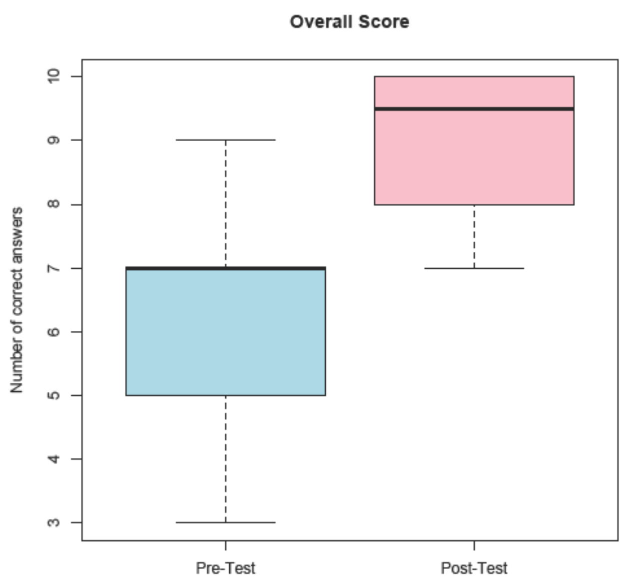


Figure 7: Box plot for participant's performance before and after exposure to OMARC. The horizontal black lines inside the boxes indicate the median score. Post-test scores were found to be statistically higher than the pre-test scores (p-value = 0.004335, paired Wilcoxon test)

3.2 Ease of use and perceived usefulness

To test the second set of hypotheses (H2.1 – H2.4) participants were asked to provide answers to several interface-related questions in the Likert scale, where 1 was “Totally Disagree” and 5 was “Totally Agree”.

Table 2. Usability & User Satisfaction Questionnaire

		Average Score ± Standard Dev.
Q1	Learning how to operate the multimedia application was easy for me.	4.6 ± 0.70
Q2	It was easy for me to become skilful at using the multimedia application.	4.6 ± 0.52
Q3	The interaction with the multimedia application was clear and understandable.	4.7 ± 0.67
Q4	Overall, I found the multimedia application easy to use.	4.7± 0.48
Q5	I found it useful to be able to hear the sounds of the case studies placed on the thorax model.	5 ± 0
Q6	Overall, I found the whole multimedia application useful.	4.6 ± 0.52
Q7	Using the multimedia application helped me have a better understanding of the sounds compared to the understanding I had from the written glossary only.	4.8 ± 0.63
Q8	I would recommend this multimedia application to other persons in my field	4.6 ± 0.70

Hypotheses H2.1 (Users will prefer the case studies with an interactive thorax model over the sounds glossary) was tested with question Q9. In Q9, the last structured question, participants were asked to express what elements of the interface they preferred by answering to the following: “Please indicate which part of the multimedia application you preferred”. The options offered to the participants were:

- The part where each case study progresses over multiple patient visits.
- The case studies having the playable sounds indicated on top of the thorax model.
- The Glossary with the playable sounds.

Figure 8 shows the results of the answers to Question Q9, which indicate a strong preference for the case studies having the playable sounds indicated on top of the thorax model (50% of participants) and for the part where each case study progresses over multiple patient visits (20% of participants), over the Glossary with the playable sounds, preferred only by 30% of the participants. This is an important finding, because it confirms hypothesis H2.1 and suggests that the elements at the core of OMARC’s multimedia experience are the ones the users prefer the most.

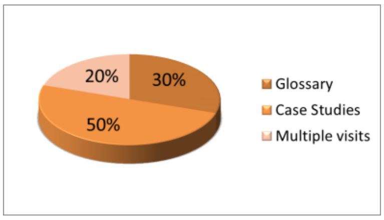


Figure 8: User preferences for the interface components.

Hypothesis H2.2 (Users will find the multimedia application easy to use) was tested with questions Q1 to Q4 in the questionnaire. The results for these questions were ranked between 4.6 and 4.7, in strong support of hypothesis H2.2. These results suggest that participants found themselves at ease when facing the application. Since they found it clear and understandable, it makes sense that they also perceived it as easy to use. Since this is the first time OMARC is presented to a set of users, the results are remarkably positive and suggest that the application was well designed. OMARC's interface design will be discussed in more detail at the end of this section.

Questions Q5, Q6 and Q7 (see Table 2) provide support for hypothesis H2.3 (Users will find that the multimedia application helped them better understand lung sounds compared to the written glossary). Question Q5 received the highest possible score, meaning all participants found it useful to be able to hear the sounds of the case studies placed on the thorax model. Question Q6 received also a high score of 4.6, meaning participants found OMARC to be useful in general. The last piece of evidence in support of hypothesis H2.3 comes from the participants' answer to question Q7 which was answered with an average score of 4.8 of respondent's agreement with the following statement: "Using the multimedia application helped me have a better understanding of the sounds compared to the understanding I had from the written glossary only."

Hypothesis H2.4 (Users are likely to recommend the multimedia application to other persons in their field) was tested with question Q8 (I would recommend this multimedia application to other persons in my field) which was answered with a 4.6 on average. This result strongly supports hypothesis H2.4. The evidence that participants were satisfied with the application to the extent that they would recommend it to other persons in their field was also supported by the written comments of the participants, described in more detail in the next section.

The high level of usability and user satisfaction reported by users of OMARC throughout the questionnaire could lead one to speculate that the high score might be a result of the low complexity of the application. However, while low application complexity might have facilitated the interaction design process, low complexity on its own does not guarantee an application will attain a high level of user satisfaction. To achieve this, an application must meet the users' needs and offer good usability. We believe that part of the reason why OMARC is highly rated by the users might rather lie on the fact that it follows several guidelines identified for good interaction design and improved usability. For instance, OMARC follows several of the general suggestions proposed by Mestre et al.[44] for creating effective tutorials, mainly: #1: create a good outline and navigation; #2: provide clear and detailed images; #3: make appropriate use of multimedia; #5: keep text to a minimum; #6.3: Make activities easy to complete without help or explanation; and #10: provide ongoing, relevant feedback. Furthermore, through the use of textual descriptions and tabs to separate each visit on a separate page, OMARC resembles the static web page approach identified by Mestre et al. to be both an effective and preferred method of interaction in the design of effective tutorials to accommodate multiple learning styles [44].

OMARC also follows several of the design heuristics proposed by Petri et al.[45] for developing highly interactive websites. Among these, the most relevant that OMARC exhibits are: #1: Make text and interactive elements large and clear enough; #2: Make page layout clear; #4: Make key content (and elements and changes to them) salient (as shown in Figure 2); #5: Provide relevant and appropriate content; #6: Provide sufficient but not excessive content (Figures 3 to 5); #10: Provide clear labels and instructions (Figure 3); #11: Avoid duplication/excessive effort by users (we achieve this through a simple interface design); #16: Follow conventions for interaction (through the use of familiar interface elements such as tabs, icons and buttons); and #19: Interactive and non-interactive elements should be clearly distinguished (for instance, OMARC's buttons, tabs and playable sounds are clearly identifiable, while non-interactive elements retain a plain look).

Finally, interfaces and their content should not be over-simplified. Research on the relationship between the layout complexity of an application and users' perceptions of good screen design indicates that users tend to prefer complex screens [39], scoring them higher as their simpler counterparts. This may explain why more users prefer OMARC's more 'complex' multimedia case studies to the simpler sounds glossary (see Figure 8).

3.3 Written Feedback from Questionnaire

After answering the questions regarding the user interface, participants were asked to provide unstructured feedback regarding the application, by writing some of their impressions or comments about the software.

Six persons out of the ten participants provided comments in this part. Comments regarding the software were quite positive, coinciding somewhat with the results on the perceived ease of use and usefulness questionnaire. For example one user wrote: "I enjoyed doing this study. I found it very helpful for myself because I was not sure what the abnormal breath sounds sounded like. I am proud to say I know them now. The glossary and case study really made me understand them and let me compare normal to abnormal. Well done", while another user wrote "This was an easy to use training application that helped me have a greater understanding of what normal and adventitious breath sounds sounded like. I appreciated this training and hope many other students in the health care field will have access to this multimedia training application".

There is a possibility that the high scores and positive feedback might have been partially influenced by the nature of the group of respondents. We speculate that there might have been a bias towards the more responsible students and/or those most interested in trying the new software being present in the study, because participation was entirely voluntary.

3.4 Technical Limitations

Since the system is implemented using Flash Builder, it requires the Adobe Flash Player to be executed. The Flash Player is installed in 90% of desktop computers and this gives tremendous coverage for most desktop computer users. However, since most smart phone providers do not support the Flash Player, the software cannot be played on a smartphone or a tablet that is not Windows. New versions of the software will be implemented in a language widely supported in mobile platforms such as Android, iOS, Windows and Blackberry. For this purpose, we are considering different options such as Unity, re-development under Flash and ActionScript or the combination of HTML, CSS and JavaScript. An interesting question we plan to explore is whether OMARC could be used offline for increased access in remote locations. While the software has been designed to work online, offline access could be implemented by downloading the OMARCs database and redirecting OMARC to a local server running on a standalone computer. This could be a feature in future versions of OMARC. Finally, a natural extension of this work is to provide a solution that also supports training for heart sounds, since they are both assessed in the chest area of the patient.

4. CONCLUSIONS

We have introduced OMARC, an online multimedia application for training health care students in the assessment of respiratory conditions. What makes this software unique is that it presents a narrative about normal and abnormal lung sounds using interactive media, showing the places in the chest where the sounds are usually found, and describing the patient conditions that are associated with these sounds via case studies designed by professional health-care providers and educators. The software presents a truly interactive experience that integrates multimedia technology and health-care education to facilitate learning, while being useful and easy to use. Results from a pilot study indicate that OMARC significantly helps to improve the capacity of the users to correctly identify lung sounds for different respiratory conditions. This improvement is with respect to the performance achieved by using traditional media while avoiding the costs and accessibility limitations of high-cost training mannequins and simulators. Participants' opinions about OMARC were positive: users were likely to recommend the application to other persons in their field, and they found the application easy to use and helpful to better identify lung sounds. To confirm the findings of the pilot study and provide conclusive evidence about OMARC's efficacy and increased learning effect, a study with a significantly larger number of participants should be done. This would not only allow us to obtain more generalizable results, but would also allow us to implement a classic experimental design. We have planned to have users go through a pre-test, then one half of the users would be exposed to the sounds glossary only and the other half would be exposed to the multimedia case studies only. At that point, the users will be evaluated again. We will then ask the users to switch tools and evaluate them with a post-test and an exit questionnaire. This design will allow us to more precisely assess the individual contribution of the sounds glossary and the multimedia case studies and the overall efficacy and learning effect of the system as a whole.

Another natural way to expand the application is to add more case studies, including more situations and also increasing the set of sounds covered. In addition, the case studies may include more advanced scenarios including more pathophysiology and medications.

CONFLICT OF INTEREST

None of the authors has any conflicts of interest with respect to the publication of this research.

ROLE OF THE FUNDING SOURCE

The development of OMARC has been partially funded by Thompson Rivers University, TRU, (Kamloops, BC). TRU had no involvement in the study’s design; in the collection, analysis and interpretation of data; in the writing of the report; nor in the decision to submit the article for publication.

REFERENCES

[1] Jarvis, C. (2003) *Physical Examination and Health Assessment* (4th Ed.) Saunders.

[2] Lippincot (2012) *Auscultation Skills: Breath and Heart Sounds.* Wolters Kluwer Health .

[3] Jenkins, G., Kemnitz, C., Tortora, G. J. (2009) *Anatomy and Physiology: From Science to Life*, (2nd Ed) Wiley.

[4] Gaumard (2014) *Gaumard simulators for HealthCare Education*, (URL) http://www.gaumard.com/respiratory-care/

[5] CESEI (2014) *Centre of Excellence for Simulation Education and Innovation*, (URL) http://www.cesei.org/simulators.php

[6] CAE Healthcare (2014) *CAE Healthcare Patient Simulators*, (URL) http://www.caehealthcare.com/patient-simulators/metiman

[7] SimStore (2014) *Emergency - Respiratory and Cardiac Patient Cases for SimMan 3G*, (URL) http://www.mysimcenter.com/product/emergency-respiratory-and-cardiac-patient-cases-for-simman-3g-sms3670.aspx

[8] Wilkins, R., Hodgkin J.E. and Lopez, B. (2004) *Fundamentals of Lung and Heart Sounds with CD-ROM*, Mosby.

[9] Mangione, S. (2000) *Secrets Heart & Lung Sounds Workshop: Audio CD.*(CDR Ed.) Hanley & Belfus.

[10] Medical Doctor Apps (2013) *Heart Sounds (+ Lung Sounds)* (URL) https://play.google.com/store/apps/details?id=appinventor.ai_shawn_m_gee.HeartSounds&hl=en

[11] Hadi Yazdi (2013) *Heart Sounds & Murmurs* (URL) https://play.google.com/store/apps/details?id=independent.android.medicine.heartsounds

[12] Noia Tech (2013) *Heart + Lung Sounds* (URL) https://play.google.com/store/apps/details?id=appinventor.ai_wilsonferraznoia.Asculta

[13] MedEdu LLC (2014) Easy Auscultation Lessons, Quizzes, Reference Guides (URL) http://www.easyauscultation.com/

[14] Ryklin Software (2013) Noia Tech *Auscultation* (URL) https://itunes.apple.com/us/app/auscultation/id335693421?mt=8&ign-mpt=uo%3D4

[15] University of Maryland, Baltimore (2014) *Spring DPTE 514 Basic Sciences III - Heart and Lung Sounds* (Podcast)

[16] Mangione, S. (2007) *Physical Diagnosis Secrets with Student Consult Online Access (*2nd. Ed.) Mosby
https://itunes.apple.com/us/podcast/spring-dpte-514-basic-sciences/id431165973?mt=2&ign-mpt=uo%3D4

[17] Wikipedia (2014) *Adobe Flash Builder* (URL)
http://en.wikipedia.org/wiki/Adobe_Flash_Builder

[18] Wikipedia (2014) *Apache HTTP Server* (URL)
http://en.wikipedia.org/wiki/Apache_HTTP_Server

[19] MySQL (2014) *MySQL: The world's most popular open source database* (URL)
http://www.mysql.com/

[20] The PHP Group (2014) *What is PHP?* (URL)
http://php.net/manual/en/intro-whatis.php.

[21] Francesco Ricciardi and Lucio Tommaso De Paolis (2014), *"A Comprehensive Review of Serious Games in Health Professions,"* International Journal of Computer Games Technology, vol. 2014, Article ID 787968, 11 pages, 2014. doi:10.1155/2014/787968
http://www.hindawi.com/journals/ijcgt/2014/787968/

[22] Lynch-Sauer, J., et al. (2011): *Nursing students' attitudes toward video games and related new media technologies.* J. Nurs. Educ. 50(9), pp. 513–523

[23] Davidhizar, R.E. (1982) *Simulation games as a teaching technique in psychiatric nursing.* Perspect. Psychiatr. Care 20(1), pp. 8–12

[24] Petit dit Dariel, O.J., et al., (2013) *Developing the Serious Games potential in nursing education*, Nurse Education Today, http://dx.doi.org/10.1016/j.nedt.2012.12.014

[25] Hazzard, Sandra (2013) *The Role of Serious Games in an Advanced Nursing Education,* University of Utah, Ph.D. Thesis

[26] De Ribaupierre, S. et al. (2014) *Healthcare Training Enhancement Through Virtual Reality and Serious Games* Virtual, Augmented Reality and Serious Games for Healthcare, Chapter 2, Intelligent Systems Reference Library Volume 68, 2014, pp 9-27, Springer

[27] University of Minnesota School of Nursing (2014) *Playing to Learn: School of Nursing uses Serious Gaming to Prepare Future Nurses* (URL)
http://www.nursing.umn.edu/magazine/past-issues/SpringSummer2011/Education/PlayingtoLearn/index.htm

[28] Zend Technologies Ltd. (2015) *Zend Framework Reference* (URL)
http://framework.zend.com/manual/1.12/en/zend.amf.html

[29] Adobe Systems Inc.(2015) *Adobe Flash Platform runtimes' Statistics : PC penetration* (URL)

http://www.adobe.com/ca/products/flashplatformruntimes/statistics.html

[30] Adobe Systems Inc.(2015) *Adobe Flash Platform runtimes' Statistics : Mobile penetration* (URL) http://www.adobe.com/ca/products/flashplatformruntimes/statistics.displayTab2.html

[31] Ribbons, R. M. (1998) *Guidelines for developing interactive multimedia. Applications in nurse education.* Comput Nurs. 1998 Mar-Apr;16(2):109-14. Review. http://www.ncbi.nlm.nih.gov/pubmed/9540255

[32] Choi J.; Bakken S. *Web-based education for low-literate parents in Neonatal Intensive Care Unit: development of a website and heuristic evaluation and usability testing.* International Journal of Medical Informatics, Volume 79, Issue 8, 565 – 575 http://www.sciencedirect.com/science/article/pii/S1386505610000973

[33] Kitajima Y.; Yamashita M.; Nakamura M.; Maeda J.; Aida K.; Kanai-Pak M.; Huang Z.; Nagata A.; Ogata T.; Kuwahara N.; Ota J. *Relationship between nursing students' preference for types of teaching materials and learning effects of self-learning tool.* Stud. Health Technol. Inform. 2014; 201:39-47. http://www.ncbi.nlm.nih.gov/pubmed/24943523

[34] Yoo, I. Y.; Lee, Y.M. *The effects of mobile applications in cardiopulmonary assessment education.* Nurse Education Today. 2015 Feb; 35(2):e19-23. doi: 10.1016/j.nedt.2014.12.002. http://www.sciencedirect.com/science/article/pii/S0260691714003979

[35] Hou, C.J.; Chen, Y.T.; Hu, L.C.; Chuang, C.C.; Chiu, Y.H.; Tsai, M.S. *Computer-aided auscultation learning system for nursing technique instruction.* In Conference Proceedings of the IEEE Engineering in Medicine and Biology Society 2008; 2008:1575-8. http://dx.doi.org/10.1109/IEMBS.2008.4649472

[36] Sestini, P.; Renzoni, E.; Rossi, M.; Beltrami, V.; Vagliasindi, M. *Multimedia presentation of lung sounds as a learning aid for medical students.* Eur Respir J. 1995 May; 8(5):783-8. http://erj.ersjournals.com/content/8/5/783.long

[37] Mangione S. and Dennis S. *CompuLung: a multimedia CBL on pulmonary auscultation.*In Proceedings of the Annual Symposium on Computing Applications in Medical Care. 1992: 820–821. PMCID: PMC2248142 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2248142/

[38] Kaveevivitchai, C.; Chuengkriankrai, B.; Luecha, Y.; Thanooruk, R.; Panijpan, B.; Ruenwongsa, P. *Enhancing nursing students' skills in vital signs assessment by using multimedia computer-assisted learning with integrated content of anatomy and physiology.* Nurse Education Today. 2009 Jan; 29(1):65-72.

http://www.sciencedirect.com/science/article/pii/S0260691708000750

[39] Comber, T.; Maltby, J.R. (1994) *Screen complexity and user design preferences in windows applications.* In proceedings of Harmony through working together: OZCHI 94, Melbourne, Vic. Computer Human Interaction Special Interest Group, Downer, ACT. http://epubs.scu.edu.au/comm_pubs/6/

[40] MacKenzie, I. S. (2013). *Human-computer interaction: An empirical research perspective.* Waltham, MA: Morgan Kaufmann. http://www.yorku.ca/mack/HCIbook/

[41] Wikipedia. (2015). *D2L* (URL) https://en.wikipedia.org/wiki/D2L

[42] Pinho, C.; Oliveira, D.; Oliveira, A.; Dinis, J.; Marques, A. *LungSounds@UA Interface and Multimedia Database.* Procedia Technology, Volume 5, 2012, Pages 803-811 http://www.sciencedirect.com/science/article/pii/S2212017312005208

[43] Sarkar, M., Madabhavi, I., Niranjan, N., & Dogra, M. (2015). *Auscultation of the respiratory system.* Annals of Thoracic Medicine, 10(3), 158–168. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4518345/

[44] Mestre, S.L. (2012). *Student preference for tutorial design: a usability study.* Reference Services Review 2012 40:2, 258-276. http://www.emeraldinsight.com/doi/full/10.1108/00907321211228318

[45] Petrie, H., Power, C. (2012) *What do users really care about?: a comparison of usability problems found by users and experts on highly interactive websites.* Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 2107–2116. http://doi.acm.org/10.1145/2207676.2208363