Cross-sectoral Competences for Physics Graduates

Mile Dželalija[1]

University of Split, Faculty of Science, Croatia[1]

Abstract

Physics, with their general concepts, principles and laws, is widely considered to be the fundamental base for other natural sciences, technology, engineering, biosciences, and many other fields. Physics involves the study of all measurable aspects of the matter, energy and interactions. It touches many aspects of peoples' lives giving elements for many key questions in the society. But, on the other hand, the perception of the society is not in line to the above when talking about physicists. Recent decade, according to discussions and conclusions at various events of physic associations, for example within the Forum of Physics and Society of the European Physical Society [1], young physics graduates have a set of strengths, but also weaknesses in relation to the society needs. Their strengths are related to the performance in health sector, energy, environmental protection and food security. The main strengths of being a physicist are strong knowledge and skills in problem solving and modelling complex systems, strong intrinsic technical and cultural motivations, effective skills for various occupations related to policy making, business, consulting, etc. Also, the key weaknesses have been identified, which are related to cultural understanding of what it means to be "physicists" and student aspiration for the career path, lacking of information of potential jobs, poor possess by students of cross-sectoral competences [2] (team work, communication, entrepreneurial skills, cultural awareness and expression, social and civic competence, etc.), lacking interests by physics graduates to spend time and effort to interact with the non-traditional labour market world, and to decode potential industrial applications. In this study we have analysed which of key competences [3] are missing by students and physics graduates, and how to integrate achievements of those competences into the formal curricula or other forms of learning, which could give graduates better position at the labour market and society. Further, we have discussed the knowledge and skills from physics that could be given to graduates in other fields, for their better competitiveness.

Keywords: *Cross-sectoral competences, physicists, formal, non-formal and informal learning.*

1. Introduction

Recent decade there are many global changes in various areas, such as: energy, health, environmental protection, and food security. Those issues are complex, and in order to be solved they need multidisciplinary approaches with physics. In addition, there is a trend of connections between basic and applied research with industrial enterprises for creating new innovative products and services, where physical knowledge and skills play one of crucial role.

Recent years, competitiveness of individuals for planning and managing their personal and professional lives are very important. Globally, the issue of youth unemployment features are highly on national and international policy agenda, in Europe and worldwide. One of the elements that should be supported by national systems is to encourage youth innovative entrepreneurship, which would give young people relevant competences to create jobs for themselves and their peers and create a favourable ecosystem for young entrepreneurs. This is in addition relevant as many entrepreneurial knowledge and skills can be effectively used as an employee within existing companies and organisations. By achievement of those competences within university curricula the transition from university to work becomes easier for youth.

To include young people in a modern competitive economy it would be necessary to take their opinions into account when creating polices aimed at addressing youth unemployment. If youth are included in decision-making processes, they are more likely to accept polices as they understand the process and why polices are implemented [4]. The basic approach to increase competitiveness of young people needs the modernisation of curricula and the support of various ways of learning, i.e. non-formal and informal learning.

Unlike to many other sectors, the unemployment of young physics graduates is not an issue as they are able to find easily their traditional jobs at research and educational public and private institutions, in the country and abroad. But, there are huge unused potentials of physics graduates to contribute in development of modern labour market and thus better employment of youth in other sectors, which could be achieved by higher level of transversal (or cross-sectoral, soft) competences.

The report on Physicists in the Market Place, from the European Physics Society at the Forum Physics and Society (CERN, Switzerland, 2012), presents that traditional physics curricula in most European universities are curricula evolved throughout twentieth century [3]. Those curricula are not well suited to modern labour market and a modern world that is strongly affected by the global trends. By the European Physics Society, the adoption of the modernised physics curricula should be undertaken with the participation of all relevant stakeholders, including students and relevant employers. As presented in the report, the physics curricula reform should include:

- Bring more emphasis on the study of complex, open dynamic systems, purely physical or combined with engineering, social and other sciences, such as: smart electrical power grids, urban environments, climate models, ecosystems.
- Greater exposure to complex problems in areas other than physics, such as: chemistry, biology, economics, sociology.
- More exposure to the industrial and commercial world in preparation for employment. Experience in industry should be long and intense enough to increase skills for teamwork, communication, innovation and user-oriented solutions. Better understanding of general engineering skills, including best practice in patenting, copyrighting and licensing procedures should be encouraged.
- More international experience, including multi-month residence in diverse cultural and linguistic settings.
- More attention to early career counselling, planning and management, especially on the part of faculty advisors and university administrators.

According to the above-mentioned report, the main strengths of physicists are: strong skills in problem solving and modelling, strong intrinsic technical, cultural motivations, learning to learn competence, and effective skills in various activities. But there are some weaknesses, such as the following:

- Cultural barriers in pursuing and appreciating job opportunities outside research and education sectors. This is because of the perception of what it means to be a physicist and individual's aspirations for his/her career path, and lacking of information of potential jobs.
- Graduates in physics posse comparatively poor transferable competences (cross-sectoral), such as teamwork, communication, business and entrepreneurial skills.
- Academics are not very willing to spend time and effort to interact with the outside world and to decode their research in terms of potential industrial applications, known as ivory tower syndrome.
- Underrepresentation of woman in the profession at the senior levels.

Recommendations for actions by the European Physics Society:

- Encourage universities to design appropriate curricula that take into account national institutional, economic and social context. The curricula should be discussed and reviewed, and the best should be promoted.
- Encourage universities to offer students opportunities for development of transferable (cross-sectoral, soft) competences.
- Encourage universities to improve orientation and job placement activities.
- Knowledge transfer to society needs to be more efficient, which requires that universities, research institutions and students be aware of the issue.
- Entrepreneurial competence and opportunities for physicists need to be promoted.

2. Cross-sectoral competences

Supporting youth across Europe in gaining various groups of competences needed for personal fulfilment, health, employability and social inclusion helps to strengthen Europe's resilience in a time of rapid and profound change. In 2006, the European Parliament and the Council of the European Union adopted a Recommendation on key competences for lifelong learning and updated in 2018 [3]. In the Recommendation, the Member States were asked to develop the provision of key competences for all as part of their lifelong learning strategies. High quality education, including extra-curricular activities and a broad approach to competence development, improves achievement levels in key competences, which are classified into eight groups of competences:

1. Literacy competence – as the ability to identify, understand, express, create, and interpret concepts, feelings, facts and opinions in both oral and written forms, using visual, sound/audio and digital materials across disciplines and contexts.
2. Multilingual competence – as the ability to use different languages appropriately and effectively for communication.

3. Mathematical competence and competence in science, technology, engineering (STEM) – as the ability to develop and apply mathematical thinking and insight in order to solve a range of problems in everyday situations, the ability and willingness to explain the natural world by making use of the body of knowledge and methodology employed, including observation and experimentation, in order to identify questions and to draw evidence-based conclusions, and applications of that knowledge and methodology in response to perceived human wants or needs.
4. Digital competence – as the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society.
5. Personal, social and learning to learn competence – as the ability to reflect upon oneself, effectively manage time and information, work with others in a constructive way, remain resilient and manage one's own learning and career, the ability to cope with uncertainty and complexity, learn to learn, support one's physical and emotional well-being, to maintain physical and mental health, and to be able to lead a health-conscious, future-oriented life, empathize and manage conflict in an inclusive and supportive context.
6. Citizenship competence – as the ability to act as responsible citizens and to fully participate in civic and social life, based on understanding of social, economic, legal and political concepts and structures, as well as global developments and sustainability.
7. Entrepreneurship competence – as the capacity to act upon opportunities and ideas, and to transform them into values for others.
8. Cultural awareness and expression competence – as having an understanding of and respect for how ideas and meaning are creatively expressed and communicated in different cultures and through a range of arts and other cultural forms.

3. Analysis of strength and weaknesses of physics graduates

We have developed a simple tool to measure the cross-sectoral (transversal) competences that physics graduates achieved during their studies. The tool has been validated by experts and has a moderate reliability. A convenient sample of successful bachelor and master candidates from the University of Split was selected. The candidates were contacted from a list of the Department of Physics. Each of them was told the purpose of this simple analysis was to compare the various competences they have achieved by formal, non-formal and informal learning during their study. In addition, professors have been asked to evaluate the achievement of those competences by physics graduates.

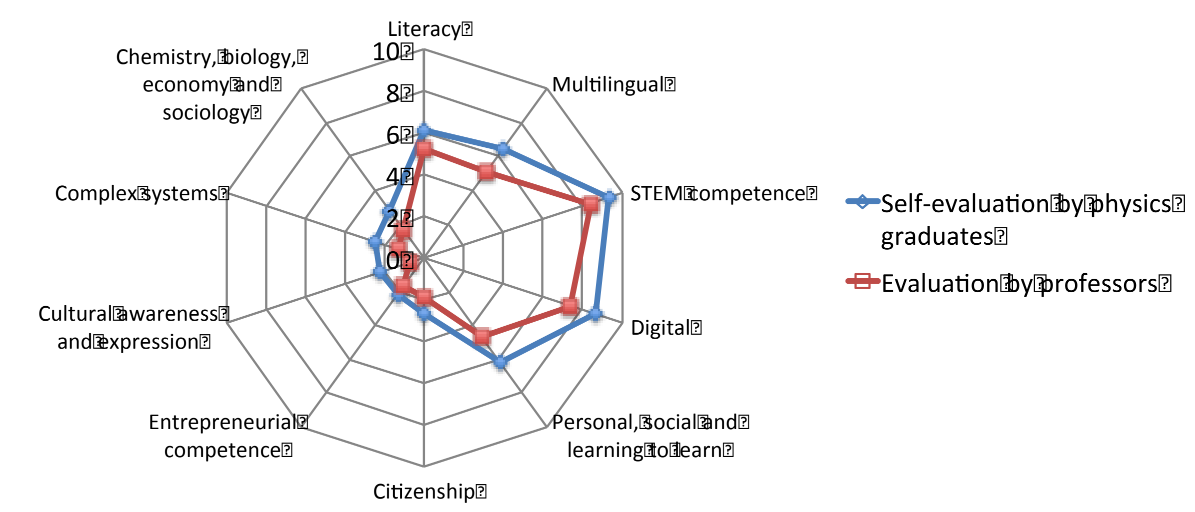

Figure1. Self-evaluation of physics graduates and evaluation by professors: Achievement of key competences for lifelong learning and additional specific sector competences by physics graduates.

In addition to the list of eight groups of key competences for lifelong learning we have added two competences that the European Physics Society discussed in its report [1] and which were not possible to relate fully within the list of key competences for lifelong learning: complex systems and chemistry, biology, economy and sociology competences. We have asked physics graduates (bachelor and master) to self-evaluate their achievements of the listed competences grading them

from 0 to 10. Independently, we have asked professors to evaluate achievement of those competences by graduates.
As it is possible to see from the Figure1, according to self-evaluation and evaluation by professors, physics graduates are very strong in STEM (mathematics competence and competence in science, technology, engineering), digital and personal, social and learning to learn competence, while in the citizenship, entrepreneurial competence and cultural awareness, expression are very weak and also in specific knowledge in complex systems, chemistry, biology, economy and sociology, and patenting and licencing. Multilingual, literacy, personal, social and learning to learn competences are at the moderate levels.

5. Discussion and conclusion

The results of this study show that there are no significant differences between the two groups of evaluation: self-evaluation by graduates, and evaluation by professors. There is only a small difference in the relative scale of the levels of achievement, which is systematically lover for all competences evaluated by professors comparing to the self-evaluation. According to the analysis, graduates have achieved at the excellent level competences related to physics, i.e. mathematics, science, engineering and technology, digital competence, and reasonable well competences in literacy, multilingual and learning to learn, problem-solving and modelling. The rest of competences related to citizenship dimensions, cultural awareness, entrepreneurship, and relevant complex systems are at very low levels.
The findings in this study are in line to the report of the European Physics Society [1], which concludes that physicists are strong in problem solving and modelling, intrinsic technical, cultural motivations, and learning to learn competences, but quite weak in competences related to team work, communication, business and entrepreneurship.
In order to strengthen the positions of physics graduates at the society and non-traditional labour market, physicists should stimulate educational and outreach actions, where parents are encouraged to be more open to the wide choice of scientific studies for their children. The curricula should give more emphasis on the study of complex, open dynamic systems combined with engineering, social and other sciences. There should be greater exposure to complex problems in areas other than physics, such as: chemistry, biology, economics, and sociology. Curricula should include experiences in industry in order to increase competences for teamwork, communication, innovation and user-oriented solutions. Physics students should have more international experience, including multi-month residence in diverse cultural and linguistic settings during their studies. In addition to traditional activities, variety of learning approaches could be integrated into the formal curricula, such as: cross-discipline learning, social and emotional learning, arts, health-enhancing physical activities, etc.. By implementation of such approaches in the curricula, also graduates in other fields could benefit a lot from physics and physicists.
The findings in this study have to be interpreted carefully. This study is based on self-perception of graduates and their professors. This study has not encompassed other indicators. Further research is needed to shed light on other aspects of physics graduates that have not been covered in this research.

References

[1] European Physical Society, Report from the Forum Physics and Society meeting, Physicists in the Market Place, CERN, Switzerland, 2012
[2] European Skills Competence, Qualifications and Occupations Taxonomy, https://ec.europa.eu/esco/portal/home
[3] Council recommendation on key competences for lifelong learning, Official Journal of the European Union, C189/1, 2018
[4] World Economic Forum, How young people can boost competitiveness, 2014, http://www.weforum.org/agenda/2014/case-youth-driven-competitiveness/
[5] Surname, N. “Title of the work”, Name of Journal/Work/Source, City, Publishing House, Year, pages.