sciendo

DOI: 10.2478/cdem-2024-0004 CHEM DIDACT ECOL METROL. 2024;29(1-2):53-63

Vladimír ŠTĚPÁNEK[1,4*], Lidmila HYŠPLEROVÁ[1], Jan KŘÍŽ[1], Filip STUDNIČKA[1]
Maria WACŁAWEK[2,3] and Antonín LYČKA[1]

CONVERGENCE OF ENVIRONMENTAL EDUCATION IN TECHNICAL NATURAL SCIENCES WITH CROSS-BORDER CZ-PL PRACTICE

Abstract: The subject of this communication is the evaluation of the results of pedagogical research focused on environmental-technical university education within the framework of a four-year PL-CZ project supported by the EU, entitled "Cooperation between the University of Opole and the University of Hradec Kralove increasing the employability of graduates on the cross-border labour market" and its three-year sustainability, which we have already reported on in a previous communication in this Journal. The aim was to increase the mutual cross-border substitutability of graduates of environmental-technical fields of study of the Faculty of Science and Technology of the University of Opole (PL) and the Faculty of Science of the University of Hradec Kralove (CZ), when looking for employment in Czech and Polish companies. There is an increasing number of graduates of environmental-technical fields of study who do not work in their fields of study, despite the fact that these workers are missing from the labour market in both countries. The convergence of study programs took place in the form of mutual cross-border teaching with the creation of Czech-Polish teaching materials focused on professional terminology and through exchange four-day field trips and fortnightly and monthly curricular internships. A team of internship tutors in companies, future potential employers of students, was created, a questionnaire for evaluating student performance in soft and hard skills was optimised and verified as part of a pilot study. Both groups of PL and CZ students achieved quite comparable results. There are also no significant differences in the evaluation of individual students in soft and hard skills. However, the number of respondents (students) was limited by the financial resources of the PL-CZ project, which were reduced during the COVID pandemic. Only selected students with a strong interest in the field of study and gaining practical experience participated in the study. Therefore, the conclusions of the pilot study need to be verified on a larger sample of respondents.

Keywords: curricular cross-border CZ-PL practice of students, evaluation of students during curricular practices, pilot study

Introduction

Regular measurement and mathematical modelling of the dispersion of emissions from large sources is required by law in all EU countries. It is used to estimate the concentration of pollutants emitted from large sources such as coal-fired power plants, large industrial plants, etc. It is also used to model the release of toxic substances from various technologies

[1] Department of Physics, Faculty of Science, University of Hradec Králové, Rokitanského 62, 500 03 Hradec Králové, Czech Republic, ORCID: VŠ 0000-0002-1196-584X, LH 0000-0001-9405-1113, JK 0000-0002-8089-6729, FS 0000-0001-6721-8678, AL 0000-0002-8911-5044
[2] Faculty of Natural Sciences and Technology, University of Opole, ul. kard. B. Kominka 6a, Opole, Poland
[3] European Academy of Sciences and Arts, Salzburg, AT, ORCID: 0000-0003-2366-0530
[4] Chvaletice Power Plant, 533 12 Chvaletice, Czech Republic
[*] Corresponding author: vladimir.stepanek@uhk.cz

and possibly even terrorist acts and to predict these dangerous phenomena. However, there is a shortage of workers with this specialisation on the labour market in most EU countries, which is starting to represent a serious societal problem.

In the USA and Canada, in order to motivate students to study this demanding specialisation, where young specialists are also lacking in most countries, it is recommended to apply the so-called comprehensive approach in university education. Its promoter is the world-renowned expert in mathematical modelling of emission dispersion in the lower atmosphere, Prof. Alex de Vischer from the University of Calgary (CA). In his monograph Air Dispersion Modelling: Foundations and Applications [1], he recommends the following procedure to motivate students to study this specialisation: In cooperation with professional companies, students first become familiar with the issue of emissions from large sources, advanced technologies for their removal, and the irreplaceable function of these activities for environmental protection. Only then do they devote themselves to the demanding study of the physical and mathematical principles of environmental modelling and practical modelling activities in PC classrooms.

Another reason for the low interest of students in this specialisation is stated by Prof. John M. Stockie, from SF University Burnaby (CA) in his monograph The Mathematics of Atmospheric Dispersion Modelling [2], as a low level of understanding of the mathematical and physical foundations of dispersion modelling, which demotivates students from choosing this specialisation. The theoretical part of the thesis presents his original approach to this part of the teaching.

The role of curricular internships of students in companies within the framework of university education in environmental-technical disciplines was comprehensively investigated by didactics professor RW Scholz from Danube University Krems and the Department of Environmental Sciences in Zurich (CH) in the article [3]. His didactic research indicates that internships within the framework of university education in environmental sciences are an irreplaceable tool for supporting students' skills and knowledge necessary for their successful involvement in practice.

The aim of the presented analyses is to assess the results of pedagogical research focused on university education in the environmental and technical field within the framework of the four-year EU-supported PL-CZ project entitled "Cooperation of the University of Opole and the University of Hradec Kralove increasing the employability of graduates in the cross-border labour market" and its three-year durability.

The role of curricular internships for students in companies

The role of curricular internships of students in companies within the framework of university education in environmental-technical disciplines has been comprehensively investigated by Prof. RW Scholz and his team from Danube University Krems and the Department of Environmental Sciences in Zurich (CH) in the article [3]. On twenty-two pages, the arguments resulting from the detailed processing of fifty-five references are presented, in which it is possible to obtain further necessary details of this extensive pedagogical research. Prof. Scholz is the author or co-author of more than five hundred and thirty publications, which have been cited more than twenty thousand times, making him an undisputed and internationally respected authority in the field. His detailed analysis of the research suggests that internships within the framework of university education in

environmental sciences are an irreplaceable tool for supporting a wide range of students' skills and knowledge.

In discussions on the social and institutional role of technical universities, it is addressed that on the one hand universities should meet the requirements of industry for a qualified workforce and on the other hand universities should provide the competence and general knowledge necessary to manage the development of society.

Research usually focuses on the following five basic areas:

1) Conceptual science skills, i.e. scientific knowledge and ecological knowledge.
2) Technical scientific skills, i.e. methodological and laboratory and field skills.
3) Managing complexity, which means the ability to uncover relevant aspects, and the ability to work independently.
4) General skills and key qualifications characterised by the ability to communicate, write reports, obtain information and organise work.
5) Solving environmental problems understanding, ability develop practical solutions.

The benefits of mandatory internships in environmental science education were examined with respect to three institutional goals of higher education:

a) training for research,
b) professional technical education for practice in industry,
c) general environmental science education for students to apply in environmentally focused institutions.

The survey investigated which student qualifications are enhanced by internships, complementing traditional higher education. Theoretical and empirical analyses have clearly shown that internships in environmental sciences (and beyond) are a good tool for developing a wide range of students' skills and knowledge. It is essential that internships be strongly supported and become a mandatory part of the curriculum [3].

The significant increase in partnerships between higher education institutions and companies has been supported by the emergence of a knowledge-based economy, globalisation and competition, budgetary constraints on organisations and, in the case of higher education institutions, a general reduction in public funding for research. Currently, there are programmes of cooperation between higher education institutions and companies across Europe, given the importance of these strategic relationships in industrialised countries, which are constantly striving to support their economic growth and development. Within the framework of a partnership between a higher education institution and a company, the interests of both parties must intersect and various forms of interaction can occur, such as joint research, contract research or research in the form of consultancy, which lead to the transfer of innovations between organisations [4].

One of the current forms of cooperation between higher education institutions and companies, aimed at mutual benefit, is cooperation mediated by internships that students carry out as part of their studies.

The growth of this type of inter-organisational cooperation is driven by mutual efforts and often pressure from the growing need for universities to adapt to the demands of companies and from the need for companies to have a highly skilled workforce that only universities can provide [5].

Through internships, higher education institutions and students have privileged access to the expectations of companies, the students' future employers, in terms of required skills and the most suitable theoretical areas of study. The experience gained in an internship can also overcome certain teaching gaps that are difficult for universities to

meet, but which companies can address thanks to their essentially practical approach. University-company partnerships can therefore be considered complementary to the teaching and learning process.

Essentially, the objectives defined by the individual stakeholders and their alignment within a common interest will determine whether the partnership will have positive outcomes and therefore whether the collaboration will be successful, with emphasis on the relevance of the internship to their academic program. If this relevance is ensured, internships become an effective means of transferring students' newly acquired competencies to the real world and increasing their understanding of their future profession. Studies show that evaluation by companies and universities provides the most effective control of interns [6].

Internships, as a form of workplace learning, are an important part of many vocational programmes in higher education. They can help students bridge the gap between academic learning and practical reality. Internships provided through partnerships between higher education institutions and businesses play a key role in introducing students to the highly competitive and relational labour market. Therefore, all parties involved in these partnerships (university, business and student) should continue to strive to increase the benefits provided by internships [7].

Excursions to firms and field trips increase students' interest in their future profession and motivation for this study [8].

Franco-Angel et al. [9] and Patacsil and Tablatin [10] analysed, if the impact that soft and hard skills have on the performance of undergraduate students in their internships.

We reported on the health consequences of air pollution from industrial activities [11] and advanced methods for reducing and measuring emissions of microparticles and heavy metals from combustion processes in the PL-CZ cross-border area in our previous publications [12].

Design-based research was used as a didactic-research method, which represents a certain analogy of research in technical disciplines (*design approach*). The essence is the orientation towards the creation (*construction*) of a new product, which brings solutions (*interventions*) for problems that have so far been only partially solved and the relevant tools and methods are in their infancy. Design research is a new trend in didactic research.

This method is recommended as suitable, for example, in the creation of didactic materials. The created solutions are subsequently tested, iteratively adapted and tested again. During the work on the creation of teaching materials, adjustments are possible thanks to this feedback. The purpose of design research can therefore be, for example, the effort to create teaching materials that will best suit the target group of students as a teaching and learning tool. The involvement of teachers and various experts from practice, objective evaluation and flexible revision of materials are essential for this concept [13].

Didactic research carried out within the framework of the PL-CZ project and its sustainability

Cross-border PL-CZ teaching of environmental dispersion modelling, creation of teaching modules

One of the first tasks was to prepare teaching materials "Physical and mathematical foundations of modelling the dispersion of pollutants in the air, analysis of environmental

data" and to verify selected parts in teaching with an emphasis on understanding the basic physical and mathematical principles of environmental mathematical modelling in connection with the previous teaching of theoretical subjects. These materials are part of the creation of educational modules and were verified in the teaching of Czech and Polish students at the Faculty of Science and Technology, University of Opole (WPT UO) and the Faculty of Science, University of Hradec Kralove (PrF UHK).

The aim of the research was to make changes in theoretical preparation and especially in practical exercises in environmental mathematical modelling of emission dispersion and subsequent curricular practices so that this specialisation is attractive to potential applicants, because there is a shortage of young experts with this specialisation throughout the EU, despite the fact that in most countries regular modelling of emissions from large sources is mandatory by law.

Preliminary research verified the significant influence of problem tasks, oriented towards the ecological problems of the region, on increasing students' motivation during practical exercises.

The first step in the research part of the thesis was to determine the scope of theoretical and practical teaching and curricular practices in subjects focused on mathematical modelling of the dispersion of pollutants from large sources at our and selected foreign physics and engineering faculties. It was found that at most faculties only theoretical teaching takes place (and mostly only marginally) without practical exercises in PC classrooms. At foreign faculties, practical teaching is mostly transferred to students' curricular practices.

Based on the requirements for the solution of the PL-CZ project, it was necessary to design and verify the use of PC templates in teaching, which represent a significant motivation for students. Each module includes the created teaching materials listed in the theoretical part of the work. A total of five modules were created, which reflect the ecological problems of the region:

- Modelling the dispersion of emissions from large combustion sources I., with the PC template Power Plant Opatovice
- Modelling of emission dispersion from large combustion sources II., with PC template Power Plant Chvaletice
- Modelling of odour dispersion from the agricultural ecological biogas station Lhota pod Libcany
- Modelling of odour dispersion from the agricultural energy-oriented biogas station Dritec
- Odour modelling from the wastewater treatment plant in Hradec Kralove

The modules include problem tasks related to reducing air pollution. The task assignments distinguish between parts intended for students with a heightened interest in the given issue.

Cross-border CZ-PL curricular internships, comparative pilot study

Professional events for students held as part of the PL-CZ project were planned before its launch, including their financial support. The COVID pandemic significantly disrupted this program. It was necessary to switch to distance learning and start using virtual internships instead of real internships. The originally three-year project was extended to four years without a financial increase. Given that these were internships paid for by the

PL-CZ project, the number of CZ and PL respondents (students taking part in internships) was limited.

The mandatory three-year sustainability of the project ends in 2024. It was subsidised on the Czech side by the project's contracting companies. The list of professional events for students in Czech and Polish contracting companies is given in Table 1.

Table 1

Professional events in contractual CZ and PL companies and numbers of participating students

Professional events in Czech and Polish contracting companies INTERREG VA, 11.3.119/1150, supported by the EU, implementation: 1.12.2017-30.11.2021, sustainability: 1.12.2021-31.11.2024										
Company	**Motivational internship 1-2 days**		**Short-term internship 4 days**		**Medium-term internship 2 weeks**		**Long-term internship 4 weeks**		**Virtual internship**	
	CZ	PL	CZ	PL	CZ	PL	CZ	PL	CZ	PL
EMPLA AG s r.o., HK (CZ) (Ecological company)	41			60	19		4	6		
Zdravotní ústav HK (CZ) (Health institute)	38	49			17		3			
VUOS a.s., Rybitví (CZ) (Research Institute for Organic Syntheses)	20	23			6		2	3		
KHP-Veolia a.s., HK (CZ) (Water supply and sewerage)	37	49			2				34	55
Elektrárna Chvaletice s r. o. (CZ) (Power plant)	23	9								
ATMOTERM S.A. Opole (PL) (Ecological company)	40	6					6			
WIK in Opole, Sp. z o.o. (PL) (Water supply and sewerage)	45	60								

During cross-border curricular internships of PL and CZ students, one of the problems solved between CZ and PL companies was the unification of the evaluation of interns by tutors.

Therefore, the first task of this research was to compile a draft Czech-Polish questionnaire for a uniform assessment of students during monthly cross-border curricular internships in cooperation with partner companies. The main objective of this research is to monitor the possibility of mutual substitution of Polish and Czech graduates of science and technology in professional companies in the cross-border region.

Research methodology

The first step was to draft a Czech-Polish questionnaire for a unified assessment of hard and soft skills of students during monthly cross-border curricular internships. The construction of the questionnaire is a complex procedure, it is not simply a set of questions. The creation of the final version of the questionnaire requires a number of verifications. Also in this case, this questionnaire was amended and supplemented several times. This optimisation was carried out in the form of semi-structured interviews with employees (tutors) responsible for student internships in cooperating PL and CZ companies. Table 2 shows the optimised draft of the cross-border interactive evaluation questionnaire, which tutors filled in after the completion of the monthly internships of PL and CZ respondents (students) included in the comparative pilot research.

The research results are presented based on the validation of the above-mentioned questionnaire. A total of 18 students (9 PL and 9 CZ) were evaluated by the questionnaire survey. The reason for the choice of this group of students is that tutors proposed to evaluate both soft and hard skills for students who took part in long-term form of internships (four weeks) since their evaluations are much more objective than those for shorter ones.

The questionnaire contains a total of 10 skill areas, which the tutor rated on a scale of 1 to 10. The first five items focus on so-called soft skills and the second five on the assessment of so-called hard skills.

Table 2

Evaluation of student performance by tutor during internship in a company originally in Czech and Polish language translated into English language

No.	**Evaluation of student performance by tutor during internship in a company** **Evaluation of the level of intern's soft skills** 0-2 poor, 2.1-4 rather poor, 4.1-6 average, 6.1-8 good, 8.1-10 very good	
1.	**Communication:** Ability to communicate clearly and effectively, level of written and oral communication	*Rating*
2.	**Teamwork:** The ability to collaborate effectively with colleagues, sharing ideas and working towards common goals	*Rating*
3.	**Problem solving:** Ability to analyse situations, identify problems, and find effective solutions	*Rating*
4.	**Adaptability and organisational skills:** Ability to adapt to new situations and changes in the work environment	*Rating*
5.	**Reliability:** Respecting rules and agreements, completing tasks	*Rating*
Total soft skills points		**0**
6.	**Theoretical preparation:** Understanding the physical and mathematical principles of measurement, modelling and data evaluation	*Rating*
7.	**Practical training:** Environmental measurement and modelling, protocol processing	*Rating*
8.	**Virtual communication and digital literacy:** Effective digital communication at a distance, adaptability to new software	*Rating*
9.	**Professional activity:** Activity in interaction with the tutor, interest in the field, gaining new knowledge	*Rating*
10.	**Professional performance:** Necessary knowledge and skills for possible employment in the company	*Rating*
Total hard skill points		**0**
Total points		**0**

Results of the pilot comparative study

Figure 1 presents the tutors' overall evaluation of the interns after a monthly internship. Figure 2 shows a graphical processing of the statistical evaluation of soft and hard skills of individual trainees by tutors from professional companies. Figure 3 shows a statistical evaluation of performance in soft and hard skills of PL and CZ groups of respondents (students) in companies; monthly internships.

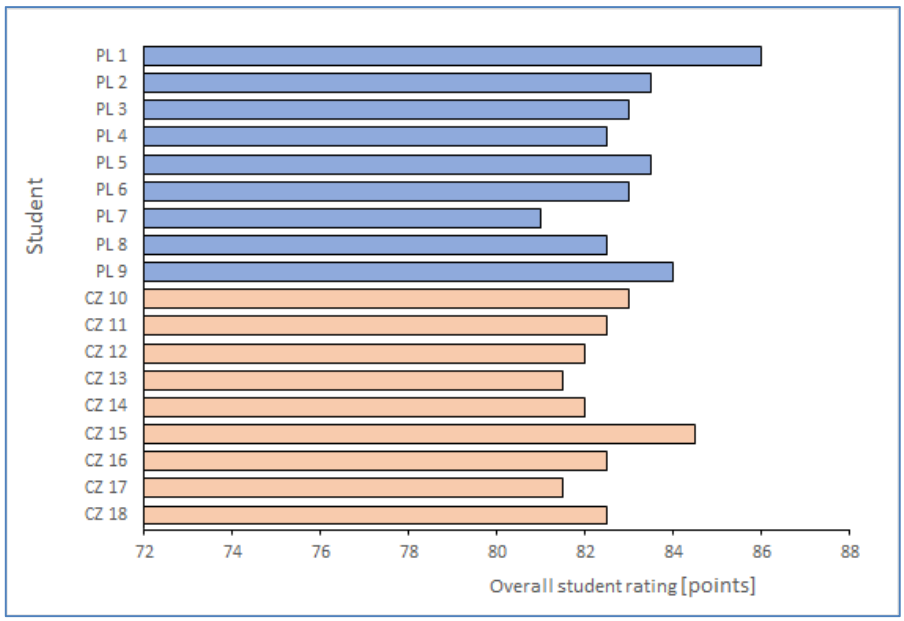

Fig. 1. Overall evaluation of PL and CZ respondents (students) in companies; monthly internships, assessed by tutors

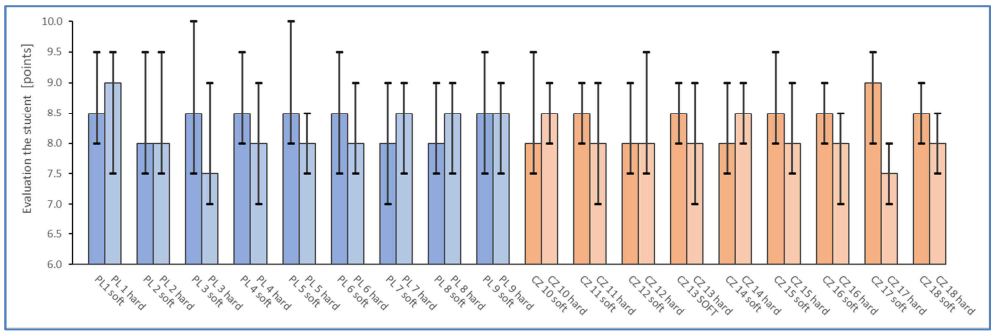

Fig. 2. Statistical evaluation of soft and hard skills of individual respondents (students) in companies; monthly internships

Summary and conclusions of the comparative pilot study

A comparative pilot study of monthly internships of PL and CZ respondents (students) included in the following evaluations:

- overall performance of PL and CZ respondents in companies
- performance in soft and hard skills of individual respondents
- performance evaluation in soft and hard skills of PL and CZ groups

It can be seen from the evaluation of the overall performance of CZ and PL respondents in companies presented in Figure 3 that both groups of PL and CZ students achieved very comparable results. The average evaluation value for PL students was

83.2 points and for CZ students 82.4 points (of theoretical 100 points). There are also no significant differences in the evaluation of individual students in soft and hard skills. When evaluating the PL and CZ groups of students in soft and hard skills, there is again no significant difference.

From this perspective, it is possible to draw conclusions that, despite a certain language barrier, Polish and Czech graduates in science and engineering fields are fully employable both in PL and CZ professional companies in the cross-border region.

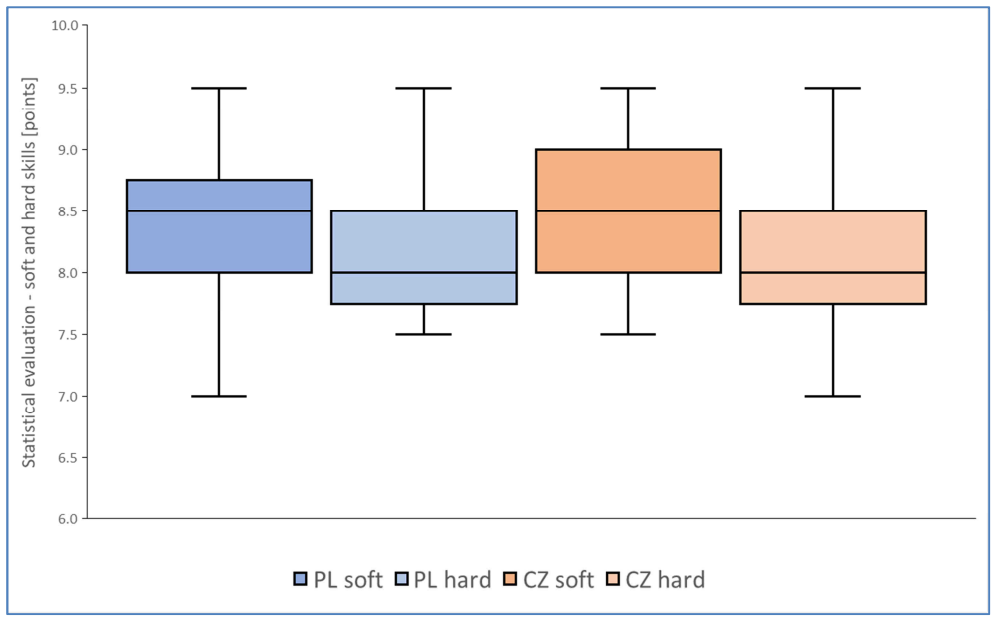

Fig. 3. Statistical evaluation of the performance of CZ and PL groups of respondents (students) in soft and hard skills during internships in companies; monthly internships

Conclusion

The educationally focused PL-CZ INTERREG VA project, supported by the EU, entitled Cooperation between the University of Opole and the University of Hradec Kralove increasing the opportunities of graduates in the cross-border labour market/Zwiększenie szans na zatrudnienie absolwentów kierunków przyrodniczych i technicznych; współpracia transgraniczna PL-CZ, implementation (1.12.2017-30.11.2021), project sustainability (1.12.2021-31.11.2024) aimed to deepen cross-border cooperation between teachers of the WPT UO, providing the first-degree engineering study program Environmental Protection (Environmental Protection), and the PrF UHK, providing the bachelor's study program Physical Measurement and Computer Engineering, now newly accredited under the name Applied Physics, specialisation Environmental Measurement, during cross-border student exchange.

Another goal was to improve mutual communication and information between cross-border neighbouring professional companies, potential employers of these graduates, ensuring exchange curricular practices for students with both Universities.

50-page teaching materials were prepared entitled Physical and mathematical foundations of modelling the dispersion of pollutants in the air, environmental data analysis and five teaching modules with PC templates focused on ecological problems of the region. Both materials are continuously verified by the author of this work both during exchange teaching at the WPT UO and during teaching the subject Monitoring systems for environmental protection and health support at the PrF UHK. A bilingual, two-column PL-CZ monograph of 247 pages was prepared.

Details of the above-mentioned research as well as the created innovative teaching materials are presented in the [14].

The research aim was achieved.

Acknowledgements

The presented research was financially subsidised by the EU-supported cross-border project INTERREG VA (2017-2021), CZ.11.3.119/0.0/0.0/16_022/0001150 „Cooperation between the University of Opole and the University of Hradec Kralove increasing the opportunities of graduates in the cross-border labour market", implementation (1.12.2017-30.11.2021), project sustainability (1.12.2021-31.11.2024) financially supported by professional companies. Our thanks go to the chief PL-CZ project manager Dr hab. A. Dołhańczuk-Śródka, prof UO, for the leadership and editing of innovative teaching materials, Dr hab. Z. Ziembik, Dr hab. D. Janecki, prof. UO and Ing. R. Hyšpler, CSc. Our thanks also go to the experts from professional companies Ing. S. Eminger, CSc., Ing. P. Král, PhD., Ing. I. Šrámek, Mgr. W. Wahlich and B. Śmiechowicz for the innovative lectures, teaching materials and organising of the exchange PL-CZ study trips and monthly student internships with student evaluation.

References

[1] De Visscher A. Air Dispersion Modeling: Foundations and Applications. Hoboken, New Jersey: John Wiley; 2014. ISBN: 9781118078594.

[2] Stockie JM. The mathematics of atmospheric dispersion modeling. SIAM Review. 2011;53(2):349-72. DOI: 10.1137/10080991X.

[3] Scholz R, Steiner R, Hansmann R. Role of internship in higher education in environmental sciences. J Res Sci Teaching. 2004;41(1):24-46. Available from: https://www.researchgate.net/publication/229576272_Role_of_Internship_in_Higher_Education_in_Environmental_Sciences.

[4] Cunningham JA, Link AN. Fostering university-industry R&D collaborations in European Union countries. Int Entrep Manage J. 2015;11:849-60. DOI: 10.1007/s11365-014-0317-4.

[5] Perkmann M, Tartari V, McKelvey M, Autio E, Broström A, D'Este P, et al. Academic engagement and commercialisation: A review of the literature on university-industry relations. Res Policy. 2013;42(2):423-42. DOI: 10.1016/j.respol.2012.09.007.

[6] Silva P, Lopes B, Costa M, Seabra D, Melo AI, Dias GP, et al. Stairway to employment? Internships in higher education. Higher Education. 2016;72(6):703-21. DOI: 10.1007/s10734-015-9903-9

[7] Franco M, Silva R, Rodrigues M. Partnerships between higher education institutions and firms: The role of students' curricular internships. Industry Higher Education. 2019;33(3):1-14. DOI: 10.1177/0950422218819638.

[8] Behrendt M, Franklin T. A review of research on school field trips and their value in education. Int J Environ Sci Education. 2014;9:235-45. DOI: 10.12973/ijese.2014.213a.

[9] Franco-Ángel M, Carabali J, Velasco MI. The internship performance of undergraduate students: Are hard or soft skills more important? Industry Higher Education. 2023;37(3):384-96. DOI: 10.1177/09504222221127213.

[10] Patacsil F, Tablatin C. Exploring the importance of soft and hard skills as perceived by IT internship students and industry: A gap analysis. J Technol Sci Educ. 2017;7(3): 347-68. DOI: 10.3926/jotse.271.

[11] Feng W, Li H, Wang S, Van Halm-Lutterodt N, An J, Liu Y, et al. Short-term PM10 and emergency department admissions for selective cardiovascular and respiratory diseases in Beijing, China. Sci Total Environ. 2018;657:213-21. DOI: 10.1016/j.scitotenv.2018.12.066.
[12] Kříž J, Loskot J, Štěpánek V, Hyšplerová L, Jezbera D, Trnková, L, et al. Modeling of mercury emissions from large solid fuel combustion and biomonitoring in CZ-PL border region. Ecol Chem Eng S. 2016;23(4):593-604. DOI: 10.1515/eces-2016-0042.
[13] Trna J. Konstrukční výzkum (design-based research) v přírodovědných didaktikách. (Design-based research in science didactics). Scientia in Educatione. 2011;2(1):3-14. DOI: 10.14712/18047106.11.
[14] Štěpánek V, Kříž J, Hyšplerová L, Keder J, Ziembik Z, Lyčka A. Environmental emissions dispersion modelling, Principles and algorithms; cross-border CZ-PL Course for master's students. Chem Didact Ecol Metrol. 2022;27(1-2):165-81. DOI: 10.2478/cdem-2022-0010.