BIOMEDICAL PHYSICS AND MEDICAL PROFESSIONALS: HARMONY OR DISSONANCE IN STUDY QUALITY IMPROVEMENT?

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ABSTRACT
Following independence, Lithuania introduced changes into the health care and higher education sectors, in order to improve the quality of medical studies in the European context. While new subjects were added to the medical curriculum, the time available for assimilating the necessary physics knowledge was also radically reduced. This situation raises important questions about the place of biomedical physics in the medical curriculum. This paper examines the point of view of medical professionals as regards biomedical physics. 309 medical professionals throughout Lithuania responded to a qualitative and quantitative survey targeting the importance that biomedical physics has for them in their practice, their opinion as to the need to give greater attention to biomedical physics in medical curricula, and the ways in which they consider curricula and courses could be improved. Qualitative data was also collected from focus group discussions and from interviews with 18 medical and physics experts. The results revealed widely differing perceptions among respondents as to the importance of biomedical physics in medicine and a considerable convergence of views as to future directions for biomedical physics in the medical curriculum. They identified those areas of physics of greatest interest to the medical professionals and the most appropriate teaching and learning methods for medical students and professionals. The need to design biomedical physics courses adapted to different levels of medical professionals, especially residents, combining traditional pedagogical methods with distance education techniques based on modular structures is also identified.

KEYWORDS
Biomedical physics, medical education, medical professionals, quality improvement.

INTRODUCTION

The fact that a strong health-care system is vital to the sustainable development of a society explains why many authors around the world pay so much attention to medical education reforms and international standards, to the quality of medical studies and to its improvement (for example: WFME, 2003; Jackson and Calman, 2006; Putnam, 2006; Šimunovic et al., 2006; Karle, 2008, and others).

The World Federation for Medical Education (WFME) clearly states in its global standards for medical education (2003) that basic biomedical sciences must be included in basic medical education in order to create an understanding of the scientific knowledge, concepts and methods fundamental to acquiring and applying clinical science. One of these sciences is physics. This and other medical education documents and training programmes show a movement towards competency-based education, with such competencies as analytical and critical thinking. As there are parallels between professional competencies in medicine and those in science (Caruana and Plasek, 2005), authors increasingly affirm the importance of the basic sciences in medical education, for example in the context of medical students' professionalism (Macpherson and Kenny, 2008), of the importance of science and its place in the undergraduate medical curriculum (Hayter, 1996; Mornstein, 2005; Phillipson, 2002; Weatherall, 2006).

Rapidly developing medical technology lies at the heart of the health care system and new discoveries in biomedical diagnostics and treatment are frequently based on the relations between different sciences such as physics, chemistry and biology. Consequently, medical students and professionals need to become more familiar with science knowledge and methods, and the medical curriculum must be updated with new knowledge in these sciences to create a basis for learning and understanding new treatment and diagnostic methods and devices. In particular, one of the characteristics of this development has been the rapid increase in the number of medical methods and devices which are based on physics principles and the consequent importance of their effective use, patient safety and personal protection (Caruana et al, 2008). The need for physics knowledge has therefore been greatly accentuated so that it now constitutes a necessary part of basic medical education. Unfortunately in some European countries the time available in the medical curriculum for learning physics has on the contrary been reduced, with a resulting negative impact on the quality of medical education and training (Karenauskaite et al, 2001). For example, for the last two decades Vilnius university in Lithuania has been experiencing an obvious decrease in the physics lecturing time allocated to medical curricula: down from 246 hours in 1980 to 48 hours in 2001 (still in force today), whereas the average time allotted to physics instruction in European medical schools is approximately between 80 and 90 hours (Letic, 2007).

In addition to the reduction in teaching time, other general problems have been identified. First, physics curricula often do not reflect the integration of physics with other sciences; second, students' background and motivation are diverse; third, there is a prevailing opinion in society that physics is detached from societal needs, and is not directly relevant to students' future professional activity, fourth there is an increasing gap between the physics taught at school level and that at universities, and lastly, difficulties have emerged in integrating the "depth" and "width" of physics content within the curriculum. These arguments have been proved by the research done by physics scholars and/or organisational research both throughout the world and in Lithuania (Alsop, 2000; Caruana and Plasek, 2005; Dresto-Alac, 2007; Garwin, Ramsier; 2003; Karenauskaitė et al, 2001; Ogborn, 2003; TIMSS, 1999, 2003, 2007; Zhaoyao, 2002 etc.). These problems are compounded in post-soviet countries such as Lithuania by a lack of modern high quality teaching aids (textbooks, equipment and tools, information technologies, and free access to worldwide data bases).

Following independence, Lithuania introduced reforms into health care education in order to improve the quality of medical studies. These reforms built on the European experience in modernising curricula. Rapid and indeed radical changes needed to be introduced into the physics curriculum within the undergraduate medical study programmes if students were to acquire the necessary knowledge. Physics content in the curriculum needed to address the expanding requirements of modern medical technology within the constraints of relatively short curriculum time and following European norms. New strategies and approaches to physics teaching and learning were necessary in order to address the fundamental questions of precisely what to learn and how to learn it.

In previous studies, the authors highlighted these issues and suggested new approaches to physics teaching and learning in medical education in Lithuania (Karenauskaite et al., 2001; Karenauskaite et al, 2006) based on the ideas of Bowden and Marton (1998), Fensham (1985), Monk and Osborne (1997), Vermunt (2003). Vilnius University has implemented two pilot projects "Medphystrain" and "Dicort" supported by the EU Leonardo da Vinci programme (http://www.ff.vu.lt/leonardo). These projects were aimed at improving the quality of biomedical physics instruction for medical students at all levels: reorganising training in the biomedical physics courses, developing redesigned, harmonised programmes of biomedical physics for all-level trainees, creating new products for teaching and learning (handbooks, illustrative materials, new equipment and materials for traditional and virtual experiments).

The subsequent project (2006 – 2008) "Realization of Medical Physics and Nanophotonics Studies", supported by European Union Structural funds, aimed to create teaching and learning materials for physics and nanophotonics studies for higher-level medical students (PhD, residents) and medical professionals. These materials focus on new medical methods and devices based on physics knowledge, and should, together with other project outputs, improve the quality of graduate and continuing medical education. The project focuses in particular on the perceptions and needs of the medical professionals in the area of biomedical physics and examines in greater detail the point of view of the medical professional and the higher-level medical student as to the place of physics in medicine, and whether their attitudes are consistent with those of physicists. A common understanding between physicists and medical professionals in this area is fundamental to improving the quality of medical studies.

The attitudes and understanding of medical professionals as regards physics and the importance it has for them were investigated in a study addressing such research questions as: (1) *How important is physics knowledge considered to be, by medical professionals of various levels, and for what reasons do they find it important?,* (2) *Does physics deserve more attention in curricula and in service courses for medical professionals?,* (3) *How could such curricula and courses be improved, according to those involved?*

METHODS

This study used an approach combining qualitative and quantitative research methods. The research was conducted from October to December, 2007. In this survey, *purposive* sampling was used to represent various levels of medical personnel, and various medical institutions. In purposive sampling, the research subjects are selected on the basis of specific characteristics, determined by research goals (Black, 2003). The sampling characteristics of our research were as follows: level of medical personnel, holders/non holders of scientific degrees, researchers and practitioners, variety of medical institutions.

At the first stage of the research 309 medical professionals (doctors, PhD students, residents, nurses, laboratory assistants and others) mainly from eight institutions (medical education institutions and the biggest hospitals in Lithuania) were surveyed using a semi-structured questionnaire, with the aim of revealing the needs of different-level medical professionals for physics knowledge and practical skills, and determining the most acceptable forms of education in biomedical physics.

The second and third research stages (expert interviews and focus group discussions) involved high-level medical professionals and physicists, all with scientific degrees. They were based on qualitative methodology, and used non-structured questionnaires for expert interviews and thematic guidelines for focus group discussions. The goals of these two stages were to reveal the experts' perception of the place of physics in medical studies, identify the areas in biomedical physics with the greatest need for educational materials and courses, and highlight the specific characteristics of physics in medical study programmes and continuing medical education.

To evaluate the attitudes of medical professionals towards the need for biomedical physics in medical studies and practice, the authors created a semi-structured questionnaire. Some questions were adapted from the questionnaires used by physicists to survey students' attitudes towards science and physics (Burazeri et al., 2005; Dettrick, Wessman, and Fuller, 2006; Karenauskaite et al., 2006), other questions were formulated regarding research goals and the specificity of physics knowledge and use in medical practice.

This paper presents the research results based on the following thematic lines:

- Knowledge of biomedical physics: the perceived importance of physics knowledge – 5 statements;
- Applied knowledge of biomedical physics in practice: (1) the need for physics knowledge in professional activities; (2) the (in-)sufficiency of physics knowledge in understanding medical technologies that are used in practice; (3) the (in-)sufficiency of physics knowledge in understanding new medical technologies.
- Directions for physics curriculum improvement: (1) the need for particular physics themes according to the respondents' specialisation – 18 physics themes; (2) Most appropriate methods of

physics teaching and learning for medical studies; (3) designing biomedical physics courses for medical professionals.

Most of the questions use the five–point Likert scale, measuring the level of agreement/disagreement with statements where “1” corresponds to the “most negative”, and “5” corresponds to “most positive” appreciation. Descriptive statistics were used to analyze the survey data from structured questions; non-parametric Mann-Whitney-Wilcoxon and Kruskal Wallis tests were used for two and three independent samples respectively ($p<0.05$) to calculate statistical differences among different groups of respondents. The data were processed using SPSS 15.0 software. Qualitative content analysis was used for open-type questions and for the data from expert interviews and focus group discussions.

RESULTS

This research was targeted at revealing the needs and perceptions of medical professionals at different levels as regards physics knowledge in their professional activities. The research results are arranged according to several thematic lines and specific sampling characteristics presented in the “Methods” section of this paper.

Knowledge of biomedical physics

In order to reveal how respondents themselves perceive the importance of physics knowledge in their professional activities, five statements were formulated, and respondents were asked to identify the level of their agreement or disagreement with each statement. The *cronbach alpha* reliability coefficient for these five statements is 0.865, identifying high internal consistency.

Table 1. Mean scores for the “perceived knowledge of physics” statements

Statements	**Total sample N=309**		**Respondents with scientific degree N=67**		**Respondents without scientific degree N=242**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Knowledge of physics can help to understand physical processes in the human organism	*3.90*	0.73	4.08	0.66	*3.85*	0.75
Knowledge of physics allows me to better understand the treatment and diagnostic methods used at work	3.83	1.02	*4.15*	0.78	3.73	1.06
Knowledge of physics allows me to better master devices used at work	3.72	1.05	3.90	0.91	3.68	1.09
I would like to know more about the application of physics knowledge in my specialisation	3.46	0.96	3.68	0.88	3.40	0.98
Knowledge of physics is important in my specialisation	3.44	0.90	3.66	0.81	3.37	0.91

Table 1 above presents the mean scores and standard deviation for each statement in the total sample of 309 respondents and in subsets of respondents holding and not holding a scientific degree. As the results show, respondents perceive physics knowledge as being needed both in their specialisations and in their practical activities. However, the tendency is to give greater emphasis to the practical applicability of physics knowledge (the mean scores of statements about the practical applicability of physics knowledge are higher than those of statements regarding the use of theoretical knowledge in specialisations). Respondents having a scientific degree consistently return higher mean score for all questions than do those without a degree, but there was no statistical difference between the results. A statistically significant difference of mean scores (p = 0.004) was detected only for the responses concerning the use of physics knowledge in understanding the treatment and diagnostic methods used at work.

The qualitative survey of experts and the focus group discussions confirmed the respondents' opinion that there is a real demand for physics knowledge in medicine and identified the principal problems in this field, in particular the fact that medical students acquire too little knowledge of physics, especially in relation to their future specialisations. Moreover, as specialised courses are not offered in resident and doctoral studies, there is a need for the development of elective courses in biomedical physics at the higher studies level. It was also perceived that biomedical physics upgrading courses are fragmented and given by medical practitioners, not by physicists.

Biomedical physics knowledge applied in practice

As the survey targeted different-level medical professionals (from nurses to highly qualified doctors), it was important to identify the main gaps in their physics knowledge as regards their daily practical activities. Such an analysis facilitates the preparation of teaching and learning materials targeting specific specialisations not only for medical students, but also for medical professional qualification courses.

As can be seen from Table 2, medical professionals with scientific degrees express a greater need for physics knowledge in their professional activities than do those without a scientific degree, and this difference between these groups was statistically significant (p = 0.000). These data also indicate that doctors give much greater importance to biomedical physics than do either nurses or laboratory assistants, and that nearly 30% of laboratory assistants, who are constantly dealing with physics-based devices, have an unexpectedly low appreciation of biomedical physics.

Table 2. Perceived need for biomedical physics knowledge in professional activities

Q: "Do you need biomedical physics knowledge in your profess-sionnal activity?"	Total sample N=309, %	Respon-dents with scientific degree N=67; %	Respon-dents without scientific degree N=228[1], %	Professional qualification		
				Laboratory assistants, N=35 %	Nurses, N=79, %	Doctors, N=122, %
Yes	36,2	56,7	30,3	5,9	20,9	47,8
Partly	55,3	40,3	59,6	67,6	71,6	49,3
No	8,5	3,0	10,1	26,5	7,5	2,9

Results from the Kruskal Wallis test showed a statistically significant difference among all professional qualifications. However, when the groups are compared by pairs (Mann-Whithey test), there is a statistically significant difference between doctors and nurses (p = 0.000), and between doctors and laboratory assistants (p = 0.000), but only a very small difference between nurses and laboratory assistants (p = 0,032).

[1] Only 228 out of 242 respondents answered this question.

In the survey, those respondents who answered “yes” or “partly” to the above question were asked why they need physics knowledge (Table 3). The need for physics knowledge is therefore primarily related to the professional aspirations of the respondents (the need to diagnose and treat patients better), and lastly to the aspiration to earn more. As in the previous question, the responses of the laboratory assistants are different from those of doctors and nurses. In this case, the different functions of laboratory assistants are clearly an important factor, and it may be that they lack a clear understanding of how the quality of their work is related to better diagnostics and treatment. Further analysis showed, as in the comparison discussed above, that medical professionals with scientific degrees give greater importance to the necessity for physics knowledge in all cases (and in this case from 1 to 10 % higher).

Table 3. The reasons for using physics knowledge in professional activity

Q: “Why do you need biomedical physics knowledge in your professional activity?”[2]	**Total %[3]**	**Labora-tory assistants**	**Nurses**	**Doctors**
Physics knowledge enables me to diagnose and treat patients better	*56,3*	24,3	*44,3*	*74,7*
Using physics knowledge and physics-based devices saves me time	40,8	37,1	41,4	45,0
Applying physics knowledge makes me more competitive	34,0	*40,0*	28,6	44,4
Mastery of the methods and devices related to physics knowledge gains me the respect of colleagues and students	25,6	22,9	18,4	31,3
Mastery of the methods and devices related to physics knowledge, increases my earnings	10,4	26,2	2,9	17,5

During focus group discussions, the majority of medical (and physics) experts considered that all levels of medical professionals (doctors, nurses, laboratory assistants, physiotherapists) need to understand the laws and principles of physics applying to medical devices in order to increase their ability to take responsibility and improve their professional qualifications.

Figure 1 presents respondents’ attitudes towards the sufficiency of their physics knowledge for using and understanding medical devices.

[2] Answered by those respondents, who answered “yes” or “partly” to the question “Do you need biomedical physics knowledge in your professional activity?”
[3] Respondents could choose up to three answers, therefore the sum is higher than 100%

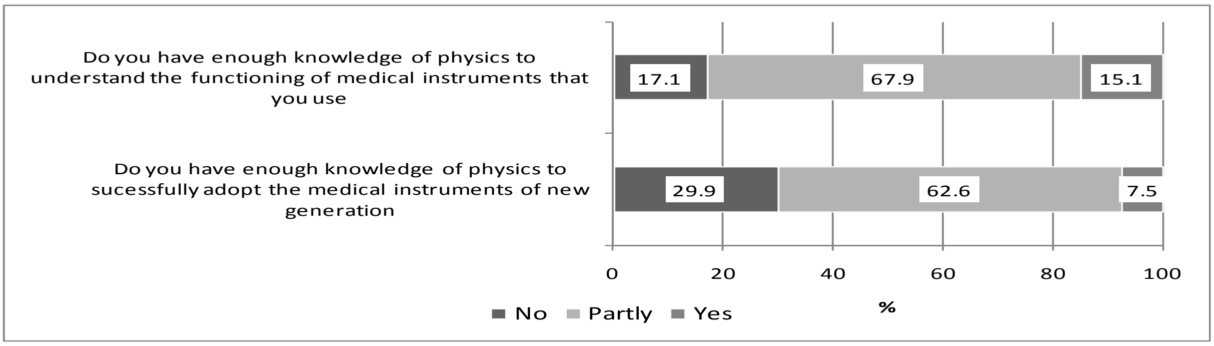

Figure 1. The sufficiency of physics knowledge for understanding the functioning of current and new medical devices, %, N=309

The results (Figure 1) indicate that only a small proportion of respondents perceive their knowledge of physics as sufficient for both understanding the functioning of the medical devices they use in practice and introducing new medical devices. The majority of respondents consider they have only a partly sufficient knowledge of physics for these purposes. In addition, it is significant that respondents evaluate more negatively their capacity to adopt new medical technologies than to understand the devices in service. The supposition here is that their understanding of the functioning of medical devices is rather instrumental: medical professionals possess the knowledge of how to use the devices without a deeper understanding of the physics principles underlying their functioning. It can also be seen that one third of respondents consider they lack the physics knowledge necessary to adopt new medical devices.

Improving the physics curriculum for health care

The research aimed not only at revealing general perceptions of physics knowledge, but also at identifying the respondents' attitudes to specific themes in physics in order to guide physics curriculum development at all levels of medical studies.

Respondents had to evaluate the usefulness of 18 physics themes, suggested by the experts group, for their specialisation (Table 4). The highest mean scores were obtained for the following themes: Ultrasound, X-ray radiation, and Light sources. The least useful themes according to the respondents were Quantum dots, Light guides and Refraction, reflection and scatter of light. Interestingly, respondents perceived the importance of physics knowledge in general as higher than the importance of certain specific physics themes.

Table 4. The attitudes of medical personnel towards various physics themes (mean scores), N=309

Physics themes	**Usefulness ***	**Lack of knowledge ****	**Physics themes**	**Usefulness ***	**Lack of knowledge ****
	Mean	**Mean**		**Mean**	**Mean**
Ultrasound	3.43	3.08	Microscopy	2.92	2.84
X-ray radiation	3.35	2.79	Ionizing radiation. Radiological protection and dosimetry	2.83	2.83
Light sources	3.23	2.95	Sound in medicine	2.70	2.73

Nuclear magnetic resonance	3.22	3.14	Mechanical properties of living matter	2.70	2.83
Electric current	3.11	2.78	Spectrophotometry	2.68	2.89
Electromagnetic field	3.09	2.93	Transport mechanisms in fluids	2.61	2.69
Lasers and their radiation properties	3.08	3.02	Refraction, reflection and scatter of light	2.51	2.71
UV, IR and visible radiation	2.97	2.86	Light guides	2.51	2.76
Radioactivity	2.95	2.80	Quantum dots	2.31	2.78

* Usefulness of themes for the specialisation: Likert scale from 1 –"not useful at all" to 5 – "very useful"
** Lack of knowledge of themes in daily work: Likert scale from 1 – "do not lack at all", to 5 – "lack very much"

When asked to indicate the physics themes for which they most lacked knowledge in their daily work, respondents identified: Nuclear magnetic resonance, Ultrasound and Lasers.

In order to improve curricula for the training of medical professionals in physics, it is important to consider what learning methods are most suitable for various target groups. Respondents were asked to identify the most acceptable teaching and learning methods for physics. Results indicate that respondents mostly support education through practical work (78.9 %) and textbooks (74.1 %), lectures (69.6 %), specialised conferences (66.6 %) and least acceptable is project work (27.8 %). Methods requiring longer-term commitment are also less popular. 41.4 % of respondents are in favour of distance learning. The responses to an open question as to the form in which respondents would prefer materials for improving their qualifications in the biomedical physics field showed that intermediate-level medical personnel more often desire traditional textbooks while higher-level medical personnel tend to prefer electronic and interactive means of learning.

As regards physics teaching and learning, the survey of experts revealed a fragmentation of the learning process at all levels (undergraduate, graduate, PhD, residents), especially related to the use of medical devices. Several ways were identified in which medical professionals acquire knowledge of the functioning of devices: (1) from colleagues; (2) during training, organised by device distributors and (3) from instruction manuals.

During focus group discussions and expert interviews the issue of biomedical physics courses for medical professionals was discussed. The main tendencies identified were:

- Courses for improving qualifications should adopt different teaching and learning methods for different levels of personnel.
- Distance learning opportunities should be included in the design of courses for medical professionals and instructors; the courses should be short, of narrow specialisation and clearly relevant.
- As only a small proportion of qualification courses for medical personnel are funded, additional courses in physics training should be free and accredited.
- Courses should place greater emphasis on the needs of residents.

Cooperation between medical specialists and physicists is another important issue regarding the preparation of high-quality teaching and learning material but, as experts (both medical professionals and physicists) pointed out, while cooperation is common in the area of scientific research it is substantially lacking in the preparation of teaching and learning materials for medical studies and qualification courses.

CONCLUSIONS AND DISCUSSION

Our study showed a strong correlation between the opinion of the responding medical professionals and that of the medical and physics experts.

The perception of medical professionals and high-level students as to the importance of physics in medicine as a whole, and in their professional activities in particular, was *mostly positive*:

- Respondents identified that *knowledge of physics is needed* both in their particular specialised field of medicine and in their practical work. The *practical skills* required to master new medical devices are *identified as more important than theoretical knowledge*. Similar findings were identified in our study of medical students in basic medical studies (Karenauskaite et.al., 2006). and also, in a slightly different context, by the 1989 study of the Committee on Training of Radiologists of the American Association of Physicists in Medicine (Caruana et al., 2008).
- The most *important factor* determining the need for physics knowledge is *professional aspirations* (the need to diagnose and treat patients better), except in the case of laboratory assistants.

The need for physics knowledge, in practice as well as in specialised fields, is valued more highly by respondents with scientific degrees and by doctors rather than by nurses and laboratory assistants. They particularly insist on the role of physics knowledge with regard to treatment and diagnostic methods. It can be assumed that studying for a scientific degree gave these respondents a deeper understanding of the importance of scientific knowledge for professional development and practice. This observation can be compared with the findings of Burazeri et al., 2005; Macpherson & Kenny, 2008 and Weatherall, 2006, which affirmed the importance of science in medical studies.

Only a small proportion of respondents indicated that their knowledge of physics was sufficient to understand the working principles of the devices they use regularly or to master the new generation of medical devices. The majority seem to know how to use devices practically without understanding their working physics principles. The fact that one third of the respondents indicated they lacked the physics knowledge necessary for mastering new generation devices also shows that there is a need to create qualification upgrading courses and teaching and learning materials specifically oriented towards the needs of medical personnel. As Bowden and Marton (1998), Monk and Osborne (1997), Vermunt (2003) have shown, such courses and materials must be used within a learning environment oriented towards understanding and not only the acquisition of knowledge.

Compared with the state of medical education in other countries (Karenauskaite et al., 2001), medical education in Lithuania does not benefit from a wide range of courses addressing the need of high-level students and medical professionals for biomedical physics content. As a result, it is our opinion that medical graduates starting their careers, especially those from Vilnius University where the time allotted to physics is particularly short, frequently do not have the necessary physics knowledge at their fingertips. This situation is exacerbated by the fact that professional upgrading courses (continuing medical education) contain only fragmented and limited biomedical physics content. High-level medical students and medical professionals consequently have no possibility of continually upgrading their knowledge of physics, and, in our opinion, cannot truly master medical devices and methods, especially those of the latest generation.

As regards pedagogy and our findings, there is wide agreement that traditional methods need to be combined with distance education techniques based on modular structures. Physics teaching and learning methods should address the different needs of the various levels of medical personnel and recognize that students and medical professionals place practical skills above theoretical knowledge.

As regards content, course development should take into account both those physics *themes* which the respondents judge most *useful for their specialisation* and those for which the respondents most *felt the need to increase their knowledge*. In particular our findings showed in which thematic directions physicists should develop their courses for medical students and professionals. Specific attention must also be paid to linking physics themes with their practical application in medicine. Our findings revealed, that in general students do not clearly associate some physics themes with real devices or methods used in their practical daily work (Light guides, Reflection to endoscopy for example).

In general, biomedical physics courses and materials should address *firstly,* the *basic general level* of physics knowledge, where courses should be given by physicists in order to provide medical professionals with a deeper understanding of the physics principles underlying medical devices, and *secondly*, *the needs of specialised fields* of medical studies and medical practical work. At this second level we recommend the inclusion of interdisciplinary courses taught jointly by physicists and by medical professionals. Such an approach encourages physics and medical educators to cooperate in developing medical curriculum at all levels. Their cooperation ensures that the needs of those medical professionals who use both theoretical physics knowledge and practical skills requiring knowledge of physics are best met.

Summarizing, it can be said that our study reveals a considerable degree of commonality between the views of medical professionals and physicists as to the current state and future directions of medical education. This should favour the harmonious development of biomedical physics and strengthen its contribution to quality improvement within medical education.

In the future, we hope to be able to develop further the findings of this pilot study and explore the directions identified in a more comprehensive research project using a far wider sample from Lithuania and some European countries.

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