

193 Sustainability in engineering education: practical examples

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Abstract

Recently, education about sustainability in engineering has faced several challenges. Firstly, many educational institutions had to transition from face-to-face to online teaching in 2020. Secondly, sustainable development requires additional expertise to be included in the scripts and discussions. Giving priority to the topics of sustainability, the global supply of raw materials and raw materials policy, the Austrian branch of the International Competence Centre for Mining-Engineering Education under the auspices of UNESCO has promoted awareness of these topics to engineering students, researchers and wider public, consisting of several practical examples including an online lecture series, the joint master's degree programme "Engineering Geocology," and international partnerships in education with a focus on sustainability. Conceptualised and coordinated by the Austrian branch, the online research and education lecture series "Sustainable Development Approaches in Engineering Research and Education" was held for the first time in the winter semester of 2020/2021. Within the International Competence Centre's network, eight international experts including five professors held lectures on the specific topics of their expertise in mining, the sustainable supply of raw materials, materials science, recycling, and engineering education. Being freely accessible without any restrictions, on average, 70 participants from more than 20 different countries attended each lecture. The new joint master's degree programme "Engineering Geocology" includes sustainable development-related courses in the curriculum, allowing the young generation of engineers to acquire this specific knowledge during their studies. Synergies of the recent widespread use of the online format in education and international collaboration

have allowed the creation of new successful opportunities to raise awareness about sustainability in engineering education.

Keywords: sustainability, engineering education

Introduction

We can assert that the sustainable development of any society is determined by the provision of its economic structures with qualified personnel. The hubs for the educations of such qualified personnel often are located at universities and higher education institutions (HEIs) in general.

The training of personnel is becoming not only the most important factor in the development of the country but also a condition for its survival. The data of experts, as well as the requirements of the labour market, confirm that it is the training of modern skilled workers and specialists that will largely determine the rates of economic growth and the quality of life.

Therefore, the reform and modernisation of vocational education in the 21st century should become the most important task of society and the state. The transition to an information society, the volatility of market structures, and the recent developments and disruptions under a global pandemic, dictate and accelerate the use of information and communication technologies. This included the introduction of distance learning in vocational and additional education.

The main goal of modern education is the formation of competencies that meet the requirements of the modern stage of society, the trend of which is the concept of "education throughout life", lifelong education or continuous education.

Today, the most demanded skills by employers are the so-called supra-professional competencies, in other words, the ability to work in a multidisciplinary environment.

Therefore, a modern engineer should be able to handle a multitude of different situations. This includes, firstly, "setting tasks" in the framework of complex design and production curtailment activities, which includes market analysis, analysis of opportunities created by new technologies, search for credit or investment resources, product development and related production processes, building sales networks, analysing the entire system and improving individual links or links between these systems.

Further, communication, management, interdisciplinary skills are becoming more and more important in engineering. Therefore, we must understand that today engineering

science, industry, education is not a separate subject, it is a complex system that cannot be built only on the development of one direction.

In addition to the above mentioned, and in the context of supporting the Sustainable Development Goals (SDGs) of the United Nations, focusing on SDG 4 Quality Education, the International Competence Centre for Mining Engineering Education under the auspices of UNESCO was established in 2019. Its vast network of global partners is, among other things, devoted to the vocational training and professional development of (mining) engineers.

With its mission “Educating today’s engineers for a sustainable tomorrow” the Austrian branch of the Centre at Montanuniversität Leoben, Austria, is giving priority to the topics of sustainability, the global supply of raw materials and raw materials policy.

Aiming to raise awareness of these issues to engineering students, researchers and the wider public, a new learning and knowledge transfer concept with interactive elements was implemented:

The online research and education lecture series “Sustainable Development Approaches in Engineering Research and Education” was held for the first time in winter semester of 2020/2021 and successfully continued in summer semester 2021.

Being freely accessible and using a variety of online tools, on average 70 participants in the first semester and 110 participants in the second semester from more than 20 different countries attended each lecture.

Bringing together eight international institutions, the lectures were weekly showcasing renowned experts who shared their expertise using selected examples in the fields of raw materials, mining, materials sciences, recycling, engineering education and digitalisation.

The online tools and platforms used included: Moodle, Eventbrite, Padlet, Zoom & Zoom Polls, Chat functions, Webex, Wordcloud, Mentimeter, and Youtube.

At the respective text passages, the online lecture series serves as an underpinning and living example of how modern knowledge transfer can function across borders.

Vocational training, continuous education and MOOCs

In general terms, it is important to understand that continuous education is a holistic process that ensures the progressive development of the creative potential of the individual and the all-around enrichment of its intellectual world (Bebnev, 2013).

In order to define lifelong education, it is necessary to quantify three main characteristics: 1) lifelong learning 2) continuing education as adult education; 3) continuing education as a continuing professional education.

At present, when professional activities are increasingly organised in an electronic environment, it is an urgent task finding and introducing online tools into the educational process for coordinating the joint activities of learners, students, researchers, enterprise specialists, and managers at various levels. In the process of joint activities, learners cooperate and unite their efforts, which ultimately leads to the acceleration and facilitation of learning, or the implementation of research, projects or events.

One of the qualitatively new phenomena in the world of education, resulting from the realities of the information society, is the widespread use of massive open online courses (MOOCs). Education experts have ranked the MOOCs among the 30 most promising trends of its development up to 2028.

MOOCs are open and free online courses (José, A., 2021). To get access to them, it is enough to have an Internet connection and speak English at a proper level.

Considering the wide variety of MOOC types, it allows us to say that this direction in e-learning is of interest to society, but at the same time it needs theoretical research to develop a single standardised apparatus. To date, there is also no agreed definition of how to interpret the concept of MOOC components, which are mass, openness, online.

To address the application of the above considerations of MOOCs, the following interpretation could be offered:

1. Availability:

Previously, for learning to take place, both learners and teachers had to be physically present in the same location. With internet technology allowing instant and convenient communication over long distances at the touch of a button, this is no longer the case. How has technology changed learning? In higher education, this has led to the possibility of online education. Some higher education institutions offer only some of their courses online, while others operate entirely online, where the participants in the educational process never meet face to face. In primary and secondary schools, this same technology enables cyberlearning where children can do their jobs from the comfort of their assignments from homes. Online learning has helped overcome geographic barriers that have long prevented many learners from entering specific educational institutions. For example, imagine someone who wants to study a highly specialised programme that is only available at one institution across the country, but cannot attend due to family obligations. Thanks to online education that person has the opportunity to pursue their studies.

Taking a look at our example, the online lecture series was available and accessible to anyone signing up for free on the ticketing website “Eventbrite”. As a result, there was participation from students, industry professionals, researchers and lecturers from

South America (Columbia, Brazil), Africa (Somalia, Ghana), Australia, Asia (Iran, Kirgizstan, Mongolia, Indonesia), Russia and Europe (Spain, Germany, Austria, Albania, Finland, etc.)

2. Flexibility:

The idea of being flexible with the Internet goes hand in hand with accessibility. Online classes have freed students from having to attend school at specific times, which is often impossible due to work or family responsibilities. Instead, course materials are available online, and students are free to study and complete study assignments when their schedule permits. Technology has opened the doors to education for many who would otherwise not be able to attend traditional educational institutions. For example, anyone who works full time will now be able to combine their work with an education. Parents with young children can also find the opportunity to attend school. Children who take sports very seriously and train for hours during the day are now free to adjust their learning to their busy schedules.

As for the online lecture series, those students who signed up within the system of their home university (Montanuniversität Leoben) had access to the recordings of each lecture until the deadline of the submission of the respective homework after the session. Further, the audience was provided with relevant pre-readings to prepare for each session in order get an even deeper understand of the respective topic during the lecture.

3. The variety of types of interaction between students and teachers:

With the development of online educational programmes, the interaction between learners and teachers has undergone a fundamental shift. There are advocate on both sides of this issue: some say that this is a change for the better, while others, for the worse. Perhaps the most useful position is that this change is neither completely negative nor completely positive, but instead has both pros and cons. For instance, since interaction takes place online classroom time is no longer the only opportunity for learners to ask teachers questions and receive information. Instead, they can use e-mail, instant messaging and text messaging to ask their professors questions anytime, rather than waiting for the next lesson when the question is no longer fresh in their minds.

4. The emergence of online testing:

Along with online education comes online testing, which is of immense benefit for a variety of reasons. Among these, one main reason is the fact that online testing is impartial and completely fair. If the machine evaluates the test and automatically corrects the incorrect answers, it is impossible to show any signs of bias. In addition, online testing can be a great solution for those who suffer from anxiety disorder and

are stressed by taking tests in a room with a group of other people. Further, it is better for those on a busy schedule who may find it difficult to get to the testing centre at certain times.

However, online testing is not without its drawbacks. In particular, it is only effective for multiple-choice tests and not for essays or short answer questions. Students can still take the online essay-based tests, but they will have to be assessed by a human examiner.

Taking our example of the online lecture series, the organisers decided that the weekly homework had to be submitted online, but had to be assessed by one of the employees of the centre. This makes the evaluation process time consuming, since it is equal to paper-based testing.

Nevertheless, for the next online lectures, starting in October 2021, it is planned to offer one final exam based on multiple-choice questions.

5. Meeting the needs of students with disabilities:

In the past, the rigorous structure of the classroom defined the academic world. Each learner had the same experience, regardless of their different needs or abilities. While some students were able to function well in this environment, others had unmet needs. Technology is increasing the ability of educational institutions to meet the needs of all types of learners. Now students with hearing, speech or vision impairments, or those who are mostly home-bound, can still receive a quality education. Regardless of what it might be, technological advances can also meet the needs of learners with intellectual, social or developmental disabilities. Technology affects education for the better, improving our ability to create learning environments that work for everyone.

6. Online availability of training materials:

Previously, training took place exclusively in the classroom. The educational tools were either textbooks or officially released videos. One of the ways the Internet has also changed education, is the opportunity to share their knowledge with the world by publishing an educational blog, an e-book or a video on YouTube. This is a huge advantage, making it easier for anyone to learn. Imagine you are planning a trip to Spain and want to get basic knowledge of spoken Spanish. You no longer need to sign up for classes at your local university or even visit your local library to check out a stack of overflowing textbooks. Now all you have to do is open your laptop or phone and find a free app to teach you.

7. Interactivity:

Traditional educational models are based on the idea of passivity, where learners are passive listeners to teachers. However, this concept leaves little room for interactivity

and student engagement. In contrast, modern online learning settings have the advantage of being more interactive. Students can connect directly with interactive models, videos and games, navigate through websites, search for information on the internet, etc.

For example, imagine the difference between trying to memorise a list of all the countries in the world from a book and an interactive tool that asked you to click on each country, when offered a name. Interactive tools help to create a broader interest in the subjects studied, which leads to interest and the desire to continue learning new material.

Taking our case from the online lecture series, interactivity was between the audience and the speakers, but also between the participants themselves was created with different tools:

One example is the “Padlet” world map where each participant was able to pin their location, share their field of studies/expertise and contact details and also after each session on learning they took away. Then, other participants could come back to the world map and get inspired by the perspectives of the others and also contact to develop joint activities.

Other interactivity tools, among the audience and the speaker, are Zoom polls, Mentimeter and WordCloud. Whereas the first ones are used for opening questions or to check the general understanding of a topic; the latter one allows to depict colourfully the perception of or the associations created about a topic. For instance: “Name 3 issues that you consider sustainability priorities for mining”. While the audience types in their replies (eg. Energy consumption, water user, emissions, biodiversity, recovery of metals, etc.) a real time world cloud grow on the screen.

On the one hand, this allows the speaker to directly elaborate on the answers. On the other hand, the audience feels included in the process and therefore paying attention and retaining information is done with ease.

8. Increased ability to keep up with current events:

The most commonly teaching tools a teacher has are textbooks, most of which contain information released at least a year ago due to a lengthy publishing process. This may not have been a problem in the past, but today the world is moving faster than ever thanks to technology. If the only information you have to share with students is several years old, you may also be decades behind. Technology allows educators to keep learners informed not only of current events but also of the latest research and cutting-edge discoveries. By leveraging PowerPoint, YouTube, blogging technology, and the power of a good search engine, educators can help their students better understand the modern world they live in and learn about its secrets.

Considering this aspect in the online lecture series, the audience is provided with the most current information and state of the art discoveries. The speakers were experts in their respective fields being involved in the development of the latest solutions. That said, the information received during the lecture allows to stay up to date, include it in one's own work or directly create synergies and cooperation. Otherwise it would take months or years until those insights are shared in publicly accessible papers or textbooks and then already be outdated.

9. Adaptability and personalisation:

Educational institutions are increasingly aware of the fact that what helps one student learn may be practically useless to another, and that what makes no sense to one student may be the only thing that makes sense to another. Everyone's brain works differently and everyone has their learning style, but over the years, all of these students have learned from the same textbook. How does technology affect education? They solve problems while leaving room for personalisation. Using modern technologies, students find the right source for themselves to gain new knowledge.

10. Changing the dynamics of learning in the classroom:

With the advent and popularisation of internet technologies the dynamics in classrooms, especially in universities, is changing. If once a professor could be the only source of knowledge, the internet has changed that. All information in the world is available on the internet, and students have the opportunity to obtain information on their own. Because of this, the forms of conducting classes are changing: students are more engaged in independent cognitive activities, studying new concepts and ideas. In the classroom, together with the teacher, they discuss, direct knowledge in the right direction and conclude. In such classes, the teacher is not a lecturer, he acts as a moderator and mentor. The same model applies to online schools, where students learn new material on their own, then share their conclusions on discussion boards and forums, and professors act as moderators. Students can connect with their professors via text or online messages, or they can spend their opening hours in local public places such as libraries and cafes.

11. Advantages of online education:

In addition to the above-mentioned positive aspects of online learning, the following should be added:

Firstly, online learning and online education offers have a low barrier to entry. This means that everyone can be trained in any direction and discipline.

Secondly, it is also the scalability of training, which manifests itself in the ability to conduct classes for a large number of students at low costs.

Thirdly, with online education a wide potential audience can be reached. This means that along with professionals, students and learners who are not yet specialised in a particular field can attend online courses.

Fourthly, the availability of data and tools for the analysis of learning activities is another advantage of online training.

12. Disadvantages of online education:

As with every new development, also the downsides should be considered.

Since books and face-to-face lectures have dominated the intellectual and academic space for so long, many people have felt a little shocked by the sudden inclusion of webinars, video conferencing, video presentations, video lectures, e-books, and podcasts into these spaces.

Limited technical capabilities and slow modems lead to delays in the transmission of sound, video and graphics, although the corresponding technologies are constantly improving.

Due to the lack of confidence in electronic means of communication and training, listeners often want to see the teacher and communicate with him/her "live".

The success of the training depends in part on technical skills in computer management, internet navigation and the ability to cope with technical difficulties.

It is also important to note, that a number of practical skills can only be obtained when performing real (and not virtual) practical and laboratory work.

Additionally, in some cases, for example in rural areas, access to the Internet is still difficult.

It should be borne in mind that the organisation of online training is also associated with challenges. For example, the difficulty of authenticating students, since at the moment it is technically difficult to provide personal access of the course for each student.

In addition, a large amount of development costs is needed at the start, because all the material is created by the course developers themselves, and it is necessary to provide technical equipment for conducting video lessons, etc.

For courses using peer learning technology and collaborative working technology, a certain level of "digital literacy" is required from the learners.

There is also the problem of the heterogeneity of the quality of online courses since different teams of developers work on the creation of training material, which may have different ideas about the learning outcomes.

Discussion

Based on the possibilities of using online courses in additional vocational education (primarily for advanced training), several main aspects of using online courses have been identified.

Firstly, online courses are currently in high demand, and the audience is expanding. In this regard, for online education, it becomes possible to form a new direction for the training of scientific personnel and use of open courses (Sofronova, 2018).

Secondly, the implementation of MOOCs involves the development of all materials for the course by qualified personnel, content taught from specialists in their field, the development of a clear schedule of the educational process and the inclusion of course assignments and an assessment procedure. Further, anyone can enroll and take the course.

Thirdly, it should be noted that online learning is not a complete substitute for or competitor to traditional training and education. After all, online learning complements the traditional model and makes learning more informative and effective.

Fourthly, the compilation of high-quality content and a well-organised teaching-learning scenario, a properly chosen combination of lectures and practical exercises are able to provide a certain level of knowledge. However, the quality of the acquisition of the material is not only influenced by the content, but also by how it is communicated when solving educational practical problems and situations.

Thus, such courses should be considered within the framework of higher education institutions in the implementation of basic professional educational programmes as a complement and expansion of opportunities for teaching listeners and students.

Fifthly, for higher education institutions, short online courses (16-48 hours) such as the online lecture series “Sustainable Development Approaches in Engineering Research and Education” may be attractive. This is due to the fact that they do not require large expenditures for the development of educational content and the time-consuming work of the specialists (Resta, 2015).

Also the control of quality of courses should be considered. We offer the main criteria for evaluating an online course (requirements): 1) a charismatic lecturer, passionate about the material; 2) high-quality visual design; 3) consistency and self-sufficiency of the course; 4) the ability of the course to engage and retain learners (gamification); 5) scalability; 6) licensed purity (materials were developed by the authors of the course or the authors have given their consent to the use of these materials).

Conclusion

The concept and features of the use of online courses in additional professional and vocational education, as well as the main types and principles of their organisation were examined. The finding found that online courses are mainly used for additional education because these courses have several advantages that allow not spending a lot of time and resources on training. In traditional teaching, online courses are used as a tool to relieve the burden of face-to-face classes in those disciplines where the focus is on practice. In addition to the advantages, disadvantages were also identified that make online courses challenging to deliver and organize.

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