(Project Number: 945301)

DELIVERABLE D3.2

Report on “Essential Radiochemistry for Society” MOOC Usage Models and toolkit pilots

Lead Beneficiary: POLIMI

Due date: 30/09/2023 Released on: 25/09/2023

Authors:	Francesca Concia, Elena Macerata, Maddalena Negrin

For the Lead Beneficiary	Reviewed by Work package Leader	Approved by Coordinator
Elena Macerata	Elena Macerata	Mojmír Němec

Start date of project:	**01/10/2020**	Duration: **36 Months**
Project Coordinator:	Assoc. Prof Mojmír Němec	
Project Coordinator Organisation:	CTU	VERSION: 1.4

Project co-funded by the European Commission under the Euratom Research and Training Programme on Nuclear Energy within the Horizon 2020 Programme

Dissemination Level		
PU	Public	**X**
RE	Restricted to a group specified by the Beneficiaries of the A-CINCH project	
CO	Confidential, only for Beneficiaries of the A-CINCH project	

Version control table

Version number	Date of issue	Author(s)	Brief description of changes made
1.0	14.09.2023	Maddalena Negrin	Draft
1.1		Elena Macerata	Version 1
1.2	28.09.2023	Francesca Concia	Version 2
1.3	16/10/2023	Jana Peroutková	MST check
1.4	17/10/2023	Mojmír Němec	Coordinator’s check and approval

Project information

Project full title:	Augmented Cooperation in Education and Training in Nuclear and Radiochemistry
33Acronym:	A-CINCH
Funding scheme:	Coordination and Support Action
ECGA number:	945301
Programme and call	H2020 EURATOM, NFRP-2019-2020
Coordinator:	Mojmír Němec
EC Project Officer:	Kateřina Ptáčková
Start date – End date:	01/10/2020 – 30/09/2023 i.e. 36 months
Coordinator contact:	+420 224 358 331, mojmir.nemec@fjfi.cvut.cz
Administrative contact:	+420 245 008 599, cinch@evalion.cz
Online contacts:	http://www.cinch-project.eu/

“This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 945301.”

EXECUTIVE SUMMARY

This document explores innovative usage models for the MOOC "*Essential Radiochemistry for Society*," a valuable resource designed during the MEET-CINCH Project for bachelor students. These models have been developed to provide educators with effective strategies for integrating the MOOC into their teaching practices, thereby enhancing the learning experiences of their students.

The document introduces three distinctive usage models, each catering to diverse educational contexts and objectives:

1. *MODEL N° 1: MOOC and MORE*

   This model engages university students specializing in scientific fields in a multifaceted learning experience. Students not only use the MOOC as a primary learning resource but also critically reflect on its contents and apply their knowledge by designing a dissemination event related to the MOOC's topics.

2. *MODEL N° 2: FLIPPING THE MOOC*

   This model presents an alternative approach to traditional teaching. It encourages students to engage with MOOC content independently before in-person classes, fostering self-directed learning and deeper interactions with course materials.

3. *MODEL N° 3: A FORETASTE OF MOOC*

   This model explores the concept of providing students with a preview of the MOOC's content to stimulate interest and enhance learning. It can be implemented at the university level or in school settings to ignite a passion for radiochemistry and science.

Each model is accompanied by real-world case studies that demonstrate its practical implementation and impact on student learning. These models showcase the adaptability and versatility of the MOOC across diverse educational settings and learner profiles.

As the landscape of education evolves, these usage models offer valuable insights and strategies for educators seeking to enrich their teaching practices. They encourage the exploration of new horizons in radiochemistry education, empowering educators to create dynamic, engaging, and effective learning experiences.

The MOOC "Essential Radiochemistry for Society" remains at the forefront of innovative pedagogy, offering educators a platform to inspire and educate the next generation of scientists and change-makers. It is our hope that these usage models will serve as guiding tools, fostering a collaborative spirit in the realm of radiochemistry education and beyond.

CONTENT

1 INTRODUCTION

The journey of a MOOC, from its inception to conception, design, implementation, and eventual publication, raises crucial questions. What happens when a MOOC is published? In particular, what happens if that MOOC deals with a very niche scientific topic and is not addressed to a general public, as our ”**Essential Radiochemistry for Society**” MOOC? (See Figure 1). Some people around the world can be really interested and sufficiently knowledgeable to study and appreciate it, but probably it will be a precious treasure in the hands of its authors, university professors who will propose it to their students.

Polimi
ERS101

Essential radiochemistry for society

Starts: August, 28 2023

MOOCs For Master of science

Figure 1 - Link to the ”Essential Radiochemistry for Society” MOOC, available on https://www.pok.polimi.it/.

The design and implementation effort required for a MOOC deserves more than being a teaching tool for a handful of students. The number of potential users risks being very small because the university curricula vary a lot among countries: if an Italian and a Latvian chemistry student will probably have the same knowledge at the end of their studies, they will achieve it through very different paths. So, a MOOC designed by an Italian teacher might not be usable for a Latvian, a Dutch, a Czech or a Portuguese course. It might.

Our task is, among others, to make sure that our MOOC can fit for a Greek, a French, and a Finnish student. Under Task 3.1 of A-CINCH project, we can carve out a small place for a reflection about our teaching activity.

The world is changing, we realise it every day. Society changes, economy changes, geopolitical balances change - if ever there were any balances in geopolitical issues. Should academic institutions also change? Should teaching change? Some are convinced of it. Some others are firmly resisting it because they strongly believe in what they have invested their lives in.

The answer is: it depends. It depends on who we are, on the need we have to respond to global change. It depends on our institution. It depends on our students. It depends on how we change: adopting an electronic white board instead of the old black board is not a change. Re-designing a course to take into consideration the importance of activating students, creating opportunities to share their opinion with peers, to guarantee a positive learning experience to those who have a disability: this can be a way to change teaching.

During their activities, teachers have a lot of stakeholders: colleagues, collaborators, communities of citizens, networks, industries, institutions, associations and students: students are the first beneficiaries of the action of teaching, but more importantly they are the actors of learning. Without them neither knowledge transfer nor future progress in science will be possible.

So, when we reflect about teaching, we must put the learning experience at the centre, because the common goal is that students can understand, remember, be able to apply and develop knowledge.

In order to guarantee student's in-depth and lasting knowledge, numerous models have been tried out in recent years. Probably some of them are more significant than others, but the common effort has been in the direction of stimulating intrinsic motivation in students, rather than leveraging on the grade, on the difficulty of the exam or other purely extrinsic motivations. If students know the why, understand the meaning and share it, their learning will be more effective. If the students can apply the acquired knowledge, e.g., through a virtual lab as that developed for A-CINCH, their knowledge will be more solid. If the students will not limit himself to the teacher's lectures and recommended textbooks, but consult other sources, their knowledge will be broader and his/her insight deeper.

Now, within this evolving landscape of teaching and learning, the MOOC "*Essential Radiochemistry for Society*'' emerges as a potent resource. This document aims to explore the creation of **usage models** that can facilitate the MOOC's integration into teaching activities, extending its reach and impact to educators worldwide. These models draw upon the experiences of the A-CINCH project partner group, who have embraced the MOOC within their teaching, and offer insights into its practical application within diverse educational contexts.

2 MOOC USAGE MODELS DESIGN

Our experiences with the first three MOOC editions gave us a wealth of information, mostly quantitative, made interesting by the analysis and comments of those who were able to share their thoughts. While the primary intention of the MOOC was to be a comprehensive learning experience, we recognized that its utility extended beyond traditional course structures.

In some cases, the MOOC was offered in its entirety, i.e., the students enjoyed it from first LESSON to last one, obtaining the final certificate. This is the main use for which it was designated. However, it became apparent that, more often, the MOOC served as an indexed and structured repository of materials, accessible and searchable. This use, while common, proved challenging to monitor and track effectively, as it merely generated numbers without revealing the motivations behind each click.

Drawing from both our experiences and relevant literature, two fundamental modes of using MOOCs emerged:

1. **Lecturer-Driven**: In this mode, instructors “assign” specific MOOC resources to students for self-study. These resources could be studied before, during, or after the course, either as core subject matter or supplementary material.
2. **Student-Initiated**: Here, students proactively seek online resources to enhance their understanding of course concepts, exercises, or applications.

This is confirmed by the literature: We see that there are further two basic behaviours using MOOCs and OERs - we can juxtapose MOOCs and OERs because in both cases they are educational materials available online and curated by accredited institutions.

This shift carries significant anthropological, social, and cultural implications. A mere two decades ago, a student who was not able to understand a challenging topic had limited options: he/she could go to the library, looking for another book, or consult fellow students, or approach their instructor for guidance. Now a student, with just a few clicks, has access to a wealth of resources - that have to be selected. The anthropological, social and cultural impact is undoubtedly very high.

The MOOC, as an open educational resource, has the potential to significantly alter the learning landscape [1]. By offering diverse perspectives and alternative explanations, it enriches the learning journey [2]. Each time an external resource—a link, a video, an exercise—is introduced, it serves as a lens through which students perceive the subject matter differently. While this may briefly disorient students, it invariably broadens their understanding.

In our quest to enhance the MOOC's utility and impact, we turn to the concept of "MOOC usage models". These models are derived from the experiences of the project partner group who have actively incorporated the MOOC into their teaching practices. Our goal is to distil the commonalities and differences from these experiences, elevating them to the status of models that can inspire and guide others.

2.1 The design of the First Model

To illustrate the practical application of MOOC usage models, the design of the first model, initiated by the POLIMI team is presented here. This extracurricular initiative was open to all bachelor students at POLIMI and first-year master's students in nuclear engineering, attracting 80 applications, of which 50 were accepted.

The initiative encompassed three primary objectives, each achieved through distinct activities. First, students acquire new competences and skills in nuclear radiochemistry (NRC) by studying the MOOC. Second, they actively evaluated the MOOC's impact on their personal and professional development, utilising tools such as focused questionnaires for each of the five weeks and a video tagging tool for providing feedback on specific video segments. Finally, students applied their acquired competencies and skills through a team-based activity.
The initiative unfolded in several stages:

- **Promotion, Enrollment, and Selection**: Students were recruited and selected for participation.
- **Launch**: The program commenced with an introduction to the topic, learning outcomes sharing, and an overview of the activities.
- **First Results Check and Role Play**: The initial impact of the MOOC was assessed.
- **Teamwork and Feedback**: Students worked collaboratively to design a MOOC for a general audience.
- **Project Presentation and Peer-Review**: Students presented their projects and engaged in peer review.
- **Promotion, Enrollment, and Selection**: The initiative concluded with recognition and feedback collection.

Recognizing the positive outcomes and student engagement, we formulated a model focused on four key learning activities (See Figure 2):

- **Self-paced Learning**: Engaging with the MOOC, "Essential Radiochemistry for Society."
- **Self-reflection**: Assessing their own understanding of the studied topics through questionnaires.
- **Teamwork**: Collaboratively designing a MOOC for a general audience.
- **Peer-review and Collaborative Discussion**: Presenting and discussing project work with teachers and peers.

This comprehensive model aims to enhance the utilization of the MOOC while fostering student engagement, critical thinking, and collaboration, thereby enriching the overall learning experience.

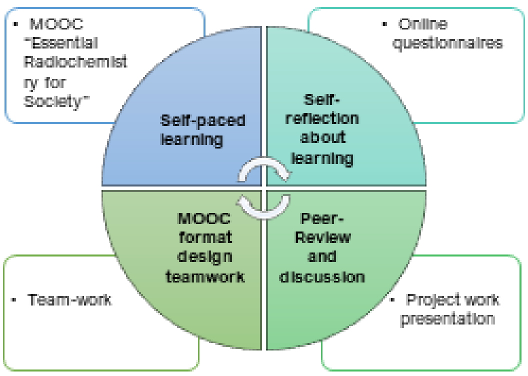

Figure 2 - A first draft of a MOOC usage pattern

2.1.1 The Toolkits

The main objective of the realisation of toolkits for teachers was the valorisation of the already developed knowledge by promoting the usage of the MOOC, along with new pedagogical approaches, among educators. These toolkits are designed to facilitate easy access to high-quality educational materials and provide guidance on implementing various usage patterns, thereby enhancing the adaptability of the MOOC in diverse educational settings.

In pursuit of this objective, we initiated the monitoring of some experiences carried out respectively in Greece, Italy, Norway, Portugal, Slovenia and Sweden in order to collect data on the application of different approaches. NRC teachers in their class proposed the MOOC as learning resources, applying different approaches: someone asks the students to study only some contents, someone indicates during the lessons which material form the MOOC watch/read before the following in-class activity, someone lets students choose something interesting among the MOOC’s contents. These models will be further tested in contexts that differ in the nationality of the students, the size of the class, and the course of study.
Once all the experiments have been completed, the models have been described both through a synthetic graphical representation and through a commentary text that lists the phases, highlights the critical issues and offers suggestions.

The usage models are the main content of the toolkits which will be shared as downloadable online resources, available in multiple languages, categorised according to some main peculiarities: age of users, number of students, learning objectives, time effort, necessary equipment, alert and suggestions.
Furthermore, the toolkits equip educators with instructions on monitoring students' activities and receiving reports to facilitate informed decision-making. A concluding survey within the toolkits allows to gather feedback, suggestions, and insights for potential new applications. This iterative process ensures that the toolkits remain dynamic and adaptable, effectively supporting educators in their mission to enhance the learning experiences of their students.

2.2 MONITORING USES

After the promotion of the MOOC across the consortium, two surveys were developed to comprehensively assess the impact and utility of the MOOC, with one aimed at gathering quantitative data and the other delving into specific experiences to refine the teaching model.

2.2.1 First Survey: Quantitative Insights

The initial survey was instrumental in understanding the extent of the MOOC's integration into teaching practices across various partner institutions. It attracted participation from UiO (University of Oslo), UH (University of Helsinki), UCY (University of Cyprus), and JSI (Jožef Stefan Institute) among others. These responses allowed us to gain insights into the diverse adoption of the MOOC within the consortium.

Educators represented a range of classes, including "Physics of neutron radiation devices," "Radioactivity" (for bachelor and master), "Environmental Chemistry-Radioactivity," "Basic radiopharmaceutical chemistry," "Medical application of nuclear physics," and "Tools for environmental quality control." These diverse classes exemplify the varied contexts in which the MOOC was employed.

The survey also provided essential demographic information about the age and number of students involved in the classes where the MOOC was employed. Notably, it shed light on the backgrounds of the students, with the majority being 22-25 year old, second-year university students, with introductory-level knowledge, or better third-year university students with more advanced understanding in mathematics and chemistry.

Additionally, the survey probed educators about how they used the MOOC within their teaching, allowing us to understand the different models of integration across partner institutions.

Details about the results of the survey are reported in Annex 1.

2.2.2 Second Survey: Detailed Experiences

The subsequent survey, offered to educators interested in providing more in-depth information, aimed to capture detailed experiences. It sought information about the universities where the experimentation took place, course specifics, participant age, knowledge entry requirements, and the number of participants.

This survey also delved into the learning outcomes, technical and didactical tools employed, and the model application's distinctive features. Educators provided insights into the duration, effort, and phases of the activity, along with plans for future adaptations.

Overall, these surveys offer a holistic view of how the MOOC is being utilized across the consortium, providing valuable data for further refinement and enhancement of the course.

3 THE MOOC USAGE MODELS

Within this document, three innovative usage models for the MOOC "Essential Radiochemistry for Society," available at pok.polimi.it, and designed for radiochemistry teachers, are presented. These models aim to equip educators with effective strategies for incorporating the MOOC into their teaching practices, thereby enriching their students' learning experiences.

1. MODEL N° 1: **MOOC and MORE**

   The first model, "MOOC and MORE," engages university students specialising in scientific fields in a multifaceted learning experience. It encourages students not only to utilise the MOOC as a primary learning resource but also to critically reflect on its contents. Additionally, this model prompts students to apply their newfound knowledge by designing a dissemination event centred around the topics covered in the MOOC.

2. MODEL N° 2: **FLIPPING THE MOOC**

   The second model, "Flipping the MOOC," introduces an alternative approach to traditional teaching. It revolves around the concept of flipping the classroom, wherein students engage with MOOC content independently before participating in in-person classes. This model promotes active learning and deeper engagement with course materials.

3. MODEL N° 3: **A FORETASTE OF MOOC**

   The third model, "A Foretaste of MOOC," explores the idea of providing students with a preview of the MOOC's content, either at the university level or in school settings. This approach is designed to stimulate interest and enhance learning by offering students a glimpse into the rich educational resources available within the MOOC.

In the subsequent sections, we will delve into each of these models, offering comprehensive insights into their structure, implementation processes, and outcomes, as illustrated through real-world case studies. These usage models serve as valuable resources for optimising the utilisation of the MOOC "Essential Radiochemistry for Society" within various teaching contexts and to achieve diverse educational objectives.

The MOOC Usage models are available in English, Italian and partially in Portuguese and are downloadable at the links reported in Annex 2.

3.1 MODEL N° 1: MOOC and MORE

This document describes a model for use of the MOOC "Essential Radiochemistry for Society" available at pok.polimi.it by radiochemistry teachers.

The model "MOOC and MORE" involves University students in scientific areas in four main learning activities (See Figure 3):

- **Self-paced learning** - To study the MOOC "Essential Radiochemistry for Society".
- **Self-reflection** about own effective knowledge of studied topics - To answer questionnaires investigating the difficulty of the contents, the interest aroused by certain topics, the best didactical solutions.
- **Teamwork** – To design a science communication event for the general public.
- **Peer-review and collaborative discussion** - To present the project-work and to discuss it with teachers and other participants.

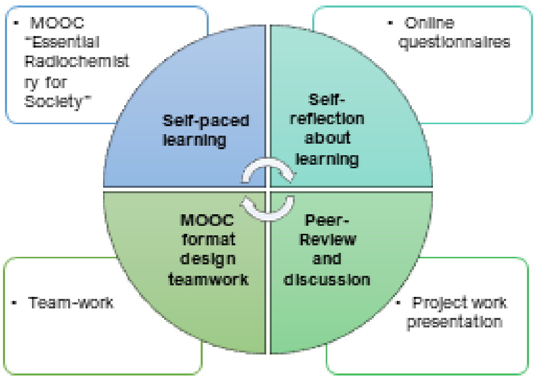

Figure 3 - Graphic representation of the "MODEL N° 1: MOOC and MORE" usage pattern.

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

This model has been tested by Politecnico di Milano (POLIMI) and JSI Ljubliana, as described in the following sections.

3.1.1 MODEL N° 1A: MOOC and MORE "PASSION IN ACTION"

Tested by POLITECNICO DI MILANO

The model has been tested by Politecnico di Milano in the framework of an initiative of extracurricular activities open to all the students with the name "PASSION IN ACTION".

Detailed description

TARGET GROUP: Bachelor's degree students in scientific areas, who are interested to enrich their personal and professional experience by deepening Nuclear- and Radio-chemistry.

KNOWLEDGE ENTRY REQUIREMENTS: The activity is designed for students who have basic knowledge of mathematics, physics and chemistry.

NUMBER OF PARTICIPANTS: 15/30

LEARNING OUTCOMES: the participants are able to list the areas of application of Nuclear- and Radio-Chemistry 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

DIDACTICAL TOOLS: Online didactical materials, Team-work, Peer-review, Role Play, Synchronous meetings, Formative feedback

TECHNICAL TOOLS: WebConference Platform for online meetings, Sharing of recorded meetings, Online Surveys, Online labs tools

Model-application peculiarities

PERIOD: a holiday period

DURATION: 3 months

PEDAGOGICAL FRAMEWORK: Multi-approach and multi-tool experience

SESSIONS NUMBER: 3

ESTIMATED EFFORT FOR STUDENTS: 30 hours

BADGE / CERTIFICATE: Recognition of university credits- 2 ECTS credits (Italian CFU)

CHRONOLOGICAL PHASES

CHRONOLOGICAL PHASES DESCRIPTION (AND SUGGESTIONS):

1. PROMOTION, ENROLLMENT AND SELECTION
   It is necessary to specify in the communication text the effort required (number of hours), the dates and duration of the lessons/sessions, and the criteria for selecting participants.

2. LAUNCH: LEARNING OUTCOMES SHARING, INTRODUCTION TO THE TOPIC, DESCRIPTION OF THE ACTIVITIES
   During the first meeting the discipline was introduced and the whole activity was described, sharing with the students the learning outcomes, the scheduling, the tools, and the "style" of the activity.

3. FIRST RESULTS CHECK AND ROLE PLAY
   After a few weeks it has been useful:
   a. to verify the number of students who enrolled in the MOOC, started studying and answering the quizzes, consulting the data provided by the MOOC platform;

   b. to verify the answers to the questionnaires, to make sure that the students have understood the activity and are carrying it out in the due time;
   c. to meet the students to discuss with them the first collected data related and to awaken the motivation (which can be dropped in a period of individual study) launching the second phase.

4. TEAMWORK AND FEEDBACK
   a. Team-work is undoubtedly the most engaging phase, also because it is project-based. It was important to explain what it required before creating the groups.
   b. Students had to play the role of experts, reflecting on one of the macro-themes of the MOOC, i.e., one of the applications of radiochemistry, in order to set up the structure of a week for a MOOC aimed at citizens. Besides the list of topics, they have to think about how to communicate the MOOC and how to involve and keep the participants interested.
   c. Students sent their work by a due date. Then they received feedback from the teachers and could correct the paper accordingly, before submitting it.

5. PROJECT PRESENTATION AND PEER-REVIEW
   During a plenary session, each team presented its project in accordance with the criteria assigned and the time set, also proposing a reflection about how the group worked and the difficulties encountered. The other students could put questions together with the teachers, with the aim of creating a situation of collaborative learning.

3.1.2 MODEL N° 1B MOOC and MORE “Tools for environmental quality control”

Tested by JSI Ljubljana

Detailed description

TARGET GROUP: PhD students in scientific areas, who are interested in enriching their personal and professional experience by deepening Nuclear- and Radio-chemistry.

KNOWLEDGE ENTRY REQUIREMENTS: The activity is designed for students who have knowledge in mathematics, physics and chemistry.

NUMBER OF PARTICIPANTS: 15/30

LEARNING OUTCOMES: the participants are able to list the areas of application of Nuclear- and Radio-Chemistry 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

DIDACTICAL TOOLS: Online didactical materials, Team-work, Peer-review, Role Play, Synchronous meetings, Formative feedback

TECHNICAL TOOLS: WebConference Platform for online meetings, Sharing of recorded meetings, Online Surveys, Online labs tools

The model has been tested by JSI in the framework of the postgraduate course "Tools for environmental quality control" of the PhD programme Ecotechnology at the Jožef Stefan International Postgraduate School during the lectures slot devoted to radiochemistry for the first year PhD students enrolled in the course.

Model-application peculiarities:

PERIOD: winter semester

DURATION: 2 months

PEDAGOGICAL FRAMEWORK: Multi-approach and multi-tool experience

SESSIONS NUMBER: 3

ESTIMATED EFFORT FOR STUDENTS: 30 hours

BADGE / CERTIFICATE: n.a.

CHRONOLOGICAL PHASES

CHRONOLOGICAL PHASES DESCRIPTION (AND SUGGESTIONS):

1. PROMOTION, GIVING INSTRUCTIONS
   Students were informed how the radiochemistry lectures will be performed within course Tools for environmental quality control. They were asked to complete MOOC until presence phase.

2. LEARNING BY COMPLETION OF MOOC
   Students had 2 months to learn and study the MOOC and to complete all activities. One week before presence phase reminder was sent to students to complete MOOC on time to be prepared for presence phase. Guided questions were sent to students to help them prepare for teamwork.

3. INTRODUCING PRESENCE PHASE
   Introduction has been made at the start of presence phase to allow students to provide their feedback on topic of study and to explain them planned teamwork activities. Due to COVID-19, in presence phase was conducted using on-line meeting platform Zoom.

4. TEAMWORK
   Students were divided in five groups, each of three students where each group had to prepare a presentation on a week of MOOC. They were asked to present to others what they have learned from that week of MOOC, what was the most interesting to them and present parts which were unclear to them. As a help they could use guided questions prepared for each week. Teamwork took place on Zoom in breakout rooms and students were randomly assigned to them. Teacher came to each breakout room to check if students understand what they need to do and if they need any clarification. Otherwise, students were left to freely prepare their projects. Students had 1.5 h to prepare the presentation.

5. PROJECT PRESENTATION AND DISCUSSION

Each team presented their work to others after which there was time for discussion on specific topics.

Comments

Very positive feedback by students about the MOOC itself and its usage during lectures

3.2 MODEL N° 2: FLIPPING THE MOOC

This document describes a model useful to inspire the adoption of MOOC "Essential Radiochemistry for Society" available at pok.polimi.it by radiochemistry teachers for their students.

The model "**Flipping the MOOC**" can be used for different purposes:

- Provide students with easily accessible, educationally designed, scientifically warranted learning resources
- Verify the value for students of "listening" other voices and learning from other instructors
- Deepen a particular theme.

Flipped classroom concept is a sort of *meta-framework* that might find application in several pedagogical perspectives. It is based on the idea that the value of time spent in the classroom is best dedicated to applying knowledge in an interactive context with the teacher and peers. To this end, some content activities are carried out at home, not inside the classroom, using materials selected or specifically prepared by the teacher, which the student studies on their own before the lesson.
The concept of flipping is linked to the idea that this approach flips the traditional allocation of the teaching-learning activities, which usually provide for the presentation of contents in the classroom and working on the assignments from home.
Freeing up the class time from content transfer activities makes the flipped classroom applicable in many situations. The flipped classroom pedagogical framework is the result of the evolutionary process taking shape within the wide range of blended learning strategies that explore the integration between online and face-to-face learning with the aim to optimize the learning advantages for both components.
Beyond the great variety of application, dependent also on the pedagogical perspectives in which it is applied, in general the flipped classroom model can be outlined as follows (See Figure 4):

1. **Study at home**
   The teacher presents the student with a set of selected materials or ad hoc products (booklets, chapters of books, articles, videos, MOOCs). The students use them to understand on their own the main contents that will be topics of the coming lesson.
2. **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.
3. **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.

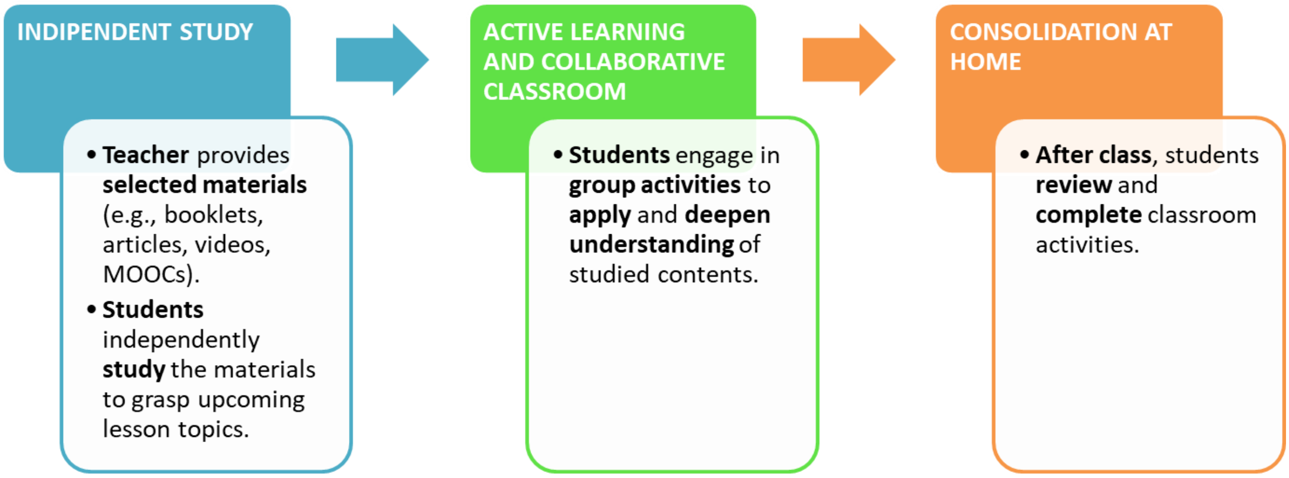

Figure 4 - Graphic representation of the "MODEL N° 2: FLIPPING THE MOOC" usage pattern.

This model has been tested by the University of Helsinki and the University of Oslo, as described in the following sections.

3.2.1 MODEL N° 2A: Flipping the MOOC "Radiopharmaceutical Chemistry"

Tested by UNIVERSITY OF HELSINKI

The model has been tested by the University of Helsinki in the framework of a curricular course "Radiopharmaceutical chemistry" under the Master's Programme in Chemistry and Molecular Sciences. The Module 2.1 of MOOC on Nuclear medicine serves as an introduction to the course.

DETAILED DESCRIPTION

- **TARGET GROUP**: students of age ~20 to ~55
- **KNOWLEDGE ENTRY REQUIREMENTS:** The course prerequisites are completion of the UH Chemistry Bachelors level course on Radiochemistry, and the UH Chemistry Masters level Basic Radiochemistry Exercises laboratory work class.
- **NUMBER OF PARTICIPANTS**: The MOOC has been used by 3, 11, and 16 students in 2020, 2021, and 2022 respectively.
- **LEARNING OUTCOMES**:
  BASIC CONCEPTS:
  - Describe and explain the basic terminology in radiopharmaceutical sciences and demonstrate application (core, knowledge, remembering and understanding)
  - Describe and explain how radiopharmaceuticals are used in clinical medicine and in biomedical research (core, knowledge and attitudes, remembering and understanding)
  - Explain requirements for a good radiopharmaceutical (core, knowledge, understanding)

<u>PRODUCTION OF RADIONUCLIDES:</u>

- Summarize the different production methods: cyclotrons, reactors, and generators. (core, knowledge, understanding)
- Explain how short living radioisotopes are produced with a cyclotron (core, knowledge, understanding)
- Calculate yield of a cyclotron production in terms of produced radioactivity. (core, knowledge, applying)Can explain the principle of radionuclide generators (core, knowledge, understanding)

<u>RADIOSYNTHESIS METHODS:</u>

- Explain the general radiolabeling techniques and radionuclide specific techniques (core, knowledge, understanding)
- Explain chemistry of the most common radionuclides (core, knowledge, understanding)
- Interpret and apply how the application influences the design of new radiopharmaceuticals and the selection of the synthesis strategy (core, knowledge, understanding and applying)
- Indicate and demonstrate which factors influence the total overall yield of the synthesized
- Solve radiosynthesis problems by examining the reaction conditions and critiquing the choice of radiosynthetic techniques (core, knowledge, applying/analyzing/evaluating)

<u>PRODUCTION OF RADIOPHARMACEUTICALS:</u>

- Explain the general procedure for development of a new radiopharmaceutical (core, knowledge, understanding)
- Indicate the general procedure for production of radiopharmaceuticals (i.e., synthesis, purification, QC etc.) (core, knowledge, understanding)
- Indicate the most common radiopharmaceuticals in clinical use and illustrate their synthesis and properties (core, knowledge, understanding)

<u>QUALITY CONTROL:</u>

- Identify the regulatory demands for quality assurance of radiopharmaceuticals for clinical use (core, knowledge/attitude, remembering)
- Can explain the general methods for QC (core, knowledge, understanding)
- Interpret the meaning of radionuclidic, radiochemical, chemical, and pharmaceutical purity (core, knowledge, understanding)
- Differentiate between the product validation and routine QC (core, knowledge, understanding)

<u>IMAGING:</u>

- Explain basics of positron emission tomography and single photon emission tomography (core, knowledge, understanding)
- Explain how imaging is performed and what factors influences the image quality (core, knowledge, understanding)

<u>APPLICATIONS:</u>

- Distinguish between therapeutic and diagnostic radiopharmaceuticals (core, knowledge, understanding)
  Summarize non-clinical and clinical applications of radiopharmaceuticals (core, knowledge/attitude, understanding)
- Explain the common methods in nuclear medicine (core, knowledge/attitude, understanding)

- **LOCATION:** Since the implementation of MOOC, the 2020 classes were onsite. 2021 and 2022 classes were completely online.

- **DIDACTICAL TOOLS:** The MOOC quizzes and the presence phase exercises were used to gauge preliminary understanding of students on the subject matter and help the teachers plan student progression in learning. The students engaged in discussions during the presence phase. They 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. The online video lectures were available on YouTube. Online surveys were performed using University of Helsinki web pages. The presence phase collaborative discussion was carried out using Flinga and Google Jamboard.

MODEL APPLICATION PECULIARITIES

PERIOD: The activities were performed early in the UH Spring semester.
DURATION: The course lasted for 2.5 months (one standard teaching period)
SESSIONS NUMBER: The lectures were carried out in 20 sessions among which 6 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 FOR STUDENTS: The overall time allocated for a 5-credit course is 135 hours. Out of this, watching lectures and face-to-face phase accounts for approximately 40 hours.
BADGE / CERTIFICATE: \
CHRONOLOGICAL PHASES: 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 th University of Helsinki hospital.

CHRONOLOGICAL PHASES DESCRIPTION (AND SUGGESTIONS) (Figure 5):

1. MOOC videos and quizzes
2. Discussion and problem solving in presence
3. Lectures from external speakers
4. Site visit to Nuclear medicine department of the University of Helsinki hospital

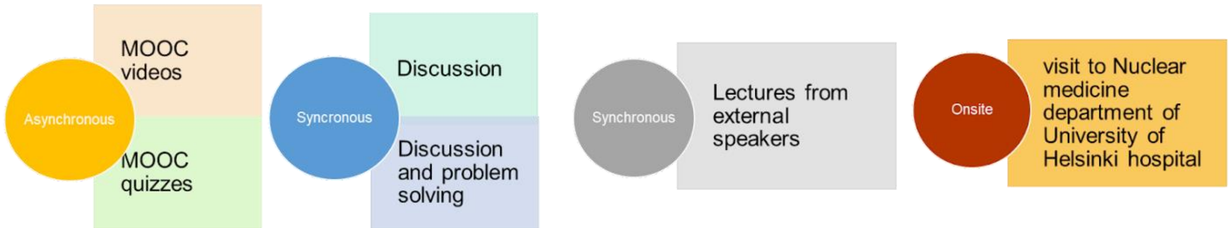

Figure 5 - Graphic representation of the "MODEL N° 2A: Flipping the MOOC "Radiopharmaceutical Chemistry"" usage pattern

RESULTS

1. Self-paced learning is one of the key features of flipped classroom approach which has been implemented. This teaching technique allows students to construct their own meaning and hence better understand the subject matter. The presence phase was collaborative and teamwork was required to solve problems. Even though the presence phase was online, students engaged in adequate discussions to achieve their learning goals. Even though the presence phase had multiple collaborative tools, they weren't flawless and some degree of human connection was lacking in online sessions.
2. The MOOC and the online lectures were developed as a part of the MEET CINCH project. The accompanying presence phase material took about 240 hours to prepare and was improved iteratively through the years.
3. MOOC and flipped classroom lectures were self-sufficient in delivering the majority of the concepts in radiopharmaceutical chemistry making them an excellent resource to be incorporated into any European nuclear education program.
4. The pre-recorded lectures were widely embraced by the students as they offered the flexibility of an on-demand learning experience. The online presence phase was also a benefit for the students as they could engage from their preferred atmosphere

PLANS FOR FUTURE

We plan to offer this activity to our students every spring as part of our core radiochemistry programme.

We modify the course every year based on student feedback / staff changes.

The presence phase sessions will now always occur onsite as COVID restrictions have been alleviated. We are investigating options for hybrid delivery as well.

3.3 MODEL N° 3: A FORETASTE OF MOOC

This document describes a model for the use by radiochemistry teachers of the MOOC "Essential Radiochemistry for Society" available at pok.polimi.it.

The model "A foretaste of MOOC" involves University students in scientific areas and high school pupils in 3 main learning activities (Figure 6):

1. **In Class:** Have you ever heard about MOOC? What are the possibilities of self-education? (evocation, brain-storming)
2. **In Class:** Presenting the MOOC and enrolment
3. **In Class:** Screen-sharing (through data projector), explanation of all the symbols (video, quiz, …) and exploration.
5. **In Class:** Individual learning of the first lesson "Natural radioactivity".
6. **In Class:** Discussion about the experience
7. **At home:** completing first lesson
8. **At home:** choosing and studying another lesson (1 bonus point)
9. **In Class:** final discussion

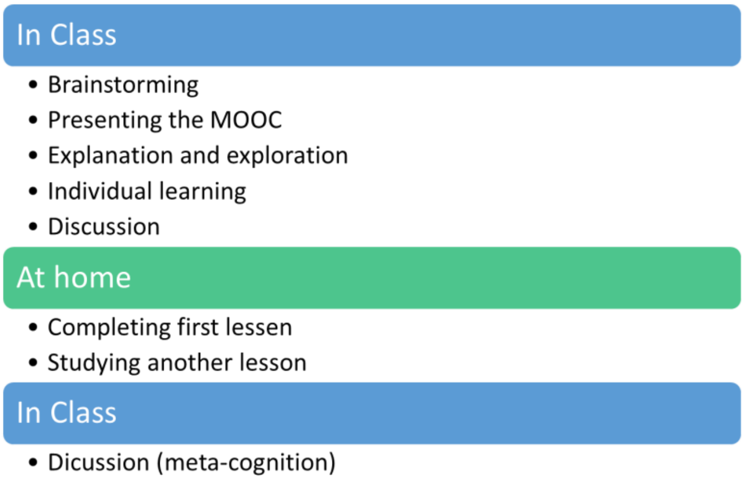

Figure 6 - Graphic representation of the "MODEL N° 3: A FORETASTE OF MOOC" usage pattern.

3.3.1 MODEL N° 3A: A foretaste of MOOC at a University

Tested by Czech Technical University in Prague

The model has been tested by the Czech Technical University in Prague in the class "General Chemistry" for students of Nuclear Chemistry (1^{st} semester).

Detailed description

- **TARGET GROUP**: Students of Nuclear Chemistry.
- **KNOWLEDGE ENTRY REQUIREMENTS:** The activity is designed for students at the beginning of their studies, with some knowledge from high schools.

- **NUMBER OF PARTICIPANTS**: 20
- **LEARNING OUTCOMES**: students will get familiar with a MOOC as a tool useful for self-education; fulfilling the lesson "Natural radioactivity" and choosing another lesson to study at home.
- **LOCATION:** Students started the activity at the classroom and they finished the work at home.
- **DIDACTICAL TOOLS:** Discussion: After working with MOOC, students shared with teachers and other students their feelings about MOOC and learned topics.
- **TECHNICAL TOOLS: -**

Model-application peculiarities

PERIOD: By the end of the semester (before the Christmas Holidays). During this time, students don't have classes: a semester is finished and they can have more time for this activity.
DURATION: 60-90 minutes in class + homework + talking about it during the exam.
PEDAGOGICAL FRAMEWORK: -
SESSIONS NUMBER: 1
ESTIMATED EFFORT FOR STUDENTS: 2 hours
BADGE / CERTIFICATE: No

Comments

At the university, we recommend using the course in combined education, i.e. as part of self-study, students are assigned a specific topic(s) to study, which will then be discussed together during face-to-face teaching, or students will solve problem tasks based on the acquired knowledge from the MOOC course (flipped class model, flipped classroom). This model was successfully verified in selected lessons with 1st-year bachelor students in the field of nuclear chemistry in the subject General Chemistry.

The second option is mastering the issue (e.g. selected radioanalytical methods) before entering the radiochemical practice. Before starting the laboratory work, students can be tested on their understanding of the topic and principles (blended-learning, the term is usually not translated into Czech). This method saves time, money and the professional capacity of educators, who do not have to explain the theoretical principles in front of everyone during the internship.

3.3.2 MODEL N° 3B: A foretaste of MOOC at school

Tested by Gymnázium Altis in Prague

The model has been tested by Gymnázium Altis in Prague in the Seminar of Chemistry – (16-19 years-old pupils).

Detailed description

- **TARGET GROUP**: Pupils of a high/grammar school
- **KNOWLEDGE ENTRY REQUIREMENTS:**
- **NUMBER OF PARTICIPANTS**: 10

- **LEARNING OUTCOMES**:
  - Students will get familiar with principles of a MOOC in general (one of the modern forms of self-education).
  - Students will know how to use a MOOC and all prepared topics.
  - Students will fulfill a lesson “Natural radioactivity” and voluntarily another lesson based on their interest.
- **LOCATION:** Students started the activity at the classroom and they finished the work at home
- **DIDACTICAL TOOLS:** Discussion: After working with MOOC, students shared with teachers and other students their feelings about MOOC and learned topics.
- **TECHNICAL TOOLS: -**

Model-application peculiarities

PERIOD: During the regular school year.
DURATION: 2 sessions 45 minutes in class + homework
PEDAGOGICAL FRAMEWORK: -
SESSIONS NUMBER:
ESTIMATED EFFORT FOR STUDENTS: 3 hours
BADGE / CERTIFICATE: No
CHRONOLOGICAL PHASES:

Brainstorming phase - questions:

1. What are the possibilities of self-education?

Students’ answers: textbooks, books, Internet, youtube, … (most frequent)

2. What can you do for best learning of something new?

Students’ answers: practice/applied theoretical knowledge in tasks, discuss it with friends/parents/teachers, find quizzes on the internet, own experience (working in company/visiting some places, travelling), …

2. Have you ever heard about MOOC?

Students’ answers: No -

Discussion phase - questions:

A. What do you like on MOOC?

Clear orientation throughout the course, varied materials, interesting links and the possibility of enlarging images/graphs for better study and understanding, ongoing quizzes providing feedback.

B. What was hard for you? How to overcome the hard part (students’ suggestions)?

Some difficult concepts appeared during the course – some of them were soon explained (in the next paragraph/lesson); too much new information and concepts.

It can be solved by dividing the working time on the MOOC into several shorter intervals (so the students can better fixate, think and understand the concepts) or writing notes while working on the MOOC. This helped the pupils to better orient themselves in the topics and also choosing the important information/terms/principles helped them to create a "backbone" for better understanding of topics and seeing relationships within lessons.

In some videos, the spoken text was difficult to understand - the pupils solved this difficulty by using the transcript and translating/looking up unknown words.

Comments

Regardless of the type of school or personal interest in completing the entire course or selected parts, we recommend to go through the first module Natural radioactivity, where radiochemistry, the nucleus of an atom, types of radioactive transformations and their characteristics, the law of radioactive transformation and transformation series are presented, as well as other concepts to help understand the following lessons. This chapter also mentions the issue of radon, which is very topical in the Czech Republic. Radon contributes 50% to the total exposure of the Czech population, within the framework of natural sources of ionizing radiation it even has a share of 70%.

As part of high school teaching, the course was verified during face-to-face teaching and as part of self-study in a chemistry seminar with pupils of the 6th and 7th years of an eight-year high school. When using the MOOC, the students particularly highlighted the clear orientation throughout the course, varied materials, interesting links and the possibility of enlarging images/graphs for better study and understanding. If a difficult concept appeared during the course of study, it was soon explained, according to the students. They also appreciated the ongoing quizzes providing feedback. They identified as a challenging component that sometimes there was too much new information and concepts. This can be solved by dividing the working time on the MOOC into several shorter intervals, so that the students can better fixate, think and understand the concepts. In some videos, the spoken text was difficult to understand; the pupils solved this difficulty by using the transcript and translating/looking up unknown words. In conclusion, we would recommend guiding students to write small notes while working on the MOOC. These helped the pupils to better orientate themselves in the topic and gain insight into the topics presented.

3.4 THE MOOC USAGE MODEL PROMOTION

The MOOC and its associated usage models have been actively promoted through various channels and events to disseminate their benefits and encourage their adoption among educators.

A dedicated poster titled "How to use a MOOC in radiation chemistry: a toolkit for teachers" (Figure 7) was showcased at The Miller Online Workshop on Radiation Chemistry, held from 10th to 12th February 2022. This poster served as an informative visual representation of the MOOC and its associated teaching toolkits, further enhancing their visibility and reach within the academic community.

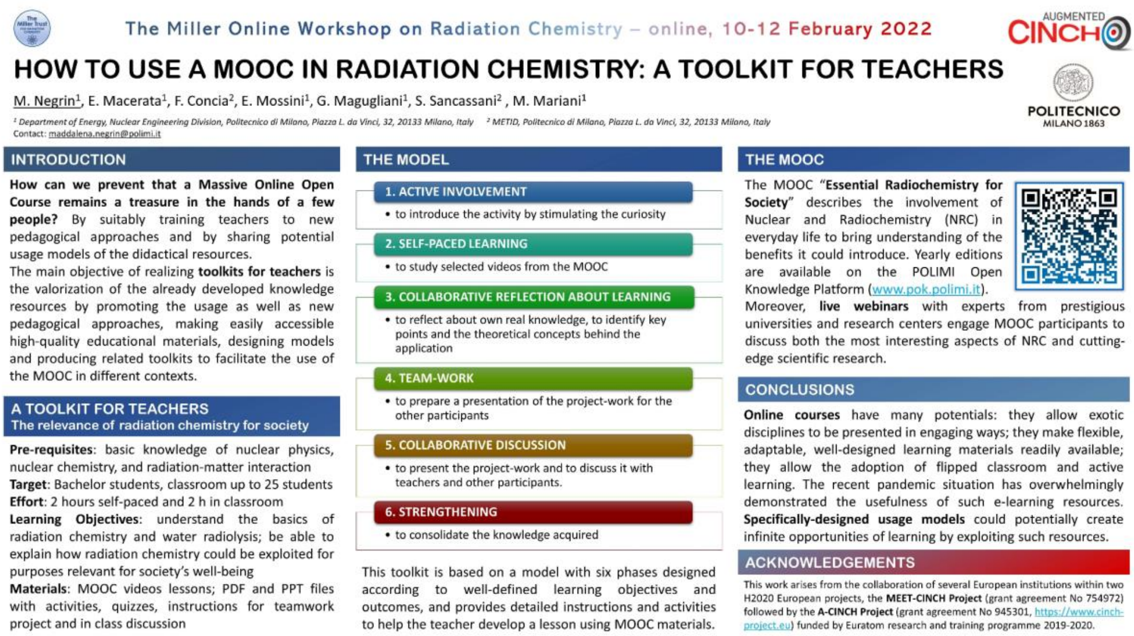

Figure 7 - Poster "How to use a MOOC in radiation chemistry: a toolkit for teachers" presented at the Miller online conference, February 2022.

A second significant promotional effort included the presentation of the first two models at the Second International Conference on Applications of Radiation Science and Technology (ICARST-2022), organized by the International Atomic Energy Agency (IAEA) in Vienna in August 2022. During this event, an engaging oral presentation titled "How to Attract New Students to Nuclear and Radiochemistry: The MOOC Experience" was delivered, providing insights into the effective use of the MOOC in teaching practices.

4 CONCLUSIONS

In this document, we have embarked on a journey through innovative usage models designed to harness the full potential of the MOOC "Essential Radiochemistry for Society", designed for Bachelor students in the scientific area. As a valuable resource for radiochemistry educators, this MOOC has been at the heart of a transformative pedagogical exploration. The aim has been to empower teachers with versatile strategies for integrating the MOOC into their teaching practices, thereby elevating the learning experiences of their students.

The exploration starts with "MODEL N° 1: MOOC and MORE," which introduces a multifaceted approach, encouraging students not only to consume the MOOC's content but also to critically engage with it and apply their knowledge in designing dissemination events. This model exemplifies the power of active learning and demonstrates the impact of holistic educational experiences.

"MODEL N° 2: FLIPPING THE MOOC" provides an alternative perspective by flipping the traditional classroom. Here, students engaged with MOOC content before in-person classes, fostering self-directed learning and deeper interactions with course materials. This model showcases the adaptability of the MOOC in accommodating diverse teaching methodologies.

Finally, "MODEL N° 3: A FORETASTE OF MOOC'' offers a unique prelude to the MOOC's content, stimulating curiosity and interest among students. Whether at the university level or in school settings, this model exemplified the potential of the MOOC in igniting a passion for radiochemistry and science.

These models, drawn from real-world case studies, exemplify the MOOC's versatility and adaptability across different educational contexts, objectives, and student profiles. They serve as invaluable tools for educators seeking to enrich their teaching practices and cater to the diverse needs of their students.

In a world where education is continually evolving, and learning paradigms are shifting, the MOOC "*Essential Radiochemistry for Society*" stands as a beacon of innovative pedagogy. Educators are encouraged to explore, adapt, and embrace these usage models to create dynamic, engaging, and effective learning experiences. As the educational landscape continues to transform, let these models inspire us to unlock new horizons in radiochemistry education, fostering a generation of learners equipped to shape the future of science and society.

5 BIBLIOGRAPHY

[1] Stracke, C. M., Downes, S., Conole, G., Burgos, D., & Nascimbeni, F. (2019). Are MOOCs Open Educational Resources? A Literature Review on History, Definitions and Typologies of OER and MOOCs. *Open Praxis*, *11*(4), 331-341.

[2] D. Andone and V. Mihaescu, "Blending MOOCs into Higher Education Courses-A Case Study," *2018 Learning With MOOCS (LWMOOCS)*, 2018, pp. 134-136, doi: 10.1109/LWMOOCS.2018.8534606.

ANNEX 1

This is a comprehensive overview of the results obtained from the first survey, reflecting the active participation and insights of the partners who participated in the MOOC experiences.

Table A1 - Countries distribution of the Partners who participated.

COUNTRIES	
Oslo	2
Lubljana	2
Cyprus	1
Helsinki	1

Table A2 - Classes distribution of the MOOC experience.

CLASSES	
Physics of neutron radiation devices	1
Radioactivity - KJM3900/4900	1
Environmental Chemistry-Radioactivity	1
Basic radiopharmaceutical chemistry	1
Medical application of nuclear physics	1
Tools for environmental quality control	1

Table A3 - Students' age distribution.

STUDENTS' AGE	
<18	0
19/21	1
22/25	5
>26	0

Table A4 - Students' number who participated to the class.

STUDENTS' NUMBER	
<20	6
20-35	0
36-60	0
>60	0

Table A5 - Students' background knowledge

STUDENTS' BACKGROUND	
T+C43hey come from high school and have limited knowledge in the field of chemistry and physics.	0
They attend their second year of university studies, but have limited knowledge of chemistry and physics.	0
They attend their third year of university and have passed exams in mathematics and chemistry.	1

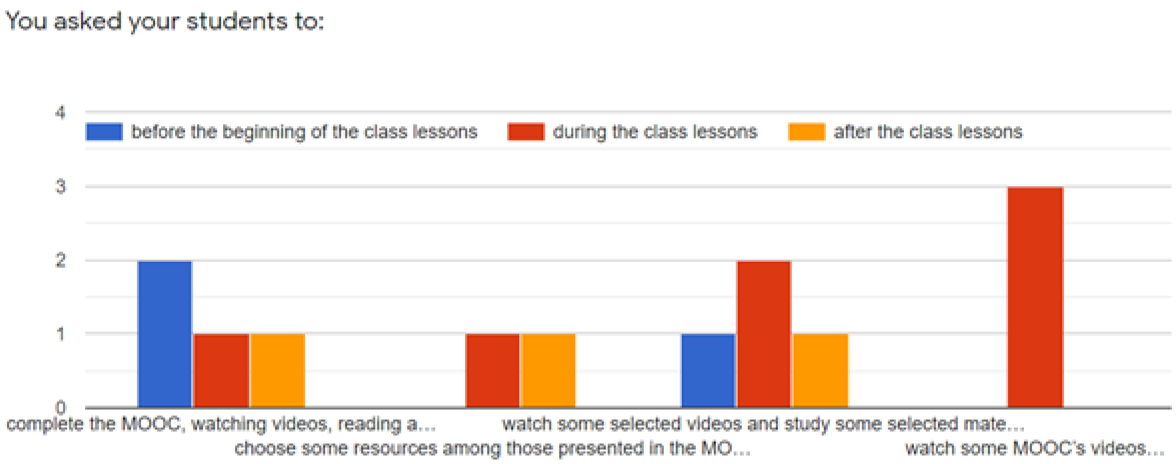

Figure A1 - Distribution on how the MOOC was used for the class

ANNEX 2

The usage models are available at this links:

https://drive.google.com/drive/folders/1Yz93cfNkANcV1ig84NeD2zjhLyyLqrZ1?usp=drive_link

MODEL 1_ EN

https://drive.google.com/file/d/1S3zWKkLiV5QnKwz4m63bWwFRc1JpfRHo/view?usp=drive_link

MODEL 1_IT

https://drive.google.com/file/d/1SNbi28mD8GjzPOHK8qlq28o0CXkPwww-/view?usp=drive_link

MODEL 1_PT

https://drive.google.com/file/d/14BtBFcmbYFc5yyXKJMKFWoY8YwkrqqUf/view?usp=drive_link

MODEL2_EN

https://drive.google.com/file/d/1F3OFQHTDqtXZeYPAHIKTPk8rTG5tOuZz/view?usp=drive_link

MODEL2_IT

https://drive.google.com/file/d/1_NE7tRIIyxd3UkB4DgiIzGXSobX2q1KM/view?usp=drive_link

MODEL 3_EN

https://docs.google.com/document/d/1go48ResB3kS4NtGY2fPLTa3PaM784N0g/edit?usp=drive_link&ouid=109577209982758382432&rtpof=true&sd=true