Deliverable D6.5

MOOC on the basis of *In the Heart of Medical Radioactivity*

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0.9	26.10.2023	Thierry Stora	Review by the coordinator
1.0	27.10.2023	Kirsten Leufgen	Final version, approved by the coordinator

Contents

Abbreviations, Participant short names

Abbreviations

ANR	Agence Nationale de la Recherche
FAQ	Frequently Asked Questions
FDG	fluorodeoxyglucose
FUN	France Université Numérique
IAEA	International Atomic Energy Agency
ISI-NucMed	Interdisciplinary School in Nuclear Medicine
MOOC	Massive Open Online Course
PET	Positron Emission Tomography
SPIN	Service de Production et d'Innovation Numérique

Participant short names

CERN	European organization for nuclear research
NPL	National Physical Laboratory
PSI	Paul Scherrer Institut
CEA	Commissariat à l'énergie atomique et aux énergies alternatives
IST-ID	Associação do Instituto Superior Técnico para a IST-ID Investigação e Desenvolvimento
DTU	Danmarks Tekniske Universitet
CHUV	Centre hospitalier universitaire vaudois
GANIL	Grand Accélérateur National d'Ions Lourds
SCK CEN	Studiecentrum voor Kernenergie / Centre d'étude de l'énergie nucléaire
ARRONAX	Groupement d'intérêt public ARRONAX
ESS	European spallation source ERIC
TUM	Klinikum rechts der Isar der technischen Universität München
KULeuven	Katholieke Universiteit Leuven
MedAustron	Entwicklungs- und Betriebsgesellschaft MedAustron GmbH
SCIPROM	SCIPROM Sàrl
MUI	Medizinische Universität Innsbruck
ILL	Institut Max von Laue - Paul Langevin
JRC	JRC -Joint Research Centre- European Commission
NCBJ	Narodowe Centrum Badań Jądrowych
GSI	GSI Helmholtzzentrum für Schwerionenforschung GmbH

LU	**Latvijas Universitāte**
INFN	**Istituto Nazionale di Fisica Nucleare**
UiO	**Universitetet i Oslo**

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Summary

This document presents the Massive Open Online Course (MOOC) entitled ***At the heart of European medical radioactivity*** proposed by PRISMAP to PhD students, young researchers and to professionals working in nuclear medicine and related disciplines.

This pedagogical tool is an extension of the MOOC *At the heart of medical radioactivity* produced by Nantes Université (France) and presents in different steps the interest of medical radioactivity, from the conception of a radiopharmaceutical drug to its use in patients.

The MOOC *At the heart of European medical radioactivity* will be hosted on the ExtraDoc tool of Nantes Université, with an access link in the Educational Resources page of the PRISMAP website. It was published on the ExtraDoc platform and linked to the PRISMAP website on 27 Sep 2023.

Participants will have access to resources, mainly videos and quiz. If a quiz is successful, the participant will be granted an "Open Badge" that demonstrates that they have followed and validated that section of the MOOC.

Additional educational content will be generated during the various thematic schools organized or supported by PRISMAP throughout the project, allowing state-of-the-art aspects to be presented as highlights. The MOOC will therefore continue to evolve beyond the initial deployment phase.

This MOOC is complementary to other educational materials provided by PRISMAP on its website, such as the video on the production of radionuclides via mass separation, produced by KU Leuven, and the video on translational research with emerging radionuclides, produced by SCK CEN.

1. Objectives

1.1 Target audience

The MOOC ***At the heart of European medical radioactivity*** is intended for PhD students and young researchers in nuclear medicine and for professionals working in related disciplines across Europe.

It provides participants with a common knowledge base essential for a proper understanding of the concepts, activities and challenges of nuclear medicine, a multidisciplinary field based on physics, chemistry, biology, pharmacy, digital sciences, etc.

It will be strongly suggested to people wishing to participate in a PRISMAP thematic school to have previously followed the MOOC.

The broad nature of the content may make it relevant to users beyond Europe as well. This possibility is being considered together with the IAEA, in the framework of their programme to train nuclear medicine specialists in developing countries.

1.2 Monitoring indicators

- Evolution of the number of registered participants
- Evolution of the number of certified participants
- Evolution of the number of questions received from participants

2. Technical challenges and solutions

2.1 Background: In the Heart of Medical Radioactivity

Figure 1: Logo of the original MOOC At the Heart of Medical Radioactivity.

Under the hospices of France Université Numérique (FUN), an online platform hosted at the French national level, a Massive Open Online Course (MOOC) with title *In the Heart of Medical Radioactivity* had been developed in France by Nantes Université in partnership with LabEx IRON and Agence Nationale de la Recherche (ANR) (see Figure 1). This MOOC, coordinated by Caroline Bodet-Milin and Mickaël Bourgeois, and piloted by Marie-Hélène Gaugler and the Service de Production et d'Innovation Numérique (SPIN) of Nantes Université, was launched in 2019, one year after the French version. It presents in different sections the interest of medical radioactivity, from the design of a radiopharmaceutical drug to its use in the patient.

This MOOC was open on the FUN online course platform from February 25 to May 5, 2019. A total of 291 students have attended this MOOC. However, it has since been discontinued and is no longer running. The original ambition to review this MOOC and expand on it was thus no longer possible.

After some negotiations, most of the material from the original MOOC could be reused to populate an entirely new MOOC, but additional material had to be produced to replace part of the content, as well as to complement the MOOC with information of relevance within PRISMAP. The author, institution, and year of creation of every content will be clearly indicated in the caption of each video.

For the production of new material, synergies with other activities supported by the PRISMAP Training Office were explored, such as the schools organised by PRISMAP in SCK CEN and DTU, or the Interdisciplinary School in Nuclear Medicine (ISI NucMed) organised by ARRONAX and Nantes Université.

One of the many issues faced by this change of organisation, was that the MOOC could no longer be hosted by FUN. Different options were considered, until finally the ExtraDoc platform provided by the Nantes Université was selected.

2.2 ExtraDoc tool

ExtraDoc is an online Moodle course facility proposed and hosted by Nantes Université. It contains course spaces hosting training content. Various layout options are available to provide an interface for access to content that is as ergonomic and as adapted as possible to the target audience, see Figure 2.

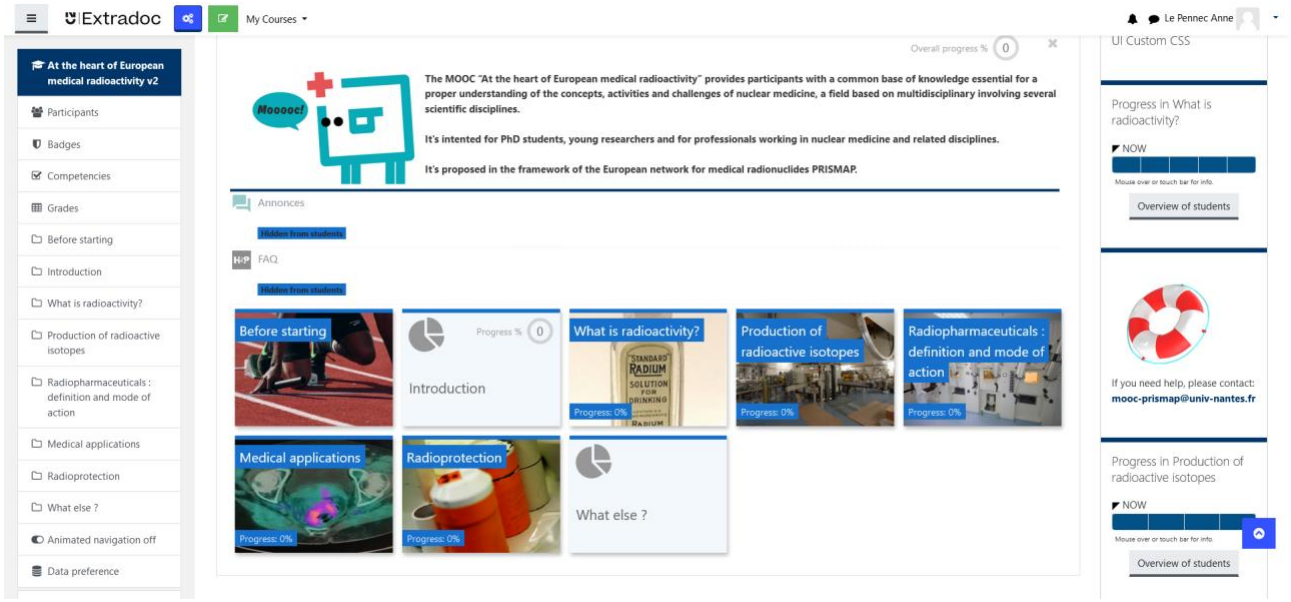


Figure 2: Overview of the PRISMAP MOOC content on the ExtraDoc platform.

ExtraDoc makes it possible to offer subtitled and chaptered videos, documents of all formats and evaluation tests. The platform can also deliver Open badges attesting to the content seen and the evaluations passed by the participant.

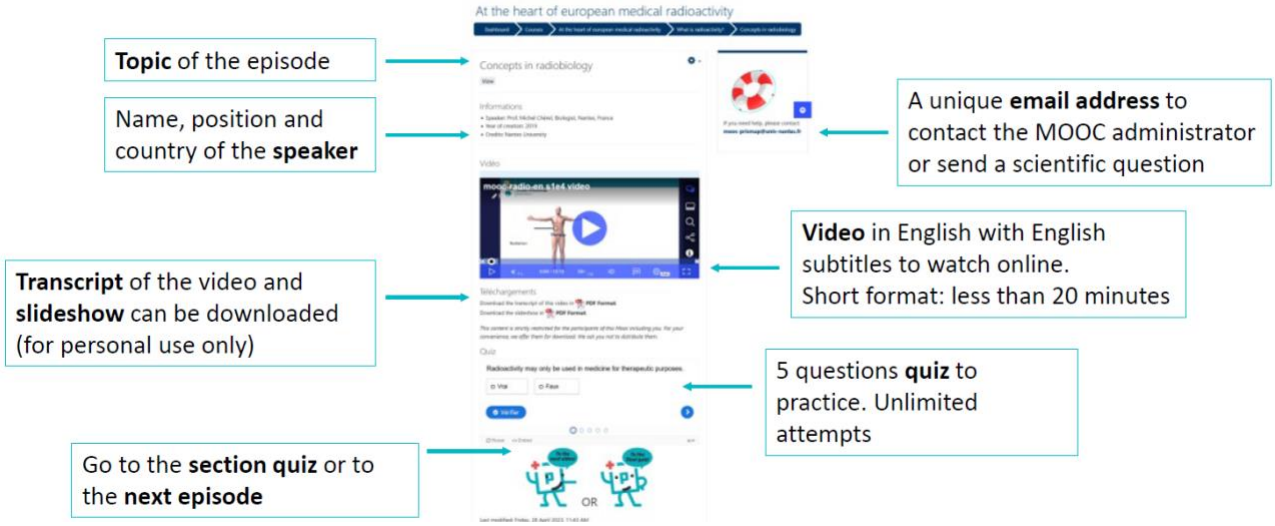
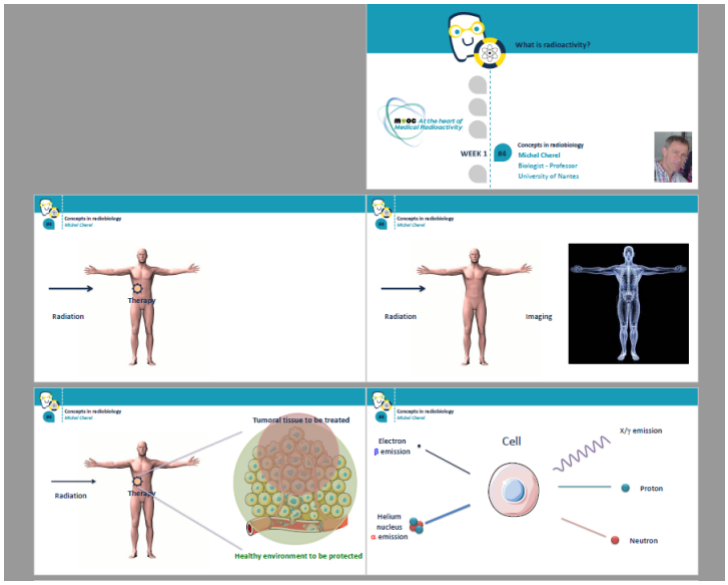


Figure 3: Example of material content on the ExtraDoc platform.

On the ExtraDoc platform, an episode consists in the following material, highlighted in Figure 3:

- The topic of the episode at the top of the viewer.
- Information about the lecturer.
- A video in English with subtitles, providing the information about the episode.
- A transcript of the video and the associated slideshow, which can be downloaded for offline studies. An example is shown in Figure 4.
- A quiz containing 5 questions for which the participants have an unlimited number of attempts and with which they can practice.



MOOC « At the heart of medical radioactivity »

WEEK 1
Concepts in Radiobiology

Teacher : Michel Chérel

Slide 1 Hello my name is Michel Chérel. I am a biologist and a research professor at the University of Nantes in the nuclear medicine department. I am hoping to give a little more enlightenment about radiobiology.

Slide 2 At the end of this first week you now know that in the medical field, emitted radiation from radioactivity allows diseases to be treated with a certain efficacy.
In addition to this therapeutic aspect,

Slide 3 radiation can also be used to visualize the inside of a human being. This is the field of medical imaging.

Slide 4 Regarding the therapeutic aspect,
the general objective is always the same. It aims to treat the disease,
typically a tumor, avoiding of course
damaging the healthy tissue or the entire environment of the tumor.

Slide 5 Now you know that radiation is an energy radiated in the form of waves or particles and that there are several types of radiation. We have mainly gamma or X-ray emissions that will allow us to make images, and different particles like electrons or so-called beta emissions that will be widely used in the protocols of radioimmunotherapy, as you will see later in this MOOC, protons, neutrons, and finally nuclei of helium named alpha particles from helium nuclei. These different emissions will be directly or indirectly ionizing if the energies are sufficient to transform the atoms of the targeted tissues into ions.

Slide 6 These different types of radiation can interact with matter and, for example, with the different constituents of a living cell. The question, and the real question, is what effects will these radiation-cell interactions have?

Slide 7 The science which studies the biological effects of radiation and in particular ionizing radiation, is called radiobiology.

Slide 8 To reiterate, the interaction of radiation with matter will generate what are called ionizations.

Figure 4: (Left) Extract of a slideshow. (Right) Transcript of a video

Contact with the MOOC administrator is centralised to an address that can easily be monitored and transferred if necessary: mooc-prismap@univ-nantes.fr.

2.3 Access

2.3.1 Via the PRISMAP website

A dedicated link on the PRISMAP website under the Educational Resources gives direct access to the MOOC from the PRISMAP interface towards ExtraDoc, where the participant may access with their own credentials (see Figure 5 for details).

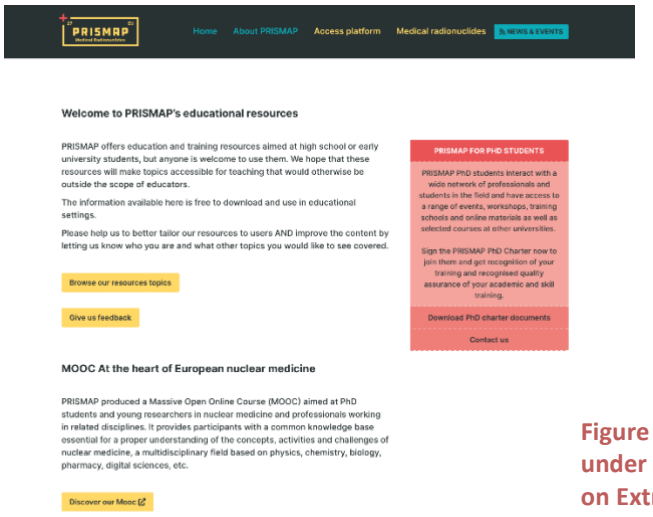


Figure 5: (Left) Access to the MOOC from the PRISMAP website, under Educational Resources. (Right) Login page for the MOOC on ExtraDoc.

2.3.2 User account creation

People interested in following the MOOC must create an account on Extradoc, see Figure 6 (Left). The creation of an account is done at this URL: https://extradoc.univ-nantes.fr/login/signup.php. Once their account is created, people can freely register to the MOOC. A registered account will remain open for a

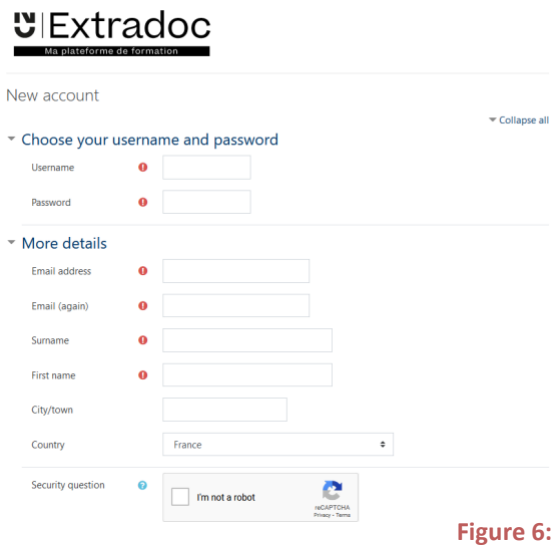


Figure 6: (Left) ExtraDoc account creation page. (Right) Registration page for the MOOC.

limited time (6 months). After this period, the codes are no longer valid.

2.4 Certificate of completion

At the end of their training, participants can obtain an Open Badge. This is an image in which verifiable and secure information about the activities performed is recorded. It certifies that the participant answered successfully at least 8 out of 10 questions from the final quiz. Each participant has only 2 attempts to earn a badge, beyond which the badge cannot be earned.

Figure 7: Badges that may be earned over the PRISMAP MOOC.

This digital badge makes visible the skills developed and embeds the work produced during the MOOC. The badge can be digitally shared. Given the multidisciplinary nature of this MOOC, multiple Open Badges may be obtained, see Figure 7, organised according to the thematic sections of the MOOC. A participant may earn all of them, or none of them, or just some of them, according to their interest and success.

3. Content of the MOOC

3.1 Existing material

The new MOOC has been produced by ARRONAX with graphical support by SCIPROM, with title ***At the heart of European medical radioactivity***. The MOOC is divided into 23 episodes, distributed across an introductory part and 5 thematic sections.

3.1.1 Introduction

- History of nuclear medicine
- Medical uses of ionising radiation

3.1.2 What is radioactivity?

- Journey to the heart of matter
- The origins of radioactivity
- The different types of radioactivity
- Concepts in radiobiology

3.1.3 Production of radioactive isotopes

- Cyclotron production: the example of Fluorine-18
- Cyclotron production: the example of Astatine-211
- Generator production: example of metastable Technetium-99

3.1.4 Radiopharmaceuticals: definition and mode of action

- What is a radiopharmaceutical?
- How radiopharmaceuticals work: the concept of molecular targeting
- Radiopharmaceuticals for diagnostic applications
- Radiopharmaceuticals for therapeutic applications

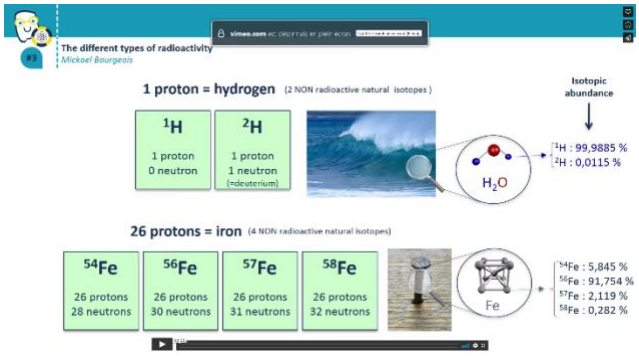
3.1.5 Medical applications

- Patient pathway – Diagnostic tests in conventional nuclear medicine: an example of bone and myocardial scintigraphy
- Patient pathway – Diagnostic tests using positron emission tomography: example of FDG PET
- Patient pathway – Therapeutic applications: an example of Iodine-131 radiotherapy
- Contribution of nuclear medicine to personalised medicine
- Contribution of nuclear medicine to the management of breast cancer
- Use of ionising radiation in external radiotherapy

3.1.6 Radioprotection

- Radiation protection: regulatory framework and theoretical data
- Practical radiation protection
- Perception of radioactivity, theoretical data

- The hospitalisation experience in a shielded room of patients with thyroid cancer treated with Iodine-131



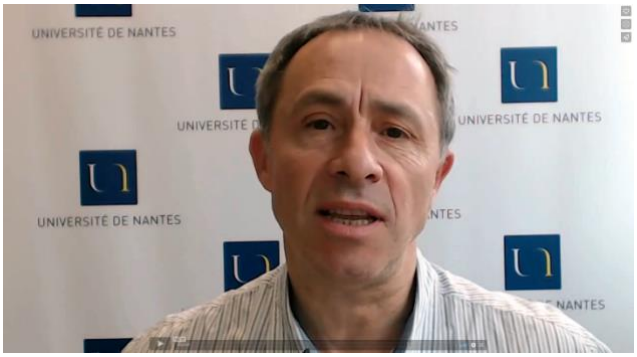


Figure 8: Sample of the video material composing the MOOC *At the Heart of Medical Radioactivity* designed by Nantes Université, and reused in the new MOOC *At the heart of European medical radioactivity*.

3.2 Additional material

In order to better represent the state of the art, some episodes will be replaced by more recent videos, bringing similar content to the participants but applying them to a more modern case, or relating to the PRISMAP expertise. For example, the storyline on I-131 could be replaced by Lu-177, which is applied to novel therapies but follows otherwise a similar pathway for production and therapy.

We will also exploit the effort put into the PRISMAP thematic schools to identify novel material that could be used to expand the MOOC to include the latest developments in each thematic section. Already 10 new episodes are being considered:

- New storyline based on Lu-177, with 1 episode on its production and 1 episode on its use for therapy.
- 1 episode on mass separation of radionuclides with the case study of Sm-153 and Ac-225.
- 1 episode on theranostics with radiolanthanides, based on the work of WP12 and the DTU school.
- 1 episode on targeted alpha therapy, either using At-211 to link with its production, or using Ac-225.
- 2 episodes on nuclear data (half-lives & branching ratios, cross sections) and their relevance to medical radionuclides, either for production or for their use in medical applications, based on the work of WP11.
- Upgrading the thematic section on *Radioprotection* to *Safety, Dosimetry, and Logistics* with 3 episodes concerning transport (link to WP9), waste management (Lu-177/Lu-177m, Ac-225/Ac-227), and alpha particle dosimetry (from ISI NucMed thematic school)

3.2.1 Production

WP6 is responsible for considering and deciding whether to add new episodes. New ideas may be proposed by the members of WP6, in particular in relation to the themes dealt with during the PRISMAP thematic schools, or on the proposal of PRISMAP members or MOOC participants. In addition to the scientific interest of the theme, particular attention will be paid to ensuring that it complements the existing episodes and respects the architecture of the MOOC. Once the new topic has been validated, PRISMAP experts are identified and asked to prepare and record the episode. Technical support may be provided by WP6 participants.

3.3 FAQ

Participants can ask questions using this dedicated email address: mooc-prismap@univ-nantes.fr. These questions will be used to setup a FAQ.

3.4 Evaluation

There are two different stages of evaluation. A quiz is provided for each episode, which can be tried several times for training purposes. At the end of each thematic section there is a 10-question quiz where you can earn the associated Open Badge if you score at least 8/10; each participant has only two attempts at each badge. Sample questions are presented in Figure 9.

The quiz material is proposed by each lecturer during the production of their episode. Based on this, the thematic quiz are produced to have a balanced coverage of the material from the entire thematic section.

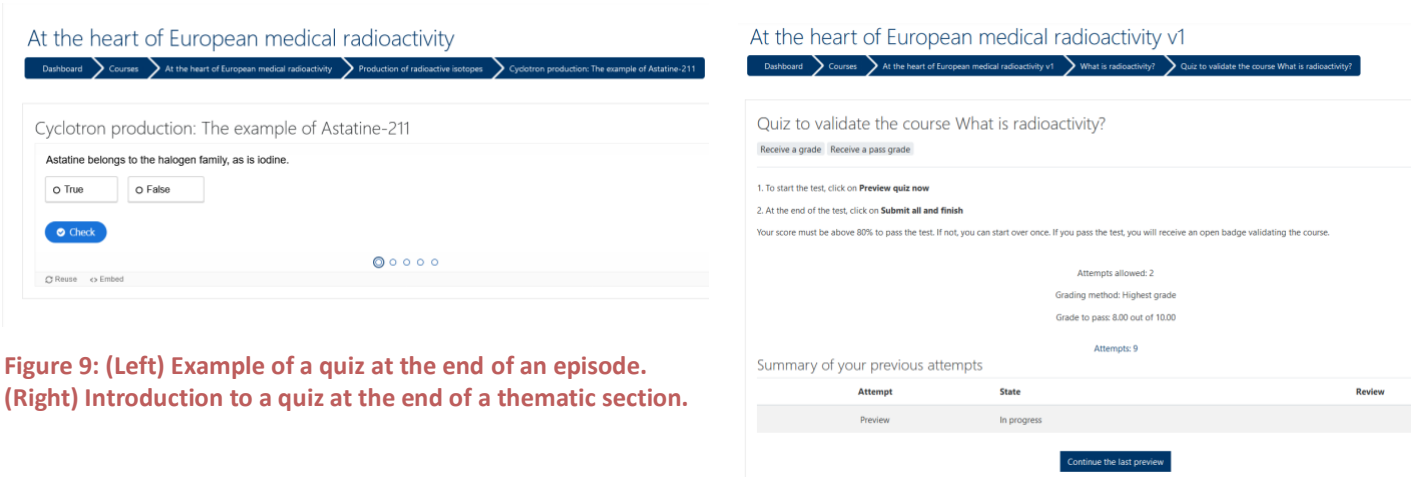


Figure 9: (Left) Example of a quiz at the end of an episode. (Right) Introduction to a quiz at the end of a thematic section.

4. Timeline from the production to the deployment

4.1 Development phase

From June 2022 to February 2023, the new MOOC was developed, including finding solutions to the technical challenges presented in section 2:

- Creation and setting of the MOOC environment on the ExtraDoc platform with the support of Nantes Université.
- Populating the existing content on the platform, including for each the evaluation material.
- Creation of the necessary missing content for the launch of the MOCC.

- Integrating the PRISMAP visual identity into the MOOC

The PRISMAP visual identity was introduced into the material using Clyde, the animated logo for PRISMAP. A new version of Clyde was specifically designed by SCIPROM to promote the MOOC, see Figure 10.

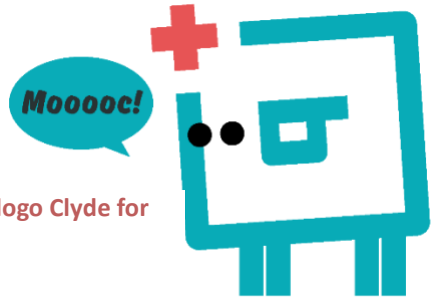


Figure 10: New version of the animated logo Clyde for the promotion of the MOOC.

4.2 Pilot project

In April 2023, a pilot project was launched, inviting a limited number of participants to follow the MOOC. The target audience was the local student population in Nantes and potential participants to the ISI NucMed 2023 edition. Three non-European participants were also invited to participate, selected by the IAEA, to explore the potential interest of this MOOC for their training programme in developing countries.

Through this pilot project, we aimed at the following:

- Exploring the technical aspects (registration, visualisation of the videos, miscellaneous questions).
- Collecting questions for the lecturers in the centralised mailbox, writing the answers, and populating the dedicated section on ExtraDoc.
- Initiating a communication campaign about the MOOC.
- Evaluating the participation according to the number of participants, the number of Open Badges, and the number of questions received.

This pilot programme was publicised and discussed at the occasion of the PRISMAP Consortium Meeting 5 in Roskilde, Denmark, in June 2023. An extended presentation with discussion was animated by Anne Le Pennec (ARRONAX) in a closed session, and she made a further contribution during the public panel discussion on the new PRISMAP services.

The pilot programme ran until 7 July 2023. Out of the 6 participants, 5 finished the MOOC and a total of 28 badges were earned. Furthermore, an exit questionnaire was used to gain feedback from the participants. Four of them answered the exit questionnaire (return rate: 66%) and expressed their high satisfaction with the quality of the MOOC's content, its scientific and educational interest, the evaluation process and the user-friendliness. This feedback also led to the correction of a number of bugs and the integration of a progress monitoring tool. The limited number of participants in the pilot did not allow to complete the FAQ page, which will rather be deployed as questions come from a larger and more diverse audience.

4.3 Deployment

The MOOC was officially launched on Wednesday, 27 Sep 2023 and linked to the PRISMAP website, under Educational Resources. The MOOC was announced on the PRISMAP social media, and via the consortium. It will also be announced in the next PRISMAP newsletter and regularly promoted through these channels.

5. Conclusions

The preparation of the MOOC *At the heart of European medical radioactivity* proved to be more challenging than expected, as it had to be re-created. Much of the content could be taken from an original MOOC at the Nantes Université, but most of the technical aspects had to be worked out from scratch.

The MOOC was successfully introduced as a pilot project over the spring 2023 and explored by 6 participants.

The MOOC is thus now ready for full deployment to the entire community. In the coming years, additional episodes will be added to the MOOC to reflect the expertise and interests from PRISMAP, ensuring that this MOOC remains at the state of the art and maintains its relevance for many generations of scientists to come.

Its structure also allows its use for targeted activities in transdisciplinary training, hereby supporting the ambitions of the PRISMAP Training Office.