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Measuring the impact of information literacy e-learning and in-class courses via pre-tests and post-test at the Faculty of Medicine, Masaryk University

Teaching basic haemorheology to medical students by individual and collaborative strategies

Simple models of the cardiovascular system for educational and research purposes

Possibilities of utilizing blended-learning in the area of language education of medical staff

The mathematical model of a LUNG simulator

Experience-based teaching of acute medicine for extra motivated medical students and young physicians — 4th Emergency Medicine Course and 6th AKUTNĚ.CZ Congress

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PREFACE

With a great pleasure we present the 2nd 2014 issue of the MEFANET Journal (MJ). MJ is dedicated to provide readers around the world with high quality peer-reviewed articles on a wide variety of topics related to applications of computer science and technology-enhanced learning in medical education. Its mission is to become the premier vehicle for disseminating information about MEdical FAculties NETwork (www.mefanet.cz), which covers all Czech and Slovak medical faculties as well as schools or faculties of health care sciences.

The six papers presented here run the gamut of e-learning, simulations and information science in medical education. The two original papers by Kulhánek et al. and by Šolc et al. focus on medical simulations covering the cardiovascular system and the breathing system respectively. The paper by Kratochvíl may encourage trainers involved in information literacy, showing the importance of this kind of training for medical and PhD students. The paper by Toksvang & Berg contributes to the knowledge, whether teacher-driven and student-driven ways of learning have different results, with an illustrative application in teaching basic haemorheology. Šulistová & Ptáčniková reports needs, design, implementation and results of a very successful project focused on blended learning in the field of foreign language education of medical staff. The final editorial material by Štourač et al. recalls the most important contributions of the AKUTNE.CZ group to education in acute medicine. Besides information about their web portal, workshops, courses and conferences, one will find interesting descriptive statistics showing their evaluation by users and participants. We are certain that the readers will benefit from the information in these papers and it is our hope that this issue will stimulate further discussion and additional research.

I would like to extend my sincere appreciation to the editorial members and reviewers, without whom this issue would not have been possible. My hope is that the whole second volume of the MEFANET Journal will be another valuable resource for the MEFANET community and will stimulate further research into the vibrant area of medical education science. The wide range of topics presented in this issue emphasizes the complexity of the use of information and communication technologies in medical education. Readers are encouraged to submit both comments on these articles as well as their own relevant manuscripts.

December 2014

Daniel Schwarz
Editor-in-chief

MEASURING THE IMPACT OF INFORMATION LITERACY E-LEARNING AND IN-CLASS COURSES VIA PRE-TESTS AND POST-TEST AT THE FACULTY OF MEDICINE, MASARYK UNIVERSITY

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ABSTRACT — ***Introduction:*** *This paper aims to evaluate the results of the assessment and comparison of the impact of information literacy in e-learning and in-class courses at the Faculty of Medicine, Masaryk University, Czech Republic. The objective herein is to show that e-learning can be as effective a method of teaching IL activities as in-class lessons.*

Methods: *In the autumn of 2012 and the spring of 2013, a total of 159 medical students enrolled in the e-learning course and completed the required pre-tests and post-tests comprising 30 multiple-choice questions on information literacy topics; another 92 PhD students from in-class courses took the 22-question test. The pre-test and post-test scores along with the number of students who correctly answered the questions were counted and the overall percentage was calculated. The final outcome was the extent of knowledge increase and the number of students with correct answers, expressed in percentage.*

Results: *On average, 95.5% and 92.5% increase in knowledge was recorded among the medical students and PhD students respectively; an average of 4.5% medical students and 7.5% of PhD students recorded low scores in the post-test. As for the number of correct answers, the average results of the 22 set questions shared among the study groups were as follows: 15 questions were answered correctly more often by medical students, 6 were answered correctly more often by PhD students and only 1 question was correctly answered in the same average percentage by both the groups.*

Discussion: *The results point to the need for proposing several key revisions. Among these include an exercise to be included in both curricula on online search for an article (Web of Science or Scopus) without full text availability via link service, while instructions on manually creating bibliographic references shall be added to the PhD course. Additional search examples shall be added to the study materials and video records of in-class lessons shall be made available to the students for later revision. Some test questions require revision so that they are based more on practical examples rather than mere definitions. The results thus assembled, and the follow-up discussion, can then help in convincing the advocates of in-class teaching of the beneficial application of e-learning in information literacy education. Additionally, arguments based on such convincing outcomes can assist other librarians in their assessments and will serve to persuade the associated academic staff of similar professional competence towards educating university students in information literacy.*

INTRODUCTION

Although information literacy (IL) has been an essential part of university curriculum for almost 40 years [1] and various studies have heralded the library as a significant partner for the academic staff in IL activities [2–5], the Czech IL did not receive serious attention until the 1990s. The first specialized Information Education and Information Literacy Working Group (IVIG) was established as recently as early in the 21st century [6], and its main goal was to highlight the need for and the promotion of implementing IL courses at Czech universities. Currently, IVIG has turned its attention to assessing the outcomes

TABLE 1 The DSVIz01 and VSIV021 contents according to general IL standards

Module Objectives	VSIV021	DSVIz01
Knowledge of general library terminology and services	×	–
Search in online catalogue	×	–
Recognize the quality of a website	×	–
Identify keywords, synonyms and related terms	×	×
Construct a search strategy	×	×
Select appropriate database for finding information	×	×
Search in online databases	×	×
Access fulltext articles via linking service	×	×
Read a text and write an abstract or an annotation	×	×
Structure of thesis/paper	×	×
Text formatting	×	–
Publication and citation ethics	×	×
Cite documents according to various citation styles	×	×
Use reference managers	×	×
Scientometry	×	×

of information literacy programmes [6]. Since 2011, IVIG has focused on assessing the outcomes via the hitherto successfully applied pre-test and post-test methods [7–12] as well as recognising them as an accepted method according to the Standards for Educational and Psychological Testing [13]. For the period 2011–2012, IVIG organised three seminars where librarians from various Czech universities created pre-test and post-test questions and discussed the technical testing options of standardising the assessment procedure at Czech university libraries.

The Masaryk University Campus Library (MUCL) was one of the initiators and an active participant of IVIG seminars. Since the autumn of 2011, measurements in assessing the differences in the knowledge levels of students of the Faculty of Medicine (Masaryk University) for the purposes of verifying the efficiency of MUCL's e-learning course, VSIV021 Information literacy, has been realised. During this period, a similar measurement concerning the PhD students of the same faculty who completed MUCL's in-class DSVIz01 course (Acquisition of Scientific Information) was also conducted. The DSVIz01 course is taught in the classical F2F form (three 2.5-hour lessons, 5 credits) as an optional course because not all PhD students are PC literate. Lessons always comprised a combination of lectures, instructions and practical tasks. The VSIV021 course was taught in the spring of 2008 as an in-class course; however, since autumn 2008 it is taught as an e-learning (10 weeks, 4 credits) course pursuant to its optional status.

Both courses are focused on essential IL knowledge and skills according to international and Czech information literacy strategies [15-16]. However, DSVIz01 does not include some topics and activities (Table 1) because PhD students acquired this knowledge and the skills from previous studies as well as from their professional and personal lives. The e-learning VSIV021 course is embedded in the Masaryk University Learning Management Sytem (MU LMS), inclusive of an interactive syllabus with the study materials (online tutorials, PDF documents, textbook and videos). For the purpose of the assessment, study materials were almost identical for both groups of students. The MUCL website (http://www.ukb.muni.cz/kuk/vyuka/materialy) includes most of the online tutorials that are available to medical students as part of the interactive syllabus. It was also recommended to both groups that they learn from the textbooks designated for the courses [16]. Two videos were available only to medical students as they contained recordings of MUCL librarian's lessons attended by PhD students (publication and citation ethics, scientific writing). Even though the medical and PhD students could theoretically have learned from the online tutorials before the course, there were no significant increase in clicks on these links which satisfied the MUCL on the the precondition that the said students did not avail these tutorials prior to the commencement.

Since the inception of the courses, the content and teaching methods have been repeatedly evaluated positively by the participants [17]. However, there is no evidence to date suggesting the real impact of the courses on the range of students' knowledge. Therefore, three basic questions [18] were asked: 1) What do I want to measure? Answer: The degree of difference between the students' knowledge at the beginning and at the end of the courses. 2) Is this the best way to assess? Answer: Yes, it is. Previous studies have shown that the pre-test and post-test method can be used for this research and that it is a simple method for evaluating [5,7,18–24], while other methods not

TABLE 2 Example of set of pre-test and post-test questions on the topic "Searching"

Pre-test questions	Post-test questions
Select a phrase you would use when searching for information about aromatherapy at childbirth: 1. aromatherapy AND childbirth 2. aromatherapy OR childbirth 3. aromatherapy NOT childbirth 4. I don't know	Select a phrase you would use when searching for information on the ethical aspects of surrogacy: 1. ethics* AND surrogacy* 2. ethics* OR surrogacy* 3. ethics* NOT surrogacy* 4. I don't know
Select a phrase you would use when searching for information only about Thermography in sports medicine: 1. thermography* AND "sports medicine" 2. thermography* AND sports medicine 3. thermography* OR "sports medicine" 4. I don't know	Select a phrase you would use when searching for information only about Magnetic resonance in medicine: 1. "magnetic resonance" AND medicine* 2. magnetic resonance AND medicine* 3. "magnetic resonance" OR medicine 4. I don't know

unsuited to the objectives and opportunties of the research bear the following: Interviewing is time consuming and requires combination of various methods [23], quiz games are recommended for young learners [18] and self-assessment is limited and students' self-perception can result in overrating themselves [20]. 3) Is what I am testing important or significant? Answer: Yes, it is because it can a) show the effectiveness of IL courses, b) help persuade the academic staff that the librarian is capable of teaching IL topics, c) reveal students' weaknesses and accordingly modify the instructions towards emphasizing on topics they are having difficulty with, and d) show that e-learning can be as effective as in-class teaching. For the above reasons, the pre-test and post-test method was selected for our assessment. Additionally, tests containing questions on students' knowledge instead of students' opinions, previously as self-assessments in other studies [20], were chosen for objective results.

This contribution has two main goals: 1) to present the results of measurements over two semesters showing increase in knowledge after completing the courses, and 2) to thereby demonstrate that e-learning IL courses can be as effective as face-to-face (F2F) IL courses.

METHODS

Given the fact that several standardised surveys exist, such as the Information-Seeking Skills Test, Standard Assessment of Information Literacy Skills or iSkills [25–26], and other researches [5,8,12,21,27], the MUCL tests have been prepared to meet the particular specifics of DSVIz01 and VSIV021 course contents including test methods as discussed in IVIG seminars. Testing is managed in MU LMS, which also includes the ROPOT (Revision, Opinion Poll and Testing) tool making it possible to generate online tests from different sets of questions. Trial tests involving medical and PhD students were conducted in autumn 2011 and spring 2012 comprising online pre-test and post-test questions. The results of the trials have been excluded from this paper since the tests were used to verify the suitability of the pre-test and post-test method and eliminate any potential errors. The outcomes also served as an opportunity for proposing additional questions at IVIG seminars. An additional advantage of the trial period was the possibility of rendering a comparison between the two different groups of students (undergraduate and postgraduate). The trial test results showed (as do the results presented in this paper) similar knowledge level of the medical and PhD students prior to completing the courses. The comparison between undergraduate and postgraduate students is in line with the research by Kate Conway [28], highlighting the lack of publications on such analogy, even though the obtained results can help the academic staff and the libraries to identify the IL areas in which their students lack necessary knowledge. Finally, a comparison of these groups was possible since no PhD student participated in VSIV021 during their previous undegraduate study; hence, they were assumed to have knowledge level similar to that of the undergraduates.

The tests comprised of questions that duly addressed the module objectives of DSVIz01 and VSIV021 (Table 1) and were based on the above mentioned standards. Most of the questions were compiled at IVIG seminars. The post-tests included questions that were dissimilar to the ones in the pre-tests; however, the questions always assessed the same knowledge level of a single IL topic (Table 2). This avoided the risk of students recalling the correct answer from the pre-test when sitting for the post-test (after the pretest, students could view their results to see what they should study most carefully in the courses). This method follows the previous studies the authors of which also needed to use questions relating to their course contents [8,12,21,25–26,29].

As mentioned above, testing was managed in ROPOT allowing for various question formats, such as multiple-choice, true/false, matching, fill-in-the-blank, short answer, etc. Recommendations [26] from IVIG seminars led to the possibility of including different formats for questions measuring the same knowledge level. Therefore, several sets of different wordings for questions (Table 2) inquiring the same knowledge level in the pre-test and post-test variants for each IL topic have been prepared. All questions are presented in the multiple-choice form, most allowing for only one correct answer and only a few with two or more correct answers. All questions included the option *'I don't know'* to eliminate the risk of guessing the correct answer and skew the results.

After preparing the sets of questions, the so-called ROPOT description was compiled. This is an application for configuring test parameters; for example, it allows one to configure how many questions are to be generated and from which sets of questions (e.g. only one question from a set of three questions on a concrete topic). ROPOT also allows the configuration of the instances a student can access the content and the time consumed to answer a question, how many points are awarded for correct answers, etc. The ROPOT description was configured to generate online pre-tests and post-tests containing questions on the topics described in Table 1, excepting questions on the above mentioned topics of the VSIV021 and DSVIz01 courses.

In the autumn of 2012 and the spring of 2013, a total of 159 medical students and 92 PhD students completed the online pretests and posttests at the beginning and end of the semester, respectively. The e-learning groups of medical students as well as the in-class group of PhD students were asked (via e-mail, library and course websites) to complete the online test electronically. The text notifying the students of the test included a highlighted notice saying that the results of tests a) have no influence on the final classification, b) are only used to compare the difference in students' knowledge at the beginning and at the end of the courses, c) will assist in recognising the topics that require further emphasis. This notification was designed to send the message to the participating students that even though they shall be completing the tests without the assistance of the MUCL librarians, they have no reason to cheat (the fact that the students did not cheat is justified in the discussion section).

The tests for medical students contained 30 questions while the tests for PhD students comprised 22 questions (this difference relates to the slightly different course content as mentioned above). Each question was worth one point; in the case of questions with two or more correct answers one point was divided *pro rata* according to the number of possible answers. When the students completed the pre-test and the post-test, MU LMS automatically counted the points and saved the final results in an online notepad where the student name and the points tally could be seen. In the MU LMS section called Answer Management, information on how many students answered each question was stored. The results ranked only those students who completed the pre-test and the post-test. The final evaluation of the results was based on simple descriptive statistics, presenting the findings in percentages pursuant to the method used and accepted in previously published studies [5,8,12,27,29]. This method is also suitable for other librarians preparing their own research and allows simple evaluation of the results regardless of the conditions in which librarians operate (e.g. no statistical support in the library). Under these conditions, the following hypothesis could be verified:

Hypothesis 1: The students of both courses will have higher scores in the post-test than in the pre-test.
The number of points gained in the pre-test and post-test were collected from MU LMS notepads and the difference was counted and then transferred into data showing percentage increase in the students' knowledge.

Hypothesis 2: Each test question shall be correctly answered by more students from both courses in the post-test than in the pre-test.
The Answer Management part of MU LMS includes a list of all questions used and shows the number of correct, incorrect and unanswered questions and the number of students who answered them. The numbers were collected according to the set of questions in which each question was included, e.g. the number of correct answers shown in Table 2 was counted and represents the number of students who correctly answered questions from the set of questions on the use of Boolean operators. The final calculation was transformed into a percentage figure.

Hypothesis 3: There will be no significant difference between the number of medical students and PhD students who correctly answer the questions in the post-test.
This hypothesis was tested through comparison of the average percentage of students from both courses who correctly answered the questions on topics taught in both courses.

RESULTS

Table 3 shows that most of the medical students (average 95.5%) as well as PhD students (average 92.5%) increased their knowledge each semester. An average of 46% of the medical students and 47% of the PhD students increased their score by 20–39% in the post-test, while an average of 36% of medical students and 42% of PhD students increased their knowledge by 1–19%. However, some students answered more questions incorrectly in the post-test than in the pre-test: an average of 4.5% of medical students and an average of 7.5% of PhD students earned lower score in the post-test than in the pre-test.

In both semesters, more medical students correctly answered the post-test questions than in the pre-test (Table 4), that is 80–99% of the medical students. Certain questions (library services, wildcards, publication ethics, citation ethics, citation methods or bibliographic references) were correctly answered in the

TABLE 3 Percentage of students in each semester in relation to the percentage rate of change in their knowledge

Rate of change in knowledge (%)	Medical students (%)		PhD students (%)	
	Autumn 2012 (n = 81)	Spring 2013 (n = 78)	Autumn 2012 (n = 48)	Spring 2013 (n = 44)
60 and more	0	0	0	2
40–59	12	14	4	2
20–39	46	47	46	48
1–19	41	31	42	41
0	0	0	0	0
deterioration	1	8	8	7

post-test by 56–79% of the medical students of the autumn and spring semesters. This is in contrast to 26–55% of the medical students from the autumn and spring semesters who correctly answered questions on the types of resources and database services.

Both groups of PhD students also answered more questions correctly in the post-test than in the pre-test (Table 4), that is between 80–100% of the PhD students. Between 63-79% of the PhD students from both semesters scored higher in the post-test than in the pretest on questions about defining keywords, wildcards, catalogue, publication ethics (first question on this topic), citation ethics (first question), citation methods, reference managers (first question) and scientometry. This is in contrast to 27–53% of the PhD students from both semesters who correctly answered in the post-test questions on database services, citation ethics (second question) and bibliographic references (second question).

Figure 1 shows the comparison between the average number of medical and PhD students who correctly answered the post-test questions. The figure shows that 15 of the 22 questions common to both groups of students were correctly answered in a higher percentage by medical students than by the PhD students. Only one set of questions, on publication ethics, was answered correctly by the same number of students from both groups. The other 6 questions were answered correctly by a higher number of PhD students than by the medical students. Questions on search, quotation marks, portal of electronic resources, link services, publication ethics (the second and third questions are about this topic) and reference managers (second question) were correctly answered in the post-test by 96–98% of the medical and PhD students. In the post-test, 77–88% of the students from both courses correctly answered questions on the use of wildcards, catalogue (first question), the structure of thesis/scientific paper, bibliographic references, citation ethics and reference managers (first question in all these cases) and scientometry. In the post-test, 63–72 % of all students correctly answered the remaining questions with the exception of questions on database services and citation ethics (second question), which were correctly answered in the post-test by less than half of all students (40–47 %).

DISCUSSION

Even though all students completed the pre-test and post-test questions without any assistance, there are two objective reasons to believe that all students passed the tests responsibly without cheating. Firstly, the average time of completion of tests by all students was 16 minutes, the median was 12 minutes (MU LMS ROPOT saved the date and time when the tests were opened and saved and the MUCL librarian counted the time taken). This proves that even though the test results had no influence on the final classification, it seems that the students avoided selecting random answers to quickly complete the test and rather spent some time reading the questions and answering them. Secondly, answers to randomly generated test questions showed the students really tried to choose the correct answer. This was especially evident in the questions where the students had to correctly sort the parts of a scientific paper or theses and the effort made was clearly evident. These facts suggest that the results can be considered as reliable.

Referring to the original hypotheses, the results show that all three hypotheses have been almost confirmed. The first hypothesis is confirmed as only 4.5% of the medical students (7 people) on average and only of 7.5% the PhD students (7 people) on average had worse results in the post-test. Although it may seem as surprising that some students had a lower score in the post-test than in the pre-test, according to the previous experience of other researchers it is not an uncommon finding. Whitehurst [12] and Craig and Corrall [5] found that even though the number of students preferring Google as an option for research decreased, some students still used this search engine. Hsieh and Holden [8] mention that a lower number of students correctly answered questions about library catalogue in the post-test than in the pre-test. Byerly et al. [30] found that, in the post-test, a lower number of students showed their ability to ask a librarian for help. Zoellner and colleagues [31] also found lower students'

TABLE 4 The percentage of medical and PhD students from autumn 2012 and spring 2013 responding correctly in the pre-test and post-test (x means the question was not included in the test)

	Medical students (%)						PhD students (%)					
	Autumn 2012 (n = 81)			Spring 2013 (n = 78)			Autumn 2012 (n = 48)			Spring 2013 (n = 44)		
	pre-test	post-test	+−	pre-test	post-test	+−	pre-test	post-test	+−	pre-test	post-test	+−
Library services	46	69	23	58	76	18	×	×	×	×	×	×
Search	69	95	26	62	96	34	88	94	6	70	95	25
Evaluation of website quality	40	76	36	33	80	47	×	×	×	×	×	×
Evaluation of website quality	87	95	8	86	95	9	×	×	×	×	×	×
Types of resources	68	32	−36	79	45	−34	×	×	×	×	×	×
Defining keywords	53	99	46	97	95	−2	68	91	23	97	98	1
Defining keywords	69	48	−21	64	55	−9	81	74	−7	70	74	4
Wildcards	66	74	8	59	81	22	81	71	−10	70	78	8
Quotation marks	87	96	9	77	88	11	74	100	26	77	100	23
Catalogue	65	88	23	64	79	15	65	76	11	73	89	16
Catalogue	68	78	10	79	83	4	71	63	−8	71	63	−8
Portal of electronic resources	35	86	51	45	92	47	50	91	41	58	93	35
Remote access	17	81	64	15	74	59	×	×	×	×	×	×
Link service	53	99	46	46	99	53	67	81	14	58	91	33
Types of resources	68	84	16	64	79	15	×	×	×	×	×	×
Database services	13	26	13	6	30	24	19	49	30	95	53	−42
Abstract/Annotation	67	47	−20	63	45	−18	×	×	×	×	×	×
Text format	80	83	3	88	77	−11	×	×	×	×	×	×
Structure of thesis/paper	61	86	25	64	77	13	70	92	22	64	93	29
Publication ethics	68	71	3	77	76	−1	85	67	−18	90	71	−19
Publication ethics	64	98	34	65	93	28	73	91	18	47	100	53
Publication ethics	94	97	3	97	98	1	98	96	−2	62	91	29
Citation ethics	49	71	22	56	76	20	58	67	9	18	71	53
Citation ethics	9	56	47	15	64	49	16	40	24	52	27	−25
Citation methods	35	64	29	37	69	32	46	77	31	70	63	−7
Bibliographic references	68	78	10	69	87	18	88	81	−7	35	79	44
Bibliographic references	32	73	41	29	82	53	56	53	−3	31	42	11
Reference managers	18	78	60	29	81	52	38	73	35	74	77	3
Reference managers	67	97	30	58	99	41	64	100	36	27	97	70
Scientometry	20	86	66	24	82	58	42	72	30	41	65	24

scores to a question on the evaluation of web page quality. Additionally, Stec [32] found that many questions (regardless of the subject) were incorrectly answered more often by students in the post-assessment while Tancheva and colleagues [33] found increase in incorrect answers on the identification of the article year in a bibliographic reference in the post-test.

Even if the number of medical and PhD students with lower score in the post-test is not significant, the possible causes of their results were identified. Several students from both groups incorrectly answered the question on the type of resources. It is very likely that students inadvertently misinterpreted a text from a popular magazine as a text from a scientific journal: the text included the phrase *'Some studies suggest …'*, the lack of citation indicated that the text was from a popular magazine. A similar problem could be the cause of low score for questions on database services. The students learned to search for the full-text of an article via a link service and therefore, they have no

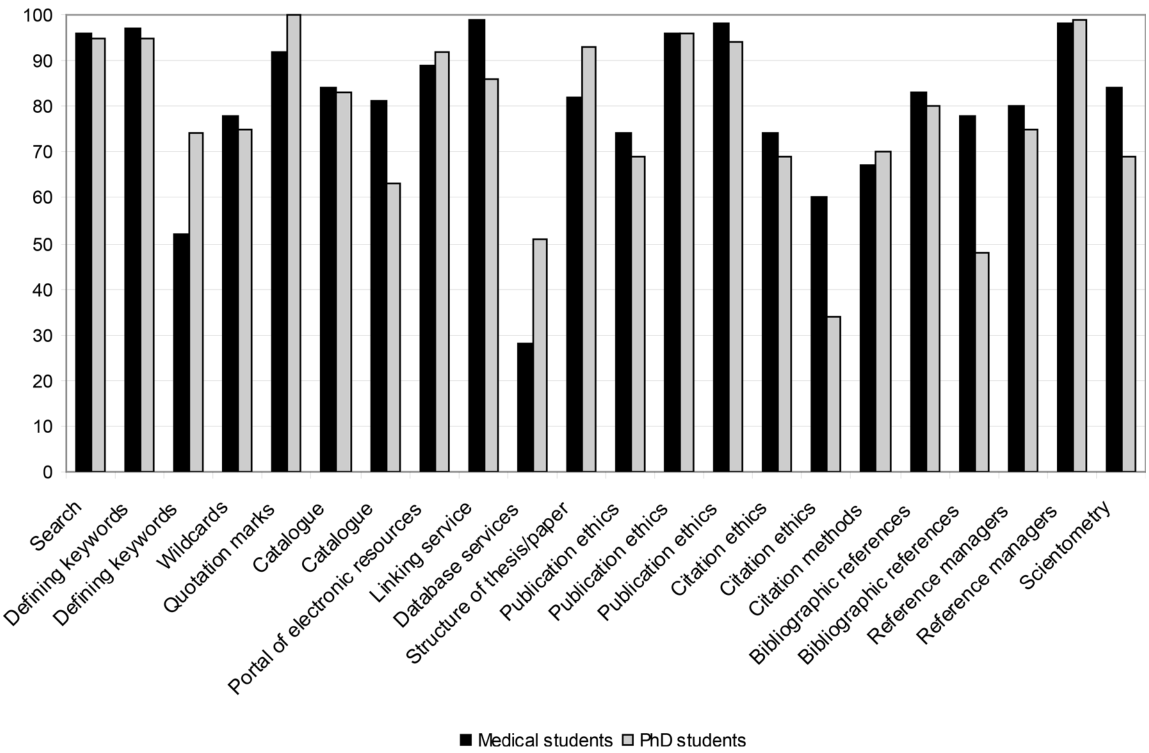

FIGURE 1 Average percentage of medical (n = 159) and PhD students (n = 92) responding correctly in the post-tests

reason to recognize if some database is only bibliographic or a fulltext. Despite discovering this problem in the PhD students' classes in the autumn of 2011 and the spring of 2012 and emphasising the difference between Web of Science/Scopus and ScienceDirect/Wiley/SpringerLink, decrease in PhD students' knowledge during the spring of 2013 was found as well as a low score in the medical students' results in both semesters.

Consequently, exercises requiring students to find on Web of Science and Scopus an article the full text of which is not available via the linking service shall be prepared (e.g. at Masaryk University the articles from some open access journals are not linked and can only be found at the journal's website). In this task, the students will discover that the Web of Science and Scopus are not full text databases and if they are looking for an article there, they will have to find another way of accessing the fulltext.

Inattention is another possible reason for poor results to the question on defining keywords as well as to the question on abstract and annotation. In the first case, students incorrectly choose *'binocular, surgery, strabismus, children, adults'* instead of *'binocular, surgery, strabismus"* for the topic *'Binocular vision after strabismus surgery of children and adults'* and didn't realize in this case that specifying the words *"children"* and *"adults"* is not necessary (in the pre-test they had a different topic with a unique patient group: *The problem of urinary incontinence in women*). With regards to the difference between abstract and annotation, they didn't pay attention to the phrase *'which generally describes'* in the definition of annotation and instead, they thought they were reading the definition of abstract (in the pre-test the question on abstract included the phrase *'which describes in detail'*). Inattention could also be the reason for the low score in the PhD students's answers on using the catalogue because for the question *'In the library catalogue you will find books about neurosurgery by'* they chose *'keyword'* instead of *'subject heading'*.

However, these mistakes could have been avoided if the questions were constructed differently. To educate the students on keywords in the future, much more examples of topics and their search queries with online study materials and in-class presentations in order for the students to realize how to proceed in various situations will have to be included. In the in-class lessons, the semantic difference between the terms *'keyword'* and *'subject heading'* will also have to be further emphasised and some searches showing this difference will have to be prepared. With regards to abstract and annotation, the students will have to be encouraged to recognize the abstract and/or annotation feature based on a sample text instead of merely the definition.

The low score concerning questions on publication and citation ethics was also due to unsuitable question construction. The students were asked to indentify a citation style in a list comprising various names without realizing that thousands of citation styles exist, and that PhD students need not know all of them (the post-test question included a real name *'Chicago Style'* and two fictitious names *'Cascading Style Sheets'* and *'Blue Style'*, while the pre-test question *'which of the following citation styles is fictious'* included two well-known names *'ISO 690'* and *'Turabian Style'* and one fictious name *'Cascading Style Sheets'*). Therefore, the question checking knowledge about citation styles usually used in medical journals will have to be changed (e.g. the student will select from the possibilities ACS style, NLM style or MLA style) because medical students and PhD students are taught on it in lectures or during tasks.

However, it should be noted that despite the failings discussed above almost all students from both groups showed increase in knowledge. As Hsieh and Holden [8] writes, *'test question construction is almost as much an art as science'* and there will always be the possibility of some student misunderstanding a question. The decrease in knowledge shown by some students could be also caused, as Hsieh and Holden [8] mention, by the lack of motivation for students to remember the knowledge gained in the courses. This could be the case with medical and PhD students who know that online study materials will always be available and updated at the MUCL website. In the light of all this, even if the first hypothesis hasn't been confirmed, increase in knowledge is significantly related to e-learning and in-class teaching.

The fact that an average of 36% of the medical students and 42% of the PhD students have increased their knowledge by only 1–19% needs further discussion in view of the results relating to the second hypothesis. Table 4 shows that almost the same average number of Medical and PhD students correctly answered the questions in the pre-tests, while in the post-tests the medical students outnumbered the PhD students in correct answers by 13%. Figure 1 shows that the medical students also correctly answered more questions. These results confirm the second hypothesis and show that e-learning can also be an effective teaching method. The results are not regarded as proof that e-learning is more effective than teaching, but lend credence to the notion that information education based e-learning can be applied. It should be noted that several studies demonstrated to the contrary: slightly higher effectiveness of in-class lessons. Nichols and his colleagues [9] found no significant percentage of in-class students had higher scores than online students, where the *'difference was less than one half of one question out of twenty'*. Several years later, at the same university, Shaffer [11] again verified the effectiveness of e-learning, confirming the previous results and finding no significant difference between the students' answers on their competence in navigating the library website, obtaining full text of articles or searching for documents. Salisbury and Ellis [10] compared the results between groups completing IL lessons as hands-on computer-based sessions in a joint classroom presentation with demonstration from an instructor and e-learning. They found that 9% more students from the latter group were able to recognise journal citations, 4–5% more students from the hands-on group were able to recognise and search for journal article citations and to search using Boolean operators than the other groups. Similar results were recorded at the University of Central Florida [34] where no significant differences in library skills were found between groups of students who had had in-class lessons with F2F instruction or web-based tutorial and groups who had had only web-based class. As already mentioned, the studies describe no significant differences and in view of the MUCL results, e-learning can be considered an effective alternative to in-class teaching. The main possible reason for the higher results by the medical students is the number of tasks (activities in table 1) which they have to complete on their own while the PhD students can immediately consult a MUCL librarian. As was mentioned above, it may reduce the PhD students' motivation to remember the relevant knowledge.

It is unclear, however, if the third hypothesis citing that there would be no significant difference between the number of medical and PhD students who correctly answered the questions in the post-test can be regarded as confirmed when there is a 13% difference between the average numbers of medical and PhD students who correctly answered the post-test questions. This 13% difference could be considered as significant even if this number seems low in the context of the previous discussion and even though a similar average number of the medical (54%) and PhD (51%) students correctly answered in the pretest. However, there are several studies finding similar differences to be minor. Anderson and May [35] evaluated their results with the understanding that some students could have obtained some IL skills in a previous course, and found no significant difference in knowledge between the students who completed IL instruction in online, blended or F2F form. Time and again, no significant difference has been found at the State University of New York at Oswego [9,11] as well as at the Oakland University [36], the University of South Florida [37], or the University of Melbourne [10]. These studies describe the experiences where a slight difference in favour of in-class teaching was recorded while at the University-Purdue University Indianapolis [38], a slight difference in favour of online tutorials has been found. However, a significant difference in favour of an online course has been found at the University of Arizona [39]. There librarians have concluded that teaching courses online is better than a one-off IL lesson since in the online course, students *'have multiple opportunities to engage with information literacy concepts that they can apply in their [...] courses'*.

These experiences suggest that the difference between the average number of medical and PhD students correctly answering post-test questions can be also taken as not being significant and then the third hypothesis can be regarded as confirmed. However, the rate of PhD students knowledge increase shows the need for changes to improve the efficiency of in-class instructions. Therefore, PhD students will be required to accomplish tasks on searching for articles the full text of which is not available via the linking service, creating bibliographic references manually and via Zotero which are the main skills they will use for their scientific writing.

A comparison of the results of measuring the impact of courses in e-learning and in-class form on the rate of medical and PhD students' knowledge shows the real possibility of using e-learning in IL activities. As mentioned above, these results should be taken as proof that e-learning can be used in information literacy education. The test results shall enable MUCL to transform the DSVIz01 course. If the autumn 2013 and spring 2014 test results also confirm the effectiveness of e-learning, then from autumn 2014 the DSVIz01 course will be offered as in-class lessons only to PhD students prefering this type of learning while others would complete the course through e-learning. It could increase the number of course participiants without implicating demands on the time spent teaching. This is an unquestionable benefit due to the fact that Czech librarians organize IL activities alongside their library work.

From autumn 2013, the results of pretests will be used to emphasise topics which fewer students answered correctly. Despite the practical implications already mentioned in the discussion, a record of the MUCL IL lessons and short videos showing the various practical tips and tricks that could help the students refresh their knowledge will be captured. Although the results discussed in this paper relate mainly to theoretical knowledge, measuring the rate of acquired practical skills will also be more closely focused upon.

The comparison presented in this paper also suggests the possibility of simple evaluation of teaching effectiveness for which no complicated tools are necessary and which could be realized using any survey tool. This opens up the possibility for libraries with financial or technical limitations to conduct their own research, the results of which could accent their important role in the fostering of an information literate society. However, each librarian considering undertaking their own measurment should carefully prepare test questions because, as the experiences detailed above show, even one overlooked word can lead a student to incorrect answers.

The results also showed no significant difference between the students from both groups at the start of courses, which confirms Conway's [29] opinion on the viability of comparing undegraduate and postgraduate students. This finding also demonstrates the necessity of holding IL courses for PhD students and confirms the role of the librarian as a professional who is able to educate.

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TEACHING BASIC HAEMORHEOLOGY TO MEDICAL STUDENTS BY INDIVIDUAL AND COLLABORATIVE STRATEGIES

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ABSTRACT — *We evaluated whether a classic article on haemorheology would lead to better learning when integrated with a collaborative rather than an individual teaching strategy in the undergraduate physiology classroom setting. A total of 88 2nd-year medical students were randomised to solve assignments based on the classic article individually (n = 42) or in groups (n = 46) during a 45-minute lesson on basic haemorheology. At the end of the lesson, students completed a test and an evaluation form. There were no differences between the two intervention groups with regard to the total test score, but students who had worked in groups rated their own effort during the lesson higher. In the present study, a collaborative teaching strategy did not lead to higher test scores than an individual teaching strategy. However, our findings suggest that students working in groups may feel a greater level of involvement during class.*

INTRODUCTION

In our experience, medical students often find basic haemorheology tremendously difficult, and although it is pertinent to the integrative understanding of microvascular physiology, it is one of the least popular topics within the cardiovascular curriculum. Inspired by the active learning approach 'using classic papers to teach physiology' [1], a classic article by Fåhraeus and Lindqvist [2] has recently been reported to be a potentially useful teaching tool when teaching basic haemorheology [3].

In the present study, we evaluated whether this approach would benefit from being integrated with a collaborative teaching strategy in the classroom setting. We hypothesised that students working with the article in groups would attain a better understanding of haemorheology than students working with the article individually.

METHODOLOGY

We offered a 45-minute lesson in basic haemorheology to second-year medical students that participated in a 5-week cardiovascular physiology course. A total of 88 students signed up for the lesson, and one week prior to the lesson, they received an e-mail with the article by Fåhraeus and Lindqvist [1] as well as specific references to relevant sections in the three physiology textbooks that are used in our medical school [4–6].

Design

The students were split up in three classes, consisting of 24 (class I), 28 (class II) and 36 students (class III). In class I, all students worked individually, in class II, all students worked in groups, and class III was split into two during the assignments, so that 18 of the students worked individually while the remaining 18 students worked in groups. Thus, a total of 42 students worked individually (intervention group A), while 46 students worked in groups (intervention group B). Each lesson started with an identical 10-minute introduction to the basic principles of haemorheology ex cathedra. During the following 15 minutes, students solved teaching points 1, 4 and 5, as outlined in our former publication on the article by Fåhraeus and Lindqvist [3]. In intervention group

A, the students solved each teaching point alone for three minutes, while students in intervention group B worked with each teaching point in groups of 2–3 and then reached a consensus regarding the correct answer within three minutes. After the students had worked with each assignment, the correct answer was highlighted during a 2-minute theoretical recapitulation.

Test

After having worked with the three teaching points, students completed a test of four multiple-choice questions in 10 minutes (Table 1). This test encompassed 1) one recall question comprising four subquestions, 2) one question that was intermediate between a recall and an advanced question and which comprised four subquestions, 3) an integrated question of moderate difficulty comprising three subquestions, and 4) an integrated question of advanced difficulty comprising three subquestions. Each subquestion was either true or false, and one point was designated to each correct answer. A total test score was calculated by adding the scores from all subquestions, with a minimal score of 0 and a maximal score

TABLE 1 The test

1.	**Which of the following applies to the passage of blood through small arteries and arterioles?** a. The blood behaves like a Newtonian fluid b. An increase in haematocrit will cause an increase in viscosity* c. There is a progressive increase in viscosity with maximal effect in the precapillary arterioles d. Changes in vessel diameter has a larger effect on perfusion than changes in blood viscosity*
2.	**The axial accumulation of red blood cells in small arteries and arterioles …** a. occurs as a consequence of the deformability of red blood cells* b. causes red blood cells to pass through the microvasculature faster than plasma under laminar flow conditions* c. causes an increase in haematocrit as vessel radius decreases d. causes the microvascular resistance to be higher at a given level than would be expected when considering the vessel radius alone
3.	**Red blood cell deformability is reduced in patients with essential hypertension, in whom blood pressure is chronically elevated due to increased arteriolar tone. The reduced deformability of the red blood cells will theoretically lead to …** a. reduced*/unchanged/increased axial accumulation of red blood cells during their passage through the microvasculature b. which will reduce/not affect/increase* the total peripheral resistance c. and thus counteract the elevated blood pressure/not affect the blood pressure/increase the elevated blood pressure further*
4.	**Over the years, several attempts to treat severe haemorrhage with haemoglobin solutions as an alternative to blood transfusion have been made. In contrast to blood, these solutions are, however, Newtonian fluids. When a haemoglobin solution, which has the same viscosity as blood in large arteries (diameter above 0.3 mm) is infused …** a. the resistance in the large arteries will be increased/unchanged*/reduced compared to normal circumstances b. the resistance in the small arteries and arterioles at a given level will be higher*/unchanged/reduced compared to normal circumstances c. a higher*/similar/lower blood pressure will be required to obtain the same tissue perfusion compared to normal circumstances

**Correct statement.*

TABLE 2 Student characteristics

	Individual work (Group A)	Group work (Group B)	p-value
Number of students	42	46	—
Mean age (SD), years	22 (1)	23 (2)	0.02
Gender, male/female	11/31	11/35	0.50
Has read the article	27 (64%)	31 (67%)	0.47
Has read recommended textbook material	34 (81%)	35 (76%)	0.36
Total preparation time			
None	5 (12%)	6 (13%)	0.43
< 30 min	7 (17%)	5 (10%)	
30–60 min	21 (50%)	19 (42%)	
60–120 min	7 (17%)	14 (31%)	
> 120 min	2 (4%)	1 (2%)	
No answer	0	1 (2%)	

of 14 points. These questions were designed so that the recall question referred directly to information presented in the article by Fåhraeus & Lindqvist [1] as well as during the 10-minute theoretical introduction. The intermediate question also referred to this content, but required the student to use this information in context of a physiological problem. The difficulty of the two integrated questions required the students to apply the haemorheological principles in an integrated physiological manner to solve a problem they had not previously been familiarised with. The integrated questions reached beyond the cardiovascular physiology curriculum in our medical school, and exceed the difficulty of their forthcoming exam.

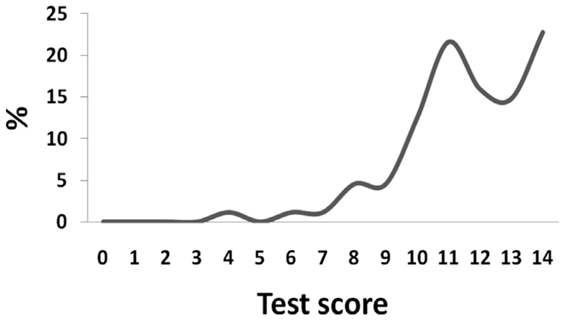

FIGURE 1 Total test scores. The abscissa shows the total test score, calculated as the number of correctly answered subquestions, and the ordinate shows the percentages of all students (n = 88)

Evaluation

At the end of the lesson, students completed an evaluation form that was based on a Likert-type scale. They rated 1) the academic gain of the lesson, 2) the quality of the teaching, 3) their own effort during the lesson, and 4) provided an overall assessment of the lesson. Each of these was rated as poor, below average, average, above average or excellent.

Statistics

All data were considered categorical and the Mann-Whitney U-test and chi-squared test were used to compare the two intervention groups. SAS statistical software version 9.2 (SAS Institute Inc., Cary, North Carolina, United States) was used to perform all statistical analyses, and $p < 0.05$ was considered statistically significant. Data are reported as median (interquartile range) unless otherwise specified.

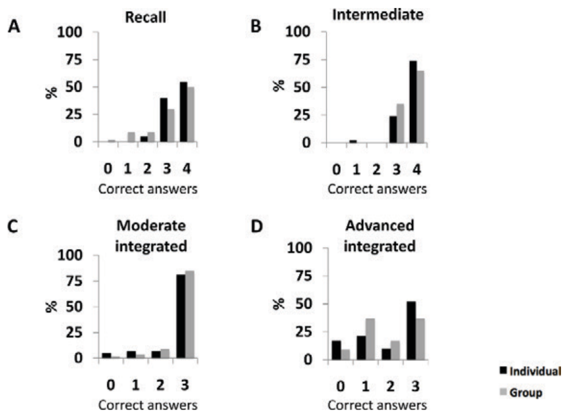

FIGURE 2 Specific test scores. The abscissa shows the number of correctly answered subquestions, and the ordinate shows the percentage of students within the respective intervention group

RESULTS

Student characteristics and preparation

Students in group B were marginally older than in group A. The two intervention groups did not differ with regard to gender or with proportion that had read the recommended article or the recommended textbook material, nor did they differ with regard to preparation time (Table 2).

Assessment of the textbook material and article

A total of 68 students (77%) had read the recommended textbook material prior to the lesson. Of these, 2 (3%) found the material easy to understand, 38 (56%) found it moderate, and 28 (41%) found it difficult. There was no difference between the two intervention groups with regard to the perceived difficulty of the recommended textbook material (p=0.69).

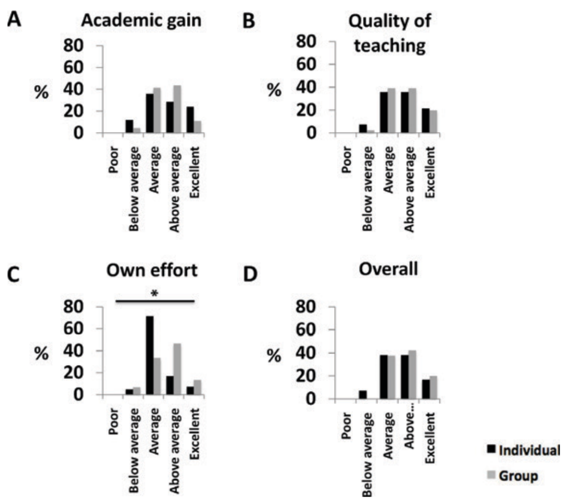

FIGURE 3 Student evaluations. The abscissa shows the evaluation score (Likert-type scale) and the ordinate shows the percentage of students within the respective intervention group. *Overall difference between intervention groups ($p < 0.05$)

Of the 58 students (66% of all students) who had read the article prior to the lesson, 1 (2%) found the article easy to understand, 39 (67%) found it moderate, and 16 (28%) found it difficult, while 2 (3%) did not reply, with no difference between the two intervention groups (p = 0.42). Of the 58 students who had read the article, 1 (2%) found the academic gain from the article to be poor, 13 (22%) found it to be below average, 35 (60%) found it to be average, 7 (12%) above average and 2 (4%) found it to be excellent, with no difference between the two intervention groups (p = 0.51).

Test scores

The total test score in all 88 students was 12 (11–13) correct answers, with 20 (23%) reaching a test score of 100% (14/14 correct answers) (Figure 1). There were no differences between the two intervention groups with regard to the total test score, nor with regard to their specific scores on recall, intermediate, moderate integrated, or advanced integrated questions (Figure 2A–D). Moreover, total test score did not differ between students that had read the article prior to the lesson and those who had not, neither when looking at all 88 students as a whole (p = 0.19) nor when looking at the two intervention groups separately (group A: p = 0.42; group B: p = 0.21). Similarly, no differences were present when looking at specific scores on recall, intermediate, moderate integrated, and advanced integrated questions separately (Supplementary Tables A and B).

Evaluation

Students in the two intervention groups evaluated the academic gain and the quality of the teaching similarly (Figure 3A–B), whereas group B students rated their own effort higher than group A students; hence 30 (71%) of the students in group A rated their effort as average, whereas 10 (24%) rated as above average or excellent, while 15 (33%) of the students in group B rated their effort as average and 27 (59%) rated it as above average or excellent (Figure 3C). Nevertheless, the two intervention groups did not differ in their overall assessment of the lesson (Figure 3D).

DISCUSSION

The main finding of the present study is that in contrast to our working hypothesis, working with the article in groups was not associated with higher test scores than working with the article individually, but the students did rate their own effort as higher when working in groups.

In contrast to a number of previous studies, which have repeatedly demonstrated that collaborative teaching strategies improve both the transfer and retention of the learned material in the classroom setting [7–10], we did not find that students who had worked in groups reached higher test scores than students who had worked individually. A remarkably large proportion of students in both intervention groups replied appropriately to integrated questions of both moderate and advanced difficulty, which may imply that working with the three teaching points enabled the students to transfer the learned material, regardless of the intervention. Based on the data at hand, we cannot rule out that an actual difference between the two intervention groups is in fact present, both due to the relatively low number of participants and because a difference is difficult to demonstrate when considering the high test scores in both intervention groups.

Although evaluations for the most part did not differ between the intervention groups, students working in groups did perceive their own effort during the lesson as higher. Notwithstanding that it cannot uncritically be inferred from our findings whether this perceived higher effort is considered positive or negative among the students, it may imply a higher level of student involvement in class. Accordingly, previous studies likewise found that collaborative teaching strategies lead to better evaluations both in the classroom [7–10] and laboratory [11] setting, presumably because it makes students more active in the educational process.

In conclusion, the present study indicates that both individual and collaborative teaching strategies may lead to acceptable test scores in basic haemorheology. Furthermore, working in groups may possibly lead to higher student satisfaction, since students then feel a greater level of involvement in class.

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SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE A Test scores in students working individually (n = 42), according to whether they had read the recommended article prior to the lesson

	Has read article (n = 27)	Has not read article (n = 15)	p-value
Total test score (correct answers, 0–14)	13 (11–14)	12 (11–13)	0.42
No. of correctly answered recall questions	15 (56%)	8 (67%)	0.86
No. of correctly answered intermediate questions	20 (74%)	11 (73%)	1.00
No. of correctly answered moderate integrated questions	22 (81%)	12 (80%)	0.98
No. of correctly answered advanced integrated questions	15 (56%)	7 (58%)	0.42

SUPPLEMENTARY TABLE B Test scores in students working in groups (n = 46), according to whether they had read the recommended article prior to the lesson

	Has read article (n = 31)	Has not read article (n = 15)	p-value
Total test score (correct answers, 0–14)	12 (11–13)	11 (9–13)	0.21
No. of correctly answered recall questions	16 (52%)	7 (58%)	0.31
No. of correctly answered intermediate questions	22 (71%)	8 (67%)	0.34
No. of correctly answered moderate integrated questions	26 (84%)	13 (87%)	0.96
No. of correctly answered advanced integrated questions	12 (39%)	5 (33%)	0.91

SIMPLE MODELS OF THE CARDIOVASCULAR SYSTEM FOR EDUCATIONAL AND RESEARCH PURPOSES

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ABSTRACT — *Modeling the cardiovascular system as an analogy of an electrical circuit composed of resistors, capacitors and inductors is introduced in many research papers. This contribution uses an object oriented and acausal approach, which was recently introduced by several other authors, for educational and research purpose. Examples of several hydraulic systems and whole system modeling hemodynamics of a pulsatile cardiovascular system are presented in Modelica language using Physiolibrary.*

INTRODUCTION

The mathematical formalization of the cardiovascular system (CVS), i.e. the models, can be divided into two main approaches. The first approach builds 3D models with geometrical, mechanical properties and the time-dependence of the compartments of the CVS. The complexity of such models implicates high demand on computational power to simulate them.

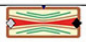
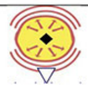
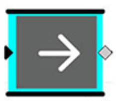
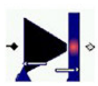
The second approach, lumped parameter approach, uses a high degree of simplification and different complex regions are generalized as single compartments characterized by lumped parameter. Using this approach, the cardiovascular system is modeled as an analogy of an electrical circuit with a set of resistors, capacitors (elastic vessels), diodes (valves) and inductance (inertial elements) in a closed loop. The relationship between pressure and volume quantities is studied throughout the modeled system. This type of model is used for the improvement of reliability in patient-specific diagnosis, for example [1,2]; or for educational purposes and training [3–9]. Technology used for modeling is either proprietary, e.g. MATLAB–Simulink or MATLAB-Simscape in the case of the CVS model introduced by Fernandez et al.[7], home grown open technology introduced by Hester et al.[3], standard grown technology from the scientific community, such as SBML [10], JSIM [11] or CellML [1,12] or industrial standard technology implemented by several vendors, such as the Modelica language [8,9].

This article introduces a modeling method which follows the second approach for modeling CVS as pressure-volume relations and introduces example models implemented in the Modelica language. We believe that one of the properties of the Modelica language — acausal modeling — seems to capture the modeled reality much better and allows connecting simpler models into quite complex systems of differential equations in an understandable form [4,13,14]. Additionally, we use a library for modeling physiology in Modelica — Physiolibrary — as the model diagrams based on the Physiolibrary components are self-descriptive in most cases [15,16].

METHODS

Modelica is an object-oriented language, thus, in further text when we refer to components, models and systems they are classes, and the one's with concrete values of parameters are instances as is usual in standard object-oriented programming. Models (classes) can inherit behavior or can be composed from other

TABLE 1 Selected components from Physiolibrary with description

Icon	Description
	**Hydraulic connectors** – declared as acausal, without prejudicing any kind of computational order. The MODELICA tool generates the following equations to keep the analogy of "Kirchhoff laws" for all connected components "non-flow" variables *p1..pn* determining the pressure and "flow" variable *q1..qn* determining flowrate: $p_1 = p_2 = \ldots = p_n$ (1) $\sum_{i=1}^{n} q_i = 0$ (2)
	**Hydraulic conductor** or (hydraulic resistor) is characterized by the parameters *G*-conductance (reciprocal value of resistance $G = \frac{1}{R}$) and models the relation between pressures p_{in}, p_{out} and flowrates q_{in}, q_{out} from the two connectors by the following formulas: $q_{out} = -q_{in}$ (3) $q_{in} = G*(p_{out} - p_{in})$ (4)
	**Elastic vessel** is characterized by these parameters: *C*-compliance (reciprocal value of elastance $C = \frac{1}{E}$), *V0* - unstressed volume, *p0* - external pressure and by equation among the variable *V*-volume and variables of the hydraulic connector *q*-flowrate and *p*-pressure: $p - p_0 = \begin{cases} 0 & \text{if } V < V_0 \\ (V - V_0)/C & \text{otherwise} \end{cases}$ (5) $\frac{dV}{dt} = q$ (6)
	**UnlimitedPump** is defined as the generator of the flowrate q_{out} based on the value "solutionFlow". $q_{out} = -solutionFlow$ (7)
	**Inertia element** is characterized by the *I* - inertance parameter and the relationship between pressure and solution flow from the two connectors by the following formula: $q_{out} = -q_{in}$ (8) $\frac{dq_{in}}{dt} = \frac{p_{in} - p_{out}}{I}$ (9)
	**Hydraulic valve** is characterized by g_{on} outflow and g_{off} backflow conductances, described by parametric equations: $dp = \begin{cases} pass/g_{on} + P_{knee} & \text{for } pass > 0 \\ pass + P_{knee} & \text{otherwise} \end{cases}$ (10) $q = \begin{cases} pass + P_{knee} * g_{off} & \text{for } pass > 0 \\ pass * g_{off} + P_{knee} * g_{off} & \text{otherwise} \end{cases}$ (11)

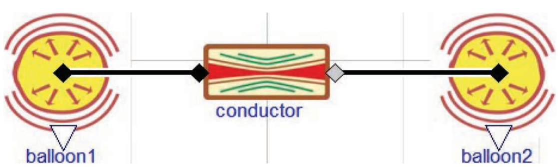


FIGURE 1 Two balloon example model diagram. It connects two balloons characterized with compliance (elastance) via a conductor (resistor).

models (classes). For the composition a special purpose class — connector — can be used to define variables of the model shared with other models.

The following models in the Modelica language are usually declared by an icon and defined either in diagram view or textual notation. The icon declares an interface of how the particular model instance can appear in other higher level model diagrams. The diagram and textual view declares the internal structure, which are in fact algebraic and differential equations among model parameters and variables.

As was mentioned earlier, Modelica models can be acausal, the equations can be expressed declaratively and the Modelica tool will decide which variables are dependent and independent based on the context upon compilation. This is extremely useful when several existing components are composed into a larger system model and the complexity is kept in a maintainable set of diagrams.

In further examples we use the following components from Physiolibrary (Table 1).

Two connected balloons

The model diagram (Figure 1) expresses the situation of two elastic balloons filled with liquid connected via an inelastic tube with characteristic resistance. Such a model diagram connects the system of equations of the two elastic vessels and one resistor and Modelica will figure out which variables will be independent and which will be dependent. In this example the pressure will be computed first from the initial volume of the two balloons by equation (5). This determines the pressure gradient, which directs the flow from the first balloon to the second one in equation (4). The flowrate affects the volume change in each elastic vessel in equation (6) and again causes the change of pressure from equation (5).

Windkessel models

The Windkessel models simplify the view on CVS as a series of compartments with capacity (compliance or elasticity of an elastic compartment), resistance (conductance or resistance of a conductor/resistor), impedance and inertance properties. They study the Windkessel effect, which maintains a relatively stable flowrate from the system, although the pulsatile flowrate comes from the pump. Several derivatives and improvements of Windkessel models were introduced [17].

Figures 3, 4 and 5 show diagrams of the Windkessel model of 2 elements, 3 elements and 4 elements in Modelica using Physiolibrary components. Additionally, the model diagrams contain component 'pulses' declared by the icon in Figure 2 and defined by following Modelica listing:

```
model pulses
  import Physiolibrary.Types.*;
  Physiolibrary.Types.RealIO.VolumeFlowRateOutput
volumeflowrate;
  discrete Time T0 "beginning of cardiac cycle";
  Boolean b(start=false);
  discrete Time HP "duration of cardiac cycle";
```

```
  parameter Frequency HR = 1.2;
  Time tc "relative time in cardiac cycle";
  parameter Time TD1=0.07 "relative time of start of
systole";
  discrete Time TD2 "relative time of end of systole";
  parameter VolumeFlowRate QP = 0.000424 "peak volume
flowrate";
equation
  b = time - pre(T0) >=pre(HP) "true if new cardiac cycle
begins";
  when {initial(),b} then
    T0 = time "set beginning of cardiac cycle";
    HP=1/HR "update length of cardiac cycle";
    TD2 = TD1+(2/5)*HP "compute end time of systole";
  end when;
  tc = time-T0 "relative time in cardiac cycle";
  volumeflowrate =
    if tc<TD1 then 0 else
    if tc<TD2 then sin((tc-TD1)/(TD2-TD1)*Modelica.
Constants.pi)*QP else
    0 "zero before and after systole, otherwise sin up to
peak flow";
end pulses;
```

This component generates regular pulses of flowrate during the systole period, which are approximated by the sinus function increasing from zero up to the peak flowrate and back to zero during 2/5 of a cardiac cycle, while at other times it generates a zero signal. The keyword 'discrete' notes the Modelica tool, wherein such variables will be changed only in discrete events, in our case at the beginning of the cardiac cycle.

A simple model of the cardiovascular system

We divide the CVS system into systemic circulation and pulmonary circulation; each circulation is characterized by a modified 2-element Windkessel model with an additional compliance component expressing the systemic and pulmonary veins (Figure 6).

The 'rightHeart' and 'leftHeart' components are instances of the model 'HeartPump'. The flowrate of the model "HeartPump" is determined by the filling pressure and by the slope of the Starling curve. The equations are defined in the following Modelica text notation:

```
model HeartPump
  Physiolibrary.Hydraulic.Interfaces.HydraulicPort_a
inflow "inflow";
  Physiolibrary.Hydraulic.Interfaces.HydraulicPort_b
outflow "outflow";
  parameter Physiolibrary.Types.HydraulicConductance
StarlingSlope;
equation
  inflow.q + outflow.q =0;
  inflow.q = StarlingSlope * inflow.pressure;
end HeartPump;
```

The non-pulsatile model shows the mean values of pressure and flow throughout CVS. To enhance the above mentioned model, we first define the pulsatile model PulsatileHeartPump by diagram (Figure 7).

We utilize the object-oriented features in Modelica to extend the non-pulsatile circulation by only replacing the heartPump instances by pulsatile heart pump instances as seen in the following listing. Note the redefinition of values (in SI units) of parameter QP, k, volume_start:

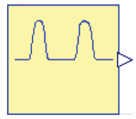


FIGURE 2 Icon of component "pulses"

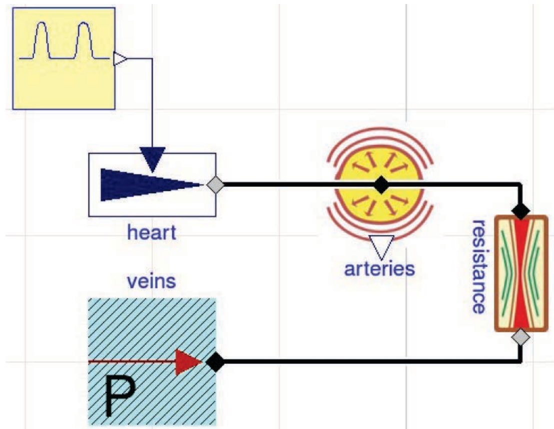


FIGURE 3 2-element Windkessel model characterized by compliance component (arteries) C = 1.4 ml/mmHg) and resistance with conductance G = 1.08 ml/(mmHg.s)

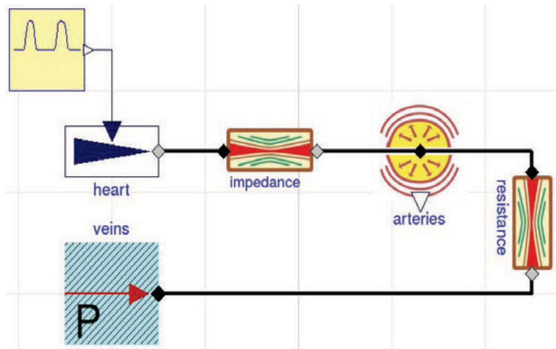


FIGURE 4 3-element Windkessel model characterized by impedance (here approximated by conductance = 200ml/(mmHg.s)), compliance component (arteries) C = 1.4 ml/mmHg) and resistance with conductance G = 1.08 ml/(mmHg.s)

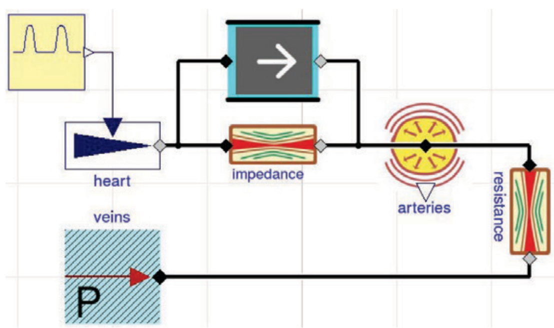


FIGURE 5 4-element Windkessel model characterized by impedance (here approximate by conductance = 200ml/(mmHg.s)), inertia I = 0.005 mmHg.s^2/ml, compliance component (arteries) C = 1.4 ml/mmHg) and resistance with conductance G = 1.08 ml/(mmHg.s)

```
model PulsatileCirculation
  extends NonPulsatileCirculation(
    redeclare Parts.PulsatileHeartPump
rightHeart(pulses(QP = 0.000338)),
    redeclare Parts.PulsatileHeartPump
leftHeart(pulses(QP=0.000338)),
    CAS(k=7.2755972857029e-09),
    SystemicArteries(volume_start=0.000603),
    SystemicVeins(volume_start=0.003991));
end PulsatileCirculation;
```

REFERENCE MODEL WITH VENTRICLES

For further comparison purposes, we have chosen model of CVS published by Fernandez de Canete et al. implemented originally in MATLAB-Simscape [7]. This model is presented in Modelica using Physiolibrary components in one diagram (Figure 8). Systemic and pulmonary circulation are presented as modified Windkessel model with inertia element connected via heart subsystem. Additionally, each side of heart is composed by two valves and a ventricle. The ventricle is modeled as an elastic compartment driven by variable elasticity generator defined by the following Modelica listing:

```
model TimeVaryingElastance
  parameter Physiolibrary.Types.HydraulicElastance Ed
“e. of diastole”;
  parameter Physiolibrary.Types.HydraulicElastance Es
“e.of systole”;
  parameter Physiolibrary.Types.Pressure Pi0 “peak
isovolumic pressure”;
  Physiolibrary.Types.Time tm
    “relative time from the beginning of cardiac cycle”;
  discrete Physiolibrary.Types.Time HP “heart period”;
  discrete Physiolibrary.Types.Time t0 “start time of the
cardiac cycle”;
  discrete Physiolibrary.Types.Time ts “duration of
systole”;
  Real a;
  Physiolibrary.Types.RealIO.HydraulicComplianceOutput C;
  Physiolibrary.Types.HydraulicElastance E;
  Physiolibrary.Types.RealIO.PressureOutput Pi;
  Physiolibrary.Types.RealIO.FrequencyInput HR “heart
rate”;
equation
  tm = time - pre(t0);
  if (tm<pre(ts)) then
    a= (1-cos(2*Modelica.Constants.pi*tm/pre(ts)))/2;
  else
    a=0;
  end if;
  E=Ed+Es*a;
  C=1/E;
  Pi = Pi0*a;
  when {initial(), tm >= pre(HP)} then
    HP = 1/HR;
    t0= time;
    ts = 0.16+0.3*HP;
  end when;
end TimeVaryingElastance;
```

RESULTS

The two balloons model (Figure 1) is used in simulators to demonstrate that a liquid (e.g. blood) flows from the part with higher pressure to the part with lower pressure. If there is no other active force, the system converges to an equilibrium, where the pressures will be equal and no other flow occurs between the balloons (Figure 9).

This model and simulation is used to demonstrate that the blood has a tendency to flow from the arteries with lower compliance and higher pressure to the veins. Without any external force, the majority of blood accumulates in veins rather than in arteries.

Simulation of the Windkessel models imitate the heart pulses by the generator controlled with the ‘pulses’ component (Figure 10).

The simulation of Windkessel model shows the Windkessel effect, which reduces a high variation of flowrate coming from the heart to a relatively stable

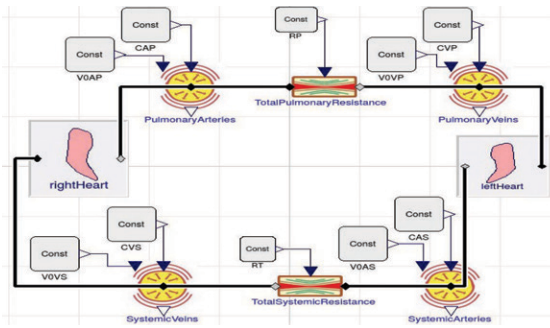


FIGURE 6 Non-pulsatile circulation model diagram. Pulmonary circulation on top of the diagram is connected via side of the heart with systemic circulation at the bottom of the diagram

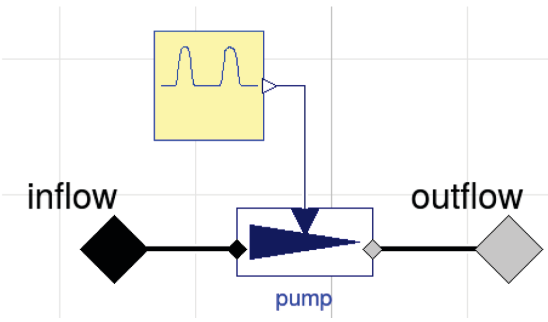


FIGURE 7 Pulsatile heart pump model

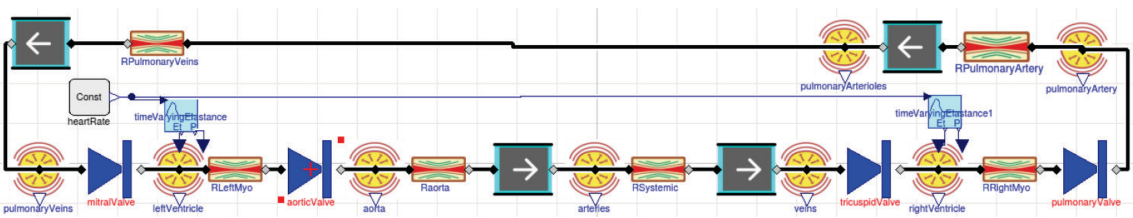


FIGURE 8 Reference model by Fernandez de Canete et al. [7] in Modelica using Physiolibrary components

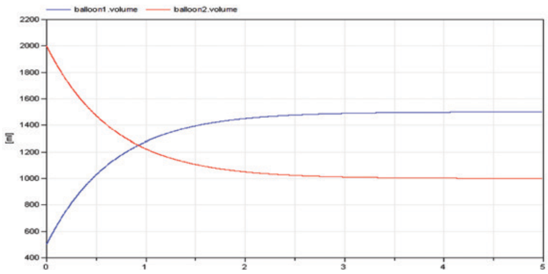


FIGURE 9 Simulation of volume dynamics from 500 ml to 1500 ml for the first balloon and from 2000 ml to 1000 ml for the second balloon. Unstressed volumes of 500 ml for both balloons and compliances of 2 ml/mmHg and 1 ml/mmHg and conductance 1 ml/(mmHg.s). After five seconds the system is almost at equilibrium

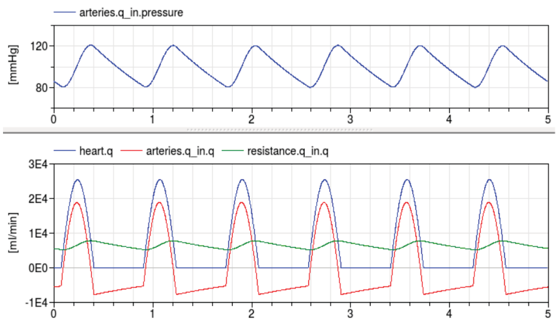


FIGURE 10 Simulation of 4-element Windkessel model characterized by impedance (approximate by conductance = 200 ml/(mmHg.s)), inertia I = 0.005 mmHg.s^2/ml, compliance component (arteries) C = 1.4 ml/mmHg) and resistance with conductance G = 1.08 ml/(mmHg.s) and initial volume of arteries at 0.97 l and unstressed volume of arteries at 0.85 l. The pressure during six beats is kept between 120/80 and the flowrate going from the heart ranging from 0 to 25 l per minute (blue) is compensated by the compliance compartment flowrate going from −5 to +18 l per minute (red) to the resulting average flowrate going from peripheral arteries 5 to 7 l per minute (green)

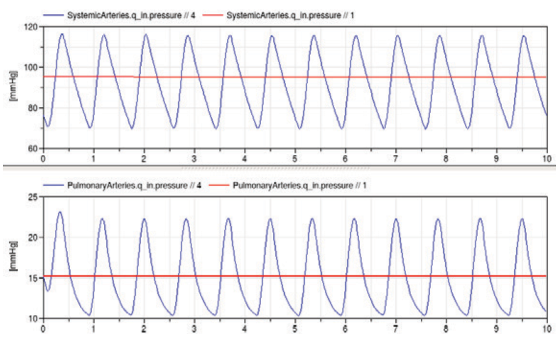


FIGURE 11 Pressure dynamics in systemic and pulmonary arteries simulated by both non-pulsatile (red) and pulsatile CVS models (red)

flowrate in the systemic peripheral vessels due to the compliance of the elastic compartment.

The simulation of newly introduced extended model with pulsatile circulation (Figure 11) shows approximate dynamic pressure in aorta and pulmonary artery compared to the same variables of non-pulsatile model showing rather a mean values. The values

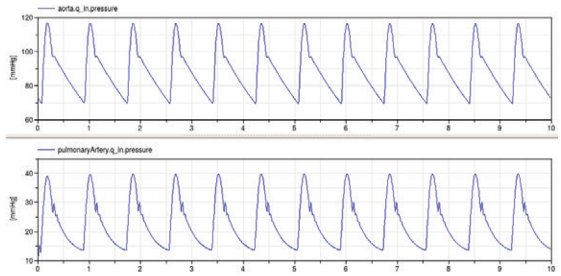


FIGURE 12 Pressure dynamics in systemic and pulmonary artery simulated in reference model by Fernandez de Canete et al [7]

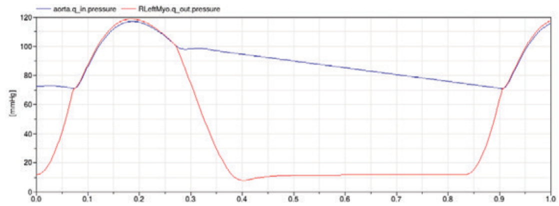


FIGURE 13 Pressure dynamics in aorta (blue) and left ventricle (red) simulated in reference model by Fernandez de Canete et al. [7]. At time 0.07s the aortic valve opens and the pressure in left ventricle is only slightly higher than in aorta allowing the blood to flow from left ventricle to aorta.

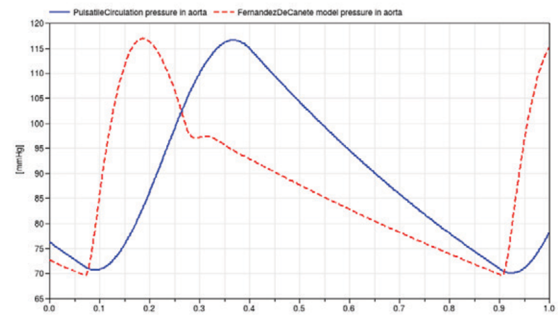


FIGURE 14 Comparison of pressure dynamics in systemic arteries simulated by simple pulsatile CVS models (blue) and by reference Fernandez de Canete model[7] implemented in Modelica (red dashed)

of parameters and initial values of state variables are in Table 2 and 3 using normal physiological units as well as SI units.

The simulation of reference model by Fernandez de Canete et al. (Figure 8) was performed using original values of parameters (Table 4). The pressure dynamics in aorta and pulmonary arteries (Figure 12) shows quite realistic dicrotic notch after closure of aortic valve. Detailed pressure dynamics of aorta and left ventricle during one cardiac cycle is in Figure 13.

DISCUSSION

Our non-pulsatile and pulsatile models generate a raw approximation of outgoing flowrate. However, other models, such as the model developed by Fernandez de Cante et al. [7,8], or that developed by Meurs et al. [5,6], introduce a heart with elastic vessels driven by variable compliance and valves rather than a pump

TABLE 2 Initial values of state variables and parameters of the non-pulsatile model of CVS in Modelica. Asterisk indicates initial volume of a component computed from steady state simulation

Parameter	Value	Value in SI	Ref.
V0CAS.k (unstressed volume of systemic arteries)	529 ml	5.29×10^{-4} m³	
CAS.k (compliance of systemic arteries)	1.5 ml/mmHg	1.13×10^{-8} m³/Pa	
systemicArteries.volume_start	672 ml	6.72×10^{-4} m³	*
V0VS.k (unstressed volume of systemic veins)	2845 ml	2.845×10^{-3} m³	
CVS.k (compliance of systemic veins)	200 ml/mmHg	1.50×10^{-6} m³/Pa	
systemicVeins.volume_start	3922 ml	3.922×10^{-3} m³	*
V0AP.k (unstressed volume of pulmonary arteries)	327 ml	3.27×10^{-4} m³	
CAP.k (compliance of pulmonary arteries)	3.01 ml/mmHg	2.26×10^{-8} m³/Pa	
pulmonaryArteries.volume_start	373 ml	3.73×10^{-4} m³	*
V0VP.k (unstressed volume of pulmonary veins)	435 ml	4.35×10^{-4} m³	
CVP.k (compliance of pulmonary veins)	30 ml/mmHg	2.25×10^{-7} m³/Pa	
pulmonaryVeins.volume_start	704 ml	7.04×10^{-4} m³	*
RT.k (total systemic resistance)	1 (mmHg.s)/ml	1.33×10^{8} (Pa.s)/m³	
RP.k (total pulmonary resistance)	0.07 (mmHg.s)/ml	9.33×10^{6} (Pa.s)/m³	
rightHeart.StarlingSlope	16.67 ml/(mmHg.s)	1.25×10^{-7} m³/(Pa.s)	
leftHeart.StarlingSlope	10 ml/(mmHg.s)	7.50×10^{-8} m³/(Pa.s)	

TABLE 3 Additional initial values of state variables and parameters of the pulsatile model of CVS in Modelica. Decreased value of CAS and changed initial volumes of systemic arteries and veins to compare with reference model. Other values inherited from non-pulsatile model (Table 2)

Parameter	Value	Value in SI	Ref.
CAS.k (compliance of systemic arteries)	0.97 ml/mmHg	7.28×10^{-9} m³/Pa	
systemicArteries.volume_start	603 ml	6.03×10^{-4} m³	*
systemicVeins.volume_start	3991 ml	3.991×10^{-3} m³	*
rightHeart.pulses.QP (peak flow of right heart)	20.28 l/min	3.38×10^{-4} m³/s	
leftHeart.pulses.QP (peak flow of left heart)	20.28 l/min	3.38×10^{-4} m³/s	
pulses.HR (default heart rate)	72 beats per min	1.2 Hz	
Pulses.TD1 (relative time of systole start)	0.07 s	0.07 s	

TABLE 4 Initial values of state variables and parameters of the reference model by Fernandez de Canete et al. [7] in Modelica. Values with reference were taken from the original publication, asterisk indicates initial values computed from steady state simulation, other values were estimated. “ZeroPressureVolume” is unstressed volume of a component, “volume_start” is initial volume of a component. “_Gon” is conductance of a valve in opened state. Compliance and conductance values were counted as reciprocal (1/×) of original elastance and resistance values

Parameter	Value	Value in SI	Ref.
aorta.ZeroPressureVolume	30 ml	3.00×10^{-5} m³	
aorta.Compliance	0.22 ml/mmHg	1.65×10^{-9} m³/Pa	[7]
aorta.volume_start	46 ml	4.60×10^{-5} m³	*
arteries.ZeroPressureVolume	700 ml	7.00×10^{-4} m³	
arteries.Compliance	1.46 ml/mmHg	1.10×10^{-8} m³/Pa	[7]
arteries.volume_start	805 ml	8.05×10^{-4} m³	*
veins.ZeroPressureVolume	2370 ml	2.37×10^{-3} m³	
veins.Compliance	20 ml/mmHg	1.50×10^{-7} m³/Pa	[7]
veins.volume_start	2443 ml	2.44×10^{-3} m³	*
pulmonaryArtery.ZeroPressureVolume	20 ml	2.00×10^{-5} m³	
pulmonaryArtery.Compliance	0.09 ml/mmHg	6.75×10^{-10} m³/Pa	[7]
pulmonaryArtery.volume_start	21 ml	2.10×10^{-5} m³	*
pulmonaryArterioles.ZeroPressureVolume	600 ml	6.00×10^{-4} m³	
pulmonaryArterioles.Compliance	2.67 ml/mmHg	2.00×10^{-8} m³/Pa	[7]
pulmonaryArterioles.volume_start	637 ml	6.37×10^{-4} m³	*
pulmonaryVeins.ZeroPressureVolume	100 ml	1.00×10^{-4} m³	
pulmonaryVeins.Compliance	46.7 ml/mmHg	3.50×10^{-7} m³/Pa	[7]
pulmonaryVeins.volume_start	659.7 ml	6.597×10^{-4} m³	*
heartRate.k	72 1/min	1.2 Hz	
leftVentricle.ZeroPressureVolume	90 ml	9.00×10^{-5} m³	
leftVentricle.volume_start	209.7 ml	2.097×10^{-4} m³	*

Parameter	Value	Value in SI	Ref.
timeVaryingElastanceLeft.Ed	0.1 mmHg/ml	1.33×10^{7} Pa/m^3	[7]
timeVaryingElastanceLeft.Es	1.375 mmHg/ml	1.83×10^{8} Pa/m^3	[7]
timeVaryingElastanceLeft.Pi0	50 mmHg	6.66×10^{3} Pa	[7]
rightVentricle.ZeroPressureVolume	70 ml	7.00×10^{-5} m^3	
rightVentricle.volume_start	180 ml	1.80×10^{-4} m^3	
timeVaryingElastanceRight.Ed	0.03 mmHg/ml	4.00×10^{6} Pa/m^3	[7]
timeVaryingElastanceRight.Es	0.328 mmHg/ml	4.37×10^{7} Pa/m^3	[7]
timeVaryingElastanceRight.Pi0	24 mmHg	3.20×10^{3} Pa	[7]
mitralValve._Gon	266.6 ml/(mmHg.s)	2.00×10^{-6} m^3/(Pa.s)	[7]
RleftMyo.Conductance	12.5 ml/(mmHg.s)	9.37×10^{-8} m^3/(Pa.s)	[7]
aorticValve._Gon	266.6 ml/(mmHg.s)	2.00×10^{-6} m^3/(Pa.s)	[7]
Raorta.Conductance	14.81 ml/(mmHg.s)	1.11×10^{-7} m^3/(Pa.s)	[7]
Rsystemic.Conductance	1 ml/(mmHg.s)	7.50×10^{-9} m^3/(Pa.s)	[7]
tricuspidValve._Gon	266.6 ml/(mmHg.s)	2.00×10^{-6} m^3/(Pa.s)	[7]
RRightMyo.Conductance	57.14 ml/(mmHg.s)	4.29×10^{-7} m^3/(Pa.s)	[7]
pulmonaryValve._Gon	266.6 ml/(mmHg.s)	2.00×10^{-6} m^3/(Pa.s)	[7]
RPulmonaryArtery.Conductance	29.62 ml/(mmHg.s)	2.22×10^{-7} m^3/(Pa.s)	[7]
RPulmonaryVeins.Conductance	9.9 ml/(mmHg.s)	7.43×10^{-8} m^3/(Pa.s)	[7]
aorticInertia.I	8.25×10^{-4} mmHg.s^2/ml	1.10×10^{5} Pa.s^2/m^3	[7]
aorticInertia.volumeFlow_start	623.1 ml/min	1.04×10^{-5} m^3/s	*
systemicInertia.I	3.6×10^{-3} mmHg.s^2/ml	4.80×10^{5} Pa.s^2/m^3	[7]
systemicInertia.volumeFlow_start	4761 ml/min	7.94×10^{-5} m^3/s	*
pulmonaryArterialInertia.I	7.5×10^{-4} mmHg.s^2/ml	1.00×10^{5} Pa.s^2/m^3	[7]
pulmonaryArterialInertia.volumeFlow_start	43.94 ml/min	7.32×10^{-7} m^3/s	*
pulmonaryVeinsInertia.I	3.08×10^{-3} mmHg.s^2/ml	4.11×10^{5} Pa.s^2/m^{3}3	[7]
pulmonaryVeinsInertia.volumeFlow_start	1335 ml/min	2.23×10^{-5} m^3/s	*

with variable outgoing flowrate. The shapes of the pressure curves in these models are closer to the real experimental measurements.

In order to study more specific phenomena, additional components can be added to the model. For instance, our implementation does not use the inertia element and valves. This seems to be useful for examining the effect of a dicrotic notch in the arterial pressure when the aortic valve closes as seen, for instance, in the model and simulation developed by Fernandez de Canete et al. [7]. Figure 14 shows comparison with simple pulsatile model.

Our implementation uses one resistance and two elastic vessel components for the pulmonary and systemic circulation with total of 16 parameters and initial values of state variables (Table 2). The pulsatile model adds new 4 parameters and redefine values of three existing (Table 4). This seems satisfactory to explain basic physiological and pathophysiological phenomena, e.g. influence of congestive left or right heart failure to volumes of blood in systemic or pulmonary veins. The more realistic models with additional components introduce also additional parameters and initial values for state variables. The CVS model by Fernandez de Canete et al. [7] has 48 parameters (Table 4) and this may cause some confusion when teaching only the effects described above. But these more complex models are, however, more suitable to study e.g. the phases within cardiac cycle as seen in Figure 12.

The non-pulsatile model (Figure 6) is a base of an existing educational application simple circulation available in the Atlas of Physiology and Pathophysiology (www.physiome.cz/atlas) [18] and is used in teaching physiology and pathophysiology of cardiovascular system of students of medicine and biomedical engineering[19,20]. The new pulsatile model is used in further development of the simulators to describe additionally the Windkessel effect. The simulators are introduced in lectures of pathophysiology for students of medicine and several basic scenarios are demonstrated. Students, according to surveys, use the simulators again at home when they prepare for tests and exams. This has been acknowledged as an improvement of understanding complex relation and mechanism in CVS compared to static text or non-interactive e-learning materials.

The models introduced above are used in teaching modeling and simulation of students of biomedical engineering. Because the physical system can be decomposed into basic components and modeled in an understandable form, the students focus much more on system analysis rather than on implementation issues [21].

There are some general limitations to the models based on the Windkessel phenomenon and modeling pressure volume relationship, e.g. wave transmission and wave travel cannot be studied.

CONCLUSION

Modeling technique and example models were introduced to demonstrate some effects that are important in understanding the physiology of the cardiovascular system, e.g. flow is determined by pressure gradient and Windkessel effect stabilizes the flowrate changes going from the heart to the peripheral vessels.

The implementation in Modelica language, utilizing the open source Physiolibrary, allows the expression of a complex system of differential and algebraic equations in self-descriptive model diagrams. The mathematics is hidden in the low level component model definition.

The newly introduced pulsatile model of CVS is used in further development of educational simulators.

A full source code of presented models is attached as supplementary materials to this paper and can be tried in the commercial tool Dymola or in the open source tool OpenModelica (www.openmodelica.org) using Physiolibrary (www.physiolibrary.org).

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POSSIBILITIES OF UTILIZING BLENDED-LEARNING IN THE AREA OF LANGUAGE EDUCATION OF MEDICAL STAFF

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ABSTRACT — *This contribution deals with the presentation of teaching materials created within the IMED-KOMM-EU 'Intercultural medical communication inEurope' internet project, having taken place under the leadership of the Institute for Intercultural Communication in Germany(Ansbach, Berlin, Jena, Erfurt). Project target was creating, testing, valorisation and permanent extending of the mentioned teaching materials, testing and certification technologies (ECL) for intercultural professional communication of foreign physicians and other medical staff. The target groups involving the already practising professionals, as well as students, should be able to utilize the existing possibilities of communication withinEuropeand to perform their professional activity or studies in the languages, in which the materials are elaborated. As a result, five complete courses of blended-learning were created, which are generally easily accessible at mutually connected web sites in Czech, Slovak, German, Bulgarian and Hungarian. Their core are modules orientated on practice with complex exercises online and offline focused on the medical communication, including the manuals for teachers.*

INTRODUCTION

A successful communication in the health system assumes that every medical employee should dispose of professional level of language competences representing the base for the effective communication with the clients as well as among medical staff at the workplace. The experience from practice show that the communication skills at least in one foreign language increase the value of the expert with such skills at the labour market in the whole EU. For this reason, IMED-KOMM-EU 'Intercultural medical communication in Europe' [1] project was created the target of which was to support the sustainable professionally orientated foreign language teaching for the purpose of acquiring the job in health system in various EU countries. The project combines the traditional form of education for the purpose of acquiring a particular qualification with life-long learning of already professionally active experts. Its concept continues preceding projects of this type, e.g. MIG-KOMM-EU 'Multilanguage intercultural business communication for Europe', terminated in 2011. In this case, materials are determined for teaching professional language and professional communication to physicians and nursing staff.

The project is, among others, based on the fact that the language variety supported by EU brings, together with the necessity of additional language education also the necessity of intercultural education and for this reason also these aspects were included into the exercises focused on the development of the communication skills. Project originators are aware from the very beginning that modern technologies facilitate the language teaching doubtlessly and make it attractive to a certain extent. However, it would be erroneous to think that the technical support of education is a cure-all. Penetration of media into our life and mobility alone does not enable to recognize the national stereotypes and does not correct the problems in communication caused by missing knowledge of intercultural differences. The finding that managing intercultural competences falls behind other knowledge and skills [2] applies practically to all the areas of human activity.

We can designate the current time as information or media time; the reality is intermediated to us through mass media, among which television and internet have a privileged position [3]. Through internet, almost everything is achievable, including educational possibilities. Information and communication technologies penetrated into all the areas of life, including educational process; they were implemented there among others in the form of e-learning, the meaning of which for school education was highlighted in several EU documents, e.g. eEurope 2002 or eEurope 2005 [4]. Besides indisputable advantages, this form of education has minimally one negative feature: it is, in principle an impersonal form of communication not being able to replace a direct contact between the pedagogue and pupil/student.

REASONS FOR CHOOSING BLENDED-LEARNING

The introduction of new technologies into education was initially welcomed with enthusiasm, e.g. in the USA, e-learning, also called tele-learning, has long tradition in connection with the distance learning. In this context it should be noted that reasons for its introduction were mainly economic, because the transmission of information via the intranet was much cheaper option, which brought the same results as conventional forms of training. Therefore, new information technologies started to be used in further education of employees in large firms, banks and insurance companies, obviously with great success [5]. As time moved on, it became apparent that this form of courses is not applicable in all forms of education. It is successful in the case of transmission of accurate data, but there are areas where immediate communication between the teacher and the student, or among students themselves, a substantial part of the curriculum. Such an area is undoubtedly the language education.

During rotation of different teaching methods in the classroom — not only foreign languages — it turned out that mere self-study by means of information technologies has not brought the expected results [6] and that the integration of the phases with direct contact between the teacher and the student is irreplaceable. Information technologies are indeed very beneficial in the educational process. It can be said that they make learning more attractive, but their function is rather supportive [7].

For this reason, the starting point for creation of the multi-language educational IMED-KOMM-EU project became the possibility of implementation of 'blended-learning', i.e. combination of E-learning with traditional contact teaching which may be defined as learning focused on optimum achieving of learning targets by means of suitable technologies [8].

The creators of the above project proceed from the fact that e-course must be composed, as Barešová shows for example, of the content of education, distribution of e-courses and the overall organization of the course in direct cooperation with the participants of the course [9]. The success rate is not guaranteed by the mere creation of educational materials focused on the specific needs of the target group, but it is also important to verify them in practice. For this reason, the materials have been thoroughly tested and evaluated and also the information about their existence was spread, e.g. in the form of newsletters or contributions at events focusing on foreign language teaching. Such events include meetings of the Association of Teachers of Czech as a Foreign Language [10].

It can be said that the project IMED-KOMM-EU is not just teaching material, but also provides comprehensive information on the issue, including links Podcasts, Videocasts or Wiki, so its results are presented in the form of web gateways with exercises designed as a blended-learning course.

The project priority is organisation of language courses focused on the training of medical communication including the professional part as well as exercises focused on the knowledge necessary for the successful communication between the clients (patients) and medical staff or medical staff mutually. During the implementation of mentioned exercises, it was assumed that the unsuitable communication by the medical staff arouses unpleasant experiences in the client which are difficult to remove and remedy. It may be said, identically as teachers are the decisive element for the positive relationship of the pupil to teaching, medical staff is influencing factor of the total attitude of the client to the treatment [4].

PROJECT TARGETS

E-learning as individualized form of teaching offers many various combinations of methods which are important to think about. First of all the aim of teaching shall be taken into consideration. The use of many methods attractive at first sight does not guarantee the success as by their not-well thought combination, the chaos and non-effective or even bad transfer of knowledge or skills at which the teaching was aimed may be caused. 'Blended- learning' is combination of e-learning with traditional contact teaching; it is a method trying to replace some disadvantages of e-learning. One of the variants of 'blended-learning' is teaching taking place in the real time and space in which all the participants accept information simultaneously and react on each other in the virtual class where they can meet in the same time by means of information and communication technologies and communicate although they are in different places. Another way may be the combination of contact teaching and e-learning course with which the participants work individually, i.e. in various time they can select the way of accepting information without possibility to react on each other mutually. Contact teaching in the seminar or workshop, implemented from time to time follows after the individual study.

TABLE 1 Characteristics of medical facility

Medical facility	
State medical facility	96%
Non-state medical facility	4%

TABLE 2 Professional focus and specialization of respondents

Professional focus	
General nurse	70%
Midwife	26%
Physiotherapist	4%

Specialization	
Internal medicine	37%
Surgery	29%
Palliative care	4%
Gynaecology/obstetrics	26%
Physiotherapy	4%

TABLE 3 Level of language skills of respondents

Level of initial language skills of respondents	
B1	70%
B2	30%

TABLE 4 Results of evaluation of teaching material

Demands of course exercises	
Appropriate	70%
Difficult	30%

Instructions to excercises	
Understandable	74%
Less understandable	26%

Topics, demands of texts	
Corresponding	100%
Non-corresponding	0%

Importance of inter-culturally focused exercises	
1	59%
2	22%
3	19%

INITITAL EXPLORATION ON THE PROJECT

The project commenced in October 2012 within innovative LEONARDO DA VINCI transfer program supported by EU, under the leadership of the Institute for Intercultural Communication, registered association (IIK Institut für Interkulturelle Kommunikation e. V., Ansbach, Berlin, Jena, Erfurt), in co-operation with other project partners, Medical University of Varna, Institute of Language and Intercultural Communication s.r.o. in Nitra, Faculty of Health and Social Studies of the University of South Bohemia in České Budějovice and Language Center of Pécs Univerzity.

Creation of teaching materials was preceded by extensive search and questionnaire investigation having enabled to determine the following project targets: creation and systematization, modernization, testing, optimization, valorisation and permanent extension of modern, innovative teaching materials and testing and certification techniques (ECL) for intercultural professional communication of foreign physicians and other medical staff in the countries of consortium as well as in other member states of EU. The target groups should be able to utilize the existing possibilities of communication in Europe and to perform their professional activities in member states of EU.

The first search concerned first of all establishing the demands on professional activities and communicative competences of medical staff in individual countries of consortium; the source of information were first of all the provisions concerning the respective qualification criteria for executing medical professions in individual countries of consortium and associated demands on language competences, which the foreign staff shall acquire before taking up the job in the respective country. The source of information became also the requirements of partners from practice and institutions educating future medical staff including the education of foreigners. In the second stage of investigation which took place in the tested groups having worked with courses already, the particular first experience of students with teaching materials was found out. The results from this phase are presented in Table 4. For a better idea, we state the results of a part of the questionnaire investigation implemented at the Faculty of Health and Social Studies of University of University of South Bohemia in České Budějovice in which 27 respondents working in nursing professions participated. Table 1 presents characteristics of the respondents according to a medical facility. Professional focus and specialization of respondents specifies Table 2. Table 3 contains the input language skills of respondents.

Moreover the respondents considered for interesting the following methods included into the course: self-evaluation, quiz, glossary and exercises focused on the development of communicative competences.

Based on the stated investigation, analysis of needs and experience from pedagogical practice, teaching materials were created which were subsequently systematized and updated based on unified conception as well as integrated into the new innovative teaching environment customized to target groups of project. In the final form, they should be used to the identical extent for the education of adults as well as for professional preparation at schools preparing the future medical professionals.

PROJECT RESULTS

As follows from project targets, the main result is the modern teaching environment, i.e. five complete courses of 'blended-learning', focused on target groups and specifics of particular country, available at web portals for intercultural medical communication in German, Bulgarian, Slovak, Czech and Hungarian in the following structure:

- Language courses German, Bulgarian, Slovak, Czech and Hungarian for foreign physicians
- Language courses German, Bulgarian and Czech for foreign medical staff
- Language courses Communication with patient in German, Bulgarian and Czech
- Language courses German for physicians and medicine students.

Besides the exercises for online and offline stages, the project brought other results:

- Research associated with the main items of project (first of all with products/materials) in partner countries and their publishing
- Creation of unified methodical-didactic concept for 5 courses, i.e. determination of topics for programmed exercises and exercises for teaching with attendance.
- Creation of manual for pedagogues with instruction how to work with courses of 'blended-learning'
- Creation of 5 mutually interconnected interactive web-sites with the 'blended-learning' course, manuals, programmed exercises and exercises for teaching with attendance, videos, audio-recordings, instructions, glossaries, tests for ECL examinations, pod-casts/video-casts, wiki, references, quiz, online questionnaires, forms, statistics, blogs and photo-galleries to the medical communication
- New testing material to ECL tests in 5 languages of partners: curricula, model tests, standard tests
- Assurance of valorisation/sustainability through advisory board, workshops and conferences.

FIGURE 1 The homepage of the project website

FIGURE 2 A screenshot from the Czech language course

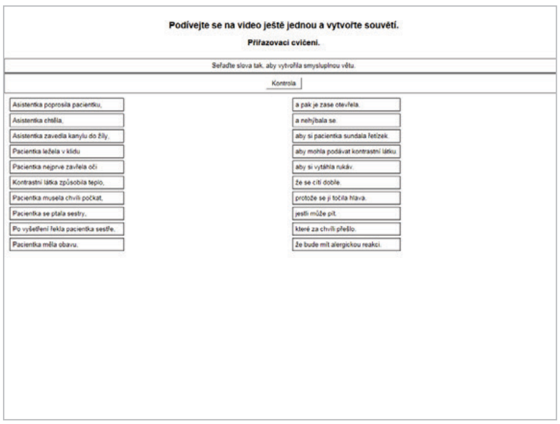

FIGURE 3 A screenshot from the Czech language course

FIGURE 4 A screenshot from the Czech language course

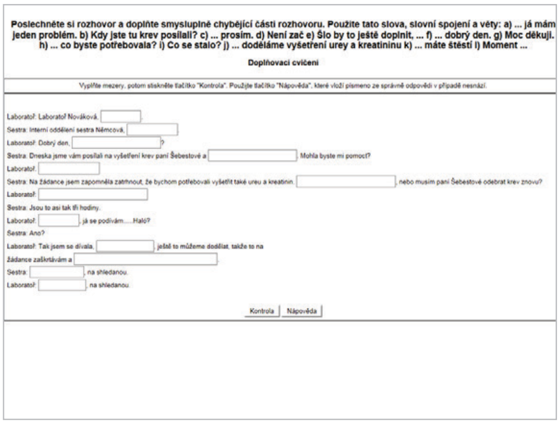

FIGURE 5 A screenshot from the Czech language course

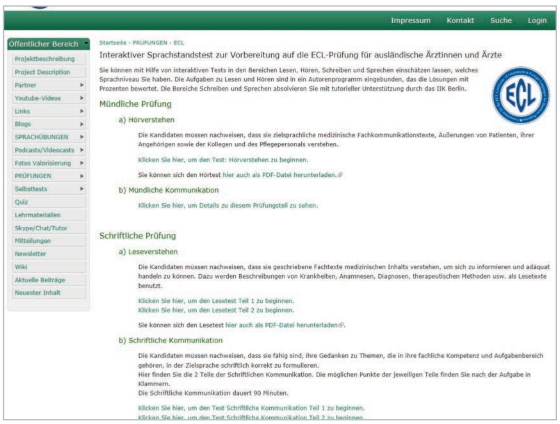

FIGURE 6 An example of a test included in a course

Structure of teaching platform

'Blended-learning' includes interactive website with several language courses representing the central part of the teaching and having a modular structure:

- Federal Republic of Germany: http://www.imed-komm.eu/
- Bulgaria: http://dp.mu-varna.bg/?q=zaglavna
- Slovak Republic: http://imed-komm.eku.sk/
- Czech Republic: http://imed-komm.jcu.cz/
- Hungary: http://inyt.pte.hu/imedkomm/

The structure of website unified for all the countries consists of several parts. A more detailed structure is located at initial website of projects partners.

Characteristics and contents of language course

Language courses in narrower sense of word (programmed exercises for self-study and not-programmed exercises for contact stage of teaching) are located at external website and they are highlighted there (e.g. through large photographs), as visible e.g. at the website displayed in Figure 1.

In modules of these courses, texts and situations may be found which could be relevant for the area of activity of course participant. At the beginning, there are printed or spoken texts and videos the participant has to go through obligatorily and the tasks follow concerning the fundamentals of the respective branch and the grammar parts making problems during the study of foreign language by foreigners. Quiz as part of self-study shall inform the course participants how good is their professional and language knowledge in the respective branch. They can decide according to them, which units or which topics they would like to study in the scope of modular arrangement.

The target of courses is the development of all the four language skills, i.e. reading with comprehension, listening with comprehension, written and oral communication, although we are aware that determination of their main items is very complicated as the requirements depend on many external as well as internal factors, first of all on the respective area of activity.

The main parts of these four language skills are developed differently, depending on specific characteristics of situation of self-study or language teaching, being implemented just now, e.g. on the used technical means. In programmed exercises, the tasks and exercises for reading and listening with comprehension or guided writing prevail; in the contact stage of the lessons, first of all the oral and free written communication is developed or supported. The selection of vocabulary for the written and oral communication is determined considerably by the choice of texts, audio-recordings and video-recordings. The selection of main grammar issues is influenced very strongly by the kind of texts; these are texts usual in the medical communication.

To have a better idea, we state the examples of several exercises from the Czech course showing the possibilities of preparing the teaching video and audio-recording for the self-study (Figures 2–5).

As already mentioned, the course contains the exercises for self-study as well as for contact stage of teaching. It is supposed that the students will be introduced into the topic in the stage with personal attendance, acquire the vocabulary, train the basic communication and subsequently exercise everything in the form of tests published at web site of the project individually. During the following contact teaching, the teachers will consult everything with students and train the parts of curriculum causing problems. In the annex we state for better idea the example of lecture for contact stage of teaching coming from the Czech course for nursing staff.

It is possible to work with course as one whole or to select only individual parts based on professional focus or sphere of interest. In case of course lead by a pedagogue the teacher will decide which parts will be selected for the contact stage of teaching and which for self-study. For this reason, the part with attendance is elaborated in PDF, so that the teacher could select the parties corresponding to topical needs of teaching in the group.

The initial level of course students supposes the knowledge minimally on the level B1 of the Common European framework of reference for languages and the structure of exercises focused on grammar is influenced hereby. The contents of exercises is based on the initial text which enables to deepen also the vocabulary together with grammar phenomena.

A part of study materials are also the exercises focused on the development of intercultural competences located in the special module 'Exercises for training of communication with patient'. The students should acquire here the key information for successful communication with clients including the clients from a different cultural environment.

Including ECL tests into project

The elaboration of standardized systems of tests and examinations has turned to be especially necessary. In the project scope, a special extensive complex of ECL tests and examinations was planned. The reason for this part of the project is that the medical staff needs professional language competence for its successful practical activity in clinic, hospital or for its own medical offices — physician at least on the level C1, medical staff at least on the level B2. For this reason, consortium decided to suggest and to offer with prospects for the future especially to these clients another type of course 'blended-learning', focused not only on the teaching of oral communication but on all four key language competences, and subsequently, after this course, the intended standardized over-regional ECL examination in professional language. The respective model tests may be found at websites of project (Figure 6).

CONCLUSION

There are currently (in comparison with the huge boom in information technology in general) relatively few studies dealing with the introduction of e-learning, respectively blended-learning in language teaching. For example, in Aula magazine, which deals with the issue of tertiary education, between the years 2010–2013 there were only 8 posts relating to information technology applied to universities, i.e. the use of e-learning in university education. However, neither of these studies dealt with the education of language. Already in 2003 Karel Květoň pointed out the low rate of e-learning in tertiary education [11]. It seems that over the years not much has changed, or the educators who use e-learning in teaching do not share their experience. Based on the above findings, it can be assumed that the project IMED-KOMM-EU, focusing on foreign language communication in the healthcare environment is rather unique. The lack of educational blended-learning materials aimed for training communication in medical environment was indeed a reason why the project was financially supported by the EU. For this reason, unfortunately, the products published on its web portals and experience acquired through evaluation of created courses cannot be compared with other studies dealing with teaching medical communication in foreign languages.

Courses of 'blended-learning' created within IMED-KOMM-EU project represent, as already mentioned, the form of teaching connecting the advantages of self-study on one hand with advantages of the direct contact between the lecturer/tutor and course participants on the other hand. The superior target of courses is the development and subsequent strengthening of key competences focused on the professionally orientated intercultural medical communication and European certification. Hereby, the project aims at contributing first of all to the life-long professional education in health system, the purpose of which is the success at the labour market, and also strengthening the European integration.

As the language courses are destined for a wide range of interested persons, i.e. physicians and other professional medical staff as well as student of medicine and non-physician branches, it is supposed that the trouble-free availability of created teaching materials will contribute to extension of foreign language communication of medical staff, very necessary for executing medical profession in the home environment as well as within EU.

Information and communication technology can be used in all forms of studies — full-time courses, part-time courses, as well as distance study [12, 258]. Created teaching materials can be effectively used in teaching a foreign language, both in the full-time and in the distance form of study at universities with medical specialization. The reason for their use is, besides possible adaption to the individual needs of students, a relatively low number of hours of language teaching, so it is useful to combine contact learning with self-study. The implementation of e-learning should make teaching certainly more efficient, which is facilitated by possible immediate feedback when solving programmed exercise.

The target of creators of the Czech project version for the next period is additional testing of German teaching materials in the lessons of professionally focused German at the Faculty of Health and Social Studies of the University of South Bohemia in České Budějovice and the parallel following to what extent the method of 'blended-learning' contributes to improving communicative competences of students, who can utilize them subsequently during their practice in medical facilities of German speaking countries. We believe that thanks to research in this area we could extend the literature on the use of e-learning in teaching foreign languages at Czech universities.

Mgr. Radka Šulistová, Ph.D.

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THE MATHEMATICAL MODEL OF A LUNG SIMULATOR

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ABSTRACT — *The paper discusses the design, modelling, implementation and testing of a specific LUNG simulator. The described research was performed as a part of the project AlveoPic — Advanced Lung Research for Veterinary Medicine of Particles for Inhalation. The simulator was designed to establish a combined study programme comprising Biomedical Engineering Sciences (FEEC BUT) and Healthcare and Rehabilitation Technology (FH Technikum Wien). The simulator is supposed to be an advanced laboratory equipment which should enhance the standard of the existing research activities within the above-mentioned study programs to the required level. Thus, the proposed paper introduces significant technical equipment for the laboratory education of students at both FH Technikum Wien and the Faculty of Electrical Engineering and Communication, Brno University of Technology. The apparatuses described here will be also used to support cooperative research activities.*

In the given context, the authors specify certain technical solutions and parameters related to artificial lungs, present the electrical equipment of the system, and point out the results of the PC-based measurement and control.

INTRODUCTION

The LUNG simulator (LS) presented in this article can operate as an active (controlled by a computer) or passive (standalone) simulator of real lungs. During the simulation of active lungs, the LS can execute standard physiological breathing or one of the five known (and most important) pathological breathing patterns. This is enabled by not only the mechanical and electromechanical parts of the simulator but also an intelligent hierarchical control algorithm realized via C-RIO hardware and the associated LabVIEW development and simulation SW system. LUNG simulator is also designed in teaching within the Master's Double Degree study program.

The electromechanical structure of the LS simulator is shown in Figure 1 [1], which generally indicates the five major components of the device. The first of these elements is a thoracic chamber, a mechanism that simulates (very approximately) the corresponding part of the human and/or porcine body, the thorax. Although the thoracic chamber cannot fully substitute for the construction of the body, it is capable of providing realistic simulation with related physiological conditions and pathological anomalies. The thoracic chamber is connected to a system of bellows and a vacuum pump, namely the second and third components of the simulator.

The bellows system induces pressure differences within the thoracic chamber via the actual movement of the bellows. The compression and extension of the bellows is in direct correlation to the ball-screw in the centre of the bellows. A motor rotates the ball-screw, enabling the bottom of the bellows to move downward or upward. The pressure change within the thoracic chamber causes an inflation and deflation of the utilised lung or lung equivalent.

The speed of the bellows' expansion or contraction is continuously controlled by the air flow to or from the lung equivalent being compared with the desired behaviour of the respiratory curve.

The vacuum pump creates a constant negative pressure in order to achieve a more realistic anatomical and physiological breathing situation; this constant negative pressure represents the adhesion of the human lung to the thorax through the pleura.

The fourth part of the apparatus consists in the lung itself. For medical research purposes, different bags from various elastic materials can be used (instead of the human or porcine lung) to simulate different anomalies in the tissue surrounding the lung;

FIGURE 1 The electromechanical structure of the LUNG simulator [1]

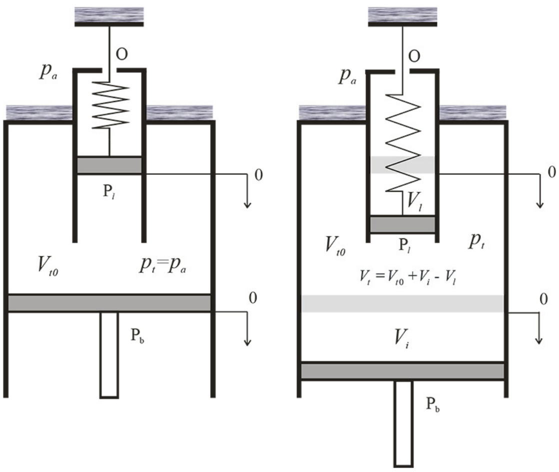

FIGURE 2 An abstract approximation of the LUNG simulator (LS)

importantly, such an alternative approach complies with EU regulations concerning experiments on animals.

The fifth component consists of the group of elements including the electronics, or the measurement and control systems which ensure the stability, accuracy and quality of the breathing process control [3].

To the best of our knowledge, the proposed lung construction and the idea of lung modelling and simulation are original; they differ from pure mathematical simulation of the lung tissue function as analysed in Ionescu et al. [4]. Also, the concept presented in this paper differs from systems that do not use a real lung or some equivalent of relevant biological tissues; an example of such approach is introduced in Mesić et al. [5]. Even though certain structures similar to ours were proposed by Tang et al. [6], we can aptly describe our system as substantially more sophisticated.

The following chapters comprise the analysis of the LS system, the identification of principal mathematical relations between elements of the model, and the evaluation of disturbances, leakages or non-linearity; these aspects are then complemented with the specification of the most appropriate mathematical model of the LS. Moreover, theoretical assumptions are compared with real properties of the system.

MATHEMATICAL MODEL OF THE THORACIC BOX

The real mechanical system was approximated by the abstract system shown in Figure 2. This abstract system consists of a thoracic box (TB) and a lung cylinder, which approximates the balloon of the mechanical model. The volume of the TB is regulated by a piston P_b, which approximates the behaviour of the bellows in the LS, and by the piston P_l of the lung cylinder. The lung cylinder is opened to atmosphere via an opening O. When the piston P_b moves down, the volume V_t of the TB increases, and when the piston P_l moves down, the volume V_l of the lung cylinder increases with the decreasing volume V_t of the TB. Thus, the abstract system works similarly as the LUNG simulator, which reproduces the breathing of a human being.

The abstract system can be described using the mathematic model below. We apply commonly used units instead of SI units where we consider it more appropriate, e.g. dm^3 or *litres* instead of m^3.

The volume of the TB is given by the following formula:

$$V_t = V_{t0} + V_i - V_l \tag{1}$$

where V_t is the volume of the TB [dm^3], V_{t0} is the initial volume of the TB (when the P_b is in the zero position), V_i is the volume added by the movement of the piston P_b and V_l is the volume of the lung.

The volume added by the movement of the piston P_b from the zero or reference position $l = 0$ is expressed as:

$$V_i = S_p l \tag{2}$$

where S_p is the area of the piston [dm^2] and L denotes the position of the piston [dm].

The position of the piston P_b is controlled by its velocity v, and thus there holds

$$\frac{dV_i}{dt} = S_p v \tag{3}$$

where v is the velocity of the piston $[dm/s]$.

To express the relationship between the volume V_t and the pressure p_t in the TB, we use the ideal gas law; we then have

$$p_t V_t = nRT = const\,, \tag{4}$$

where n is the amount of gas (measured in moles), R is the universal gas constant, and T is the absolute temperature of the gas. Using commonly applied units, the equation can be rewritten in the following form:

$$100 p_t V_t = nRT = const\,, \tag{5}$$

where n is the amount of gas $[mol]$, R is the universal gas constant $[J\ mol^{-1}K^{-1}]$, T is the absolute temperature $[K]$, V_t is the volume of the TB $[dm^3]$ and p_t is the pressure of the gas inside the TB $[bar]$.

Assuming constant temperature of the air in the TB to be $20\ °C$, which gives $T = 293.15\ K$ and $R = 8.31$ $J\ mol^{-1}K^{-1}$, the gas law equation can be expressed in the form

$$p_t V_t = 24.35 n = const \tag{6}$$

At the beginning of the working cycle of the LUNG simulator, we can assume atmospheric pressure in both the TB and the lung cylinder (balloon). Thus, the following equation is valid:

$$p_t V_t = p_a V_{t0} = 24.35 n_0\,, \tag{7}$$

where p_a is the atmospheric pressure, and n_0 is the initial amount of the air inside the TB.

As the TB is not tight enough, the amount of the air inside will be changed during the operation of the simulator, and we thus have. Then, using (7) and (6), we derived the final formula between the volume and the pressure inside the TB:

$$p_t = \frac{p_a V_{t0} + 24.35 \cdot n_0}{V_t} \tag{8}$$

where m represents the leakage of air into the TB. We assume the time rate of leakage in the form

$$\frac{dm}{dt} = C(p_a - p_t) = C p_v\,, \tag{9}$$

where is the vacuum in the TB, and C $[mol\ s^{-1}\ bar^{-1}]$ is the leakage constant.

Let us suppose $V_t = V_{t0} = const.$; then the above formula (8) yields

$$p_t - p_a = p_v = \frac{24.35}{V_{t0}} m \tag{10}$$

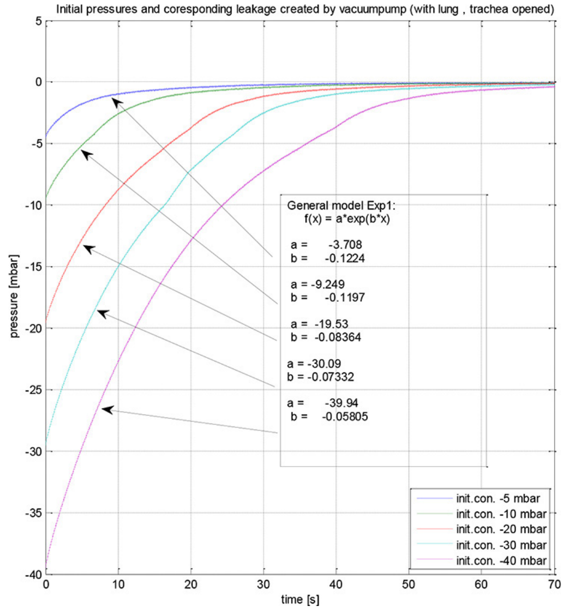

FIGURE 3 The leakage measurement

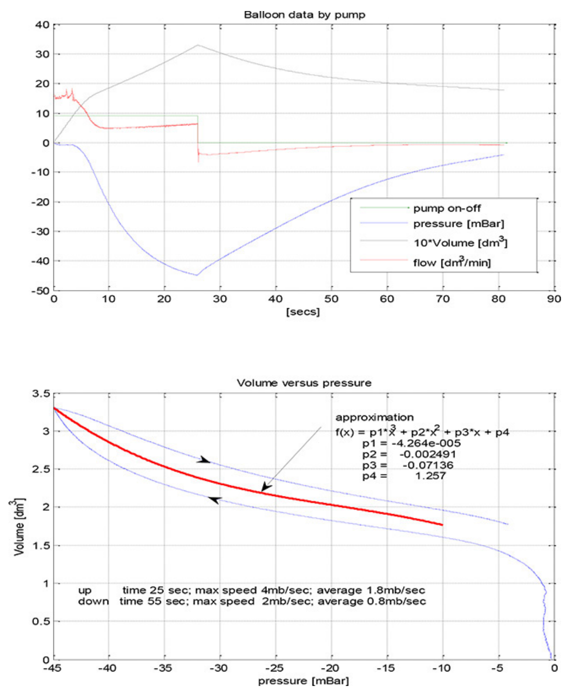

FIGURE 4 The volume pressure characteristics of the used balloon

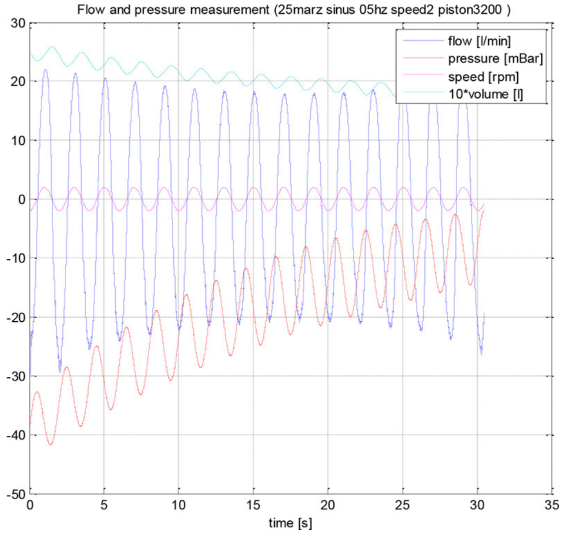

FIGURE 5 A frequency response to the input Vi

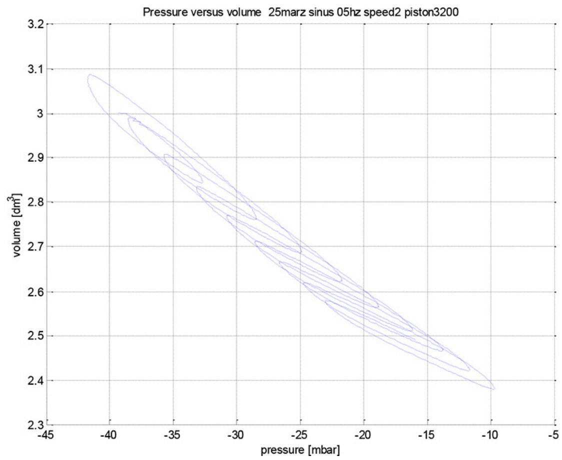

FIGURE 6 The volume pressure relationship from Figure 5

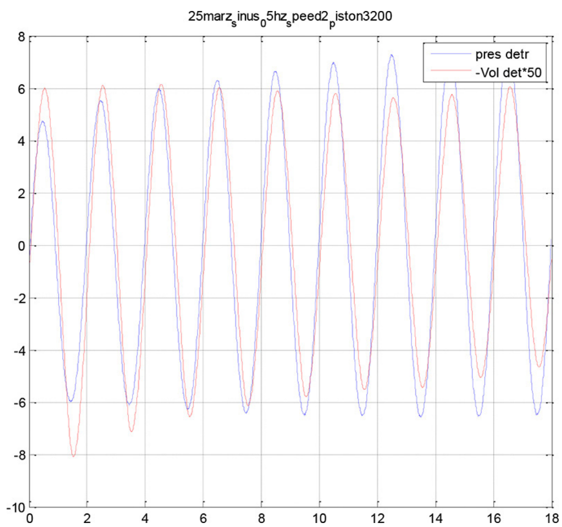

FIGURE 7 The detrended signals of the TB pressure and the balloon pressure volumes oscillate around −40 mbar; the negative volume oscillates around 2dm^3

Substituting p_v from (10) for *m* in (9) will yield

$$\frac{dp_v}{dt} = C\frac{24.35}{V_{t0}}p_v\,; \tag{11}$$

thus, the transient response of the vacuum to the initial condition $p_v(0)$ is

$$\frac{dp_v}{dt} = C\frac{24.35}{V_{t0}}p_v\,, \tag{12}$$

where b = 24.35 C / V_{t0}

Eq. (12) allows us to evaluate C by measuring the change of pressure in the TB. The initial vacuum in the TB is developed by a vacuum pump, and the transient response is measured. The results of both the measurement and the curve fitting procedure are shown in the Figure 3.

The measurement results yield $C \approx -0.07$ [$mol\ s^{-1}\ bar^{-1}$].

MATHEMATICAL MODEL OF THE LUNG EQUIVALENT

As providing a mathematical model of a lung tissue is an extremely complicated task, we chose a rubber balloon as the lung substitute. However, even a mathematical model of the balloon can be provided only with difficulty [7]; let us therefore start with the simplest linear model of the balloon in the form of the cylinder shown in Figure 2. The following equation then represents its function in the lung simulator:

$$\ddot{x} + \frac{B}{m_p}\dot{x} + \frac{K}{m_p}x = \frac{F}{m_p}\,, \tag{13}$$

where x is the position of the piston, B is the damping parameter, K is the stiffness of the spring, m_p is the mass of the piston, and F is the force acting on the piston.

Equation (13) can be written in the more abstract form

$$\ddot{x} + 2\xi\omega_0\dot{x} + \omega_0^2 x = \omega_0^2\frac{F}{K}\,, \tag{14}$$

where ξ is the damping coefficient, and ω_0 is the natural frequency. Both these coefficients characterise the dynamic properties of the balloon substitute.

The behaviour of this mathematical model obviously does not match the behaviour of a rubber balloon (and not even that of human lungs) in an exact manner; however, we can assume some average values of the dynamic coefficients ξ and ω_0 and nonlinear stiffness of the spring, which will lead us to the equation

$$\ddot{x} + 2\xi\omega_0\dot{x} + \omega_0^2 x = \omega_0^2 f(p_v), \tag{15}$$

We also assume constant atmospheric pressure inside the cylinder (balloon), and thus the force acting on the piston will be proportional to the difference of the atmospheric pressure and pressure in the TB. Taking into account the linear relationship between the position of the piston and the volume in the cylinder, we can then rewrite eq. (15) into another form:

$$\ddot{V}_l + 2\xi\omega_0\dot{V}_l + \omega_0^2 V_l = \omega_0^2 f(p_v), \tag{16}$$

where

- V_l the volume of the balloon [$dm^{\wedge 3}$]
- ω_0 the natural frequency [rad/sec]
- ξ the damping coefficient $\xi > 0$
- p_v the vacuum [bar]

The fundamental difference between the balloon and its mechanical substitute cylinder will be diminished by an appropriate choice of the nonlinear function $f(p_v)$, which in fact represents the steady state volume of a balloon subjected to constant vacuum. Unfortunately, there is no direct measurement of V_l, and its value can thus be obtained only by flow integration, which is measured directly. We have

$$V_l(\tau) = \int_0^{\tau} q(t)dt + V_l(0), \tag{17}$$

where q [$dm^{\wedge}3/sec$] is the flow of air in/out of the balloon.

Furthermore, we are unable to carry out the measurement in a steady state practically. To avoid a time or phase delay between the input p_v and the output V_l, we must apply a very slow change of p_v. Thus, we increase the vacuum by the vacuum pump and decrease it via pure leakage of air from the TB. The measurement results are shown in Figure 4; the initial volume of the balloon is assumed to be zero.

The reasonable working region of the volume pressure characteristics is between −10 mbar and −45 mbar of vacuum, where the balloon attains a spherical shape. For the vacuum between 0 mbar and −10 mbar, the balloon attains a shapeless form.

The measurement of the volume pressure characteristics shows rate-independent hysteresis. As there are no means of measuring the hysteretic behaviour in detail, we use only the average behaviour of the balloon for further modelling. Average approximation can obviously influence the design of the feedback controller because we, in fact, neglect phenomenon similar to phase or time delay. This should be borne in mind during the designing of the controller.

The following hysteresis approximations were performed:

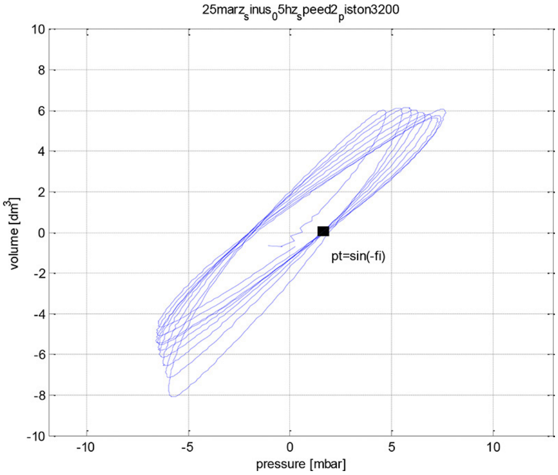

FIGURE 8 The volume pressure relationship from Figure 6

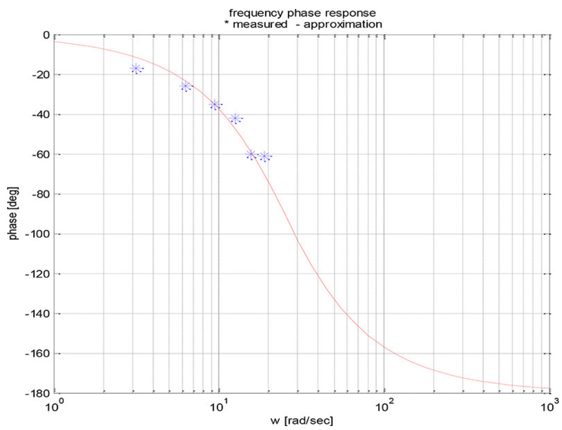

FIGURE 9 The frequency phase response approximation

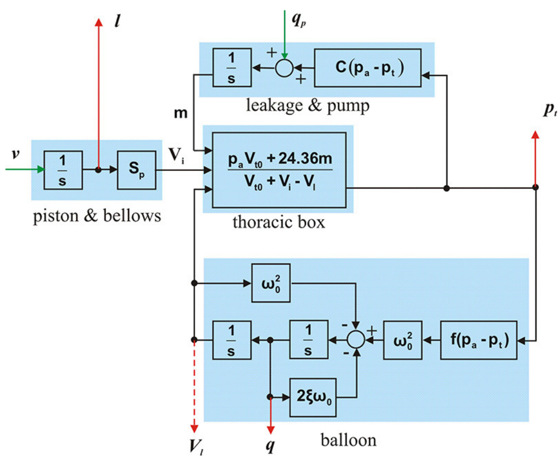

FIGURE 10 The simulation scheme of the mechanical lung simulator

$$V_l = p_1 p^3 + p_2 p^2 + p_3 p + p_4$$
$$p_1 = -4.26 * 10^{-5} \qquad p_3 = -7.13 * 10^{-2}$$
$$p_2 = -2.49 * 10^{-3} \qquad p_4 = 1.257 \qquad (18)$$

where $p = 1000 p_v$ is the vacuum in millibars.

To estimate the parameters ξ and ω_0, we measured several frequency responses of the system to the sinusoidal input signal of the piston velocity v. A typical response is shown in Figure 5.

The sinusoidal velocity of the piston v corresponds to the sinusoidal position of the piston l and to the sinusoidal input volume V_i. The flow and vacuum in the TB are changed not only due to the sinusoidal input signal but also due to the leakage, which begins the trend of output signals. The graph in Figure 6 presents the relationship between the pressure and the volume reveals a 'hysteresis' caused by both the rate-independent hysteresis and the pure phase lag between the signals in the dynamic system of the balloon (16). To evaluate this phase lag, we must remove the trend induced by the leakage.

When we remove the influence of the leakage on the pressure and flow by detrending these output signals, we obtain the graphs of the volume and pressure displayed in Figures 7 and 8.

The graph in Figure 8 enables us to evaluate the phase lag between the pressure (input) and the volume (output). We know that the input signal is and the output signal corresponds to $V_l = V \sin(\omega_t + \varphi(\omega))$. Thus, for $V_l = 0$ we have $\omega_t + \varphi = 0$ and $p_t = P \sin(-\varphi)$.

In the figure, this point is denoted by the black square. Now we perform the same procedure for several frequencies of the input signal v; the results are shown in Figure 9 and Table 1.

All the measurements were performed with the same piston position amplitude, and we thus obtained several points of the Bode plot phase of the system.

Comparing the phase plot from Figure 9 with the phase plot of the 2nd order system (16), we obtain $\xi \approx 0.8$ and $\omega_0 \approx 25$ *rad/sec*, which yields the settling time of the system's step response in the form $t_s \approx .5$sec.

TABLE 1 The results of the phase shift measurement

ω [rad/sec]	P [mbar]	pt [mbar]	φ [deg]
3.14	6.12	1.8	17
6.28	6.21	2.7	26
9.42	6.29	3.6	35
12.57	7.00	4.7	42
15.71	7.53	6.5	60
18.85	8.01	7.0	61

MATHEMATICAL MODEL OF THE VACUUM PUMP

In the final section of the paper, we propose a model of the vacuum pump of the lung simulator. The pump is designed to compensate any leakage of air into the TB; it sucks the air out of the TB, thus increasing the vacuum inside. The mechanism is controlled by an on–off switch and reaches a 10 mbar drop of pressure in approximately 3 secs when on. The pump is used during the starting period to provide the initial vacuum of <–40;–30> mbar, it is switched on irregularly to keep the vacuum inside the TB within the prescribed limits. During the feedback control of the flow or volume of the lung, we can consider the action of the pump as a disturbance which must be suppressed by the flow or volume controller. Thus, our model of the pump activity can be rough; we propose a simple model in the form:

$$\frac{d\Delta m}{dt} = q_p = -0.01 \qquad \text{when on (19)}$$

and

$$\frac{d\Delta m}{dt} = q_p = 0 \qquad \text{when off (20)}$$

This completes the mathematical model of the lung simulator with a balloon. The simulation scheme of the model is shown in Figure 10.

At this point, let us recapitulate some parameters and important data of the model:

- V_t the volume of the thoracic box (max. *40 dm³*);
- V_{t0} the initial volume of the TB (when the Pb is in the zero position): *30 dm^³*;
- V_i the volume added by the movement of the piston P_b (max. *5 dm^³*);
- V_l the volume of the lung (max. *3 dm^³*);
- S_p the area of the piston (*2.7 dm²*);
- p_v the vacuum inside the thoracic box (max *–50 mbar*).

COMPARISON OF THE COMPLETE MATHEMATICAL MODEL WITH THE REAL OPERATION OF THE LUNG SIMULATOR

Let us now compare selected results of the simulation and measurement with the real system. The simulation is performed with the same LUNG simulator parameters as mentioned above.

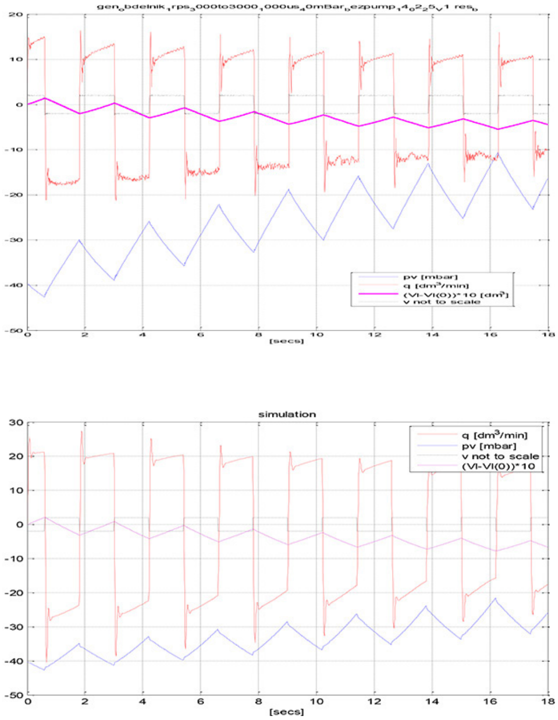

FIGURE 11 A comparison of the simulation and the real experiment

1st experiment

The real experiment is performed with the input piston velocity of a square form. The piston position amplitude l is A_l = 0.12 dm, and the amplitude of the input volume is V_i = 0.324 dm³.

The amplitude A_{vl} of the balloon volume is approximately 0.25 dm³.

The piston velocity amplitude is *1 rps*, which corresponds to $v = 0.2$ *dm/sec*; this yields the input signal period of $T = 4 * A_l / v = 4 * 0.12 / 0.2 = 2.4$ sec.

The amplitude of the 'input flow' is $A_{if} = vS_p = 0.2 * * 2.7 = 0.54$ *dm³/sec = 32.4 dm³/min*.

See also Figure 11.

2nd experiment

The real experiment is performed with the input piston velocity of a sinusoidal form. The piston position amplitude corresponds to l A_l = 0.12 dm, and the input volume amplitude is $V_i = 0.12 * S_p = 0.12 * 2.7 = = 0.324$ dm³.

The amplitude A_{vl} of the balloon volume is approximately *0.25 dm³*.

The piston oscillation frequency is $f = 0.5$ *Hz* or $\omega = 2\pi f = 2\pi 0.5 = \pi$ *rad/sec*, which corresponds to the oscillation period of $T = 1/.5 = 2$ *sec*. The piston velocity amplitude is $A_{vl} = A_l\omega = 0.12\pi = 0.37$ *dm/s*.

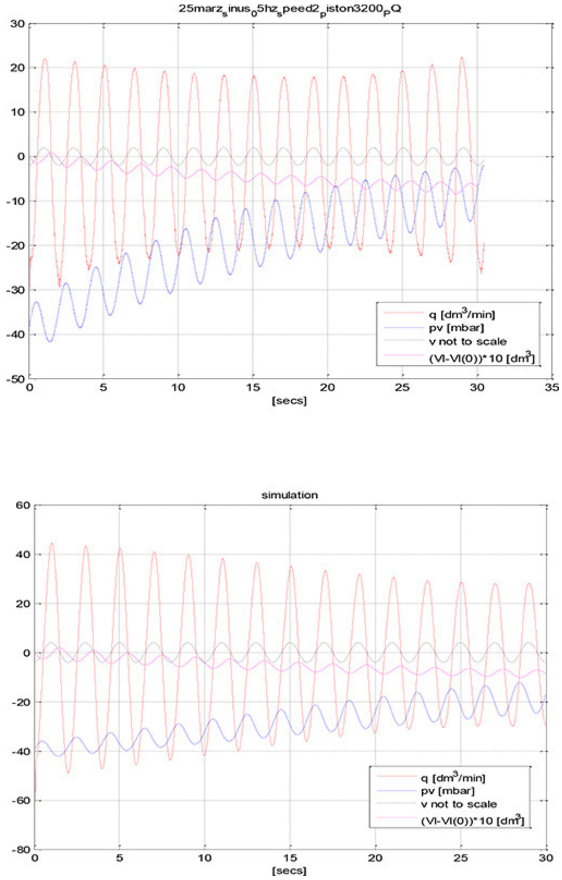

FIGURE 12 A comparison of the simulation and the real experiment

The amplitude of the 'input flow' is $A_{if} = A_{vl}S_p = 0.37 * * 2.7 = 1$ *dm³/sec = 60 dm³/min*.

When comparing the behaviour of the mathematical model with that of the real system, we must remember that the model is constructed for vacuum higher than *–20 mbar*.

General agreement can be observed between the simulation behaviour and the reality for this range of the vacuum. The main discrepancies between the mathematical model and the real system can be identified in amplitudes of the variables, the flow of air in and out of the balloon in particular. This can be explained by the rather rough evaluation of the compliance of the balloon and also by the rather rough modelling of the bellows used in the LUNG simulator. Above all, then, the flow amplitude is rather sensitive to the parameter S_p (the piston area). A smaller piston area provides lower values of flow.

CONCLUSION

The lung simulator described and analysed in this article was one of the main goals of the research project

AlveoPic — Advanced Lung Research for Veterinary Medicine of Particles for Inhalation. We expect to apply the simulator also in the 'double degree study programme', which was a part of AlveoPic too. The lung simulator is original especially in the usage of real lungs or their substitution in the form of a balloon of various shapes and materials.

Experiments with the real lung simulator proved the basic theoretical ideas and revealed some deficiencies in the mechanical structure of the simulator. The main imperfection was identified in the leakage of the thoracic box; this problem was nevertheless eliminated through the use of the vacuum pump and its relatively simple on–off feedback control. The control of the lung air flow and the pressure in the thoracic box via the vacuum pump proved to be robust enough for the simulator to reproduce various types of breathing. Very good results were obtained during the simulation of 'harmonic breathing', namely a process where the air flow from and to the lungs is a harmonic function of time. Good results were also obtained in simulating the physiological breathing curve. Some experiments not mentioned in this article were carried out with porcine lungs, and these also pointed to the fully satisfactory functioning of the simulator. We suppose that the simulator can be used both for pedagogical as well as research goals.

prof. Ing. František Šolc, CSc.

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SPOLUPRÁCE CZ-KOOPERATION AT

EUROPEAN TERRITORIAL CO-OPERATION
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Gemeinsam mehr erreichen. Společně dosáhneme více.

Evropská unie
Evropský fond pro regionální rozvoj

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EXPERIENCE-BASED TEACHING OF ACUTE MEDICINE FOR EXTRA MOTIVATED MEDICAL STUDENTS AND YOUNG PHYSICIANS — 4TH EMERGENCY MEDICINE COURSE AND 6TH AKUTNĚ.CZ CONGRESS

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ABSTRACT — *Faculty of Medicine of the Masaryk University (MU), and especially its departments focusing on acute medicine, make an active effort to find and to support extra motivated students by organising courses and congresses with simulation-based learning sessions for them. 4th Emergency Medicine Course (EMC) and 6th AKUTNĚ.CZ Congress were organised during 2014. EMC was held during a weekend in mid-April for 80 medical students. The congress was held on 22 November 2014. A group of more than 700 enthusiastic professionals including physicians, nursing staff and medical students interested in acute medicine met again in Brno at the University Campus Bohunice. We also report the evaluation of effectiveness of different types of sessions, as well as its influence on practical skills and the fixation of memory footprint. The website AKUTNĚ.CZ (www.akutne.cz) is freely accessible, and anyone can find and watch all the videos and presentations there.*

Rising numbers of medical students and related limitations (spatial, economic, personnel, lack of appropriate didactic cases) have led to a crucial shift from traditional methods of teaching and learning to modern ones. Simulations are among suitable options.

SIMPLE AND ADVANCED PATIENT SIMULATORS

Among the most common simulators in the process of acute medicine teaching, there are mechanical simulators of propaedeutic skills (peripheral or central vein or artery cannulation, regional anaesthesia techniques, etc.) on the one hand, and comprehensive patient simulators for acute clinical scenarios on the other hand. The advanced simulators can be enriched with complex physiological models.

STANDARDIZED PATIENT

A properly masked and instructed actor is the next step when aiming to increase the credibility of simulation of clinical situation. Nevertheless, due to its personnel and time requirements, it is mainly used only for single events and exercises.

EDUCATIONAL AND PUBLISHING PORTAL AKUTNĚ.CZ® [ISSN 1803-179X]

The first chapter of a successful project of educational and publishing portal AKUTNE.CZ [ISSN 1803--179X] began in 2007. AKUTNĚ.CZ is nowadays part of the network of Czech and Slovak medical faculties for the development of e-learning, called the MEFANET (Medical Faculties NETwork). Over the past six years, the portal has undergone a rapid development, and

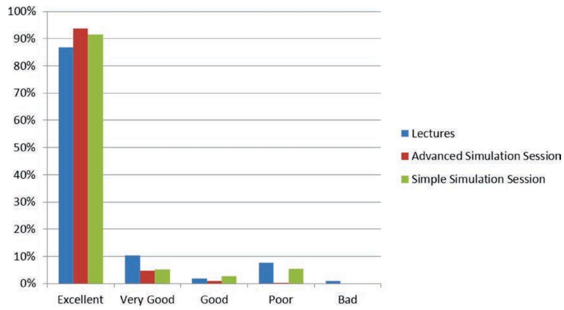

FIGURE 1 Evaluation of effectiveness of different types of sessions and its influence on practical skills and fixation of memory footprint during the Emergency Medicine Course (n = 78)

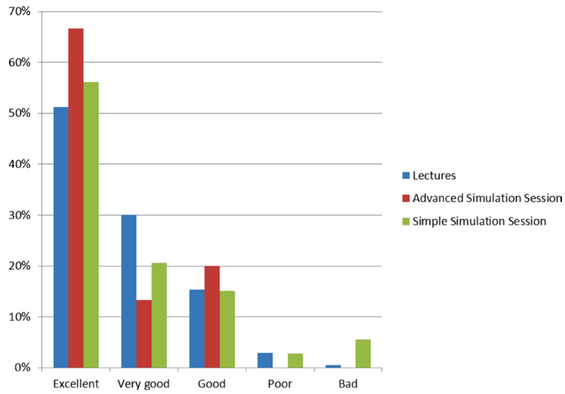

FIGURE 2 Evaluation of effectiveness of different types of sessions and its influence on practical skills and fixation of memory footprint during the 6th Congress AKUTNĚ.CZ (n = 198)

followed up on its activities to several other projects. The portal focuses its activities on senior medical students and provides comprehensive information on acute medicine: like an invisible line, this clinical field goes through all clinical disciplines. Another goal was to bring a new perspective into the education of emergency medicine, and to involve the direct development of teaching materials among the modern methods of teaching of clinical skills. Students themselves nowadays present an essential part of the AKUTNĚ.CZ team, taking part in individual projects and thus gaining their first experience in clinical, organisational, and publishing field of emergency medicine.

Where should a medical student gain experience with the practical implementation of the above-mentioned modern simulation techniques? Each year, two important events focused on teaching emergency medicine for motivated students, involving the implementation of advanced simulation techniques, are held at the Faculty of Medicine at MU. We provide short characteristics of this year's events, and the comparison of participants' satisfaction with prior lessons/workshops with (standardised patient and advanced patient simulator) or without advanced methods (mannequins, simple simulators).

4th EMERGENCY MEDICINE COURSE

The Emergency Medicine Course always takes place in the spring in cooperation with all three Anaesthesiology and Intensive Care Medicine departments of the Faculty of Medicine of MU and Emergency Medical Services for two regions of the Czech Republic. Students themselves became the initiators of a two-day workshop. More than 300 students from the 4th, 5th and 6th year of the Faculty of Medicine of MU completed the course during the past four years.

An evaluation survey was performed, showing that even students themselves perceive the practical benefit of lessons using advanced simulation techniques (patient simulator, standardised patient) compared to those using simple simulation techniques or just lectures (Figure 1).

6th CONGRESS AKUTNĚ.CZ

The onset of autumn sleet and depression was brightened by the 6th year of an already traditional event: the Congress AKUTNĚ.CZ. It is no coincidence that the term is close to the International Student's Day because the conference is unique in its focus on senior medical students and young physicians. Beside the main section, there were two parallel sections focusing on nursing staff and on hot topics in anaesthesiology (toys for anaesthesiologists, anaesthesiology case reports from delivery room, simulation in acute medicine). This year's congress had a record attendance of more than 720 participants (446 in medical section; 150 of them were medical students), who could choose among 26 presentations in the medical section, and 16 presentations in the section for nursing staff. Figure 2 shows the evaluation of effectiveness of different types of sessions and its influence on practical skills and fixation of memory footprint during the 6th Congress AKUTNĚ.CZ.

HANDS-ON WORKSHOPS

In light of the fact that the congress intentionally focuses on young physicians and medical students of higher grades of study, there are hands-on workshops called 'It's about time…'; a workshop oriented on the management of difficult airways, bronchoscopy workshop, Advanced simulator of acute patient — METI® oriented on medical students, Communication with difficult patients, Coagulopathies and ROTEM® Basic, and Advanced or workshop of ultrasound navigated regional anaesthesia. This year's innovations involved

FIGURE 3 AKUTNĚ.CZ Congress — mechanical simulator: bougie-assisted cricothyrotomy

FIGURE 4 AKUTNĚ.CZ Congress — advanced patient simulator: METI®

FIGURE 5 Emergency Medicine Course — standardised patient: immobilization techniques

the HAL advanced patient simulator, laparoscopic (LAP Mentor®), as well as ultrasound (U/S Mentor®) virtual reality simulators Simbionix.

What next? Some photos of extra motivated students during courses and congresses (Figures 3–6) and … just SAVE the DATES … 7th congress AKUTNĚ.CZ … 21 November 2015 and 5th Emergency Medicine Course … 11–12 April 2015 … in Brno.

MUDr. Petr Štourač, Ph.D.

FIGURE 6 Emergency Medicine Course — mechanical mannequin: orotracheal intubation

MEFANET JOURNAL PROFILE

Aims and Scope

The journal is intended to present within a single forum all of the developments in the field of medical informatics, medical education, e-learning and thereby promote the synergism among these disciplines. The journal is the premier vehicle for disseminating information about MEdical FAculties NETwork, which covers all Czech and Slovak medical faculties.

The journal enables medical teachers and scientists to share and disseminate evidence demonstrating the actual practice in on-line education in medicine and healthcare sciences by focusing on:

- research in medical educational informatics and learning analytics
- applications of medical informatics into education
- design, usage and results of novel e-learning tools and innovative pedagogical methods in medical teaching and learning
- other interdisciplinary topics related to information and communication technology in medical education

In 2009–2012, MEFANET report was published as one volume per year and was printed in 1000 copies. Since 2013, MEFANET journal has been published biyearly.

Subjects of interest

- E-health and telemedicine
- E-learning
- Information science
- Innovative teaching methods
- Medical educational informatics and learning analytics
- Modeling and simulation
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- Social media pedagogy
- Evidence-based medicine in education

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Facta Medica

The Facta Medica Ltd. publishing house, based in Brno, was founded in 2008 by Dr. Boris Skalka, Dr. Eliška Skalková, and Assoc. Prof. Zdeněk Susa. The publishing house was founded with the aim of focusing on the publication of specialized literature from the field of medicine and health care – both periodical and non-periodical, but also medicine-related literature of fact and that of fiction. Since 2009 the publishing house has been represented by B. Skalka and E. Skalková.

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