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Transformation of the RESPO Decision Support System to Higher Education for Monitoring Sustainability-Related Competencies

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Abstract: A result-oriented engagement system for performance optimisation (RESPO) has been developed to systematically monitor and improve the competencies of individuals in business, lifelong learning and secondary schools. The RESPO expert system was transferred for use in higher education institutions (HEIs) based on successful practical application trials. The architecture and functionality of the original RESPO expert system have been transformed into a new format that will collect information on the required competencies and the available educational programmes to help students effectively develop competencies through formal and non-formal education. First, the initial version of the RESPO system and its functionality were tested on a selected group of students and higher education staff to validate and improve its effectiveness for the needs of HEIs. This paper summarises the key findings and recommendations of the validators for transforming the RESPO application into an application for HEIs. In addition, the selection of competencies in the RESPO application database has been adapted to align with selected study programmes and the need to develop sustainability-related competencies. These findings can support professionals working in higher education institutions in developing students' future competencies and fostering the targeted use of learning analytics tools.

Keywords: higher education; competencies development; decision support; STEM education; sustainability

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1. Introduction

As the current crises, from epidemics to wars to energy crises, drive up the prices of raw materials, final products and food, motivated and well-educated employees are becoming a key factor for any successful organisation. Formal educational programmes do not always meet the needs of employers. Therefore, acquiring knowledge and skills through non-formal forms of education is essential to fill the gaps in developing competencies in vocational education and training (VET) and universities. Employers are becoming more demanding both for technical and soft skills required to work effectively. Therefore, there is an urgent need in education to help individuals identify, capitalise on, and manage their learning. Integrating formal and non-formal learning in higher education is crucial in this respect by improving learning methodologies that can better serve self-directed learning and self-management skills.

This challenge is even more significant if the specificities, needs and expectations of the new generation of students currently experiencing the transition from education to employment, i.e., the millennial generation, are considered [1]. This fact is highlighted in several recent documents published by the European Commission [2–8] and other international organisations, such as the Organisation for Economic Cooperation and Development (OECD) [9] and the World Economic Forum (WEF) [10]. Successfully bridging formal education and non-formal training requires tools that enable individuals to identify competency gaps and find the most appropriate training to fill them. The RESPO is a tool that will collect information on the required competencies and the available educational programmes to help students effectively develop competencies through formal and non-formal education.

Although the concept of sustainable development has its origins in the 1987 World Conference on Earth and Development (WCED) [11] and the 1992 Rio Conference [12], its implementation has been significantly improved by the 2030 Agenda for Sustainable Development Goals [13] from the United Nations. To achieve these ambitious goals, widespread lifelong learning has become a necessity. Unsustainable patterns of human behaviour and the shift of human activities towards sustainability require the strengthening of sustainability competencies, as they enable a critical reflection on prevailing values, policies and practices and help to make difficult decisions towards a better environment for all people [14]. The European Commission has, among other things, prepared a list of key competencies for lifelong learning [3] that can contribute to systematic learning. RESPO was initially designed around these competencies, but through practical application of the system and users' feedback (HE professors, students), it became apparent that the list of competencies should be adapted to assess, monitor and develop individuals' competencies more systematically. The competencies of study programmes, individual subjects, qualifications, the jobs they can be employed in after their studies and the needs of employers in the future should be considered when designing the competencies database for the RESPO application. Furthermore, Ferreras-Garcia et al. [15] found that the gender of students also plays an important role in developing competencies for innovation-oriented action. The gender of students should be considered when organising training for students, so that both genders can acquire the same competencies and gender differences in the later transition to the labour market can be reduced.

Decision Support Systems (DSS) are usually understood as computer systems that mimic the decision-making ability of relevant human experts. They have been used in education for decades and have proven valuable in assessing competencies and helping select the training most conducive to improving competencies [16]. Sánchez et al. presented an interesting system for competency-based evaluation of student curricula [17], and the European Com-ProFITS project assessed competencies using an expert system for human resource management (HRM) [18]. Achcaoucaou et al. used the Tricuspoid online competency assessment tool to determine students' level of skills for course organisation, course content selection and teaching/learning procedures [19]. They focused on the development of soft skills, namely entrepreneurial competencies. The tool application allowed students to identify their strengths and weaknesses and develop personal strategies to improve their competencies. It provided teachers with additional information on the impact of their contribution on students' competency development. Kleimola and Leppisaari [20] conducted a case study to determine which competencies future higher education students should acquire during their studies and how learning analytics can support these competencies' development. The results of this study showed the great potential of learning analytics to support the development of their competencies, as it provides a tool for reflection on learning and competency development and increases self-awareness of strengths and weaknesses in competency development. In addition, learning analytics promoted goal orientation, metacognition and learning to learn, active participation and learning self-confidence.

As conventional education is migrating to online training, especially in the crucial crises we have been facing in recent years, self-regulated and self-managed learning of indi-

viduals is an important factor influencing the success of the learning/training process [21]. Therefore, on one side, DSSs supporting career advisors, supervisors and professors are becoming crucial in monitoring the career and progress in the competency development of individual students as lifelong learners. On the other side, it allows learning analytics on larger social groups, e.g., the analysis and visualisation of social interactions and the design of dedicated learning groups and community development practices. Furthermore, the DSSs were also applied to higher education management. For instance, Teixeira et al. proposed a DSS to select students for Erasmus+ short-term mobility based on students' enrolment and grades as well as their hard and soft skills [22]. Alisan and Serin [23] proposed a DSS that can maintain the quality and competitiveness of HEIs' departments and their course portfolio. The proposed DSS provides valuable information on which departments should be established or closed and the appropriate course offer and course content design. In this way, students are better informed when choosing universities, departments, courses or further career paths.

In this paper, first, the structure of the original RESPO application is defined, tested and validated by end users, i.e., a small group of students and higher education staff. The key findings and recommendations of the validators for transforming the RESPO application into an application suitable for higher education institutions are summarised. In addition, the selection of competencies in the RESPO application database has been adapted to align with selected study programmes and courses in nanoscience and nanotechnology. This study provides valuable insights into the relationship between the important elements of learning analytics in monitoring competencies in higher education and decision making based on advanced decision support tools. At the same time, the study's findings extend our previous research and development and contribute to the conceptualisation and application of decision support systems in higher education.

The developed web-based decision support tool will be further tested through transdisciplinary training activities in higher education institutions in four EU countries (Slovenia, Spain, the Netherlands and Belgium). Based on the evaluation of the progress in the development of students' competencies, a handbook of recommendations will be produced, with the main aim of encouraging other higher education institutions to integrate the results of the RESPO X application into their institutional educational strategies. The RESPO X decision support tool will contribute to filling the skills gaps of students as future employees and researchers who can overcome barriers to the adoption and deployment of new technologies in companies and research institutes, increasing the productivity and sustainability of future factories and the scientific performance of universities and research institutes. The RESPO X key findings will also offer recommendations for other higher education institutions, employers and policymakers to invest financial and human capital in additional training to upskill the future workforce.

2. Decision Support System Transformation for Competencies Monitoring in Higher Education

RESPO was first designed to monitor employees' competencies in the companies participating in the Competence Centre for Factories of the Future (KOC-TOP), established at Jožef Stefan International Postgraduate School (IPS), Ljubljana, Slovenia. Later, the system was extended to monitor the competency development of secondary school students in the RESPO project under the Slovenian national programme "Students Innovative Projects for the Benefit of Society". Based on successful practical application trials, we wanted to transfer the developed system to higher education institutions. The architecture and functionality of the original RESPO system were transformed into a new format that will collect information on the required competencies and the available educational programmes to help students effectively develop competencies through formal and non-formal education.

2.1. Basic Conceptual Design of RESPO Decision Support System

The basic structure of the RESPO system is shown in Figure 1. The multi-criteria system to support decision-making in developing competencies is presented in more detail in our previous contribution [24]. RESPO first assesses the current level of each competency of each individual. Ideally, this assessment is done through an objective test or exam. If this is not possible, the assessment is carried out by a supervisor who works closely with the candidate and is, therefore, able to make a relatively good assessment. Each competency level is assessed when the individual attends one of the available training programmes. This way, an assessment is made of how each training programme improves each competency. Although these assessments of the effectiveness of training programmes are somewhat arbitrary and subjective and vary considerably between different learners, this method provides valuable information on effective training programmes.

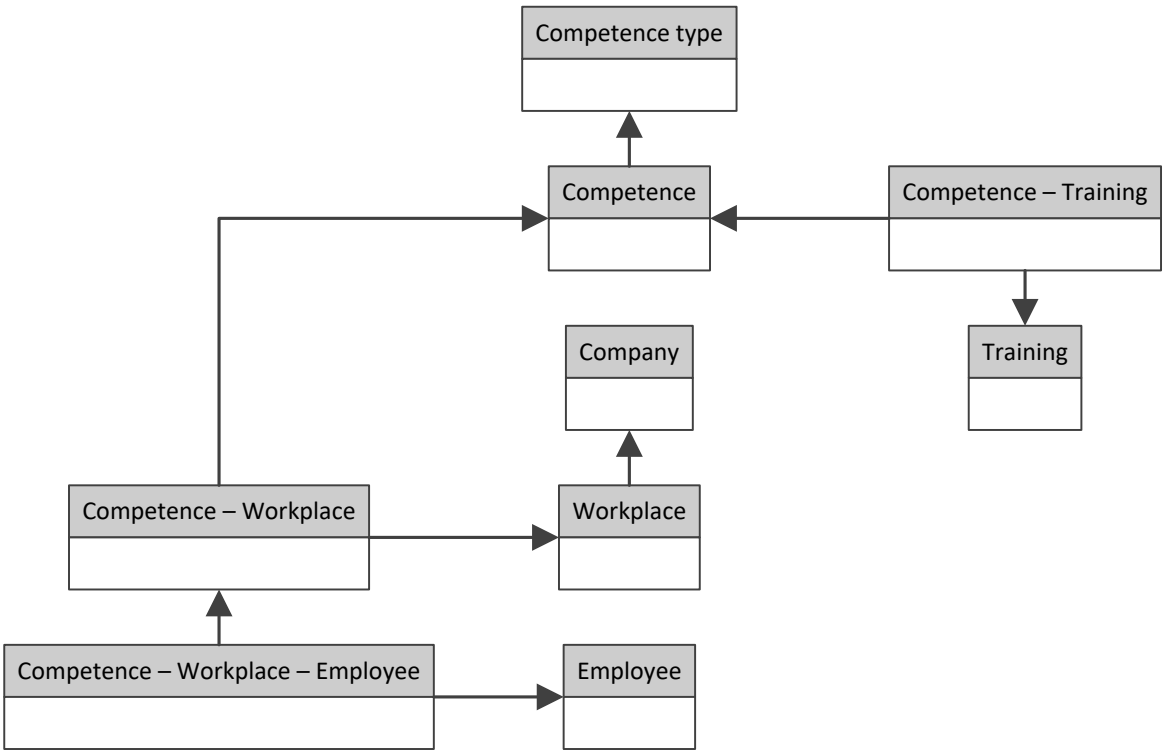

Figure 1. The basic structure of the RESPO system [25].

2.2. Structure of RESPO Application

The first version of the application is adapted from the previous projects RESPO and KOC-TOP (coordinated by IPS) and the transformation from a company to higher education institution was performed during the four-day training in Greece in the RESPO X project. The RESPO application was presented to a small group of validators (three undergraduate information and communication (ICT) students, one postgraduate ICT student, four higher education (HE) professors and two persons from non-governmental organisations (NGOs) related to training) from two aspects: a student and an administrator. In the following paragraphs, the structure of the RESPO application is presented.

2.2.1. Main Menu

The main menu shows the username and the user's function/role in the organisation. Below the user's info section, the submenus are divided into:

- Upload;
- Employees;
- Competencies;

- Workplaces;
- Trainings;
- Analytics;
- Status;
- Options.

The current version of the RESPO X application still originated from the RESPO application, which was intended to be used in the companies for their employees. These categories' names were transferred during the training to the higher education systemic nomenclature.

2.2.2. Upload

The "Upload" submenu allows users to import some data from Excel files (Figure 2). Currently, competencies and trainings can be uploaded. Templates are available for the import data. In the RESPO X project, the ESCO (European Skills, Competencies, and Occupations) platform (https://esco.ec.europa.eu/en (accessed on 30 November 2022)) was recognised as a very useful tool whose competencies can be extracted and included in the RESPO X application. This "import ESCO" allows users to upload competencies from the ESCO database regarding the selected occupation type, e.g., managers, professionals, etc.

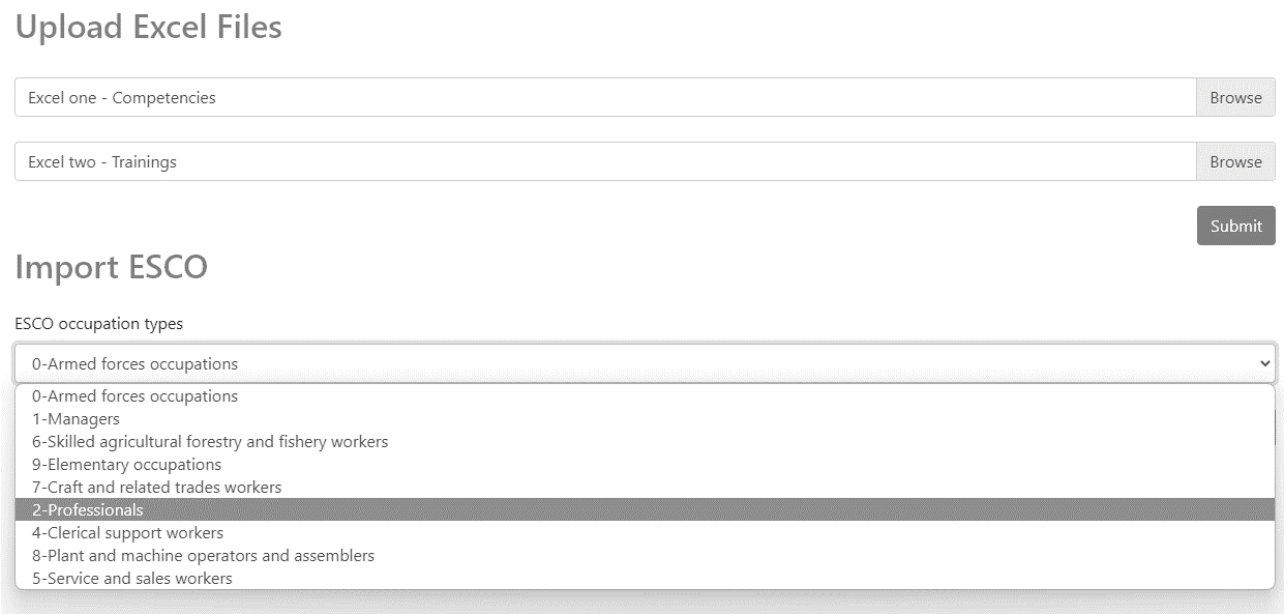

Figure 2. Upload and import functions in the RESPO X application.

2.2.3. Employees = Students

Under the "Employees" submenu, the users can type the employee's details, such as name, phone, city and country, e-mail address and username. A special selection container here is "Workplace", which can be added under the submenu "Workplaces" together with the competencies needed to perform work at this workplace. The workplaces represent study programmes in the transformation of the nomenclature into HEIs. The administrator (i.e., supervisor, professor, career centre staff) can also see the list of all users and edit or delete each. Under the section "History", the administrator can follow each user's progress in the competencies' development during a defined period. The progress is also presented on the graph.

2.2.4. Competencies

The submenu "Competencies" allows users to add each specific competency. The competency type, Hogan ID, name and description for each competency must be defined. All added competencies can be found under the section "All competencies", where the competency type is first given and the list of added competencies can be seen by clicking on each type (Figure 3). Competency types and competencies can also be edited or deleted by the administrator.

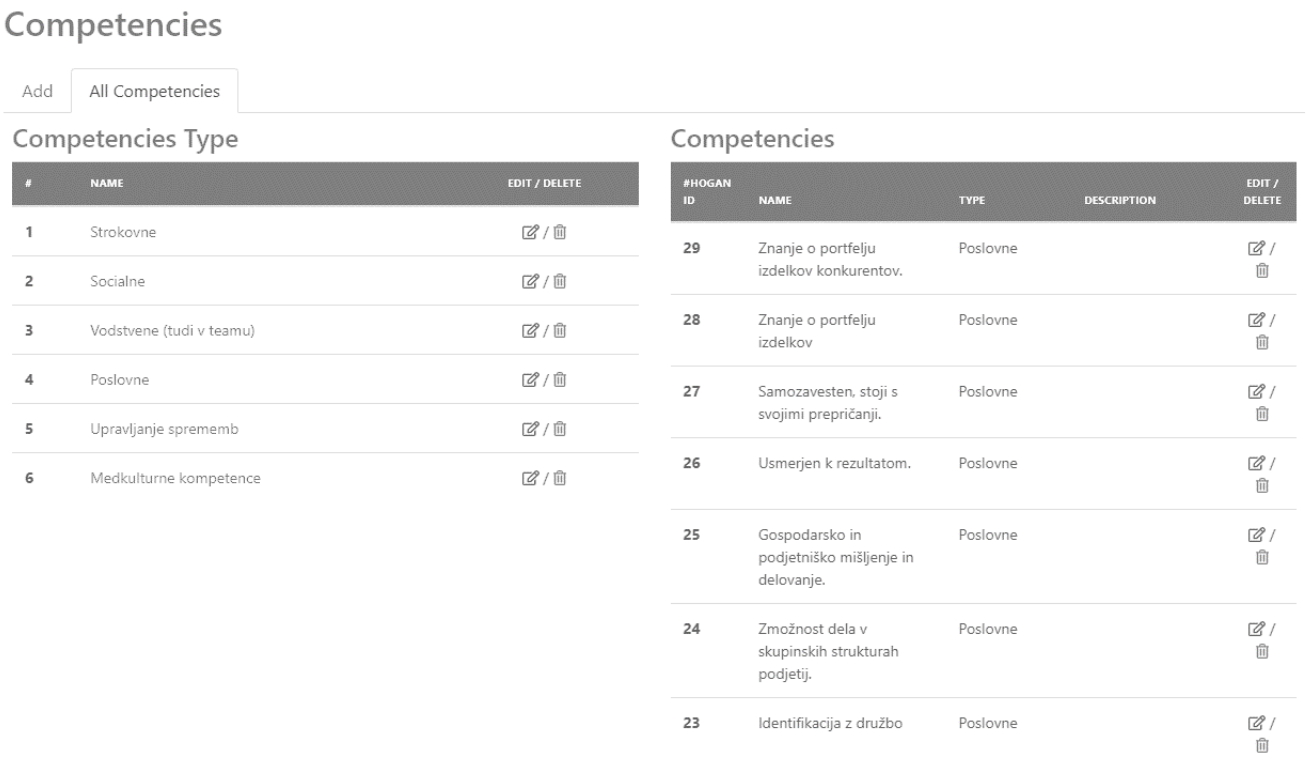

Figure 3. Defining competencies in the RESPO X application (competencies are given in Slovenian, the translation for the competencies type is as follows: 1. Professional, 2. Social, 3. Leadership (including in a team), 4. Business, 5. Change management, 6. Intercultural competencies).

2.2.5. Workplaces = Study Programmes

This submenu allows users to add workplaces considering the job systematisation in each company. The user must add a short description and required competencies for each workplace. The relevance of each competency needed at a specific workplace is estimated and scored. Under the section "Workplaces", all added workplaces can be found. A list of needed competencies is provided with their relevance and minimum scores required by clicking on a specific workplace. Herein, the application also offers the input of new competency. As mentioned, the workplaces represent study programmes transforming the nomenclature into HEIs.

2.2.6. Trainings

This submenu is dedicated to trainings. The users can add appropriate trainings and determine its name and description as well as the duration of training with start and end dates. For each training, relevant competencies must be specified and selected from the list. The selected competencies will ensure that the users improve their competencies by attending the selected training. The administrator can also see all added training with its specifications and covered target competencies.

2.2.7. Analytics

Under this submenu, the administrator can select among four different algorithms, which assess the user's lack of competencies and suggest the training from the database that the user could attend to improve their competencies and minimise this lack of competencies. The lack of competencies is estimated based on users' current level of competency, the relevance of this competency for the employee's workplace and the relevance of the training targeting this competency. If RESPO finds appropriate training in its database, a suggestion is offered to the administrator, who can send an invitation to the employee. The employee still has the option to decline the invitation.

The RESPO expert system uses different algorithms to find the best-suited training course for each user/learner. It uses information on the individual competencies, competencies required in the education programme, and the potential of each training course to improve each competency. This "Analytics" section is significant for supervisors to select an appropriate algorithm and to understand what each algorithm is considering when estimating the student's lack of competencies.

The RESPO system uses four different algorithms to select the most optimal training for the student. It considers the current level of development of each competency the student has before the training and the level required to pass each course and study programme in which the student is enrolled. In the future, we intend to incorporate advanced technologies such as machine learning into the algorithms, where the system would also consider the needs of employers for each competency for the workplaces where students can be employed.

2.2.8. Status

The "Status" submenu shows which users were invited for each training and which accepted or declined the invitation. The administrator has the option to resend the invitation or even cancel the training. The second tab under this submenu shows the list of training for each user, both accepted or declined.

2.2.9. Options

This submenu is currently devoted only to users' password recovery by the administrator.

2.3. Validation of RESPO Application

As part of the RESPO X project, training for RESPO validators was carried out in Larissa, Greece, in September 2022. The training was intended for the HE staff (professors, technicians, researchers, career centre staff, etc.) and a small group of ICT students to validate the developed RESPO application. The training directly supported the main objective of the project, i.e., the development and optimisation of the online accessible RESPO X application to offer a systematic solution for students when selecting the most optimal training to enhance their professional and personal competencies and skills for future jobs. The participants validated the functionality and architecture of the main features of the online application. Special attention was also given to the elements ensuring the user-friendly and disability-friendly tool, which allows access and use also to those with disabilities. Based on participants' feedback, a comprehensive report for further decision support system optimisation was prepared and summarised in this contribution. According to the above-described RESPO structure, the validators' findings and suggestions are summarised in Table 1.

2.4. Translation of Nomenclature from RESPO to RESPO X Application

The most important first step in transforming the RESPO application in HE is translating the nomenclature from a company to higher education institutions. During the validation training, the translation of the main menu presented in Figure 4 was suggested. According to the application structure, the corresponding database will also be updated.

Table 1. Validators' suggestions and feedback on the RESPO application testing.

App Structural Feature	Validator Suggestions and Feedback
Registration and login	• The registration should be simplified, especially defining a username (it can be automatically created by name or e-mail). • Phone format must consider the international level (e.g., +386 for Slovenia). • Autocompletion from Google for city, country, etc.
Main Menu	• Translate the nomenclature from a company to higher education institutions.
Upload	• A download option should be added to the upload option, allowing the download of a .csv file with all saved data (if possible as different files for competencies, trainings, study programmes and students).
ESCO integration	• Sort the ESCO list alphabetically. • Verify if the "qualifications" pillar can also be included in the RESPO application.
Employees = Students	• Replace the workplace with a study programme. • Additional data under the "Employee Details" section: name of the study programme, level of the study programme (Bachelor, MSc, PhD), enrolment year in first grade, year of study, supervisor name, HE institution, etc.—consider international HE systematisation (different countries use different education levels). • Different confidential levels for different users (administrator, supervisor, student) so that sensitive data are visible only to those with appropriate rights. • Anonymisation of data (pay attention to exported files). • Check data protection (GDPR, data disclaimer for app and institution) on the institutional level (application user) and the level of application (owner of the application). • Enable search by study year and study programme, in addition to the employee's name. • Add filter for search (basic and advanced search). • Adapt content for different displays (laptop, tablet, PC). • Add a slider instead of numbers for competency scores for students' competencies. Use only whole numbers, no decimals. • Add tips for more complex inputs. • Each supervisor can see only their students and courses. • Find a solution to reduce the long name of competency on the dropdown menu.
Competencies	• Add tips when necessary. • Limit the field for competency description (max 350 characters). • Add a button to import data from Excel for competencies. • Set different privileges to access/add/edit/delete/see data (administrator, supervisor—teacher, student). • Use the dropdown option or a pop-out window for adding specific capabilities for competencies.
Workplaces = Study programmes	• Only the admin has privileges to add/delete/edit study programmes. • Add study years according to the Bologna process (bachelor, master, doctoral degree). • Divide competencies into general and specific. • Competencies must be connected to study courses. • Add tips explaining how to determine the relevance and minimum required score. • Adapt content for different displays (laptop, tablet, PC). • Add search with advanced filter. • Add a slider determining the relevance of each competency.

Table 1. *Cont.*

App Structural Feature	Validator Suggestions and Feedback
Trainings	• Add the type of training: formal or informal, etc. • Add measuring training to get a score for training. • Add advanced filter for search. • Add a field to determine a study programme to which this training belongs. • Add a new window to add competencies and for filtering competencies. • Add some fields to determine if the training measures one competency or a group of competencies. • Add a column showing the assessment of individual training. • Enable the export of grades from the RESPO system (JSON export, .csv export). • When evaluating the training and competencies, it is necessary to consider the country where the training takes place and various grading systems (e.g., grade converter between countries). • Add a pop-out window for a description where the evaluator must explain why they changed the competency's scores (after training, manually by the supervisor), only in cases when the total score is reduced and always in cases when the score is changed manually. • If there is a more precise definition of a competency assessment than a subject/course assessment, the more precise option is used. • A supervisor can assess all competencies or each competency itself. • The lecturer can prepare a questionnaire before and after training. Self-evaluation can also be considered.
Analytics	• Enhance with an advanced search filter by adding other parameters, e.g., course, specific competency, group of competencies, academic year, whole class or institution. • The results should be more informative. • Algorithms should be adapted to the competency type (social skills, professional-specific competencies, etc.). • Use machine learning to improve algorithms and their application by selecting the appropriate algorithm. • Keep simplicity—keep some preferred options when choosing an algorithm that makes the work of teachers easier. • Get insight/overview of the development of competencies for the whole institution, one study programme, one academic year, one teacher-supervisor and one student.
Status	• Add a time frame to see which training was implemented and which trainings a student attended. • Add an advanced filter. • Add an option for export (JSON, .csv) so that users can export data and manage it in another application to add other features. • Add the possibility that the user can send feedback/suggestions to the application owner or administrator.

2.5. Elements Ensuring the User-Friendly and Disability-Friendly RESPO Application

When developing and optimising the RESPO application, the needs of users with different disabilities (visual, auditory, physical and cognitive) will be considered. Our goal is to create a helpful decision support tool and support people in need. Since the EU is discussing ways to enforce accessibility with regulation to improve accessibility for services and products, making our app accessible to everyone is ethical as it can potentially create a significant learning advantage. The validators gave several important recommendations for further application development and optimisation:

- Use a unique colour palette (e.g., clear contrast between foreground and background) and configurable buttons and text that deliver clear and easy-to-read texts (e.g., users have the option to zoom in, no cursive or curly font types).
- Add tips with explanations on complex fields.
- Create an instructional video, which will be enhanced with transcriptions, subtitles and captions.

- Use assistive technologies such as screen readers or voice-overs and haptic feedback (e.g., vibrations).
- Adapt the application structure to different displays (tablet, mobile, laptop).
- Use simple and short sentences supported by clear and recognisable iconography.
- Choose only a few crucial features to be shown on the main screen to keep users focused. All additional functionalities are still available in the menu, but in contrast to most of today's apps, the main screen should contain just a few of the most important elements.

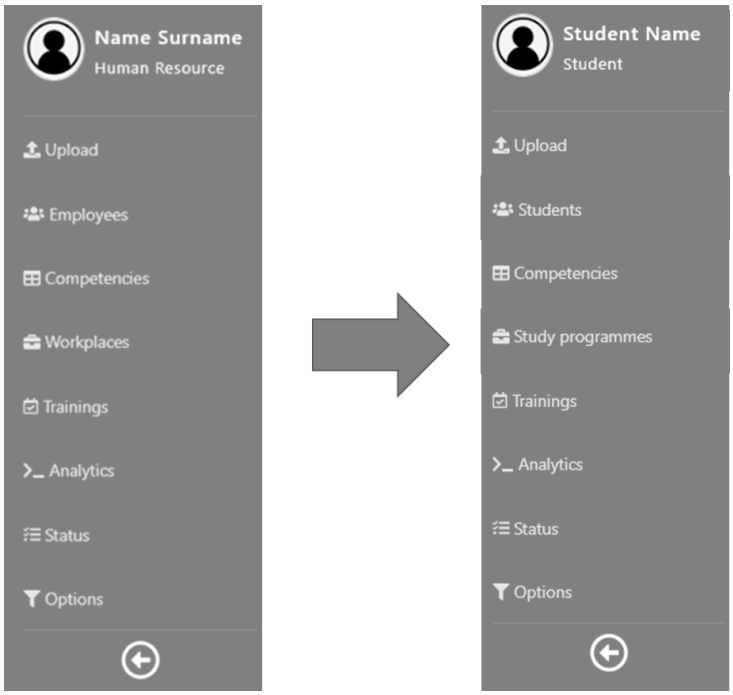

Figure 4. Translation from business to HE nomenclature.

3. Key Competencies for Science, Technology, Engineering and Mathematics (STEM) Education and Learning

The upgrade of the RESPO system for higher education in nanofields was initiated under the RESPO X project of the Erasmus+ programme. The first step was to identify the most relevant competencies for students by comparing the study courses' competencies and outputs with the European Commission's list of key competencies. The ESCO classification of competencies was used [26]. We found that most of the competencies related to nanoscience and nanotechnology were missing in the ESCO system. The first version of the RESPO X application includes datasets from the ESCO platform, i.e., occupations with skills. Currently, the user can upload the ESCO occupation pillar, which includes and distinguishes between skill/competency concepts and knowledge concepts by indicating the skill type. There is, however, no distinction between skills and competencies.

It was also found that the competencies base in the RESPO expert system needed to be adapted to the curricula and employers' needs, considering the recommendations of the European Commission, UNESCO, the OECD and the WEF. In the framework of the Norway grant-funded RESPO-VI project, a comprehensive report on 21st-century competencies will be prepared, focusing on those that are or will be needed by science, technology, engineering, and mathematics (STEM) students. We will shortly produce a list of key competencies aligned with employers' needs, selected study programmes and international and EU policy strategies and guidelines. Thus far, the RESPO X project has identified the first relevant competencies for the participating STEM students, which are listed in Table 2 in Section 3.2.

Table 2. Identified competencies in the RESPO X project.

EU Key Competencies	Specific Competencies
Literacy competency	• Communication skills to present research and technological achievement. • Skills for effective communication between development planners and environmental protection experts and activists.
Multilingual competency	• Ability to communicate with experts from other disciplines and fields. • Ability to competent communication, both within the field of ICT and with other research areas. • Ability to communicate in English in the field of synthesis of nanomaterials.
STEM competencies	• Understand the basic characteristics of pollution of the environment. • Design solutions for the rehabilitation of degraded and contaminated environments. • Understand environment quality control tools. • Ability to independently develop new methods and applications of computational creativity in real-world problems. • Basic understanding of scientific knowledge structures and activities, as well as computer methods to support their automation. • The ability to comparatively analyse sensor data based on their properties and in relation to the application requirements. • Constructing a meaningful, feasible pipeline for handling and pre-processing sensor data and connection to other data. • The capability of selecting and applying sensor data analysis methods on a potentially large amount of data potentially arriving with high intensity over the data stream. • The capability of evaluating and comparing results of sensor data analysis. • Analysis of nanoparticle risks in their life cycle. • Monitoring and measurement of exposure to nanoparticles. • Characterisation of nanoparticle properties, including the potentially toxic effects. • Apply knowledge of modern microscopic methods for the characterisation of the structure of nanomaterials. • Able to select a suitable method of synthesis of a given nanomaterial considering experimental limitations and advantages/disadvantages of a selected method. • Mastering selected research methods in the field of nanosciences and nanotechnologies. • Apply knowledge of electrical, optical and magnetic properties of nanomaterials acquainted with the use of optical spectroscopic methods for the characterisation of materials and application in photonics. • Master research methods in the physics of nanomaterials. • Develop proficiency in using physics specific to nanomaterials systems. • Understand basics of the characterisation of advanced metallic materials, biomaterials and engineering materials, properties of metallic materials and their structures. • Understand the thin film growth by all forms of sputter deposition, plasma techniques and materials engineering in order to control and tailor microchemistry, microstructure, and hence, physical properties of metals and alloys. • Apply the analytical techniques for characterisation of thin and ultra-thin films, and nano- and microstructure and analytical methods for chemical analysis of metallic materials. • Basic applied knowledge about up-to-date X-ray absorption spectroscopic and microscopic methods with synchrotron radiation for the characterisation of the atomic and molecular structure of (nano)materials. • Understand basic mechanisms giving rise to diverse soft material-based nanocomposites. • Understanding of key properties of soft materials and corresponding theoretical modelling. • The ability to evaluate the procedures and conditions of sample analysis during experimental work with nanomaterials and biological systems at the same time. • The ability to improve the procedures and conditions of sample analysis during experimental work with nanomaterials and biological systems at the same time. • The ability to monitor the results of analysis and interpretation of the influences of matter on structural changes within the body, tissue or cell.

Table 2. *Cont.*

EU Key Competencies	Specific Competencies
	• Integration of acquired knowledge to identify and solve the problems related to the development and optimisation of nanomaterials. • Knowledge of principles of plasma-surface interactions and material processing, which leads to surface activation, selective etching, cold ashing, surface nanostructuring and synthesis of new materials. • Understanding of basic concepts from mathematics and statistics, familiarity with state-of-the-art methods and knowledge of application examples in many areas of informatics and engineering. • Ability to apply knowledge of the theory of nanomaterials.
Digital competency	• Understanding of basic concepts from the field, familiarity with the state-of-the-art methods, the capability of independent use of artificial intelligence and machine learning methods for solving scientific problems while following the principles of open science. • Understanding the concepts of data visualisation. • Ability to design visualisations that are accessible and trustworthy. • Skills to make efficient presentations.
Personal, social and learning to learn competency	• Develop critical thinking and self-assessment. • Cooperation and group work ability. • Ability to carry out independent as well as team R&D work. • Ability to use the knowledge in practice. • Development of an integral way of thinking. • Mastering of R&D methods, procedures and processes, critical thinking and synthetic work. • Comprehensive consideration of development applications (projects, plans, programmes and policies). • Critical viewing of strong and weak points of development applications. • Ability to apply conceptual blending and bisociative discovery of new concepts. • Comprehensive understanding of the advanced ICT topics. • Ability to apply in their research work: possibilities, opportunities and threats resulting in processes of business and education; "state of the art" educational tools and approaches, applicable to the concrete environment. • Understanding diverse physical phenomena present in low-dimensional structures and their applications in nanotechnology. • Ability to carry out independent research work and to use the knowledge in practice in the field of nanosciences and nanotechnologies. • The ability to inform about the influences of matter on structural changes within the body, tissue or cell. • Ability to solve independent research and development tasks in the field of plasma-assisted nanostructuring of surfaces and nanomaterials, which includes basic concepts, proper selection of processes for the preparation of surfaces and growth of nanomaterials with plasma.
Citizenship competency	• Master selected research methods, procedures and processes in the field of sustainability. • Knowledge transfer into practice. • Mastering methods and techniques of scientific research work in the field of sustainable development, economics, national and business innovation management. • Mastering methods and techniques of scientific research in the field of circular economy. • Cooperation and teamwork. • Understanding of problems connected with societal, cultural and ethical relevance of scientific and technical achievements. • Systemic understanding of dynamic processes in nature and society. • Knowledge of the relationships in civil society.

Table 2. *Cont.*

EU Key Competencies	Specific Competencies
Entrepreneurship competency	• Ability to design thinking within the development, evaluation and implementation of innovative business products. • Ability to prepare a business plan. • Apply knowledge from the development and commercialisation of innovative technologies. • Apply management of research and development (R&D), technology and innovation, as well as related intellectual property. • Understanding the basic underlying infrastructure enabling e-business and e-commerce. • Ability to correlate physico-chemical properties of nanoparticles with potential applications. • Ability to design nanoparticulate materials and their synthesis for potential applications. • Critical assessment of the applicability of processing technologies for materials in practice.

3.1. EU and Other Relevant Strategies as a Basis for the Selection of Competencies for RESPO Application

The European Council has repeatedly stressed the key role of education and training for the EU's future growth, long-term competitiveness and social cohesion. To achieve this, it is crucial to strengthen the education element of the knowledge triangle "research-innovation-education", starting at an early age—in schools. The competencies and learning habits acquired at school are essential for developing new skills for new jobs later in life. A more flexible learning environment is required to help students develop different competencies while maintaining basic knowledge. Suggested approaches included new pedagogical and cross-curricular approaches to complement and involve learners more in the design of their curricula. Literacy and numeracy are essential components of key competencies, as they are fundamental for further learning. Numeracy, mathematical and digital competencies and an understanding of science are also key to full participation and inclusion in the knowledge society and the competitiveness of modern economies. Today's job seekers need to be able to work collaboratively, communicate and solve problems—skills that are developed primarily through social and emotional learning. Combined with traditional skills, these social and emotional skills will equip learners to succeed in the evolving digital and green economy.

KeyCoNet (http://keyconet.eun.org/ (accessed on 30 November 2022)) is a growing network of more than 100 organisations funded by the European Commission under the Lifelong Learning Programme to improve the delivery of key competencies in school education. The European Commission uses the word "competence" instead of "competency", so we use their spelling when we refer to the documents of the European Commission. The KeyCoNet network uses the European framework on "Key Competences for Lifelong Learning" as a reference point, which defines the following eight key competencies:

- Communication in the mother tongue;
- Communication in foreign languages;
- Mathematical competence and basic competencies in science and technology (STEM);
- Digital competency;
- Learning to learn;
- Social and civic competencies;
- Sense of initiative and entrepreneurship;
- Cultural awareness and expression.

These key competencies are all interdependent and closely related to seven transversal skills:

- Critical thinking;
- Creativity;
- Initiative;
- Problem-solving;
- Risk assessment;

- Decision making;
- Constructive management of feelings.

WEF listed the following 21st-century skills for students according to three categories [9]:

- Foundational literacies: literacy, numeracy, scientific literacy, ICT literacy, financial literacy, cultural and civic literacy.
- Competencies: critical thinking and problem-solving, creativity, communication, collaboration.
- Character qualities: curiosity, initiative, persistence and grit, adaptability, leadership, social and cultural awareness.

According to WEF reports, the top 10 work skills will change over the next decade. Workers and job seekers will have to be more analytical, critical, systematic, innovative and creative. They will need to become active lifelong learners who will be able to handle stress and be ready to adapt to rapid changes. Figure 5 shows how the list of the top 10 skills that employers will look for in employees, including students, when they enter the labour market has changed over the past decade and will change over the next few years. Some skills, such as complex problem-solving, remain on the list throughout the period. Creativity slowly gives way to originality and ideas. Skills that emphasise the individual being able to learn actively through various learning strategies while remaining analytical, decisive, judgmental, rational and systematic are becoming more and more dominant.

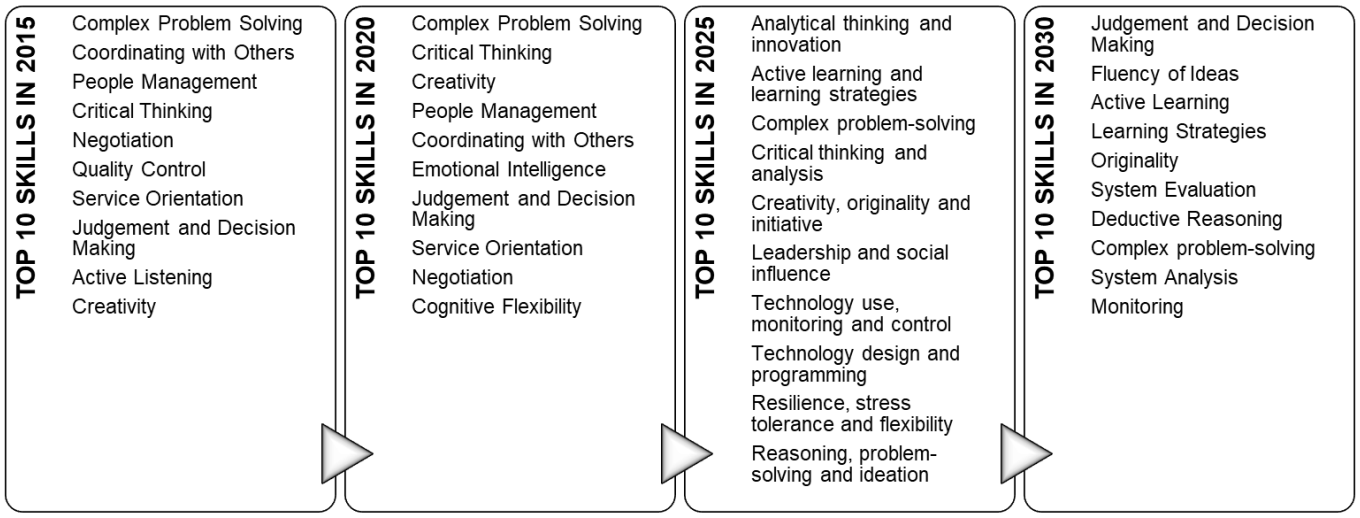

Figure 5. The changing top 10 skills between 2015 and 2030, according to WEF reports.

3.2. Selection of Competencies from Study Programmes in Nanoscience and Nanotechnology

As part of the validation training, the list of relevant courses by higher education institutions participating in the RESPO X project was reviewed. A short selection of all the courses on the list of selected study programmes was made. This selection will be updated with a few additional courses from the partnership HEIs and with lecturers outside the partnership. Such courses were selected through which the students will have an opportunity to develop and enhance a core set of skills for researchers, which will enable them to make a more substantial contribution to sustainable development. Barth et al. found that the development of key competencies for sustainable development combining formal and informal learning can enhance the skills required for sustainability [27].

At the training, the participants also compared the selection of a core set of skills for students with those included in transdisciplinary training courses at the participating HE institutions. Three categories of skills were selected that can contribute the most valuable sustainability-related skills to engineering students. These categories include **digital**, i.e., information technology and skills with a focus on artificial intelligence, professional **STEM**

skills with a focus on materials science and advanced technologies for developing new, more environmentally friendly materials and **sustainability** skills, including environmental responsibility, which will be more valuable in future jobs. The participants selected the most appropriate courses and lecturers for the student training in each category. The selected courses are, therefore, divided into three modules, where some new courses can still be added:

- Digital: Introduction to Artificial Intelligence, Data Warehouses, etc.
- STEM: Advanced Processing of Materials, Materials Structure and Characterisation, Materials Technology, Plasma Nanoscience, Gas discharges, etc.
- Sustainability: Economics and Society, Introduction to Circular Economy, etc.

The specific competencies identified in the RESPO X project as important to the participating student are listed in Table 2. The selected competencies are ranked into eight categories of Key Competencies, as defined by the European Commission.

After completing the list of RESPO X competencies, the existing RESPO database will be updated and algorithms for selecting the most effective education programmes will be reviewed and improved to allow the learners to improve their competencies in a shorter time and at a lower cost.

4. Discussion on the Drawbacks of RESPO X

There were some obstacles to transferring the RESPO application from the business environment to the higher education system. The first difficulties appeared in changing the terminology, namely the use of study programmes and the more detailed fields of study that appear in some HEIs. In some study programmes, there are also modules which divide subjects into compulsory and optional, thus changing the relevance of the competencies to the specific study programme.

The other major obstacle relates to the introduction of the assessment method. The method chosen in this study is rather subjective, as it is an assessment by the training provider or lecturer. This problem will be solved by introducing standardised multiple-choice questionnaires to be filled in by students before and after the training. There is also the question of whether competencies are assessed only by the lecturer or course provider, the student's supervisor or the person who manages the student's career progress at HEI. One possibility is even to introduce 360-degree assessment as it is known in companies. As different countries use different assessment systems, it is also necessary to introduce a grade converter from one system to another. European Union rules already exist that need to be incorporated into the RESPO X system.

A third disadvantage is that the current system does not consider that different subjects may have the same competencies of varying relevance for each subject. With the introduction of advanced machine learning algorithms, the RESPO X system can look for similarities between subjects and weigh the importance of a competency according to its relevance to a particular subject.

The fourth obstacle, and probably not the last one, is related to ensuring the protection of personal data, namely the need to ensure compliance with GDPR rules and to introduce layers of data protection at the level of the institution using the application and at the level of the owner of the application.

5. Conclusions and Future Work

European Union policies and guidelines highlight skills as key to sustainable competitiveness, resilience and social inclusion. This realisation is also at the core of the European Skills Agenda, which focuses on investing in lifelong learning (upskilling and reskilling) to sustain recovery from the COVID-19 pandemic and to meet the challenges of a digitalising world and a greener economy. As these changes are already under way and accelerating, Europeans will need to acquire new skill sets or improve their existing skills to better adapt to the rapid changes ahead and to succeed and be satisfied in the future labour market. However, knowledge and skills have become key factors for individual well-being and

economic success in the 21st century. Without investing in people's knowledge and skills, a high quality of life in society, technological progress, economic competitiveness and innovation cannot be expected. Countries need to focus on creating the right mix of skills and ensuring that these skills are fully exploited in the labour market.

During the first practical trials of the RESPO application, it was realised that the RESPO database of key competencies needs to be updated and adapted to educational programmes, employers' needs and international as well as EU strategies and recommendations. Therefore, in another project, RESPO-VI, funded by Norwegian grants, a selection of competencies for the RESPO database will be prepared, which will also be adapted to EU policies and strategies and other relevant recommendations (OECD, WEF, UNESCO) as well as employers' needs. The selected RESPO X competencies represent a starting point for a comprehensive list of the most relevant competencies for students and researchers in the field of nanotechnologies, which will evolve throughout the project and become a standard reference for nanotechnologies professionals.

The RESPO X application, when fully developed, will be tested among the students of four HEIs during the training, which will be prepared in an international environment at the Universitat Politecnica de Catalunya (UPC) in Spain in spring 2023. The planned training will be implemented to cover one or more skills for smart green transition defined by the partnership, which will be included in the RESPO X expert system and online application. Lecturers from all participating HEIs will collaborate to prepare joint training composed of several courses, which will be performed by lecturers or experts from these HEIs. They will focus on content, which will provide participants with a set of skills for the smart green transition, mainly digital competencies, STEM skills (material science including plasma science and gas discharges, advanced research and technology), environmental responsibility and sustainability skills. Each participating HEI will select several students, according to a priori known selection criteria, who will attend the lectures and monitor their competencies' development through the RESPO X application with support from the HE staff. The students from all participating HEIs will attend the courses to develop or enhance their competencies and skills and to become efficient professionals at future jobs after completing their studies. Thus, an evaluation of the effect of the RESPO X decision support system on competencies development will be prepared as a handbook on policy recommendations based on validation of the RESPO X application and the students' transdisciplinary training.

The presented transformation of the RESPO expert system into the RESPO X application provides excellent opportunities for significant improvement of the learning process, both in higher education and in lifelong learning. The findings can help professionals working in higher education institutions create appropriate conditions for developing students' future competencies and foster the targeted use of learning analytics tools.

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