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ORIGINAL PAPER

Designing an innovative educational toolbox to support the transition to new technologies

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Abstract
Our economies and societies are becoming more and more knowledge based which implies that increasing numbers of people need to be educated and trained on new subjects and processes. Thus, the reduction of the effort needed to design and prepare educational and training programmes that meet the needs of the society and the market is of paramount importance. To achieve this goal, first, we define a learning programme model so that programme designers can easily exchange and re-use programme structures and learning materials. The proposed model additionally enables easier creation of interdisciplinary programmes which is another need of today's market. Second, we deploy a web-based tool that adopts this model towards facilitating the re-use of structures and materials. Third, to reduce the time required for the training actors to sense the market needs, we propose the establishment of an educational programme marketplace. All three endeavours have been validated in the energy transition sector and (positively) evaluated by experts during an international workshop.

Keywords Educational programme modelling · Education resource re-use · Effective programme design

Introduction

Technology progresses very fast and revolutionises many diverse sectors of the economy, where the application of novel solutions is beneficial. In order to maximise the benefits of the new technologies for both the society and the economy areas, many people in different geographical areas and of diverse backgrounds—acting in different roles (Sum and Jessop 2013)—need to be trained. This involves educating students, raising awareness of citizens and (re-)training of workers; this is

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not coming as a surprise since our societies are moving towards a knowledge-based economy. The times when a worker learned and executed one specific process or used the same specific machinery throughout their work life are gone.

An excellent paradigm of this situation is the energy sector, where the energy transition is considered a great societal and sustainability challenge that has to be jointly addressed by all actors (e.g. society, market, policy makers, employees of the sector at all levels, scientists, technology experts etc.). If we want the technologies that enable and support the energy transition to penetrate the market, young engineers/students and already employed engineers need to be trained. Also, business model designers and solution marketers need to understand the new systems and services (e.g. flexibility services) in order to decide how to sell them. Even more importantly, the society members must get ready to understand and respond to the challenge selecting and using the most appropriate services and making energy-wise choices. Policy makers and authorities, which are catalysts of the energy transition, should have the opportunity to learn more on the different aspects of energy transition.

Currently, there is a huge gap between the knowledge, skills and competence needs of the involved organisation, and the corresponding availability in the society (Cedefop 2015). The gaps are in (a) knowledge of novel technologies, (b) understanding the inter-dependence between technology and societal needs and (c) soft skills such as problem solving, conflict resolution, critical and strategical thinking. A first cause of this gap is the inertia of the academia, i.e. the fact that educational and training actors sense the job market at a very low pace compared to the speed of technological evolution and market needs change. Second, even when these needs are identified (as is the case for the energy sector (Czako et al. 2018), it is not easy to bridge these gaps, due to the required effort to develop novel programmes for each of the above groups (technicians, students, managers, policy makers, citizens) across different countries, adopting different languages. For example, whereas academic institutions conduct research on relevant technological areas and possess knowledge on novel technologies, they only cater to their own students. Also, the renovation of curricula and the integration of new courses and activities is subject to the boundaries of schedule and approval paths of the Institutions and hampered by the internal organisation based on disciplinary separation (Faculties, Departments). Furthermore, multidisciplinarity has been poorly addressed by universities and even more poorly by vocational training up to now. For example, to deliver an Internet of Things (IoT) solution tailored to a smart grid, the designer must understand the basic principles of both IoT (which is a topic usually studied in Information and Communication Technology Departments) and energy system operations (which is usually taught in Electrical Engineering Departments). In other words, this knowledge is not integrated in Acadmia, and thus, it is difficult for engineers to combine the disciplines of information solutions and power systems. The situation is similar in other sectors (e.g. energy sector, Industry 4.0, public services) and technologies like Artificial Intelligence and Big Data to name a few. Additionally, the people who possess this knowledge and are in charge of transferring it to the learners in other disciplines are mostly technology experts with very limited knowledge of educational design and instructional design methodologies. Even more importantly, they currently do not use tools that would enable course design and material sharing. Currently, in practice, professors and tutors do not use collaborative tools to design their courses while for the materials, they use, in practice they share them with their students through Learning Management Systems. These systems do not facilitate the sharing of the course designs and learning materials. If they had such tools, the penetration of technology in the society would be much easier and more efficient.

Our aim is to define and deliver a set of tools that will support academia and training organisations to tackle the current mandate for technology-relevant education/training worldwide. Namely, we aim to address the following research questions: (a) how can we overcome the inertia not only mainly of academia but also of training organisations in sensing the market needs, i.e. shorten the required time to sense the needs of the market and society? (b) How can professors and tutors of technological subjects share course designs and materials so that they educate/train more people in diverse settings, i.e. reduce the time to design a new programme and reduce the time required to develop learning materials. In this article, it is proposed a graph-based structure to model educational programmes, which consists of three hierarchical levels: (a) the learning topic, (b) the learning outcomes and (c) the learning materials. The educational programme designer creates the instance of such model for an educational programme with a specific learning topic, targeting different groups (e.g. students or employees of a company), embracing different learning modes (e.g. face to face, distance learning or blended), because they share the same set or subset of learning outcomes and set or subset of learning materials.

The instances of such model are created for an educational programme with a specific learning topic, the educational programme designer can easily create courses targeting different groups (e.g. students or employees of a company) embracing different learning modes (e.g. face to face, distance learning or blended) because they share the same set or subset of learning outcomes and set or subset of learning materials. Also, to allow tutors/professors/training programme designers across the world to share these structures and material, a web-based platform was developed, where they create and share resources. Furthermore, to help the training providers (academia and training organisations) to sense in a direct way the market needs, the establishment of an educational/vocational programme marketplace is proposed, where those in need of skills and training meet those who can offer them. It is considered that addressing these research questions will have a major impact (a) in the educational activities of our societies, as these will reach larger audiences and (b) in the sustainability of our societies, as citizens will be well informed to decide which technologies should accept/reject, businesses and policy makers will be able to recognise which technologies to adopt to tackle their challenges (e.g. energy efficiency, environmental impact).

The rest of this paper is organised as follows: in "Related work", a brief overview of the efforts to standardise the description of educational assets and of instructional design methodologies are provided. In "The requirements", the energy sector is considered as a use case to elaborate the requirements for education and training that need to be met and are also highlighted other sectors that exhibit the same requirements. In "Graph-based learning toolbox", the proposed model is presented, along with the rationale of the choices. The web-based tool used in the implementation and validation of the proposed model is presented in this section. The educational programme marketplace is also presented in this section. "Assessment results" reports the evaluation results collected from an international audience of professors/trainers and students/trainees. In "Discussion", the discussion of the evaluation's results, the results from the group interviews as well as quality and sustainability issues are presented. Finally, "Conclusion" concludes the paper.

Related work

Learning design is the framework that supports learning experiences and refers to deliberate choices about what, when, where and how to teach. Instructional design is the process by which instruction is improved through the analysis of learning needs and systematic development of learning experiences. According to this definition, instructional designers have two primary functions (a) to analyse learning needs and (b) to systematically develop improved learning experiences. Instructional designers often use technology and multimedia as tools to enhance instruction. In the domain of learning and instructional design, a set of models have been used to scaffold learning activities and processes (see also Koper and Bennett 2008) like the Analyse, Design, Develop, Implement and Evaluate (called in short, ADDIE) model initially presented back in 1975 (Kurt 2017), the Merrill's Principles of Instruction, the Gagne's Nine Events of Instructions, the Bloom's Taxonomy with its revised versions (Bloom 1956) and others. These theories and models have solid grounds in psychology and pedagogy sciences and have been used by teachers and instructors for decades, especially when targeting non-adult education. According to Bloom's taxonomy, learning is in fact a sequential and hierarchical process which starts from lower order thinking skills such as *remembering* and *understanding* to higher-order thinking skills such as *creating*, *evaluating* and *analysing* (Rust et al. 2003). Classifying the learning outcomes in the different levels of the Bloom pyramid helps the designer to specify the purpose of the learning experience they design and hence, specify appropriate tools. This approach is inherently appropriate when the topic at hand is related to technology as this is built in a hierarchical way.

All these theories contribute in assisting the instructors in their duty, learning experience design and deployment, which is an extremely complex process as they should pay attention to dozens of factors to design the perfect learning experience. In any case, adopting a model ensures that the learning design will achieve a certain quality and will not neglect important aspects of the experience design. However, they do not pay attention to the re-usability of the designs and learning materials, since these are aspects related to the classification's ontologies of learning objects on a higher level of abstraction.

As technology entered the learning experience era, more than fifteen years now, different new attempts to standardise aspects of the learning process have been made. One of the first attempts of content packaging is Shareable Content Object Reference Model—SCORM (SCORM 2004), which focuses on digital learning objects that can be (re-)used through different Learning Management Systems (LMS). The main feature of SCORM is the transferability of content among different

LMSs based on a common metadata structure. This formalisation paves the way for a more adaptive learning environment which provides the learner with the freedom to choose his own study paths. A step forward happened with xAPI (xAPI 2020), a standard for learning experiences, which can be further personalised by tracking cross-platform and multiple format learning activities and micro-behaviours. In parallel, UNESCO, under the Open Educational Resource framework, gathers materials fostering their re-use (UNESCO 2020). The value of Open Educational Resources (OER) was recognised, as testified by numbers of technical and policy reports (Santos 2019). The Joint Research Report outlines the ten dimensions of open education based on the OpenEdu Framework (Santos and Punie 2016). Also, it shows how academics can establish Open Educational Practices (OEP) to prompt inclusion and innovation as important values, starting from their day-to-day activities such as teaching, knowledge creation and research. The aim is to create (make, own and control copies of the OER) without digital rights management restrictions, re-use (use the OER partially or completely for their own purposes in a wide range of ways), revise (adapt, adjust or modify the OER), redistribute (share the OER with others) and remix (combine existing resources in order to create a new resource). Several search engines and directories targeting the sharing of OER like MERLOT (MERLOT 2020) exist today. However, MERLOT is focussed on learning material sharing whereas the objective of the work presented here is to extend the sharing to educational programme design. A different effort focussed on the evaluation of OER defining the corresponding rubric. Guidelines for the design of distance learning experiences have also been produced as, e.g. by OpenUpEd (OpenUpEd 2015). Similarly, CEDEFOP has provided guidelines on the definition of learning outcomes so that interested parties have a common way of describing and re-using them (CEDEFOP 2017). Further research aims at the definition of methodologies, ontologies and contents have been proposed as, e.g. in Boyce and Pahl (2007). In Tsatsou et al. (2017) and MaTHiSiS (2020), a graph-based approach was developed to model the learning experience in order primarily to enable learning experience personalisation and secondly to share learning design and resources.

As a consequence of the co-evolutionary process of developing new learning technologies for online environments and of sharing of learning material, a novel approach is to combine a standard system of metadata for content classification with a common structure of the learning process. Fostering multidisciplinarity is not a secondary goal of such an approach. In the following section, we will see how and with what results. The combination of a standard system of metadata for content classification with a common structure of learning process is an enabler to sharing learning materials and structures in a flexible and efficient manner. No standard or common way to achieve is yet in place.

The requirements

The modern knowledge society and labour market have rendered lifelong learning a mandate. The quote "knowledge is power" has nowadays been transformed into "Knowing how to learn is power". Thus, the focus is on establishing a common model to optimise the design, delivery and dissemination of educational programmes. To make the requirements as concrete as possible, they were defined in the context of the energy sector, which is the sector included in the list of the top Sustainability Development Goals defined by OECD (OECD 2015) as it has direct impacts on our societies and then discusses similarities with other sectors. The main intricacies that create novel educational requirements in the selected sector are the following:

- Energy transition employees need upskilling to understand and use the novel technologies that penetrate the market. Educating such large numbers of individuals in few years is almost impossible and brings training efficiency to its limits.
- Energy transition employees need today multidisciplinary understanding, with most of them having graduated when multidisciplinarity was not at the forefront of education systems.
- Problem-based solving and case-based solving are an important issue as the problems in each new energy facility is quite unique in the sense that there are few replicas similar enough that the same methodologies can be blindly applied. This also points at the need for highly educated/trained people in this sector with high problem-solving competence.
- Energy transition relies on the evolution of multiple and very diverse scientific disciplines ranging from mechanical engineers and nano-technology to flexibility service design which is rather a business development topic. This mandates the intensification of scientific research in multiple domains at a high pace.
- For energy transition to become a reality, awareness in society needs to be raised. People need to understand the severity of the physical resource sustainability problem and how their actions can affect the situation. The understanding of shared responsibility definitely needs to be enhanced.
- Different learning modes (e.g. face-to-face, online synchronous, asynchronous or blended modes) must be supported to fit the needs to the diverse audiences. Face to face may be the preferred style for students, but asynchronous online is better suited to professionals and employees, as well as citizens. Today, blended and Massive Open Online Courses (MOOC)-based learning could significantly help in enriching the skill set and knowledge based of all people (students, employees and citizens alike).
- An easy and direct way for the market and professionals to declare their needs for skills, competences and knowledge enrichment is needed. This would enable academic and training actors to continuously sense the needs and prepare corresponding programmes.

The sector of industry 4.0 is another sector where different novel technologies are combined to improve the efficiency of the processes which mandates the re-training of the employees. For example, Internet of Things, Artificial intelligence and Big Data are technologies that drive industry 4.0 vision. Additionally, understanding both manufacturing processes and new technologies (e.g. artificial intelligence) requires a multidisciplinary approach. On the other hand, the citizens need to become familiar with novel technologies that industries put in place to communicate with them. In the public sector, technologies like Artificial Intelligence, Big Data and Internet of Things can bring significant improvements. Examples include artificial intelligence techniques for prediction of needs for resources (e.g. number of servants needed for a specific event or occasion). All these require (a) technical experts with understanding of the processes to design and develop them, (b) citizens feeling safe and confident to use the technologies and (c) policy makers to understand the potential benefits and establish appropriate frameworks.

In summary, multiple sectors of the economy can benefit from diverse technologies. To enable this improvement, large numbers of experts/professionals need to be educated/retrained and the awareness of large audiences (comprising of citizens with different backgrounds) across the world regarding the use of novel technologies and approaches need to be raised. Still, tools that would allow educators to share resources (instructional designs and materials) and thus reduce the required effort are not yet in place. Similarly, online spaces where the people interested in training would join organisations offering it are not yet widely spread.

Graph-based Learning toolbox

The learning model

For the definition of any course programme, the basic elements of instructional design are (a) Learning topics, i.e. general statements of what we want our students/trainees to learn, which express the main learning goal and hence are usually broad. (b) Learning objectives, which are measurable sub-goals of lecture/units. (c) Learning outcomes, which consist of the specification of what a student is expected to learn as the result of a period of specified and supported study. Learning outcomes are concerned with the achievements of the learner rather than the intentions of the teacher (expressed in the aims of a module or course). For each programme/course, different learning materials are prepared and used to achieve the set of defined learning outcomes.

As a first step towards defining a more concrete structure/organisation, it is proposed that each learning topic is sub-divided in multiple learning objectives, each learning objective is associated with multiple learning outcomes and each learning outcome can be achieved through multiple learning materials. As a second step to facilitate resource sharing, the "learning objective" was replaced by a direct link between the learning outcomes with the learning topic. The structure now becomes as shown in Fig. 1.

As a third step, the attributes of each element of the graph were defined so as to make search and re-use easier. Namely, the learning topic reflects the subject of the whole educational programme, and it is categorised under a specific field. This classification can be performed according to the well-established taxonomies, specifically (OECD 2015) and (IEEE 2019), and additionally, relevant keywords could accompany the topic to facilitate search. Each learning topic is characterised based on the following attributes: (a) thematic field under which is classified (e.g. smart and flexible energy systems, energy storage, renewable

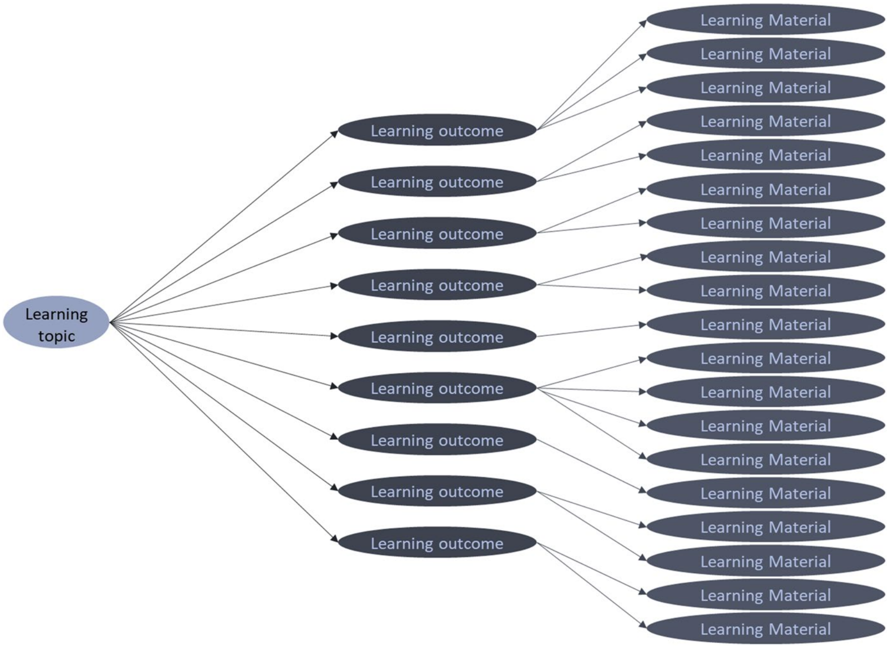


Fig. 1 The proposed educational programme model

energy, etc.), (b) title: this is the name of the instance of the learning graph model, (c) relevant keywords: to facilitate search from tutors looking for similar topics and (d) author and organisation.

For the learning outcomes, the widely used definition was adopted and existing guidelines on how to phrase a learning outcome were followed (Kennedy 2006). We consider that each learning outcome is associated with (a) a specific learning topic, (b) title: this is the name of the learning outcome, (c) relevant keywords: to facilitate search from tutors looking for similar topics and (d) author and organisation.

Finally, learning materials are whatever can be used by a learner to achieve a learning outcome. It can be a lecture offered by a professor, a serious game, video-based lessons, documents and presentations, problem-solving projects (described in any format), web-based materials like quizzes, 3D objects, native mobile applications that can be executed anywhere, robot-based activities or HoloLens-based materials or any other. Each learning material is associated with the following attributes:

- Target learning outcome
- Targeted European Qualification Framework (EQF) level
- The targeted learning/delivery mode (e.g. face to face, online, blended etc.)
- The targeted audience
- Format
- Content
- Author and organisation.

A web-based application supporting the design of learning graph instances and the sharing of resources among all users of the application has been developed and is presented in the following section.

The web-based tool to design learning programme

A web-based application supporting the design of learning graph instances and the sharing of resources among all users of the application has been developed (ASSET 2020) using content management system technology. The learning graph tool helps learning/instructional designers, professors and tutors that find (a) available course structures (to avoid conceiving them from scratch) and (b) available learning materials of different types. Once they find learning materials that can cover (most likely partially) their needs, they can autonomously adjust them using appropriate tools. They are also free to insert their (newly created) structures to help other tutors/instructors in their work. The possibility to trade both structures and material is foreseen to be supported in the future so that the platform becomes a hub for all types of contents.

The landing page is shown in Fig. 2. The users, after completion of the authorisation process, can create their own learning graph instances. For the search, as

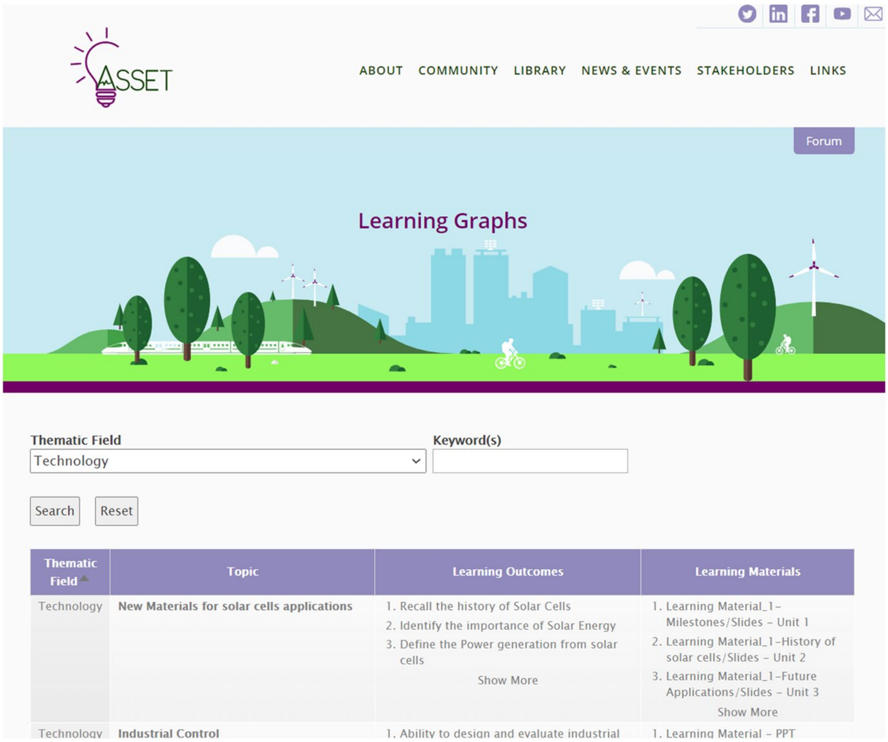


Fig. 2 The web-based learning graph creation tool

shown in the figure, the user may fill in either the thematic field or/and some keywords. The graph instances of the relevant educational programmes appear with their first learning outcome shown as well as the relevant learning materials. To see the rest, "show more" should be selected, as is the case for the first graph for topic "New Materials for solar cells applications" in the figure. Any user can create new learning graphs based on existing ones for the same or similar topics using the "clone" option without affecting the initial structure. This way it is easy to create (a) variations selecting the elements (learning outcomes and learning materials) that other tutors have created and (b) combinations to serve multidisciplinary topics.

Additionally, there is the option to create a new learning graph and select to populate it with existing or new learning outcomes and link them to existing or new learning materials. For this purpose, the tool supports the user to link a new learning outcome with any mix of existing and new learning materials. To facilitate this "mix and match" process, search functionality on learning outcome level and learning material level is supported as shown in Fig. 3.

The proposed learning model and the accompanying digital tool are meant to *significantly facilitate* sharing of *learning graphs and materials* because professors/instructors can create quickly learning programmes targeting:

- *Different EQF levels*, since these usually share common graphs (e.g. learning topics and outcomes). For example, assuming a professor has created an educational programme on electrical vehicles for undergraduate students, an instructor interested in preparing an educational programme at EQF level 4 can inspect the available graph (through the tool) and keep (re-use) a part of the graph.
- *Different teaching models* (face to face, MOOC, blended or other) may have common components e.g. online test, case-based modules, lectures or educational apps. So, the same learning graph with additions or replacement of a subset of the learning materials can be used and thus significantly reduce the time required to prepare the new programme.
- *Different subjects* that may share subsets of the learning model structures (e.g. learning outcomes).
- *Multiple disciplines* since these may share structures associated with each of the involved disciplines plus additional ones.
- *The society at large* As the tool contains structures on different subjects, less effort is required to create a course for the citizens or to prepare a seminar using the available materials. Furthermore, MOOCs created for the citizens can very well be promoted by trainers and professors so that these reach wider audiences.

In all these cases, the tutors can re-use the whole learning programme and associated graph (organised in outcomes and associated with materials) obviating the need to design and develop everything from scratch.

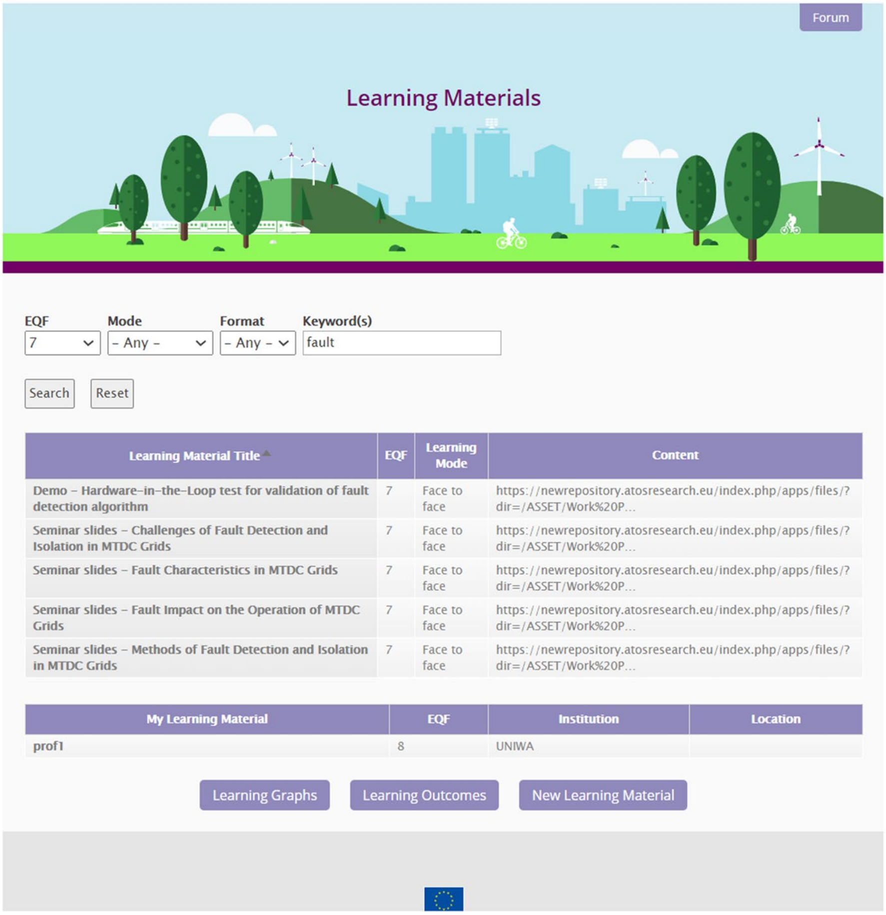


Fig. 3 The web-based learning graph creation tool

The educational programme marketplace

To bring academia and training organisations in direct link with the society and the market needs, the establishment of an educational online marketplace is proposed. In this marketplace, all training/education providers announce the programmes they offer indicating the topic along with keywords, the targeted EQF level, the learning mode (face to face, MOOC, blended), geographical data if the course is offered as face to face and information on how to reach the entity that provides the educational programme. On the other hand, companies that want to train their employees, or professionals or citizens may search the available educational programmes according to the same attributes. If they find a programme that satisfies their needs, they contact the relevant provider and enrol in the programme. If they do not, the marketplace supports them in placing enquiries. These enquiries for educational programme creation are delivered to the education/training organisations that are members of the marketplace community. These actors then decide whether to prepare an offer. It is worth stressing that taking advantage of the learning graph tool, it is easier for them to create the requested educational programme, thus the preparation time and the cost of the programme is reduced. This way, all involved actors (companies from the different market sectors, citizens and educational/training organisations) are benefitted. The proposed marketplace for the energy sector was developed using a content management system and delivered to the audience. It is worth stressing that for registering an educational programmes, the registration of the relevant learning graph in the learning graph tool is a possibility but not a prerequisite.

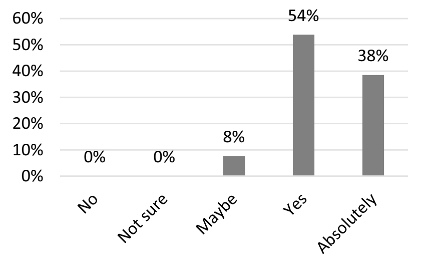
Assessment results

In order to validate the proposed approach and tools, we have pursued two evaluation paths: one with the tutors and another one with the students/trainees. We collected feedback through questionnaires and group interviews. The results are described in the following sections.

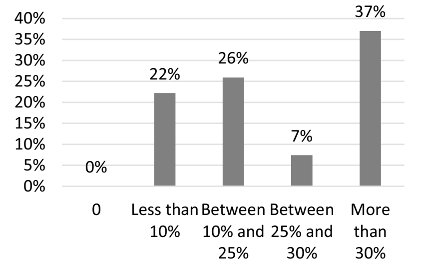
Evaluation with the professors/tutors

To evaluate the proposed model and tools, two workshops with tutors/professors were organised: one in the framework of the 16th International Conference on Intelligent Tutoring Systems (ITS2020 2020), which attracted 50 attendees reporting 14 different affiliations across Europe, most of them coming from universities and vocational training organisations and another one in Spain (held in October 2020) which attracted more than twenty people. During the first workshop, instructors from academia and training organisations received a 10-min introduction and then experimented with the presented models and tools for one hour during which they created new programmes with the tool and then announced them in the marketplace. At the end of the workshop, they filled in an anonymous questionnaire providing their comments. After that, a group interview followed that allowed us to capture comments and collect feedback in a descriptive narrative way. During the second workshop, which followed the same structure but with more lengthy sessions (reaching a two hours workshop), a group interview was conducted. Next, we present, first the results from the questionnaires and then from the interviews. It is pointed out here that in the instance of the tool used in the workshops, twenty-two educational programmes—with targeted duration of three months—, were available covering topics from the energy sector (fourteen courses), social sciences and humanities and entrepreneurial and business aspects (eight courses).

With respect to the validity of the concept of the learning model, as shown in the left-hand side of Fig. 4, 92% consider that the concept is valid and only 8% did not like the learning graph approach. With respect to “the time they estimate that could be saved through the use of the learning graph concept and the accompanying tool”, nobody declared they consider no time will be saved. A small per



Response to the question: "Do you consider the learning graph model valid? "

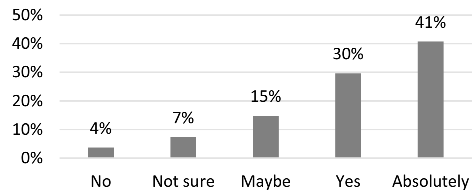


Response to the question: "How much time to you estimate could be saved through the use of the presented model and tool?

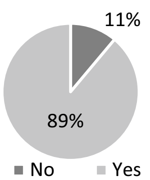
Fig. 4 Feedback collected from tutors with respect to the validity of the concept and the estimated time reduction

cent, (namely 22%), consider they will save time but this will be less than 10%, while a significant percentage of *44% consider they will save more than 25%* as shown in the right-hand side graph of Fig. 4. This is considered a major success as this was one of the main targets of our work. Saving time in the preparation and development of a new educational programme is anticipated to release significant part of the professors/tutors/instructional designers' effort which can be devoted to delivering the programmes to additional or larger audiences (Fig. 4).

They were also asked if they would be interested in joining the established community and sharing their own learning materials and structures openly. The results (shown in Fig. 5) indicate that more than 70% are willing to join and share their materials and structures. This is important since as more structures and content are injected in the web-based tool, the number of attracted users is expected to raise accordingly. The more valuable resource they find, the more they will come back and contribute. This issue is revisited in "Discussion", addressing the approximate 30% which is not sure about their intention to engage and provide their materials openly. With regard to the "validity of the concept in other sectors" outside the energy transition sector, *89% answered "Yes" and 11%*



Responses to the question: would be interested in joining the established community and sharing their own learning materials and structures openly

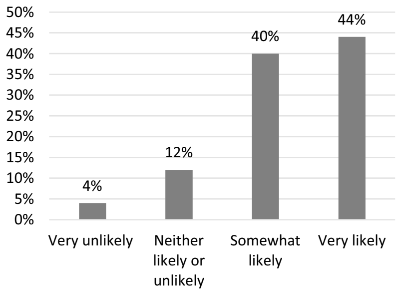


Responses to the question: do you consider the approach valid in other sectors?

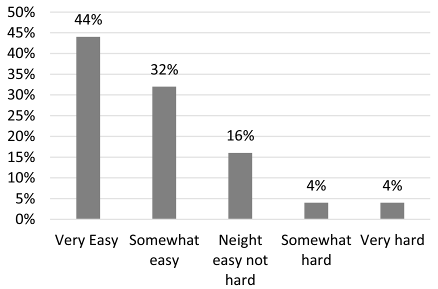
Fig. 5 Results from the feedback collected from the tutors regarding their intention to engage with the approach and to apply in other sectors *answered "No",* as shown in the pie chart of Fig. 5. The audience included people from engineering, agro-food, sociology and bio-medicine disciplines.

Another interesting result was that, despite the limited volume of available materials at the time of the workshop, (as shown in Fig. 6a) 84% of the respondents declared they consider it likely or very likely to update their current educational programmes with learning materials already available in the tool. This shows that there is strong interest in incorporating learning outcomes in educational programmes that are already in place or in the phase of preparation. Additionally, assuming that the numbers of the learning graphs and learning materials included in the tool will increase, the interest is expected to increase as well. Fig. 6b shows the opinion of the attendees regarding the easiness to use the learning graph tool which was (as already said) a tool developed using a widely deployed CMS. The higher percentage of 44% declared that they found it quite easy to use, with another 32% declaring somewhat easy. A really low percentage considered it somewhat hard or very hard to use. Plans for its improvement are already in place based on detailed comments received from the audience.

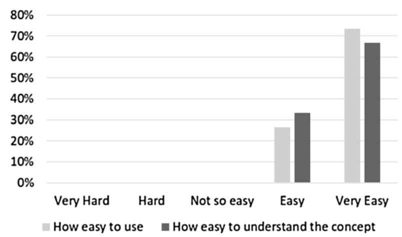
Turning our attention to the *marketplace*, after presenting it to the audience, we asked them (a) "How easy it is to understand the concept and value of the ASSET marketplace?" and (b) "how easy to use is the marketplace?". The results



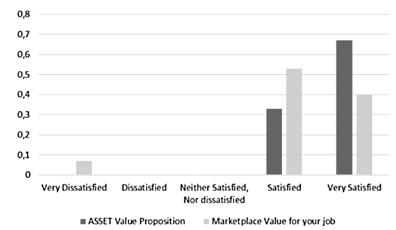
(a) Response to the question: How likely you consider to use the existing materials in your courses?



(b) Responses to the question: How easy-to-use is the learning graph tool?



(c) Responses to two questions: "How easy it is to understand the concept and value of the marketplace?" and b) "how easy to use is the marketplace?"



(d) Responses to two questions: "How valuable for your job is the marketplace" and "how much to you value the overall proposition (model, learning graph tool, marketplace)

Fig. 6 Results from the feedback collected from the tutors with respect to value proposition and willingness to use the existing materials are shown in (Fig. 6c) and show that the concept was easy to understand and the tool was considered as easy to use.

They were also asked how valuable is the marketplace for their job and 93% considered it to be useful as shown in (Fig. 6d). This is an important outcome because easiness to use does not guarantee further use and engagement; offering value is the prerequisite for engaging in its use regularly and sustainability. This result implies that training and academic organisation consider this marketplace an easy and valuable way to sense the market needs.

Finally, they were also asked to express how satisfied they are from the holistic proposition including the learning graph model, the learning graph tool and the educational programme marketplace. As shown in (Fig. 6d), *nobody was waverer*. They all declared satisfied with the majority of them (67%) declaring “very satisfied”. The collected results and the comments showed that people need such tools and they are ready to use them.

Evaluation with the students/trainees

Our instructional designs were evaluated with four hundred (400) students from European countries. We developed twenty (22) educational programmes among which 7 were offered as Massive Open Online Courses. They were all designed according to the learning graph concept and tool. From the total number of students/trainees, 197 followed the face-to-face programmes and the rest the MOOCs. The number of complete responses that were taken into consideration in the following analysis was 176. Regarding gender, the sample under examination showed a clear prevalence of men (69.54%). These data seem to clearly demonstrate that the areas related to education in engineering are still preferred by male students. Over 95% of the interviewees are aged between 15 and 34 years. Obviously young people are generally more predisposed to increasing their skills. Regarding the education level, the questionnaire highlighted a clear majority of graduates (82.74%) while only a minority has a master’s degree (14.21%) or a Ph.D. (3.05%). The data seem to show a greater predisposition to follow the provided courses among those who have not yet greatly increased their skills. This is not surprising as the course providers were mostly universities which had the opportunity to promote their offerings to their students.

Table 1 summarises the results of the evaluation with the students. The Likert Scale was used to measure some specific characteristics of courses students followed in the face-to-face mode, so as to have a broad evaluation of the face-to-face offer. The results are quite encouraging: courses are considered engaging, comprehensive, multidisciplinary, flexible, useful, integrative, and preparing for in-depth education. However, they seem to be not exhaustive compared to the student’s expectations.

The 53.18% said that they enjoyed the experience and 45.09% said the course was well organised. Interesting, however, is that 46.24% of the respondent found the course "Truly formative” and 42.2% the courses helped them to complement their previous knowledge into the field. During the lessons, to deepen the topics studied, students were provided with various teaching materials that the respondents have

Table 1 Results from the feedback collected from the students/trainees

	Completely agree (%)	Fairly agree (%)	Neither agree nor disagree (%)	Disagree (%)	Fairly disagree (%)	Completely disagree (%)
It is engaging	22.54	52.60	19.08	4.05	1.16	0.58
It is comprehensive	18.50	45.09	30.64	3.47	1.73	0.58
It is exhaustive	6.36	15.61	31.21	20.81	13.87	12.14
It offers a multidisciplinary perspective	21.39	46.24	24.28	6.36	1.16	0.58
It offers flexibility in learning paths	23.70	49.13	20.81	4.05	1.73	0.58
It is innovative	29.48	41.62	20.81	4.62	2.89	0.58
It is useful	38.15	48.55	8.67	2.31	1.16	1.16
It is complementary to acquired knowledge	19.65	50.29	24.86	2.31	1.73	1.16
It is preparatory for an in-depth education	17.92	49.13	26.01	4.62	1.73	0.58

judged updated (36.42%), of right quality (54.34%), and matching the expectations (53.76%).

In Fig. 7, a series of statements on the function of quizzes and assignments were evaluated (adopting Likert Scale). First of all, the number of tasks assigned is perceived just right for the 75.72% of respondents. In this case, the respondents agreed that it was a good way to experience the course (51.45%). They believe in their educational function (49.71%) and it is a good opportunity for self-assessment (46.82%) and engaging (46.82%). The answers probably mean that the students feel the need to rework the knowledge acquired through quizzes and homework because they see their educational importance to be involved in the lesson. Also, this practice gives the students the opportunity both to self-assess and to receive feedback from the teacher.

Finally, as can be seen in Fig. 8, the respondents assessed their experience with the programme as fairly or extremely good. It emerges that the *courses are of high quality* according to their expectation.

With respect to the courses offered in the form of Massive Open Online Courses, the relevant results showed the same tendencies. To corroborate the positive assessment of the courses is 66.45% who said they learned a lot during the courses and 55.48% said liked it, while 50,3% said they would propose it to a friend.

Discussion

In this section, a set of issues raised during the group interviews is discussed as well as the collected quantitative results and issue linked to the quality of the approach and platform. We consider the presented approach deserves further investigation and adoption as it succeeded in collecting positive comments from the students/trainees (as reported in "Evaluation with the students/trainees") and from the professors/tutors (as reported in "Evaluation with the professors/tutors"). The students/trainees

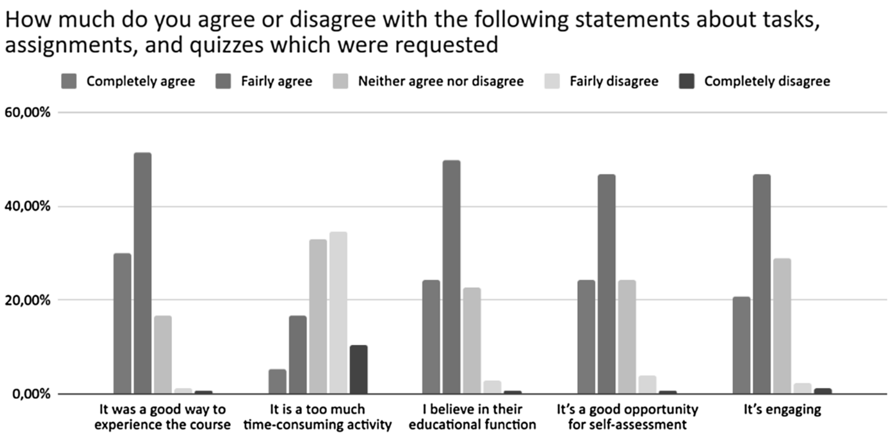


Fig. 7 Feedback collected from the students about tasks, assignments and quizzes

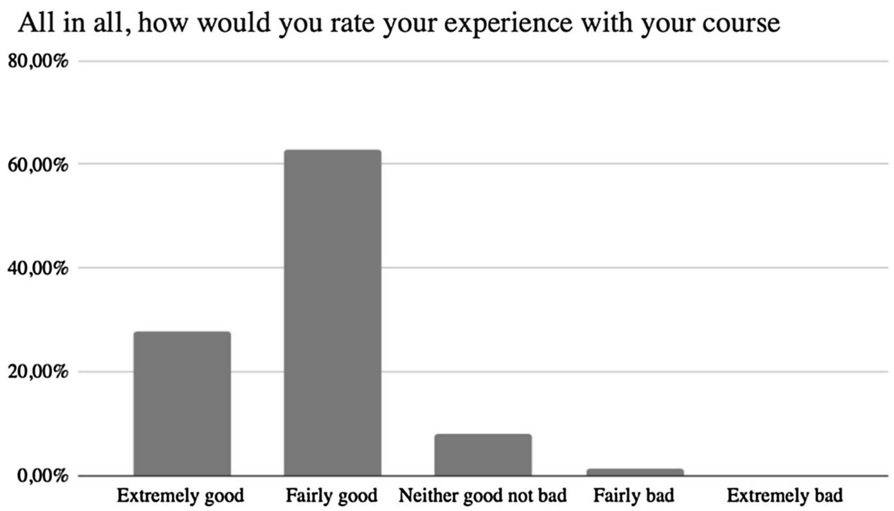


Fig. 8 Results from the feedback collected from the students on the course experience

found the learning experience very good and the only aspect that must be revisited is the exhaustiveness of the educational programmes.

Turning the attention to the model and tool that led to this experience, the quality of the provided educational programme designs/models and materials is an issue that was pointed out by three attendees (professors/tutors) during the organised workshops. Quality is tightly bound to the sustainability of the relevant platform and approach, as any platform is of value if its content is of high value. Up to now, the quality was ensured by the fact that the offered resources are provided by excellent European Universities and by the fact that currently user account creation is controlled. However, the vision is to leave the platform open to any organisation and enable the different users evaluate the structures and materials (e.g. provide a score), hence, implementing crowd evaluation. Additionally, from the beginning of this endeavour, it was defined that the platform will support both open and paid materials as many organisations are making profits out of them. This way creators can have full control of the access to their structures and materials. We consider that this would help increase the currently 70% percentage of potential users declaring they are willing to engage as reported in "Assessment results". There, they were asked whether they would engage if the materials were offered openly.

Recognising that the value of the platform increases as the offered structures and materials (of high quality) increase and that similar challenges are faced in other disciplines, we also emphasised the applicability of the concept in other sectors and thus raised relevant questions during the group interviews. During the group interviews, it became clear that the attendees considered it can very well be applied in other sectors and reported that the discipline they are working in could very well be such a case. Furthermore, investigating the free text answers in the questionnaires, it seems the 90% of the comments positively addressed exactly this applicability in other disciplines. This indicates that the platform can expand further to additional sectors and technological areas and be of value to significantly more people. This in turn means that the model adoption will have a significantly higher penetration potential and users will devote the time that is required to learn and use it, which will lead gradually to its adoption by a continuously increasing audience.

Emphasis was placed during our evaluation in the capability of the model to support *multidisciplinary* programme creation. The graph structure allows the instructional designer to create multidisciplinary courses by implanting parts of one graph (say graph A corresponding to one discipline) to another graph (say graph B of different discipline). For example, the smart grid fundamentals include topics from computer networks and power systems. So, to take advantage from related programmes which successfully run in the past, the educational programme designer can first study the graph of computer network topic (graph A) and the graph of power systems (graph B) and then decide what learning outcomes from the original graphs serve their purpose. This way they create a new graph that may include elements of graph A, of graph B plus possibly additional ones. The learning outcomes inherited from graph A and B come with accompanying learning materials which may be useful for the newly created graph (and the relevant course). This way they exploit our model to combine two (or potentially more) graphs to create new and innovative educational programme.

Another interesting observation is that there are learning materials serving more than one learning outcomes. This is also supported by our web application. When tutors create a learning material to serve learning outcome A, they accompany this with keywords. If another tutor (who tries to find learning materials to serve another learning outcome B) searches using keywords, they may reach the same learning material. In this case, a replica of the learning material (in the tool) is associated with the learning outcome B. Thus, learning materials can be flexibly associated with learning outcomes.

An additional advantage of the presented approach is the easy enrichment of currently available programmes with new materials or learning outcomes that lead to soft skills currently in lack in the market. (See also the relevant comment in "Evaluation with the professors/tutors"). The provided tool supports professors in finding materials on aspects (like "growth mindset") and either use them, or prompt the students enrol in a MOOC course to get a better idea or even identify the expert and invite them to give a lecture. This way a more holistic approach to teaching can be offered.

Another important observation is that the scientific fields distinguished in the standardised taxonomies mentioned in "Graph-based learning toolbox" above are quite broad. To facilitate sharing of structures and materials, two directions can be pursued: to create and formalise a *vocabulary* or to use keywords. This vocabulary will allow tutor/educational programme designers to establish a common understanding on the available topics/structures and materials. As any such effort takes time to penetrate, the fact that the tool supports keywords to accompany all elements of the graph contributes in its applicability and easiness of use. The definition of a vocabulary can also be pursued and has good potential as there is an ongoing effort to define specific skills and knowledge per sector and link them to educational/training elements. The definition of the vocabulary would contribute to the formal description of sub-thematic areas complementing and to the enrichment of current works (instead of competing with them) to reach a point where all these constitute an added value.

To summarise the evaluation process, the users that adopted the proposed model and used the tools reached the conclusion that this is a valid method that can significantly facilitate new and multidisciplinary educational programme design and delivery. They also proposed that the learning outcomes can be associated with the skills or competences they target so that a more direct association with the skills in need is achieved. For example, the learning outcomes could be associated with skills from the list defined in the European Skills, Competences and Occupation—ESCO (ESCO 2020) framework. Once this is done, the educational programme would inherit the skills and competencies targeted by the included learning outcomes in the learning graph.

Conclusions

To address the intense needs for education, training and upskilling of large audiences across different countries, we defined a graph-shaped model and a digital tool that significantly accelerates the creation of educational programmes through sharing and re-using course structures and learning materials. Different alternative mechanisms ensuring the quality of the resources offered through the learning graph tool have been outlined. Additionally, business models to ensure revenue creation and sustainability have been proposed. The international audience (of professors/tutors and students/trainees) that was attracted to evaluate the model and the tool. The course designers confirmed that the model is valid and applicable to a rich set of sectors (apart from the energy sector). The tool was considered easy to use while their interest in sharing their resources or integrating in their programmes the resources that are currently available in the digital tool was vivid. Additionally, to support the education and training providers in easily and promptly sensing the market needs accelerating knowledge penetration, an educational programme marketplace was proposed and presented. This was judged by external users as being a valuable tool for their job. The overall evaluation message was that the "offered toolbox" comprising the Learning graph model, the learning graph tool and the marketplace was considered a very satisfying holistic offering from education and training actors. From the students/trainees perspective, the collected results showed that they found the offered learning experiences interesting and engaging and they enjoyed the level of self-assessment materials. The future steps will include further evaluation of the proposed model and tools with additional audiences, comparative analysis and application in additional sectors.

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Author contributions With respect to the contributions of the authors, Prof. HCL defined the idea of the tree-shaped learning graph and the concept of applying it to the energy transition sector. Prof. FP and

CSP contributed in the instantiation of the graph model for the energy transition sector learning programmes. They also contributed in the study of the intricacies and requirements that this approach satisfies. Prof. RR led the evaluation with the users and the analysis of the results. Prof. PAK led the design and implementation of the digital tools for the support of the learning graph model as well as for the marketplace and focussed on the evaluation of the proposed approach with the tutors. Prof. PAK also undertook the editing of the paper.

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Data availability The data generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

ASSET (2020) ASSET Community page. Available at: https://community.energytransition.academy/asset-services. Accessed 20 July 2020

Bloom BS (1956) Taxonomy of educational objectives: the classification of education goals. Longman, Cognitive Domain

Boyce S, Pahl C (2007) Developing domain ontologies for course content. International Forum of Educational Technology & Society

CEDEFOP European Centre for the Development of Vocational Training (2017) Defining, writing and applying learning outcomes: a European handbook. Available at: https://www.cedefop.europa.eu/en/publications-and-resources/publications/4156. Accessed 20 July 2020

Cedefop (2015) Skill shortages and gaps in European enterprises: Striking a balance between vocational education and training and the labour market. UNESCO, open educational resources, https://en.unesco.org/themes/building-knowledge-societies/oer

Czako V, Sales Agut C, Kottari M (2018) SETIS Magazine: jobs and skills in the energy transition, Publications Office of the European Union, Luxembourg, JRC113582

dos Santos AI (2019) Practical guidelines on open education for academics: modernising higher education via open educational practices (No. JRC115663). Joint Research Centre (Seville site)

ESCO (2020) European skills, competences, qualifications and occupations. Available at: https://ec.europa.eu/esco/portal/home. Accessed 20 July 2020

IEEE (2019) IEEE Taxonomy V1.0, IEEE, 2019

ITS2020 (2020 I ntelligent Tutoring Systems Workshops 2020. Available at: https://its2020.iis-international.org. Accessed 20 July 2020

Kennedy D (2006) Writing and using learning outcomes: a practical guide. University College Cork

Koper R, Bennett S (2008) Learning design: concepts. In: Kinshukm J, Pawlowski JM, Sampson DG, Adelsberger HH (eds) Handbook on information technologies for education and training. International handbooks on information systems. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-74155-8_8

Kurt S (2017) ADDIE Model: Instructional Design. In Educational Technology, August 29, 2017

MaTHiSiS (2020) WP8 deliverable. Available at http://mathisis-project.eu/en/deliverables. Accessed 20 July 2020

MERLOT (2020) MERLOT. Available at: https://www.merlot.org/. Accessed 20 July 2020

OECD FM (2015) Guidelines for Collecting and Reporting Data on Research and Experimental Development (2015), p. 2017. Available at: https://www.oecd.org/publications/frascati-manual-2015-9789264239012-en.htm. Accessed March 20 2020

OpenUpEd (2015) Definition of massive open online courses. Available at: https://www.openuped.eu/images/docs/Definition_Massive_Open_Online_Courses.pdf. Accessed 20 Jul 2020

Rust C, PriceO'donovan MB (2003) Improving students' learning by developing their understanding of assessment criteria and processes. Assessment & Evaluation in Higher Education 28(2):147–164
Santos A, Punie Y (2016) Opening up education: a support framework for higher education institutions (No. JRC101436). Joint Research Centre (Seville site)
SCORM (2004) A technical overview of the SCORM standard. Available at: https://scorm.com/scorm-explained/technical-scorm/ [Accessed 20 Jul 2020]
Sum NL, Jessop B (2013) Competitiveness, the knowledge-based economy and higher education. J Knowl Econ 4(1):24–44
Tsatsou D, Vretos N, Daras P (2017) Modelling learning experiences in adaptive multi-agent learning environments. In Proceedings of the 2017 9th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games) (pp 193–200). IEEE
UNESCO (2020) open educational resources. Available at: https://en.unesco.org/themes/building-knowledge-societies/oer. Accessed 20 July 2020
xAPI (2020) Experience API. Available at: https://xapi.com/. Accessed 20 July 2020

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