

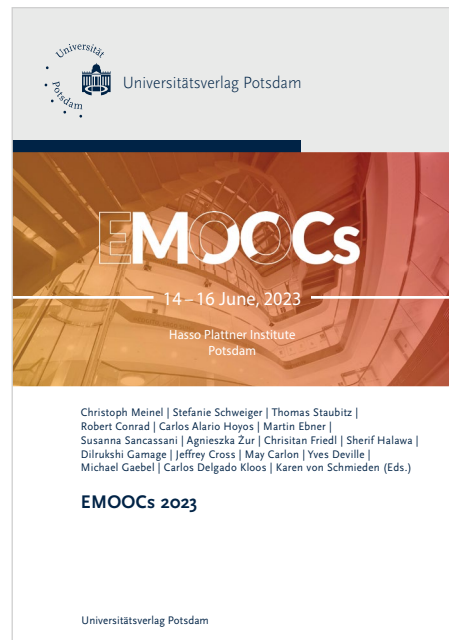
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An Experience in Developing Models to Use MOOCs in Teaching and to Advocate OERs

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Loss of expertise in the fields of Nuclear- and Radio-Chemistry (NRC) is problematic at a scientific and social level. This has been addressed by developing a MOOC, in order to let students in scientific matters discover all the benefits of NRC to society and improving their awareness of this discipline. The MOOC “Essential Radiochemistry for Society” includes current societal challenges related to health, clean and sustainable energy for safety and quality of food and agriculture.

NRC teachers belonging to CINCH network were invited to use the MOOC in their teaching, according to various usage models: on the basis of these different experiences, some usage patterns were designed, describing context characteristics (number and age of students, course), activities’ scheduling and organization, results and students’ feedback, with the aim of encouraging the use of MOOCs in university teaching, as an opportunity for both lecturers and students. These models were the basis of a “toolkit for teachers”. By experiencing digital teaching resources created by different lecturers, CINCH teachers took a first meaningful step towards understanding the worth of Open Educational Resources (OER) and the importance of their creation, adoption and sharing for knowledge progress. In this paper, the entire path from MOOC concept to MOOC different usage models, to awareness-raising regarding OER is traced in conceptual stages.

1 Introduction

In this article, the authors aim to provide an account of the process that took place from the development of a Massive Online Open Course (MOOC) under an international partnership with funding from Horizon 2020 to the creation of different patterns for presenting the MOOC to students.

The article also discusses the use of “external” educational resources as essential for innovation of teaching practices. The authors share their reflections on the use of the MOOC in various ways by different teachers and students, and the challenges they encountered in integrating it into their teaching practices.

Through this article, they hope to shed light on the potential benefits of using MOOCs and Open Educational Resources (OER) in education and encourage teachers to explore these resources for their courses.

2 “Essential Radioc-Chemistry for Society”

2.1 A first motivation: loss of scientific expertise

Expertise in Nuclear- and Radio-Chemistry (NRC) is crucial not only in the nuclear industry, but in several vital applications for modern society [3]. This expertise is fundamental for facing the challenging issues related to safe nuclear power plant operation, their future decommissioning, and nuclear waste management, but also for assuring several NRC applications in non-energy fields. Progress achieved in diagnostics and therapy within nuclear medicine is one of the most meaningful examples of how society could benefit from continuous enhancement in scientific knowledge within NRC. Similarly, other fields, such as radiation protection and radioecology, nuclear forensics and safeguards operations, as well as dating techniques for geology and archaeology, are all based on NRC knowledge.

Given the broad scope of applications and the strategic importance of NRC expertise, it is essential to promote and enhance education and training in this field. The development of educational resources such as MOOCs and OERs can play a significant role in this regard, by providing accessible, flexible, and high-quality learning opportunities for students and professionals around the world. Despite its relevance, NRC is not widely taught in high schools and universities [10]. It is perceived as being a non-modern field of chemistry, and even where available, it is not among the most selected subjects. Several studies reported on the lack of perceived relevance as the main reason for low interest in science study and career [13, 7]. In addition, younger generations perceive these disciplines related to radioactivity and in general to nuclear industry as something to be afraid of.

Consequently, in recent years, the availability of few engaging curricula and few career prospects in NRC, along with a misperception of this subject and a low awareness of its relevance, is causing a serious lack of interest among younger generations and consequently of NRC expertise in many parts of the world [6, 2]. Indeed, the missed turnover in knowhow due to retirements of the skilled workforce, and decreases in recruitment of newcomers, is leading to a serious skills shortage in NRC expertise.

2.2 Proposed solution: a MOOC to spark interest in students

In response to the NRC skills shortage and low uptake of students to NRC courses in higher education, a Massive Open Online Course has been selected as an educational approach to achieve three main goals: i) increasing students' awareness about the relevance of a controversial and specialized discipline such as NRC, ii) clarifying fears and misconceptions about anything related to “nuclear” and iii) increasing the number of students in NRC programs and related careers [5, 9].

A MOOC can be easily adapted to spread knowledge on different topics by addressing different target groups and going into the required level of detail. Additionally, a MOOC is open and available online, providing the ability to reach large numbers of students worldwide.

The MOOC titled “Essential Radiochemistry for Society” was designed and made within the H2020 MEET-CINCH project⁵ through the collaboration of 12 partners from nine European countries, including universities, research institutions and partners from industry [4].

MOOC design started from a careful analysis of target audience and context in order to develop a completely online learning path aimed at achieving effective awareness and durable knowledge. The main target group was identified as being students already pursuing scientific studies: in chemistry first, but also physics, biology, nuclear medicine and engineering. Taking into consideration the prerequisites and time needed to acquire a basic comprehension of such a difficult discipline, bachelor students were selected. General didactical goals and the learning objectives were consequently identified to address the target needs [8].

Organization of topics within the MOOC followed a logic of application areas: Radiochemistry “for the environment”, “for health”, “for industry”, “for nuclear energy”, and “for society”, so that it was easier for users to understand why NRC is useful with respect to the fields in which it is applied, highlighting the consequences of each application in terms of advantages and disadvantages.

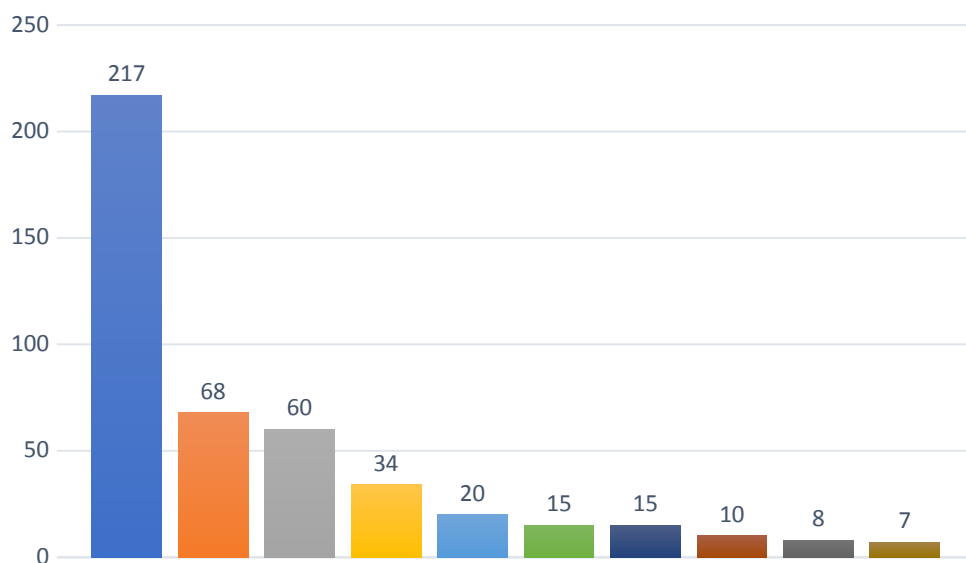
⁵<https://www.cinch-project.eu/meet-cinch/>

The whole course consists of 152 lessons, comprising 52 videos, 23 infographics, 34 exercises and 33 articles, and the estimated effort to complete it is about 30 hours⁶.

2.3 Data collection and analysis

Currently (March 2023) 663 users have enrolled on the MOOC since it was made available in June 2020.

Figure 1: User numbers, per country, for the “Essential Radiochemistry for Society” MOOC



2.4 First edition (pilot, 2020)

203 users (57 women, 75 men, 71 not declared) took part in the first edition of the MOOC. The users were mainly 20 to 25-year-old students studying in scientific areas, from 24 different countries all around the world. The main origin countries

⁶The MOOC “Essential Radiochemistry for Society” is available on Polimi Open Knowledge Platform <http://www.pok.polimi.it/>.

for the students were Italy (65), Slovenia (38), and Germany (10); 25 % of users completed the course and obtained the Certificate of Accomplishment.

To assess the MOOCs effectiveness, clarity, and completeness, as well as to highlight critical aspects, a small group of students at Politecnico di Milano were asked to take part in a focus group and answer questionnaires about workload, level of knowledge acquired, interest aroused, lesson formats, difficulties encountered, contents, quizzes etc. Analysis of collected data, together with the results obtained by a focus group, enabled us to derive useful information.

Students declared to have devoted on average 4.2 to 5.3 hours to complete each MOOC “Week”, judging the workload coherent with what indicated.

Similarly, requested pre-requisites were considered enough to understand the course.

A relevant percentage of students (30–50 %) stated that they gained enough knowledge to be able to explain NRC to other people, and just as many stated that they understood the main topics and were able to understand general situations related to them.

Concerning the course structure, students appreciated alternation of different lesson formats (videos, infographics, articles, link, exercises, quizzes) to explain topics, with intermediate self-assessment, and guided exercises to apply competences.

Some considerations could be done concerning the average score achieved in the final exam. It is equal to 0.91/1, supporting the effectiveness of the overall MOOC materials.

Thinking to the grades achieved, it is possible to state that modules showing a lower average grade are characterized by (i) presence of complex concepts and/or several technical details, such as the module on “Nuclear Medicine, Sterilization and Tracer technology”; (ii) few video-lessons, such as the module on “Confinement and waste management”; (iii) complex concepts presented as infographic, such as in the module on “Nuclear forensics and proliferation”; (iv) lack of practical examples; (v) presence of long articles with too many details.

Concerning the impact of the MOOC on users’ personal and professional experience, data collected highlighted that interest in the topic and the level of engagement achieved are paramount to captivate users and thus to drive their future involvement.

2.5 Second edition (2020–2021)

The second edition was attended by 193 users (59 females, 84 males, 50 not declared), mainly belonging to the same target group (20 to 25-year-old students in scientific areas), with students participating from 32 different countries: 44 % from Italy, 9 % from Finland, 7 % from Slovenia, and 5 % from Kazakhstan. The

percentage of users who completed the course was 19%, with a high average score in the final exam (0.82/1).

2.6 Third edition (2021–2022)

The third edition was attended by 130 users (46 females, 56 males, 28 not declared), again mainly belonging to the target group (20 to 25-years-old students in scientific areas), and enrollees were mainly from Italy (55), and Slovenia (11), from 27 different countries.

2.7 Fourth edition (2022–2023)

The fourth edition is currently online, and thus far has been attended by 175 users, (58 females, 77 males, 40 not declared), about half mainly belonging to target group mentioned before, from 26 countries, with enrollees mainly from Italy (44), Finland (36), Czech Republic (27), and Slovenia (12).

Table 1: Numbers of enrolled users (gender, origin) to “Essential Radiochemistry for Society” MOOC for each edition

	Enrolled users	Females	Males	Not declared	Origin Countries	Italy	Finland	Czech Republic	Slovenia
First edition	203	57	75	71	24	65	2	6	38
Second edition	193	59	84	50	32	72	15	0	11
Third edition	130	46	56	28	27	55	8	2	11
Fourth edition	175	58	77	40	26	44	36	27	12
	701	220	292	189	109	236	61	35	72

Taking the case of Politecnico di Milano, we have observed a threefold increase in the enrollment of students in the Master’s course for Nuclear Engineering since the launch of the MOOC. During the first edition of the MOOC, we introduced a short course for bachelor students about it. While this may be a possible reason for the significant increase in enrollment (due to the exact timing), we need to conduct

a further investigation to confirm this hypothesis. If proven true, it would confirm the objective of the MOOC.

Table 2: Number of enrolled users to “Essential Radiochemistry for Society” MOOC from Politecnico di Milano

		Enrolled users	Italy	Students from POLIMI
First edition	2020	203	65	28
Second edition	2020–2021	193	72	59
Third edition	2021–2021	130	55	37
Fourth edition	2022– <i>in progress</i>	175	44	29
		701	236	153

3 MOOC Usage Models

With “MOOC usage models”, we mean studying how lecturers in the CINCH partnership adopted the MOOC in their teaching activities, finding commonalities and differences due to: (i) context characteristics (student numbers, scheduling of classes and availability of time, possibility to have class both in presence and online); (ii) methodological choices (blended learning, flipped classroom, active learning); (iii) specific content in order to identify possible patterns.

Models created for the MOOC “Essential Radiochemistry for Society” can actually be adopted and adapted for many MOOCs and online resources in general.

MOOCs are exceptional learning resources, often created within prestigious institutions, by teachers who are passionate about their subject and wish to spread knowledge as widely as possible. “Essential Radiochemistry for Society” is a complete course, born out of an international collaboration, designed by a multidisciplinary team and reviewed by experts in each specific field of the subject, so it is an opportunity to learn more about NRC and understand all its applications.

Hence the desire that it can be used in whatever way it can be useful for learning.

3.1 A second motivation: encouraging to use the MOOC

Users enrolled in one of the four editions of “Essential Radiochemistry for Society” and used the course in very different ways: some completed the course and

obtained the final certificate, while others left it after a few lessons; some users found a video on YouTube channel and looked for other videos to deepen their understanding of some unclear concepts. The variety of motivations and behaviors of individual users is beyond our ability to trace paths and understand them [11].

Therefore, we focus our inquiries on teachers' approaches. It is interesting to see how teachers belonging to the follow-on A-CINCH⁷ project have adapted the use of the MOOC to their specific needs and goals for their courses. Some have used it as a complete course, while others have focused on specific topics or used it as a resource repository. This flexibility in usage shows the potential of MOOCs and other online resources in providing educators with additional tools to enhance their teaching and provide students with a variety of learning opportunities. The use of online educational resources can also contribute to a more collaborative and interconnected educational landscape, where educators can share and adapt materials to better serve their students.

3.2 Proposed solution: a kit for teachers

As we encountered resistance from some teachers to adopt 'external' teaching resources within their courses, we investigated the reasons for this opposition. While some of the answers are not easily addressed, others, such as (i) lack of time for redesigning the didactic activities of the course, (ii) distrust of online tools, and (iii) lack of trust in content created by experts from other countries with slightly different programs can be addressed. Our solution is a kit with mapped paths and steps that can be followed. The "Essential Radiochemistry for Society" kit for teachers describes MOOC content, structure and possible usage patterns, along with the peculiarities of application cases in project partners universities.

3.3 Model 1: MOOC and MORE

The first model to be experienced and drawn was called "MOOC and MORE" and is addressed to university students in scientific areas and structured in four main learning activities:

- Self-paced learning: study of the MOOC "Essential Radiochemistry for Society".
- Self-reflection about own effective knowledge of learnt topics: responding to questionnaires investigating difficulty in understanding contents, interest aroused by certain topics and the best didactical solutions.

⁷<https://www.cinch-project.eu/>

- Teamwork: designing a science communication event for general public.
- Peer-review and collaborative discussion: presenting project works and discussing it with teachers and other participants.

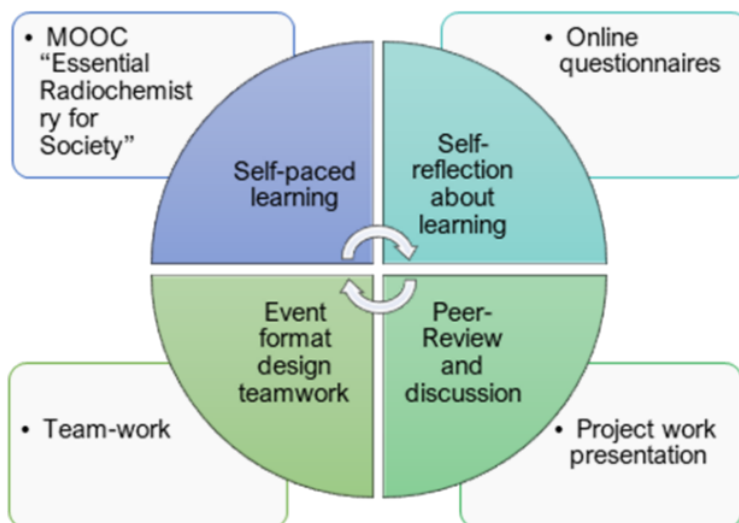


Figure 2: "MOOC and More" Model

According to this usage model, MOOCs are a starting point to learn about the main topics of the discipline: students have to study all lessons and pass all quizzes, but it is also the subject of meta-cognition, since the students have to design a dissemination event about the MOOC's topics.

MOOC and MORE have been tested at Politecnico di Milano in the framework of "Passion in action", an extracurricular initiative open to all students, and at the Jožef Stefan International Postgraduate School in the postgraduate course "Tools for environmental quality control" that is part of the PhD Program Ecotechnology during the lectures slot devoted to radiochemistry for the first year PhD students enrolled in the course.

Table 3: Comparison of two experiences at a glance

	“Passion in action” at Politecnico di Milano	“Tools for environmental quality control” at the J. Stefan International Postgraduate School
Target group	Bachelor’s degree students in scientific areas, who are interested to enrich their personal and professional experience by deepening Nuclear- and Radiochemistry	PhD students in scientific areas, who are interested to enrich their personal and professional experience by deepening Nuclear- and Radiochemistry.
Knowledge entry requirements	This activity is addressed to students who have basic knowledge of mathematics, physics and chemistry	Activity is addressed to students who have basic knowledge of mathematics, physics and chemistry.
Number of participants	30	20
Learning outcomes	The participants are able to list the areas of application of Nuclear- and Radiochemistry in everyday life, to describe the results and the advantages it could introduce, to choose the topics for a general public, adapting the language for a general public.	The participants are able to list the areas of application of Nuclear- and Radiochemistry in everyday life, to describe the results and the advantages it could introduce, to choose the topics for a general public, adapting the language.
Location	University classrooms/online	University classrooms/online
Didactical tools	Online didactical materials, teamwork, peer review, role play, synchronous meetings, formative feedback	Online didactical materials, teamwork, peer review, role play, synchronous meetings, formative feedback
Technical tools	Web conference platform for online meetings, sharing of recorded meetings, online surveys, online lab tools	Web conference platform for online meetings, sharing of recorded meetings, online surveys, online lab tools
Period	holiday period	winter semester
Duration	three months	two months
Pedagogical framework	Multi-approach and multi-tool experience	Multi-approach and multi-tool experience
Sessions	three	three
Estimated effort	30 hours	30 hours
Badge/ Certificate	Recognition of university credits: 2 ECTS (Italian CFU)	n.a.

3.4 Model 2: Flipping the MOOC

The model “Flipping the MOOC” can be used for different purposes:

- providing students with easily accessible, educationally designed, scientific resources,
- introducing different approaches to learning experiences,
- deepening the understanding of a particular theme.

The flipped classroom concept is a meta-framework that can be applied in several pedagogical perspectives. It is based on the idea that the classroom time is utilized best for interactive learning activities with teachers and peers, while activities based on content are carried out at home. The teacher selects or prepares the materials that the students study independently before and after the in-classroom activities. The “flipping” concept is linked to the idea that this approach reverses the traditional allocation of the teaching-learning activities. Typically, teachers present content in classrooms and assign memorization, systematization, retrieval and self-assessment as homework. By freeing up time in the classroom from content transfer activities, the flipped classroom approach can be applied in many situations. It is a result of the evolutionary process in the range of blended learning strategies that explore the integration between online and face-to-face learning aiming to optimize the learning advantages for both components.

The model has been tested by the University of Helsinki (UH) in the framework of an optional curricular course “Radiopharmaceutical chemistry” under the Master’s Program in Chemistry and Molecular Sciences. Module 2.1 of MOOC on nuclear medicine serves as an introduction to the course.

Beyond the great variety of application, depending also on the pedagogical perspectives, the flipped classroom model can be outlined as follows:

- Study at home: the teacher presents students with a set of selected materials or ad hoc products (booklets, chapters of books, articles, videos, MOOCs). Students use them to understand (on their own) the main contents that will be topics of the following in-class lessons.
- Active learning and collaborative classroom: the teacher proposes collaborative activities intended to provide in-depth analysis and guidance to the application of previously studied contents, thus enhancing consolidation and comprehension through group dynamics.
- Consolidation at home: after the lesson, the student goes back to the classroom activity to complete it or integrate it by going over the more complex topics, before starting to prepare for the subsequent lesson.

Table 4: University of Helsinki experience at a glance

	“Radiopharmaceutical chemistry” under the Master’s Program in Chemistry and Molecular Sciences at the University of Helsinki
Target group	students of age ~20 to ~55
Knowledge entry requirements	completion of the UH Chemistry Bachelor’s level course on Radiochemistry, and the UH Chemistry Master’s level Basic Radiochemistry exercises laboratory work class.
Number of participants	MOOC has been used by 3, 11, and 16 students in 2020, 2021, and 2022 respectively.
Topics	Basic concepts, production of radionuclides, radiosynthesis methods, production of radiopharmaceuticals, quality control, imaging, applications
Location	Since the implementation of the MOOC, the classes were onsite in 2020. The classes of 2021 and 2022 were held online.
Didactical tools	The MOOC quizzes and presence phase exercises were used to gauge the students’ preliminary understanding of the subject matter and help teachers plan student progression in learning. Students engaged in discussions during the presence phase, and were divided into smaller breakout rooms where they could engage in problem solving as a team.
Technical tools	The online presence phase was carried out using Zoom. Online video lectures were available on YouTube. Online surveys were performed using the web pages of the UH. Presence phase collaborative discussion was carried out using Flinga and Google Jamboard.
Period	The activities were performed early in the UH Spring semester.
Duration	The course lasted for 2.5 months (one standard teaching period).
Pedagogical framework	The course starts with the introductory MOOC videos and quizzes followed by the presence phase. The course is offered in a flipped classroom format where each online lecture is accompanied with a presence phase. There were also lectures from external speakers and a site visit to a nuclear medicine department of a University of Helsinki hospital.
Sessions	The lectures were carried out in 20 sessions among which six of these are always online as they are recorded lectures. The rest of the lectures can be performed online or in a classroom.
Estimated effort	The overall time allocated for a course with five ECTS is 135 hours. Out of this, watching lectures and face-to-face phase accounts for approximately 40 hours.
Badge/ Certificate	none

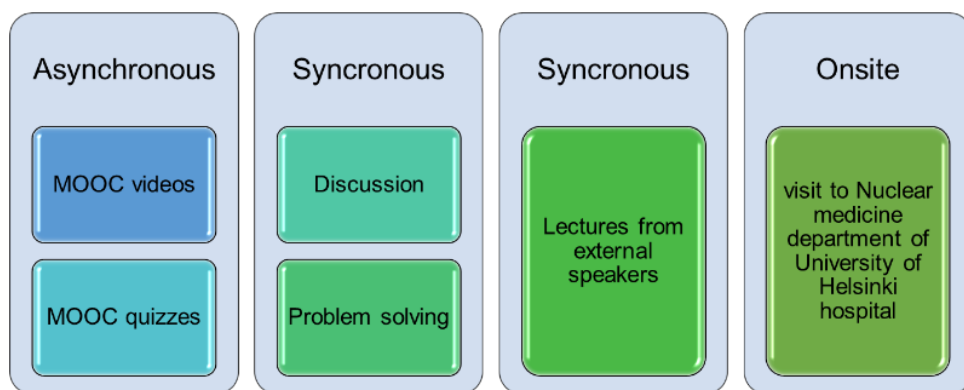


Figure 3: "Flipping the MOOC" Model

3.5 Current activities

During the last weeks new experiences have been carried out. In Czech Republic a teacher conducted two different tests: one at Czech Technical University in Prague in the class General Chemistry with 20 students of Nuclear Chemistry (mostly 19 and 20 years old) with content about decay law and the second one at Gymnázium Altis in Prague, with pupils mostly 16 to 19 years old with content about radioactivity, properties of ionizing radiation, the use of f-metals, and radiation accidents. At the University of Oslo, a team of teachers chose some specific MOOC materials to be studied by students, putting special emphasis on quizzes and assessments.

From these experiences new models will be available soon.

3.6 Results of the first experiences

Based on feedback analysis, it has become clear that the experience had a highly positive impact. Students appreciated the self-paced learning approach because it allowed them to construct their own understanding of the subject matter and offered the flexibility of an on-demand learning experience. Additionally, the presence phase was found to be necessary for building relationships and connections among students and with lecturers. When this phase was organized as a collaborative and teamworking activity aimed at problem-solving it was particularly effective. Even during the COVID-19 pandemic, the online presence phase was beneficial for students because they could engage with the course materials, maintaining relations with peers and lecturers.

Overall, these findings highlight the importance of providing students with both self-paced learning and collaborative activities to enhance their understanding and enjoyment of the course material.

4 Open Educational Resources

Massive Open Online Courses and Open Educational Resources share many characteristics: they are both available online, contribute to open education, are emerging in the context of international higher education as possible responses to the social, economic, and cultural changes of recent years. They also can be integrated into synchronous teaching and are useful sources for self-study and in-depth study. MOOCs and OER have the potential to accelerate didactical innovation processes by providing an opportunity for new kinds of collaboration between different institutions in the higher education sector, overcoming disciplinary and organizational boundaries [1].

4.1 A third motivation: promoting Open Educational Resources

One of the objectives of the A-CINCH project is to promote the use of Open Educational Resources. OER offer teachers the opportunity to reflect on their personal teaching practices, the effectiveness of their approach, the methodologies used by their colleagues, the needs and characteristics of their students, and the value of instructional design, as well as assessment methods. Such reflection is crucial for every teacher, and it can be stimulated by using and creating resources with an open license – where “open” means not just free, but also free with permissions. The link between the experience of MOOCs and OER was initially unknown to us, but became evident later. Some researchers have previously investigated the connection between them, going as far as to consider MOOCs released under an open license as a subset of OER [12].

In this article, we do not intend to take sides in this debate, but rather to highlight how the analysis of MOOC usage patterns in teaching practices has laid the groundwork for achieving a second goal: encouraging teachers to experiment with and value blending online resources created by other experts in nuclear and radiochemistry courses. Lecturers who used MOOC in their courses have appreciated the value of having easily accessible, well-structured resources, in-depth materials, and self-assessment quizzes, created by experts in the field.

Students have also appreciated the possibility of easily accessible learning material from any device and in different formats, allowing for different learning styles.

It seems that the experience of A-CINCH project is similar to that of teachers and students who use any open resource.

5 Conclusion

In this article, we have summarized the long journey that led from the concept of MOOC “Essential Radiochemistry for Society” to its production, thanks to the collaboration of experts from various European nations, up to its delivery to groups of European students. The data we report are promising in terms of the possibility that a greater number of students can enroll in a specialization related to the nuclear sector, so that knowledge in this area does not get lost over time.

We believe it is interesting to emphasize the versatility of the MOOC that we have observed in the different experiences conducted which proves the potential of MOOCs: not only a complete course, but also a pool of stand-alone and thematic resources. Moreover, the same resource used in different contexts offers truly multifaceted learning opportunities.

The encouragement to experience the use of MOOCs has triggered teachers to consider how students learn, how much study effort is required, and whether it is possible to adopt previously untried didactic approaches to achieve specific learning objectives.

This MOOC in particular, made it possible to overcome the differences (contents, approaches) existing between the curricula of European countries, offering a single and shared reference.

This experiment led us to take the first step towards another goal, not strictly related to the MOOC, namely promoting Open Educational Resources among the partners of A-CINCH project and their institutions. In fact, they had already experimented with the redesign of a course to include online resources – also thanks to the COVID-19 pandemic – and verified the flexibility of the approach and the positive impact on student engagement.

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