Project title: Radiation risk appraisal for detrimental effects from medical exposure during management of patients with lymphoma or brain tumour (SINFONIA)

Grant Agreement: 945196

Call identifier: NFRP-2019-2020

Topic: NFRP-2019-2020-14 Improving low-dose radiation risk appraisal in medicine

Deliverable D6.1 - Report on dosimetry, radiobiology and radiation protection education in the field of medical imaging and radiation oncology

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Work Package:	6
Delivery as per Annex I:	Month 12 (31.08.2021)
Actual delivery:	Month 20 (30.04.2022)
Type:	Report
Dissemination level:	Public

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Table of Contents

1. Introduction

Deliverable 6.1 is part of Task 6.1 “Evaluation of dosimetry, radiobiology and radiation protection education for clinicians, medical physicists and other healthcare professionals”.

An online survey was conducted to gather information on the dosimetry, radiobiology and radiation protection courses in the current academic and professional study programs of radiologists, nuclear medicine physicians, radiation oncologists, medical physicists and other healthcare professionals throughout Europe.

The main aim of the survey was to identify potential differences in course content, learning outcomes, teaching and evaluation methodologies. In addition, the impact of the COVID-pandemic on the latter courses was investigated.

The survey specifically targeted the organisers and lecturers of these dosimetry, radiobiology and radiation protection courses.

2. Methodology: online survey

The EU-wide survey was set up using the LimeSurvey online survey tool (https://www.limesurvey.org). The survey is available on the website https://www.enquete.ugent.be/survey322/index.php/425553?lang=en .

The questionnaire collects information on

- **the respondents**: country, profession, affiliation, …

- **the courses on dosimetry, radiobiology and radiation protection**:

    - course content, course material and study load
    - teaching and evaluation methods
    - an evaluation to what extent the course contributes to the *core topics* as identified in the “Guidelines on Radiation Protection Education and Training of Medical Professionals in the European Union” [1]
    - an evaluation to what extent the course contributes to the *learning outcomes* as defined in the “Guidelines on Radiation Protection Education and Training of Medical Professionals in the European Union” [1]
    - impact of the COVID-pandemic on the courses

The respondents had to specify the target audience for their dosimetry, radiobiology and/or radiation protection courses (radiologists, nuclear medicine physicians, medical physicists…). Moreover, respondents could indicate whether the course versions for different target audiences were different or not.

The learning outcomes used in this survey were based on the learning outcomes presented in the Guidelines on Radiation Protection Education and Training of Medical Professionals in the European Union” [1].

- 47 learning outcomes were included for the topic of (medical) radiation protection:
    - Explain and discuss the latest evidence of low-dose effects on workers (e.g. interventional radiologists)
    - Assess the cumulative effective dose for a series of exams for a given individual patient
    - Estimate organ doses and effective doses for commonly used examinations, based on measurable exposure parameters (KAP,DLP)
    - Principles of justification on a case by case basis, including asymptomatic patients and apply the three levels of justification in daily practice in particular, the justification of ionising radiation in case of pregnant women, children or breast-feeding mothers
    - The importance of using clinical information from previous examinations in the justification process Inform patient about benefits and risks of diagnostic and therapeutic procedures
    - Follow-up patients to check for the appearance of deterministic effects Explain concepts of patient dose measurements and dose calculations for commonly used modalities and procedures
    - Define ALARA and the concepts and tools for dose management of adult and paediatric patients
    - Investigate and manage accidental/unintended exposures
    - Explain the factors influencing image quality and dose in frequently used procedures
    - Apply radiation physics to select the optimal imaging modality and to optimise the protocols in order to obtain minimal exposure and the needed image quality level for the task
    - Use the technical features of the specific equipment and take advantage of all quality-improving and dose-reducing capabilities while recognising the limits of the machine
    - Explain concepts of staff dose measurements and dose calculations for commonly used modalities and procedures
    - Double check the appropriate protection measures when exposing a pregnant woman (size and positioning of the x-ray field, gonad shielding, tube-to-skin distance, correct beam filtration, minimising and recording the fluoroscopy time, excluding non-essential projections, avoiding repeat radiographs)
    - State how time, distance, shielding, monitoring and audit can be used to minimise dose received by staff, patients and public
    - Explain the relevant dose limits for the patient, worker, comforters, careers, and the general public
    - Describe the principles of radiation protection, as outlined by the ICRP
    - Surveillance of medical radiological devices and evaluation of clinical protocols to ensure the on-going radiation protection of patients and staff
    - Explain clinical consequences of administration to a pregnant patient or a patient becoming pregnant in the weeks following a radionuclide therapy
    - Carrying out, participating in and supervising everyday patient radiation protection and quality control procedures to ensure on-going effective and optimised use of medical radiological devices
    - Provide technical advice and participate in the specification, selection, acceptance testing, commissioning, installation design and decommissioning of medical radiological devices in accordance with the latest published European or International recommendations

    - Continuously check image quality to recognise and correct technical defects
    - Define DRLs and develop an organisational policy to keep doses to the personnel ALARA
    - Find and apply the relevant regulations and guidance for any clinical situation
    - Define QA and apply standards of acceptable image quality

  - Describe the principles and process involved in intravenous, oral, inhaled radiopharmaceutical administrations and misadministrations
  - Explain how a radionuclide dose should be administered such that no, or very little, residue is left within the dispensing device
  - Be able to prepare, manipulate and administer radioisotopes to patients while assuring prior and post-administration radioprotection measures
  - With good practice in mind, explain how a radioactive spill should be dealt with Explain the physical principles of how radionuclides can be generated and shielded
  - Explain the nature and sources of internal and external radiation exposure for workers and the public
  - Explain the principle and process of QA for non-imaging devices such as activity meters (dose calibrators) and probes
  - Explain the principle and process of QA of NM imaging devices, such as gamma camera, SPECT, PET (and their combination with CT)
  - Define target absorbed dose specification in external RT and brachytherapy
  - Recommend appropriate dose and fractionation schedules for curative and palliative external beam radiotherapy and brachytherapy treatments
  - Understand the purpose and importance of patient shielding, identify various types of patient shielding and state the advantages and disadvantages of each type
  - Identify the differences between continuous and pulsed fluoroscopy and use each mode when appropriate
  - Understand how patient position affects image quality and dose to radiosensitive organs
  - Explain the options for optimising patient dose from CT when using combined imaging modalities like PET/CT, SPECT/CT etc
  - Explain the concepts and tools for scaling activity in paediatric nuclear medicine procedures and apply it in clinical situations
  - Describe and apply general rules for working with unsealed radionuclides
  - Describe the key considerations relevant to radiation protection when designing a new facility
  - Describe and implement the regulatory requirements for the management and disposal of radioactive waste and the transportation of radioactive substances
  - Knowledge and understanding of Gross Target Volume (GTV), Clinical Target Volume (CTV), Planning Target Volume (PTV), Organs at Risk (OAR) and Dose-Volume Histograms (DVH) and be able to critically evaluate the dose distributions and DVHs
  - Perform treatment planning including 3D planning, virtual and CT simulation and apply these procedures to plan patients' treatments
- 16 learning outcomes were specifically linked to dosimetry:
  - Describe how X-rays interact with image detectors to produce an image.
  - Explain concepts of patient dose measurements and dose calculations for commonly used modalities and procedures.
  - Explain concepts of staff dose measurements and dose calculations for commonly used modalities and procedures.

  - List expected doses (reference person) for frequently used procedures.
  - Calculate organ doses and effective doses from frequently used procedures, based on measurable exposure parameters (KAP,DLP).
  - Describe the principles and process involved in intravenous, oral, and inhaled radiopharmaceutical administrations.

  - Understand biological and physical half-lives of the radiopharmaceuticals used for diagnostic and therapeutic procedures.
  - Describe and illustrate algorithms for 3D dose calculations.
  - Explain the concepts and tools for scaling activity in paediatric nuclear medicine procedures and apply it in clinical situations.
  - Explain the concepts of the MIRD scheme, including time-integrated activity in source region (cumulated activity) and time-integrated activity coefficient (residence time).
  - Calculate organ dose and effective dose from residence times, using tools such as OLINDA/EXM.
  - Be able to measure the daily entrance and exit dose and the dose level of critical organs.
  - Use an integrated dose meter (DAP) and compare the measured values against DRLs and/or threshold doses for deterministic effects in order to prevent deleterious effects on patients whenever possible.
  - Compare dose measurements (DAP, DLP, KAP, ESD, CTDI, glandular dose) readings to National or European DRLs and take appropriate actions in case of non-conformities.
  - List the different types of commonly used detectors, explain their function and their relative pros and cons.
  - Carry out in vivo dosimetry and dose calculations.
- 14 learning outcomes were used for radiobiology:
  - Describe the normal tissue, solid tumour and leukaemia systems.
  - Describe radiation effects on cells and DNA.
  - Describe radiation effects on tissues, tumours and organs.
  - Describe the differences between healthy tissue and tumours regarding the mechanisms of radiation response, repair and cell survival.
  - Explain cell survival curves.
  - Describe the types and magnitudes of radiation risk from radiation exposure as a function of patients' dose, age and prognosis.
  - Describe stochastic and teratogenic radiation effects and tissue reactions.
  - Describe the models of radiation-induced cancer.
  - Inform patients of their health problems and the planned procedure.
  - Inform patient about benefits and risks of diagnostic and therapeutic procedures.
  - Explain the effect of time-dose fractionation, Linear energy transfer (LET), different radiation modalities and the interaction between cytotoxic therapy and radiation.
  - Describe predictive assays in radiation therapy.
  - Explain the effects of oxygen, sensitizers and protectors in radiation therapy.
  - In particular, describe the radiation effects on adults, children and conception.

All 10 core topics of the previously mentioned guidelines were integrated in the survey as well:

- Atomic structure, X-ray production and the interaction of radiation with matter.
- Nuclear structure and radioactivity.
- Fundamentals of radiation detection.

- Biological effects of radiation.
- Risks of stochastic and deterministic effects.
- General principles of radiation protection (justification, dose limitation and optimisation).
- Particular radiation protection for patient and staff.
- Typical doses from diagnostic procedures.
- Dose management of children, pregnant women.

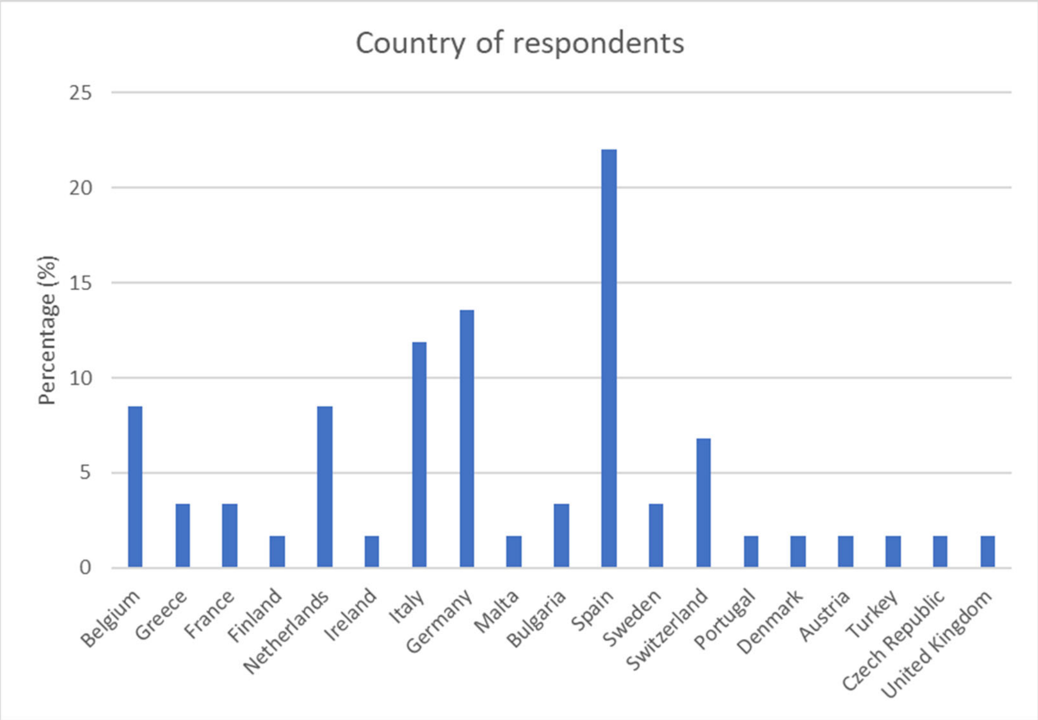
- Quality control and regulations.
- Management of accidents/unintentional exposures.

The survey was distributed among the SINFONIA consortium partners and was widely advertised using the EIBIR communication channels. In addition, individual emails to lecturers in the field were sent to maximize the survey response.

3. Results

3.1 Information on the respondents

A total of 98 responses from 19 countries were received until 20 April 2022. The countries involved, together with their relative contribution to the total number of responses are indicated in the figure below.

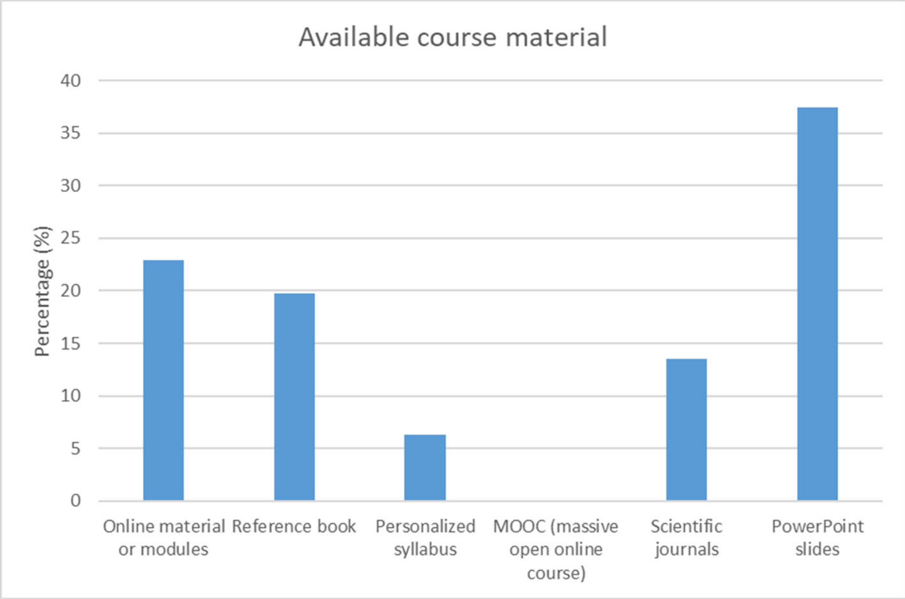


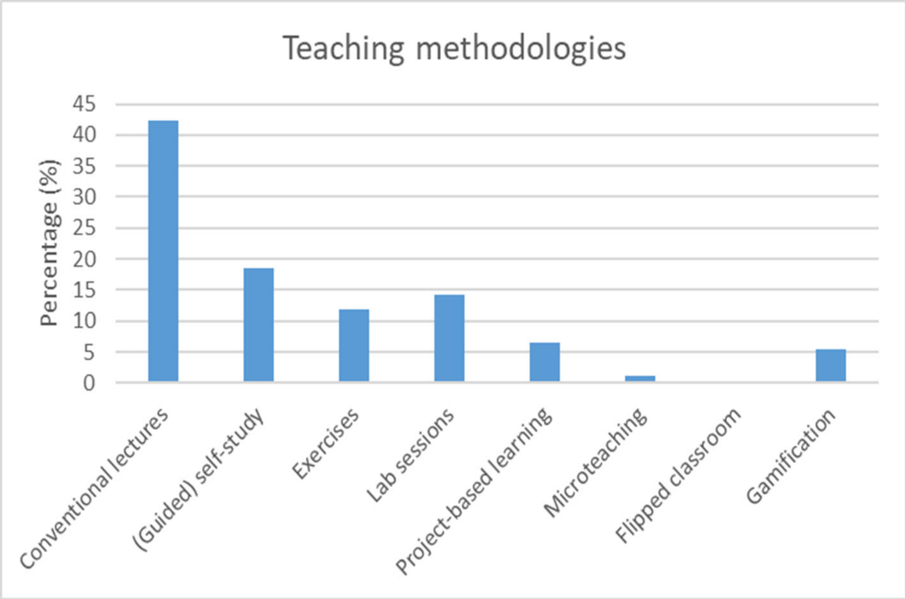
Almost half (47%) of the respondents were linked to a university; 27% of the responses came from professional and scientific organizations. 19% of the respondents had a position in a hospital, whereas the remaining 5% was linked to other institutes such as regulatory agencies. Most of the respondents where medical physics experts (47%), followed by radiologists (16%), radiographers (10%) and nuclear medicine physicians (7%).

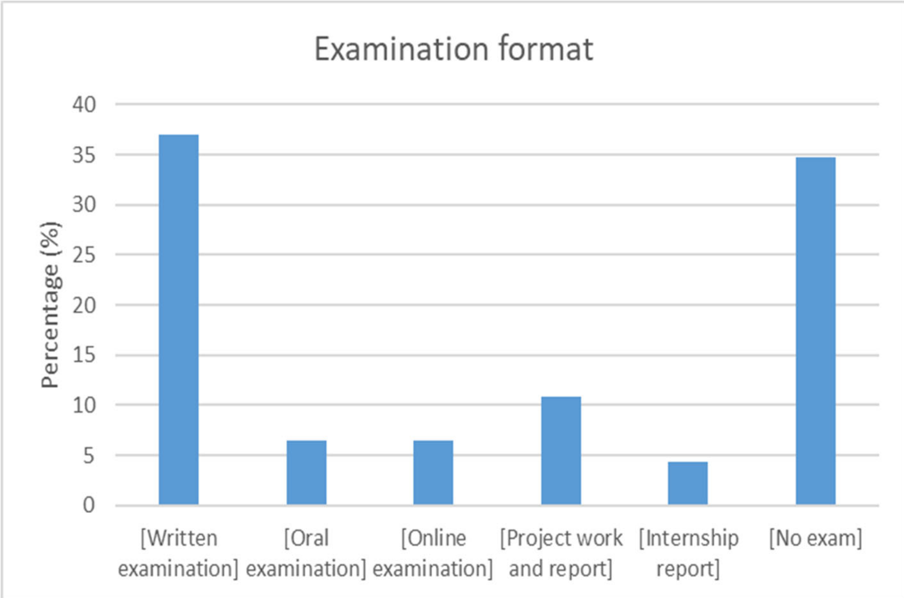
Most probably, some more survey responses will come in. If so, this deliverable will be updated accordingly.

3.2 Courses on dosimetry

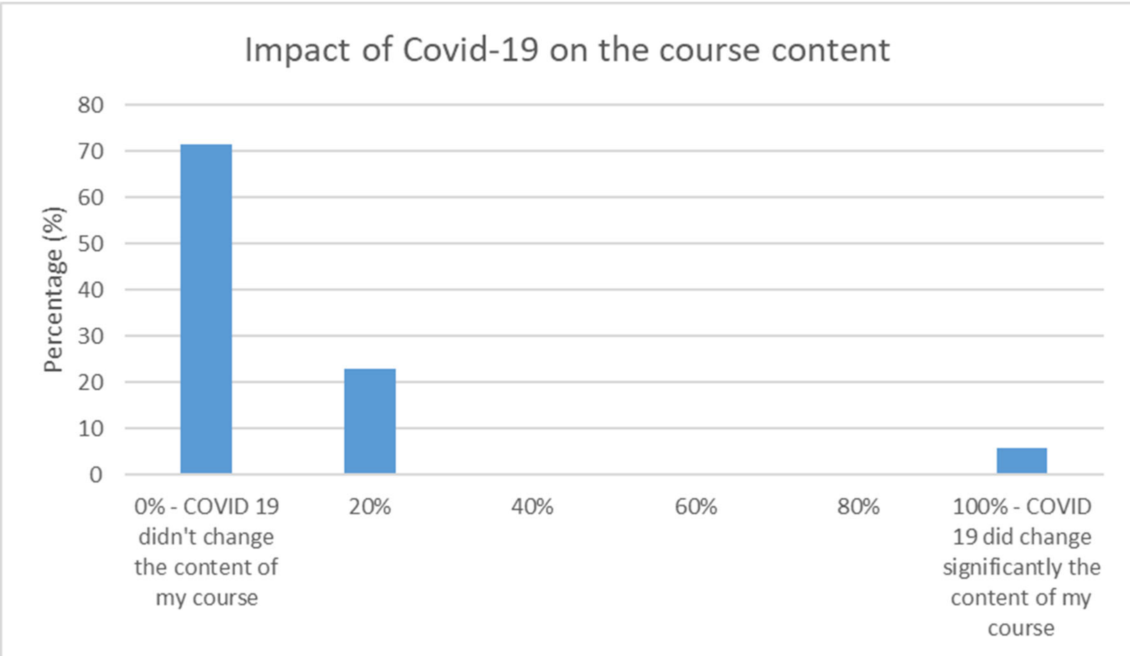
- **Practical organisation of the course**: course material, teaching methods, evaluation

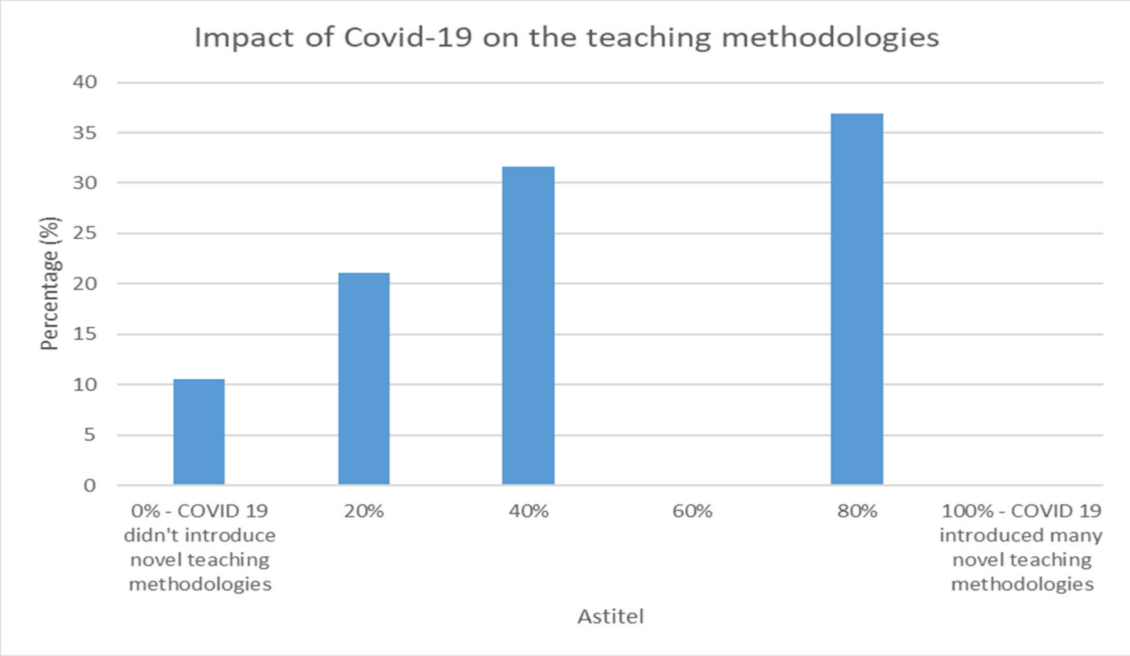






- **Impact of the COVID pandemic**:




Impact of Covid-19 on the teaching methodologies
Percentage (%)
40
35
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0% - COVID 19 didn't introduce novel teaching methodologies
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80%
100% - COVID 19 introduced many novel teaching methodologies
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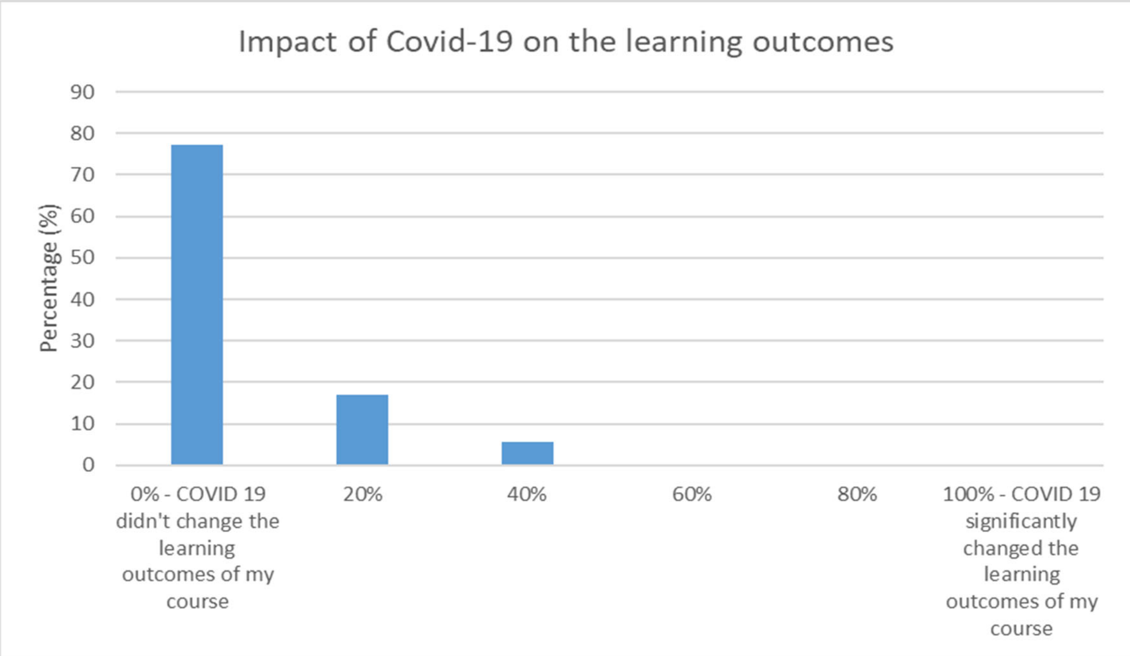
Impact of Covid-19 on the learning outcomes
Percentage (%)
90
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0% - COVID 19 didn't change the learning outcomes of my course
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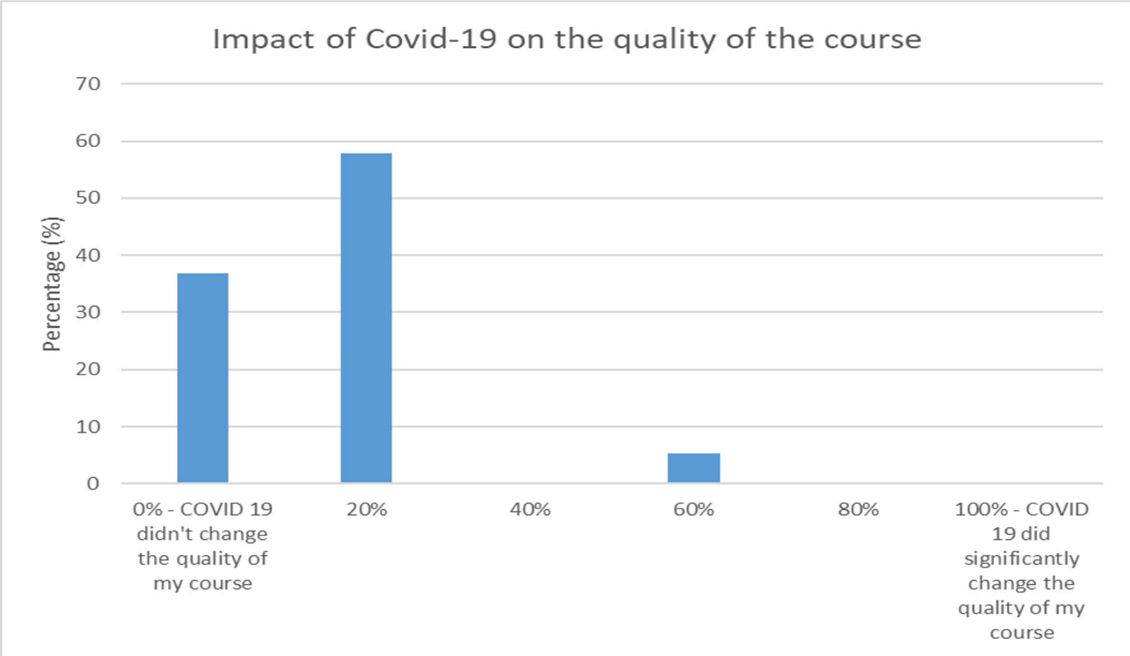
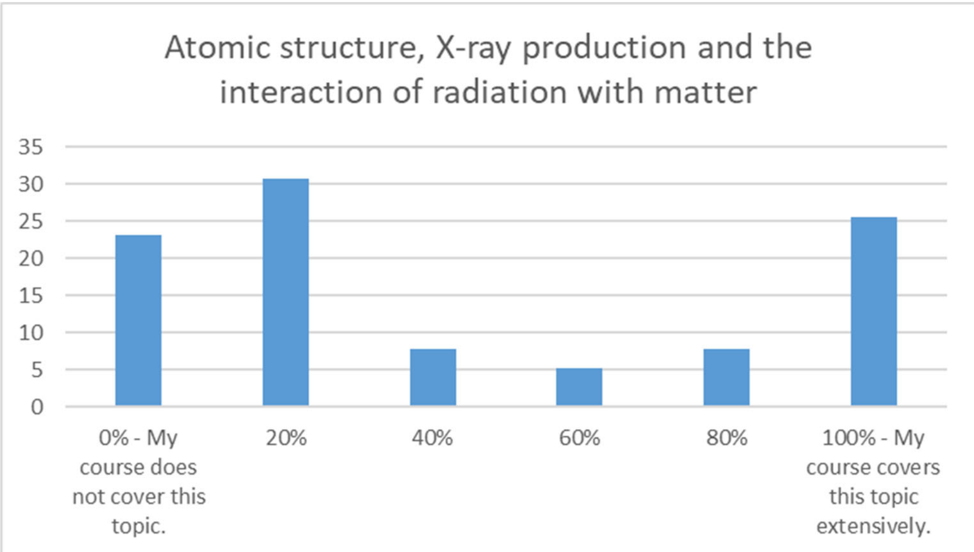
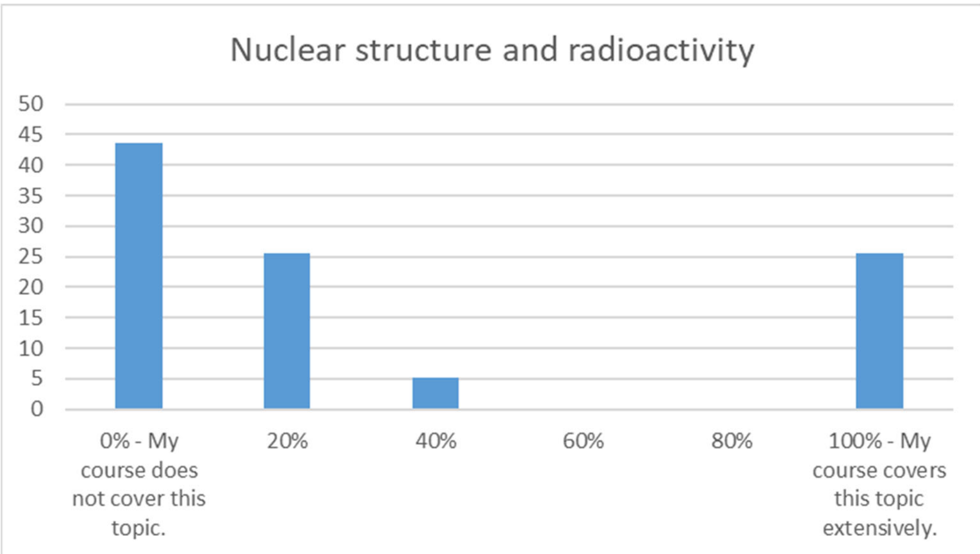
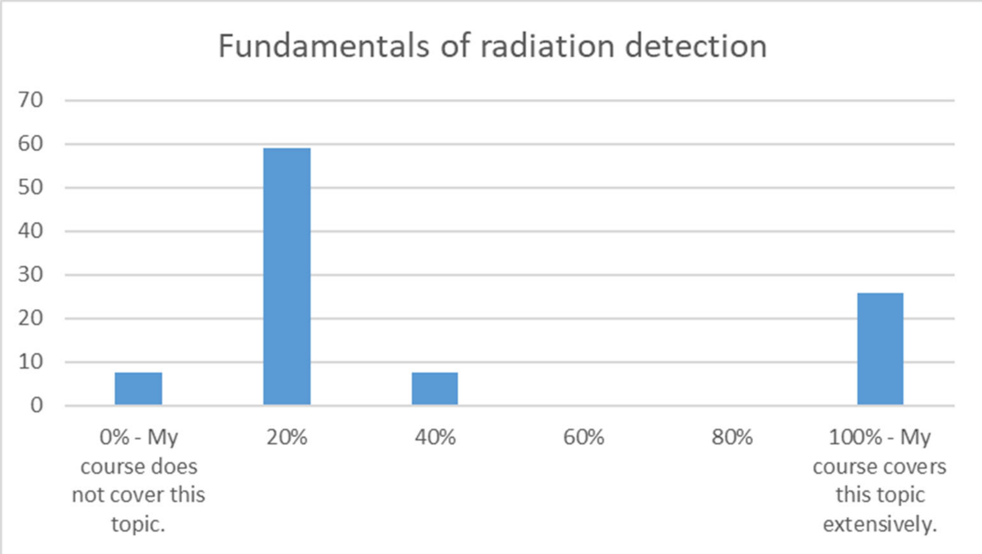
100% - COVID 19 significantly changed the learning outcomes of my course



- **Course contribution to the core topics defined in RP 175** [1]






Fundamentals of radiation detection
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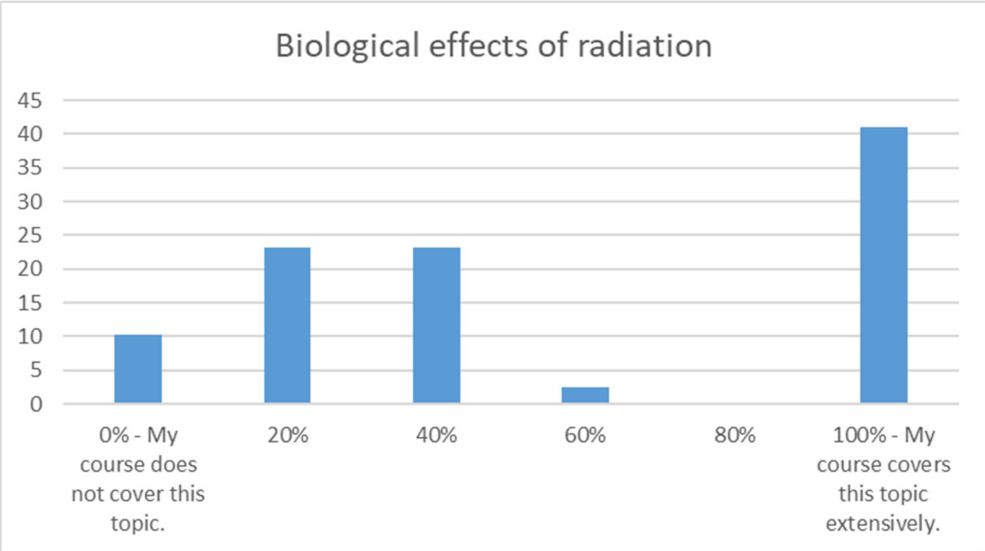
100% - My course covers this topic extensively.


Biological effects of radiation
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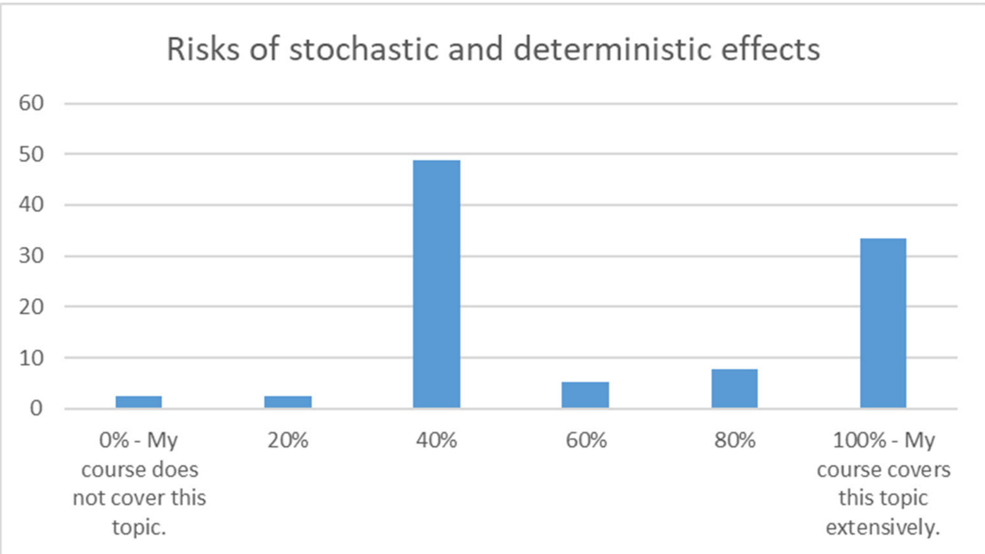
Risks of stochastic and deterministic effects
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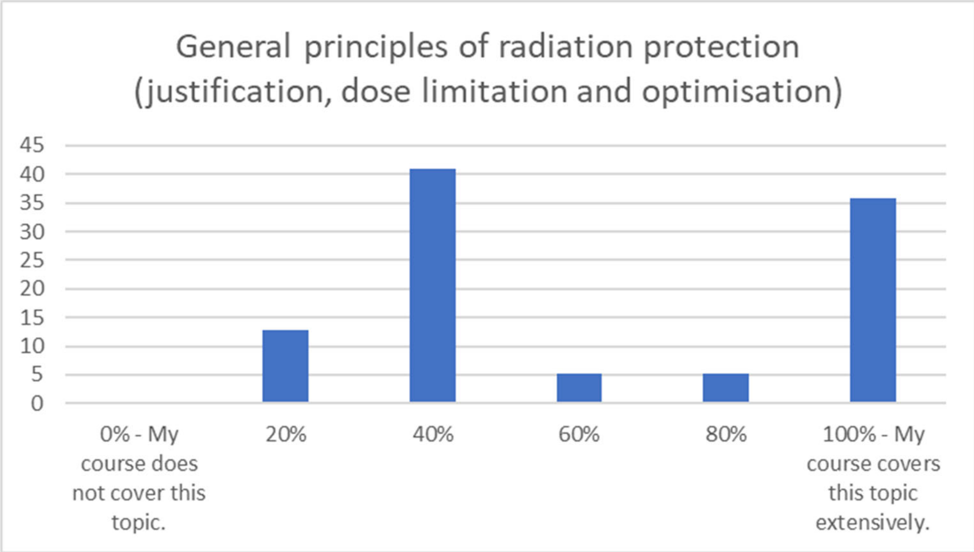
General principles of radiation protection (justification, dose limitation and optimisation)
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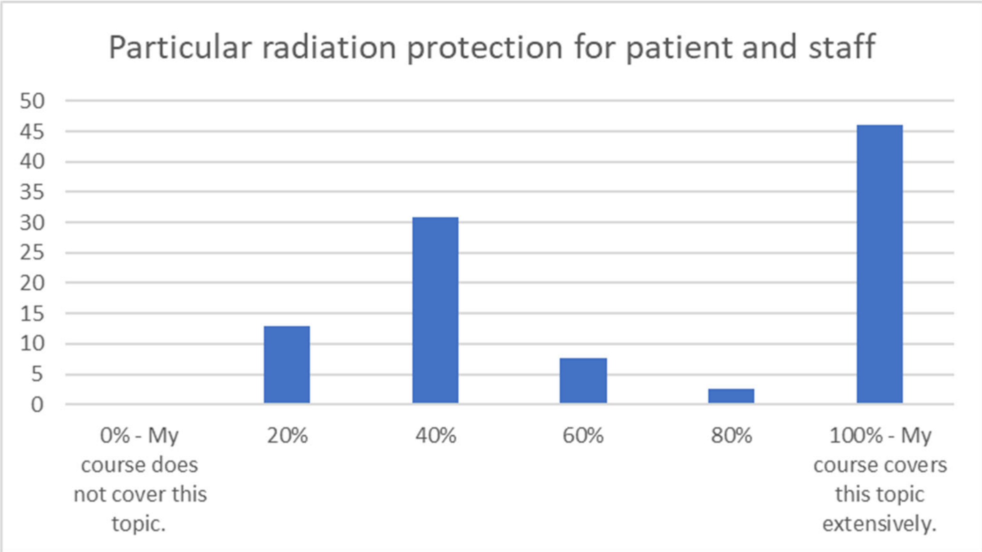
Particular radiation protection for patient and staff
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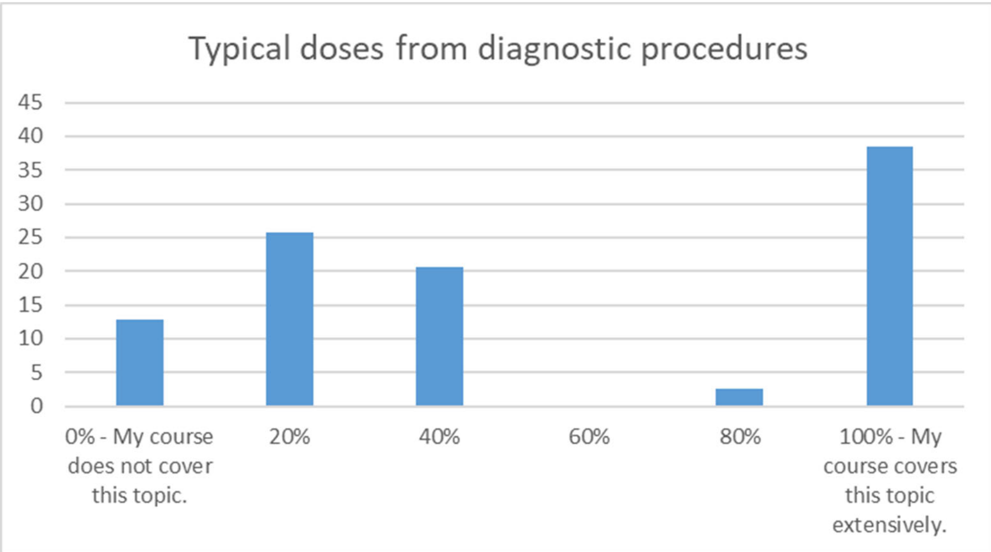
Typical doses from diagnostic procedures
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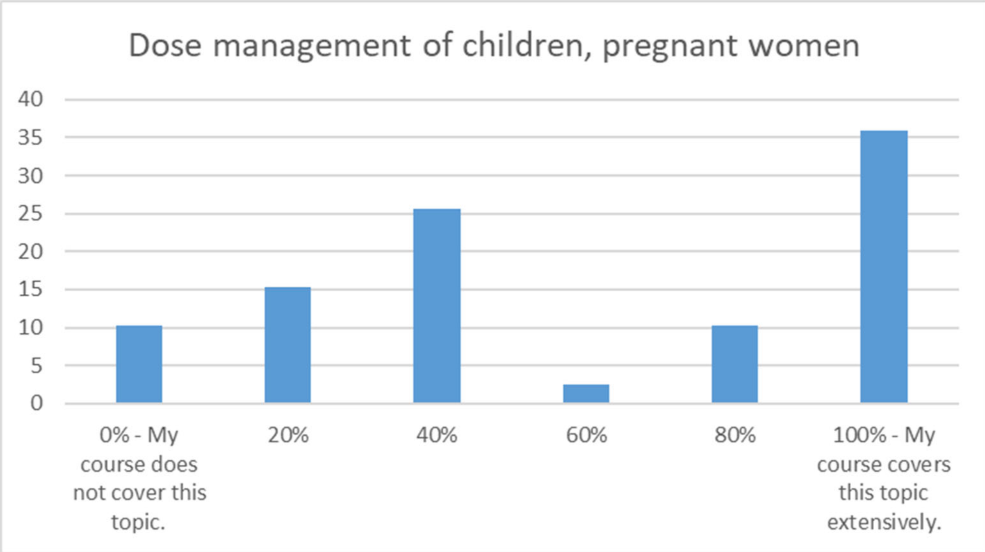
Dose management of children, pregnant women
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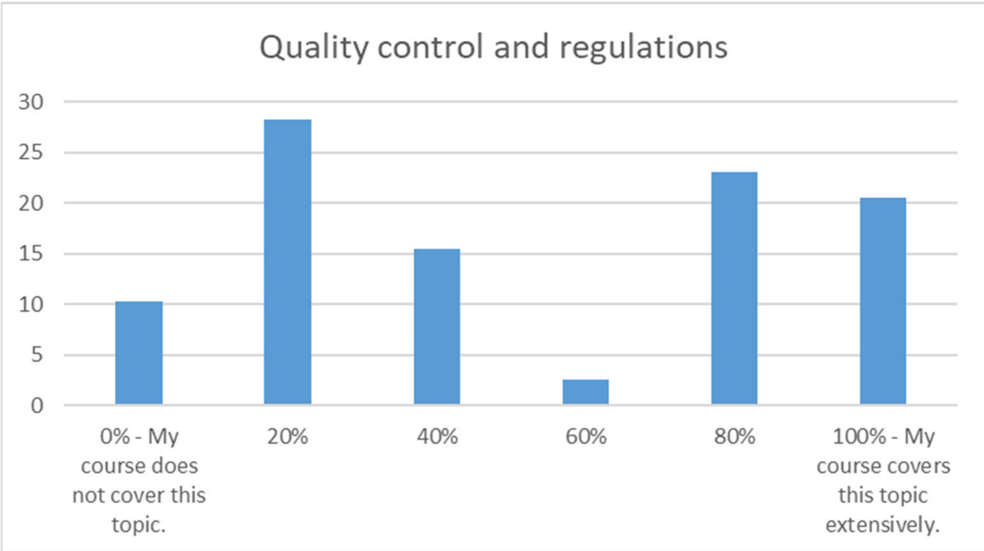
Quality control and regulations
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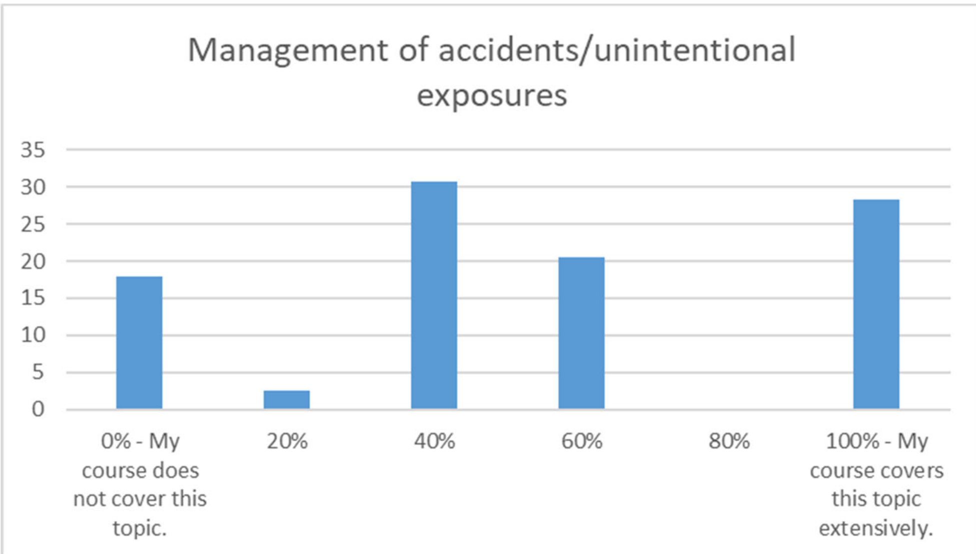
Management of accidents/unintentional exposures
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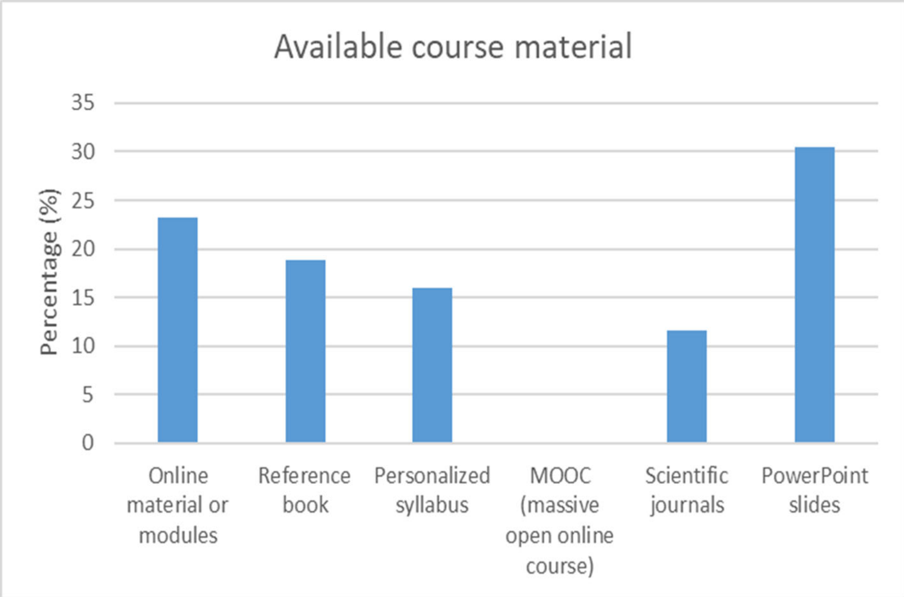
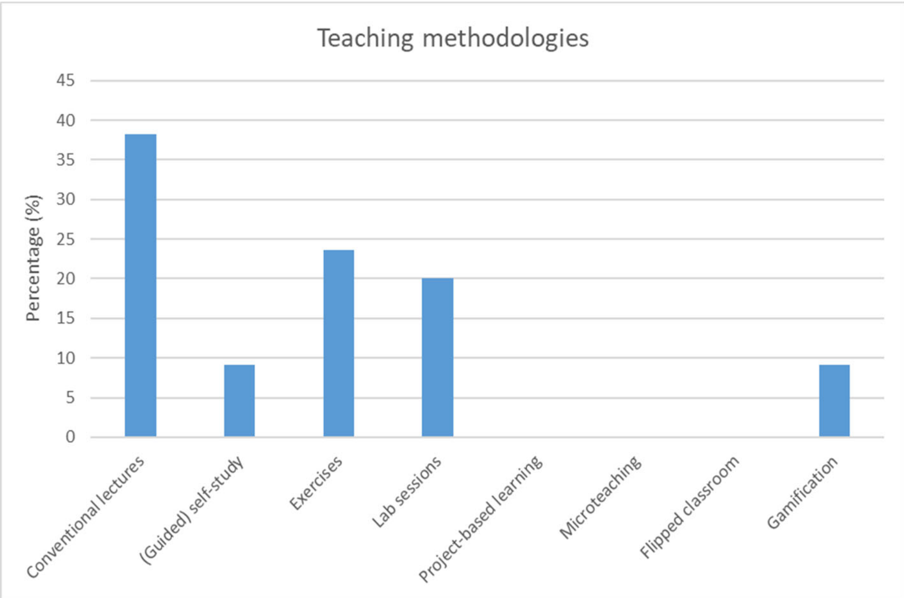
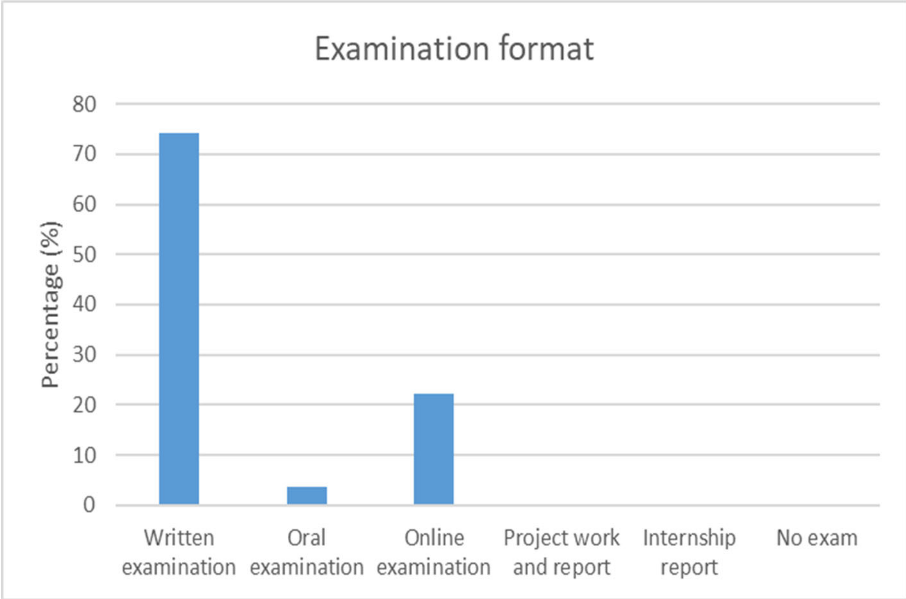
3.3 Courses on radiobiology

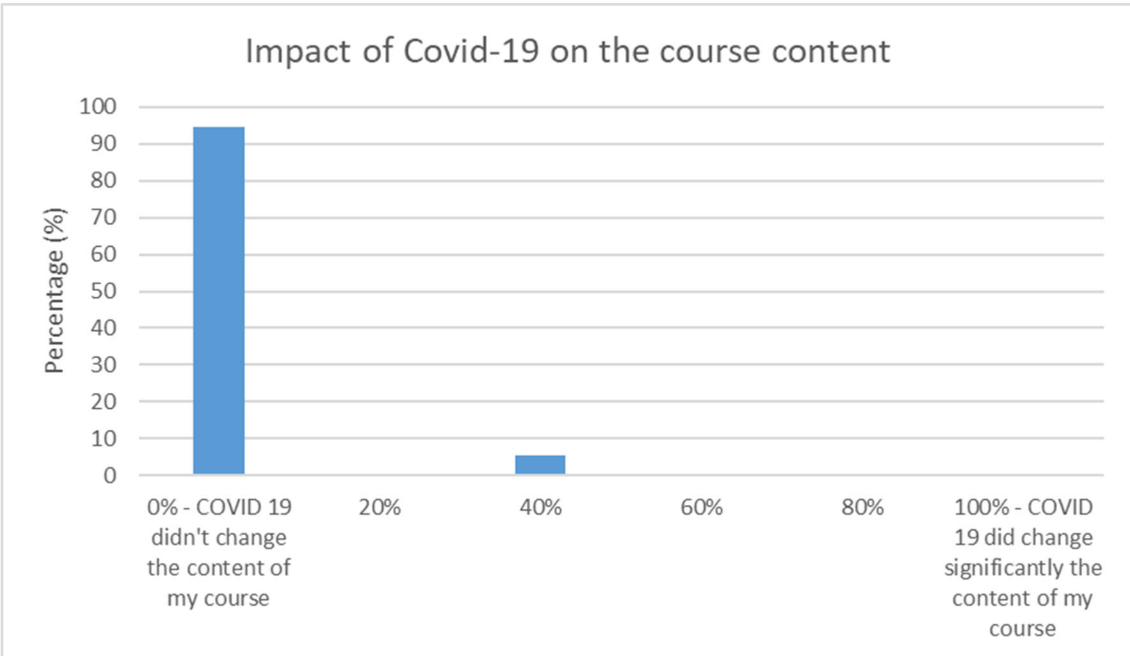
- **Practical organisation of the course**: course material, teaching methods, evaluation

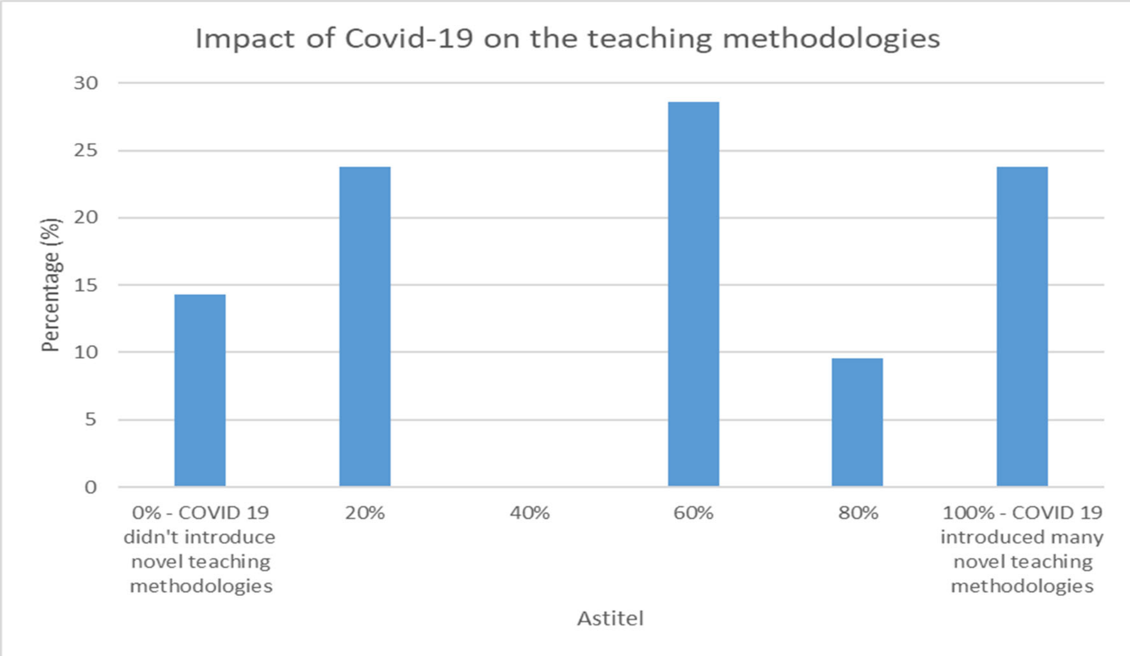






- **Impact of the COVID pandemic**:




Impact of Covid-19 on the teaching methodologies
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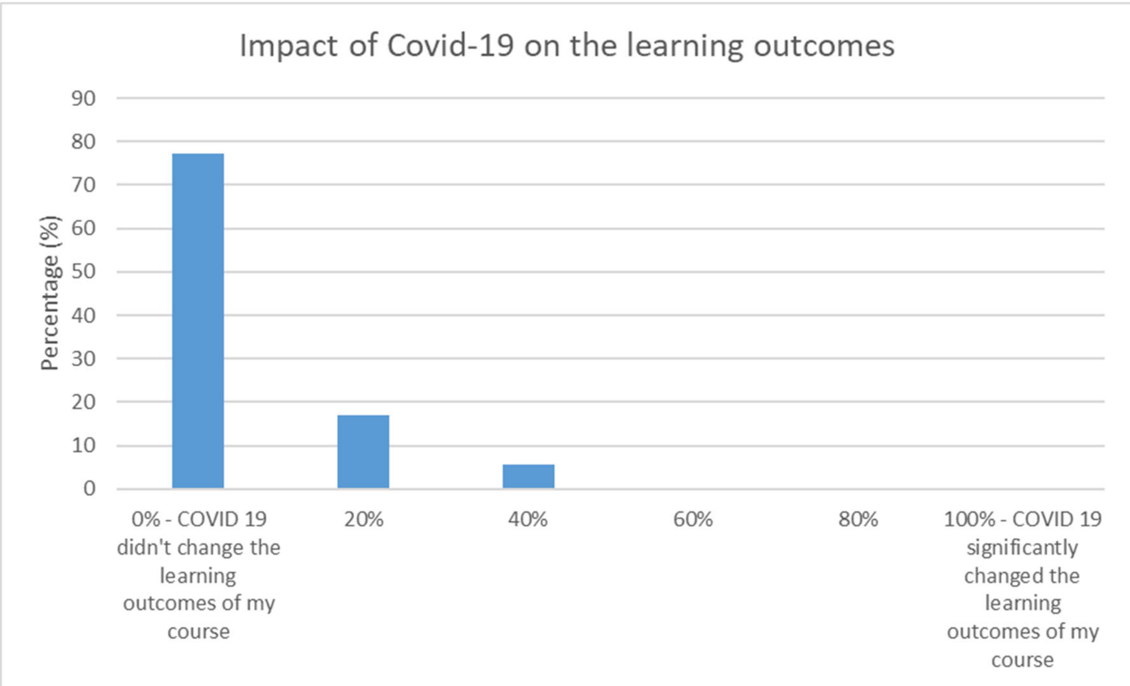
Impact of Covid-19 on the learning outcomes
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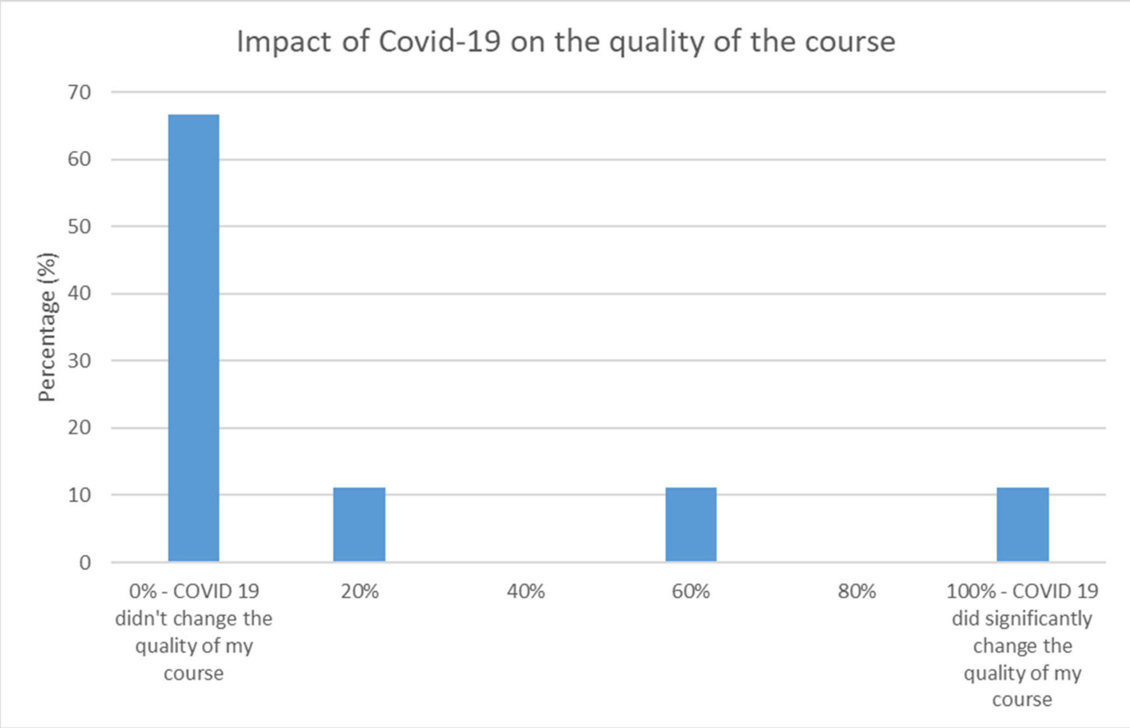
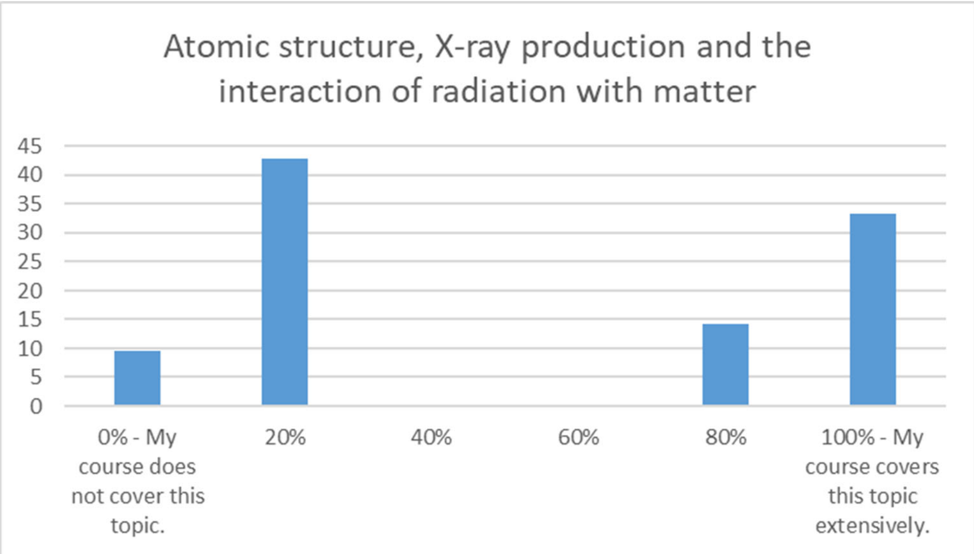
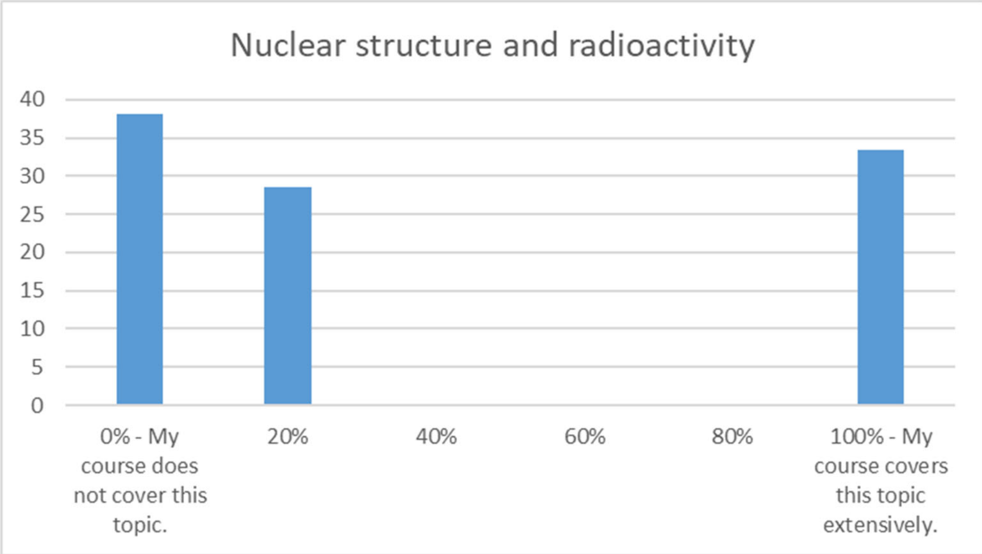


- **Course contribution to the core topics defined in RP 175** [1]




Nuclear structure and radioactivity
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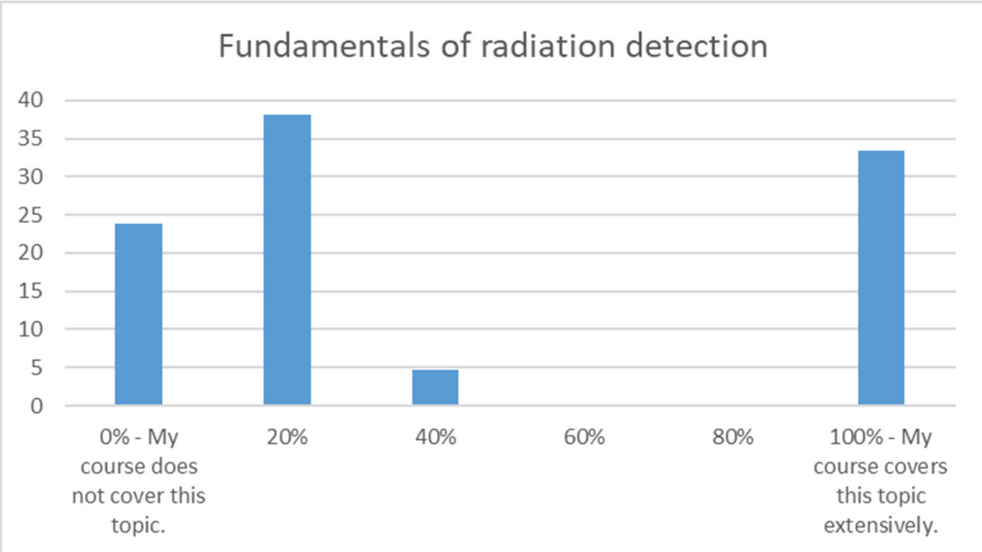
Fundamentals of radiation detection
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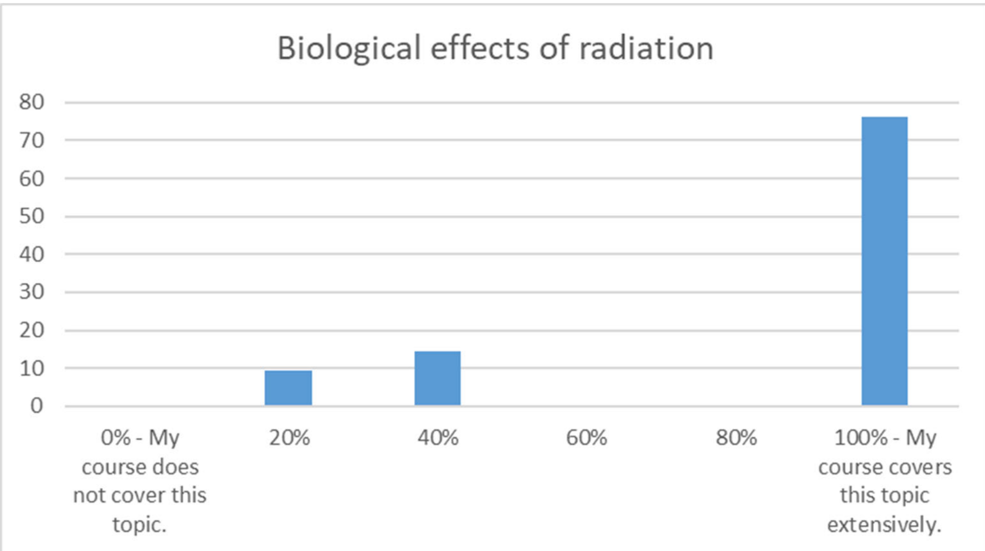
Biological effects of radiation
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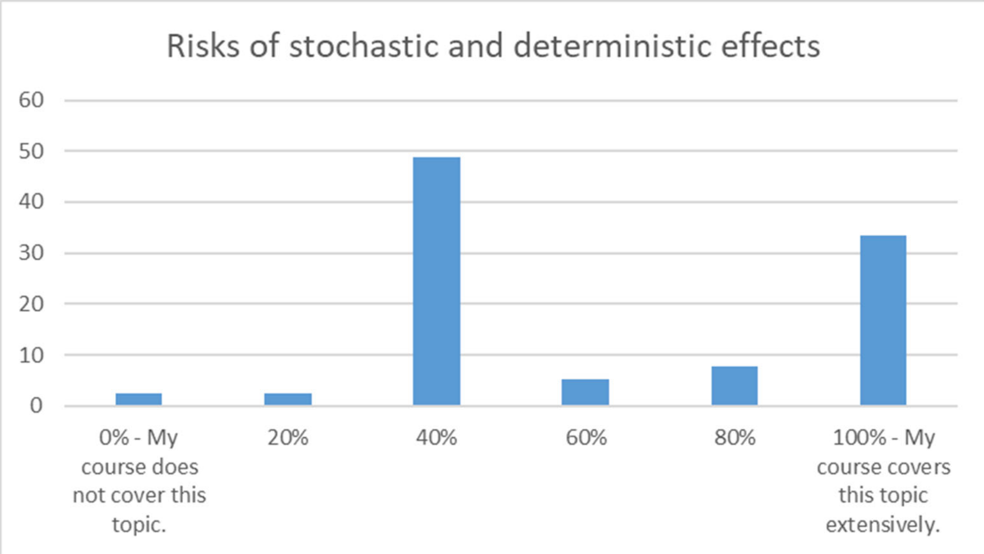
Risks of stochastic and deterministic effects
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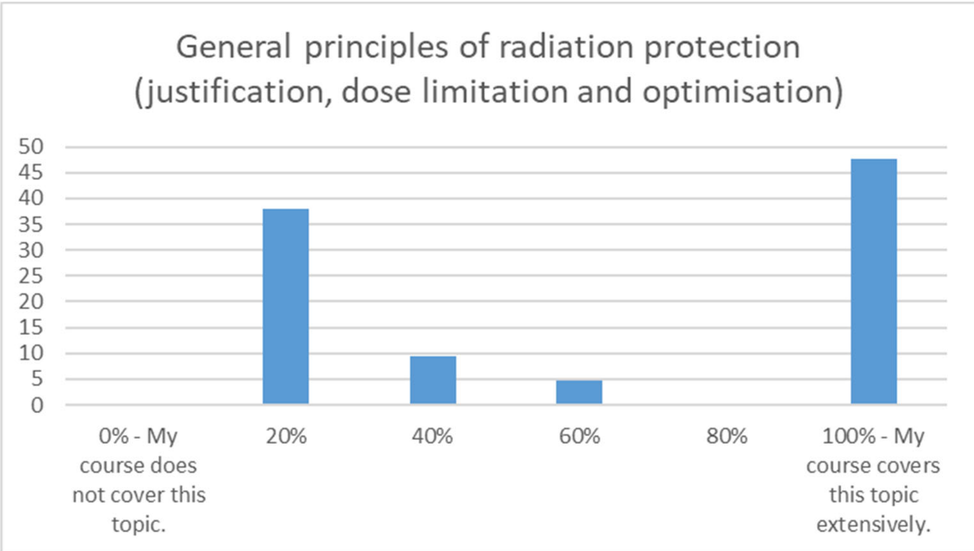
General principles of radiation protection (justification, dose limitation and optimisation)
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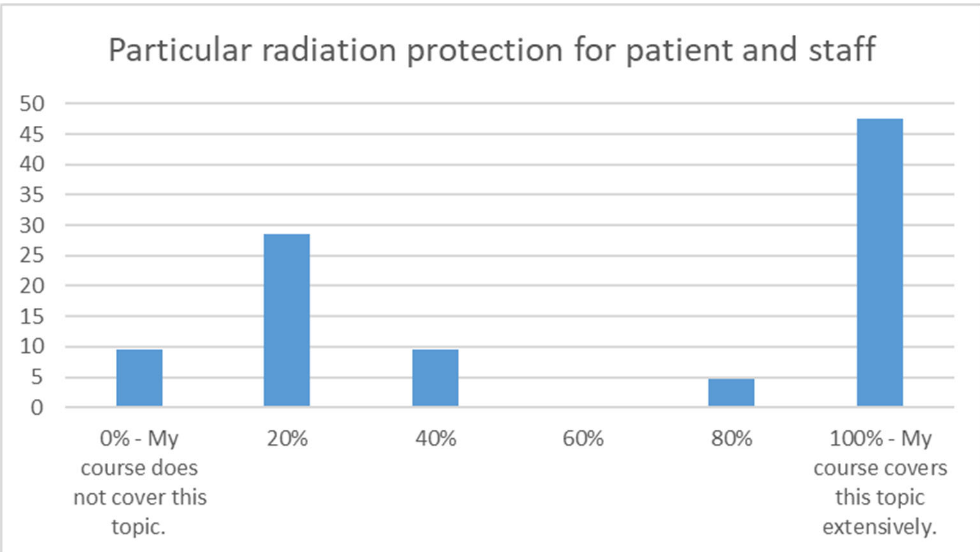
Particular radiation protection for patient and staff
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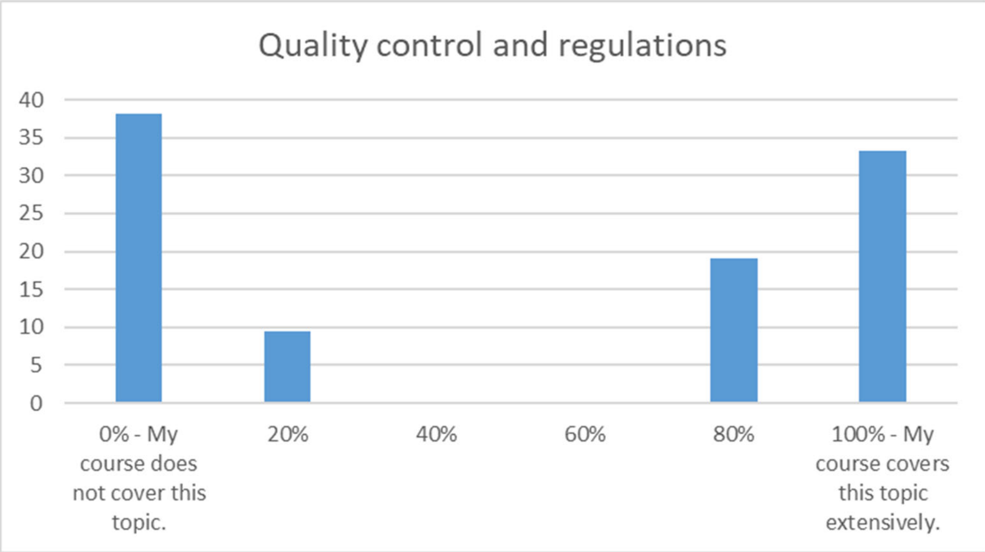
Quality control and regulations
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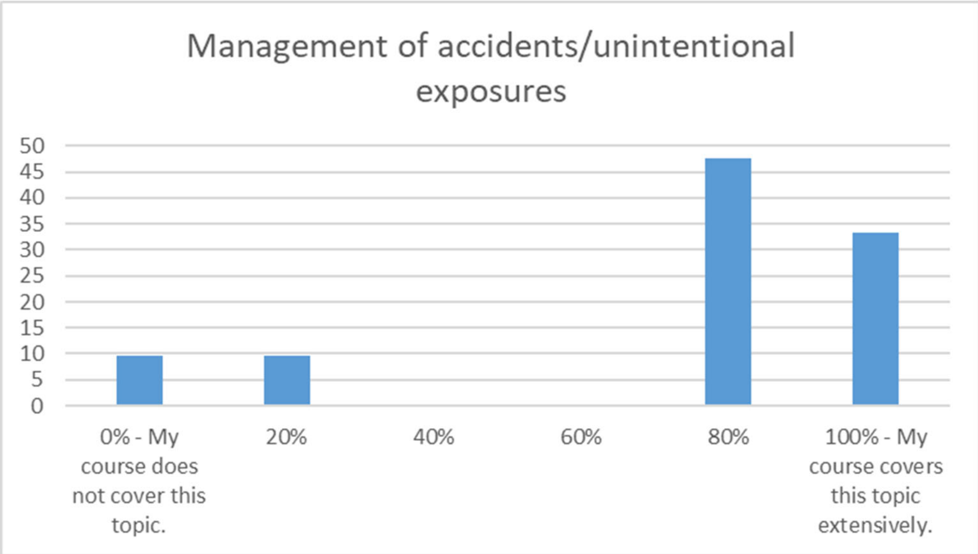
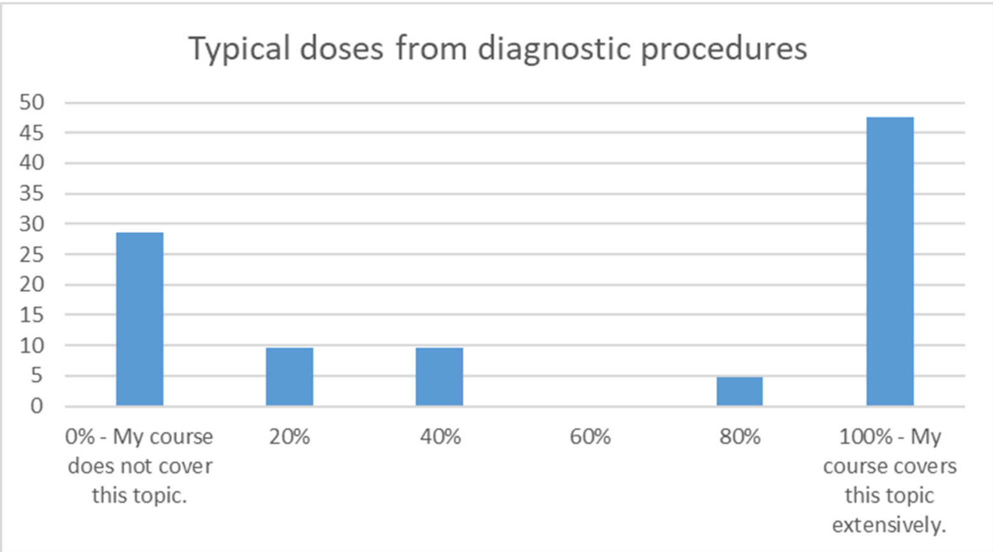
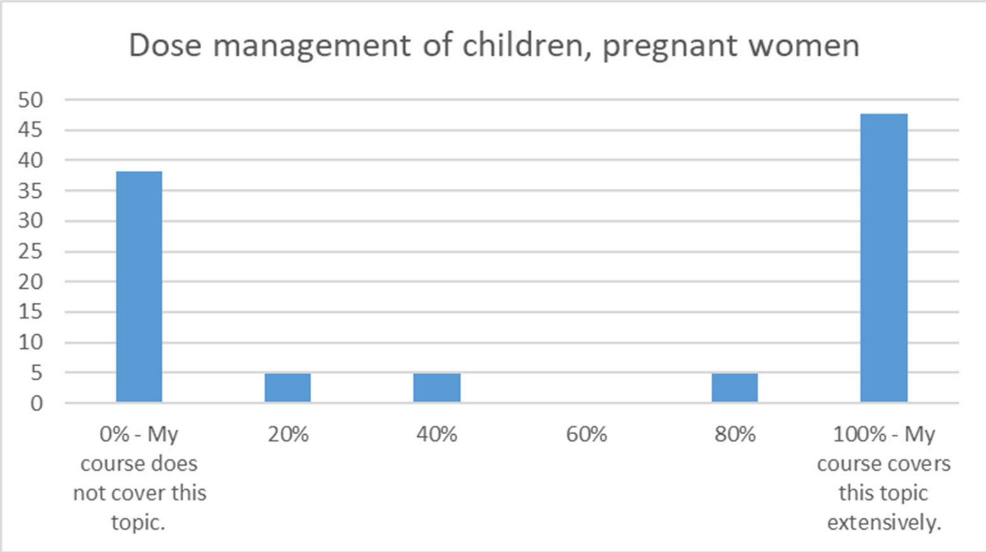
0
0% - My course does not cover this topic.
20%
40%
60%
80%
100% - My course covers this topic extensively.

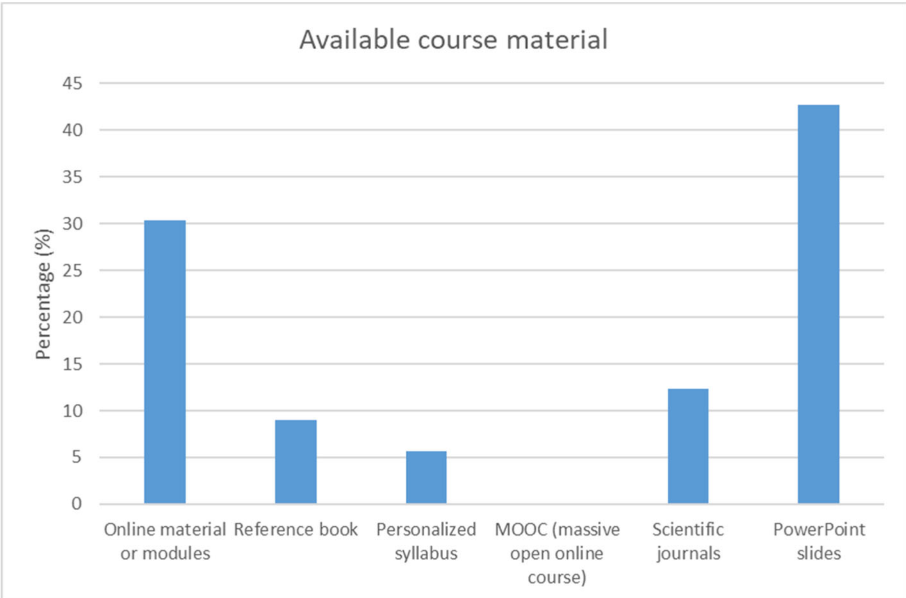

Management of accidents/unintentional exposures
50
45
40
35
30
25
20
15
10
5
0
0% - My course does not cover this topic.
20%
40%
60%
80%
100% - My course covers this topic extensively.

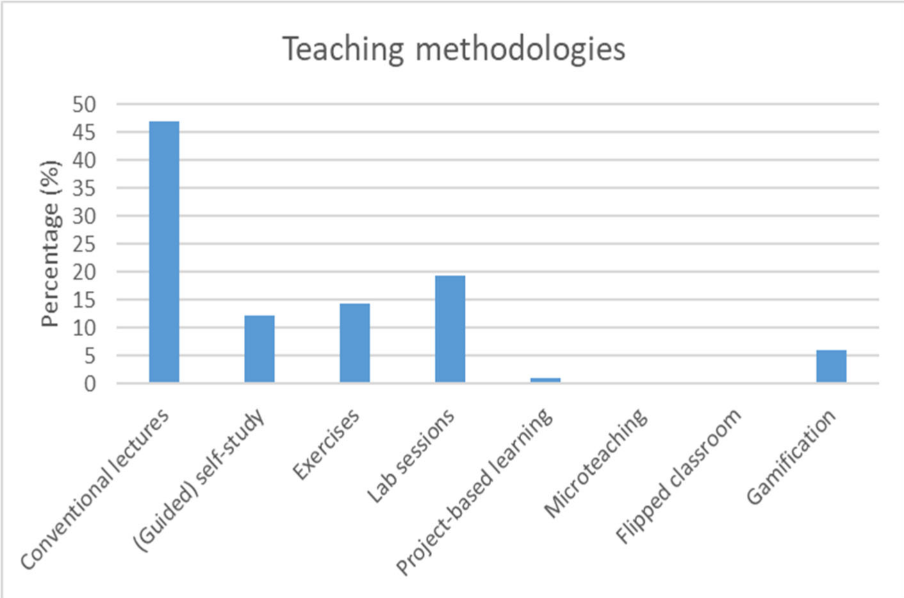

Typical doses from diagnostic procedures
50
45
40
35
30
25
20
15
10
5
0
0% - My course does not cover this topic.
20%
40%
60%
80%
100% - My course covers this topic extensively.

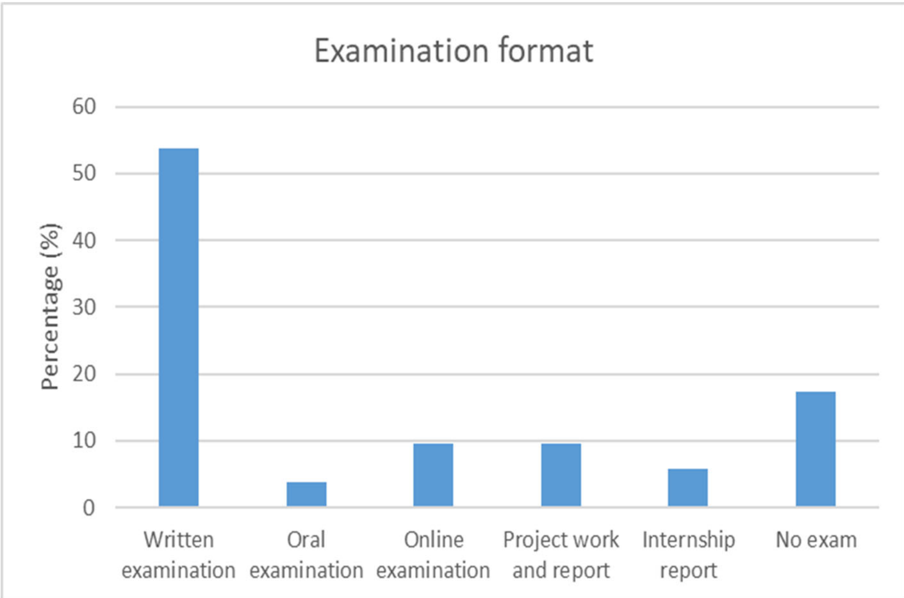


3.4 Courses on radiation protection

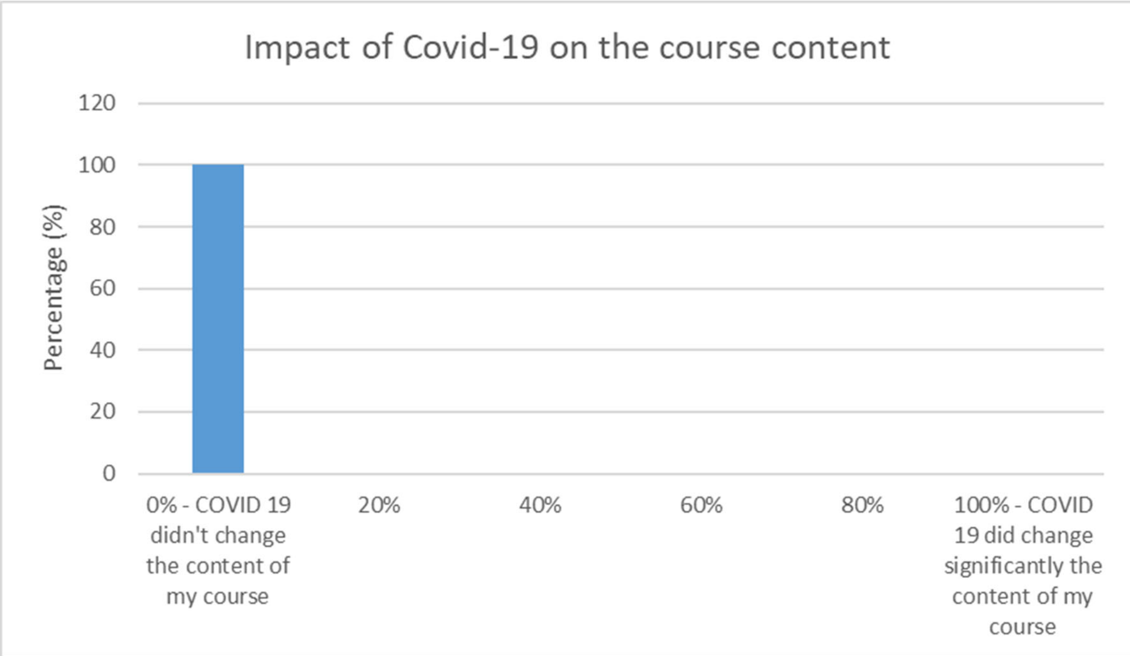
- **Practical organisation of the course**: course material, teaching methods, evaluation

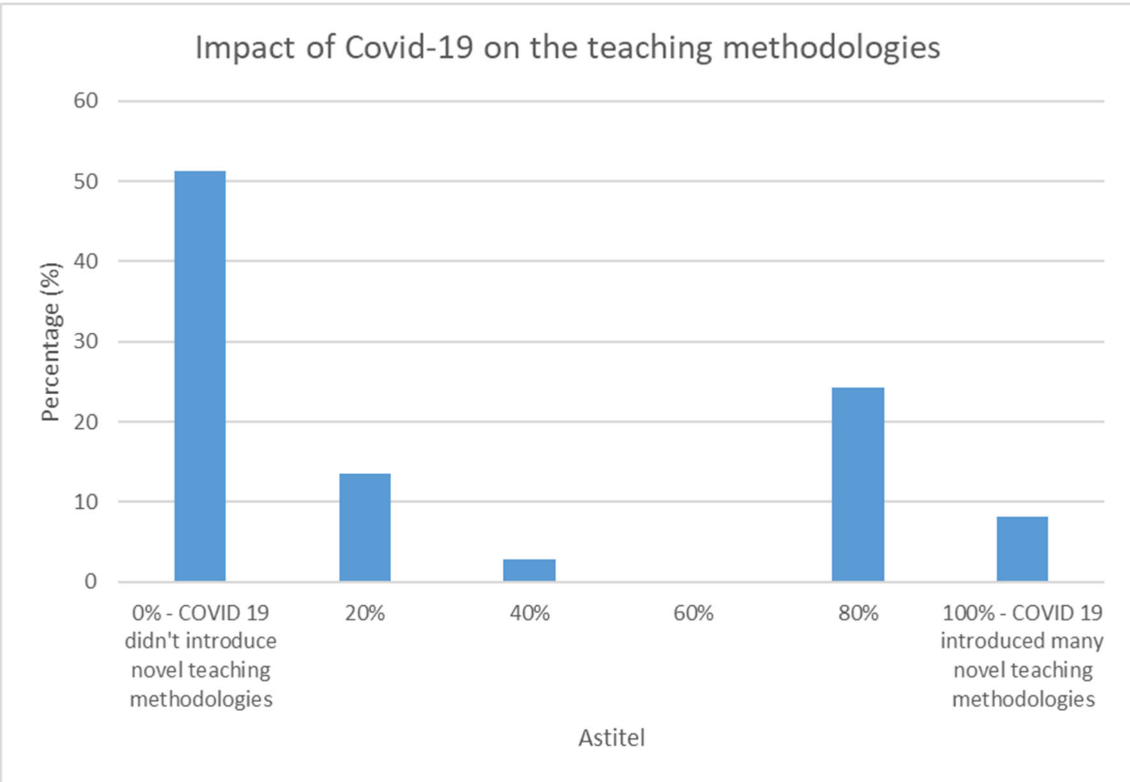


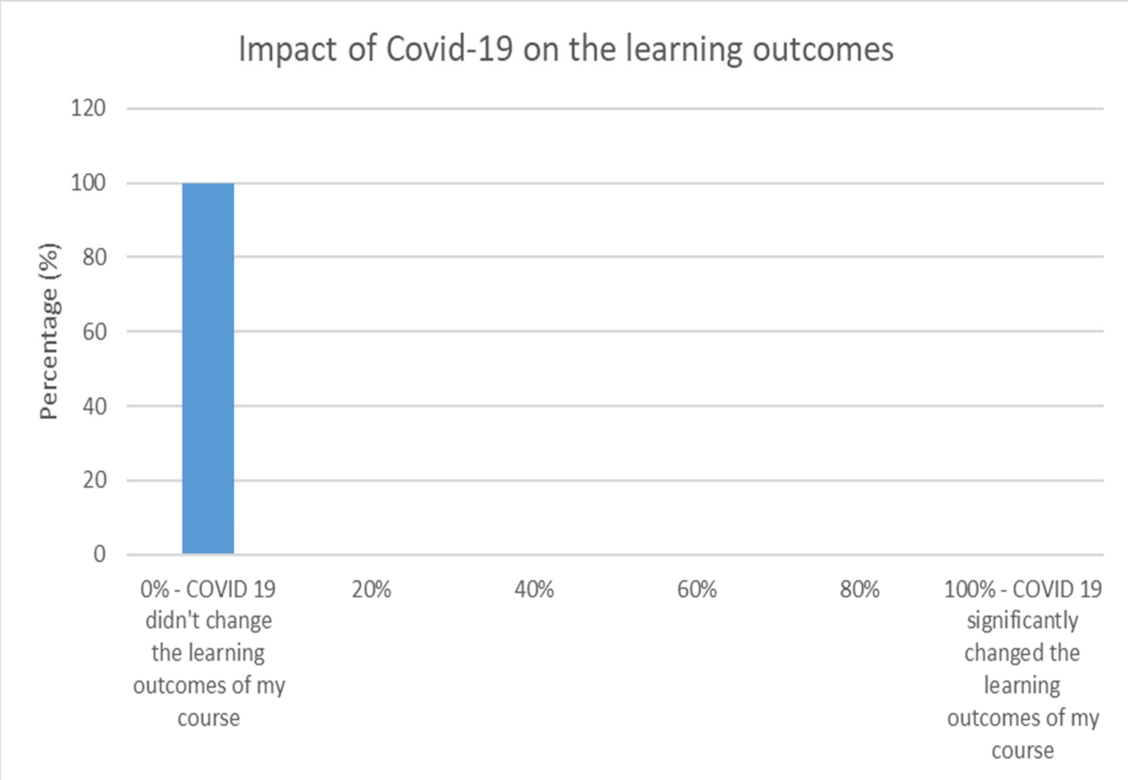

Teaching methodologies
Percentage (%)
50
45
40
35
30
25
20
15
10
5
0
Conventional lectures
(Guided) self-study
Exercises
Lab sessions
Project-based learning
Microteaching
Flipped classroom
Gamification

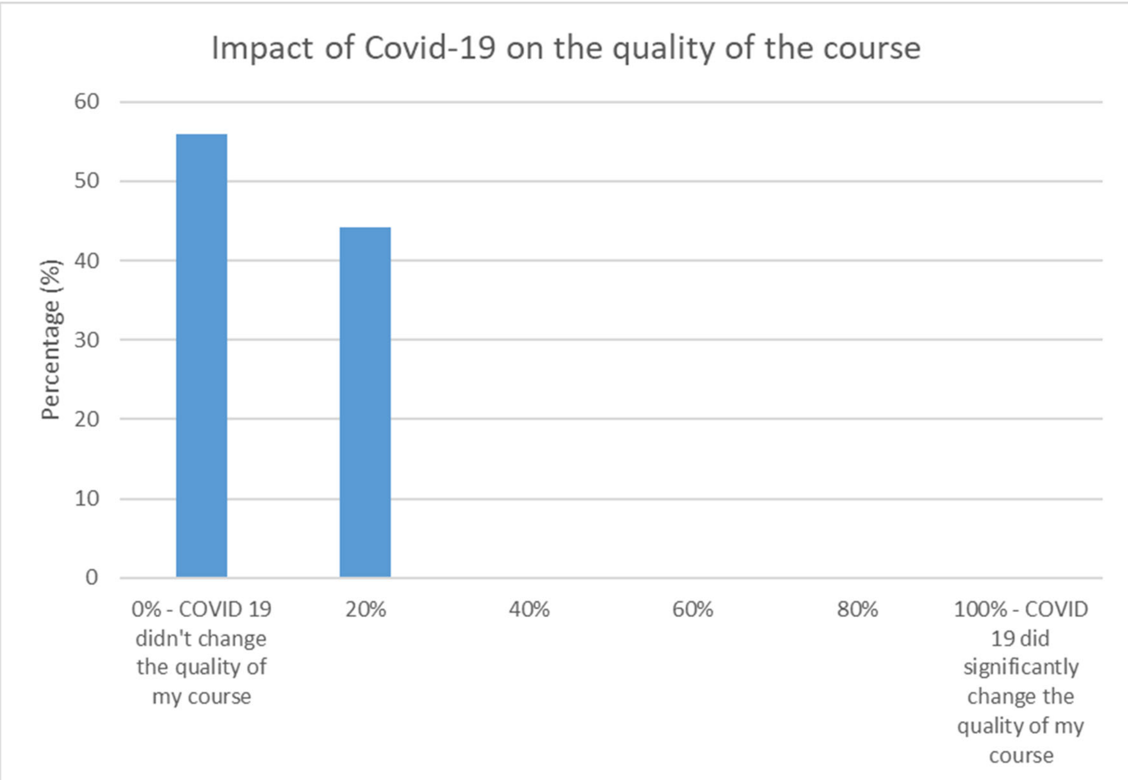

Examination format
Percentage (%)
60
50
40
30
20
10
0
Written examination
Oral examination
Online examination
Project work and report
Internship report
No exam

- **Impact of the COVID pandemic**:

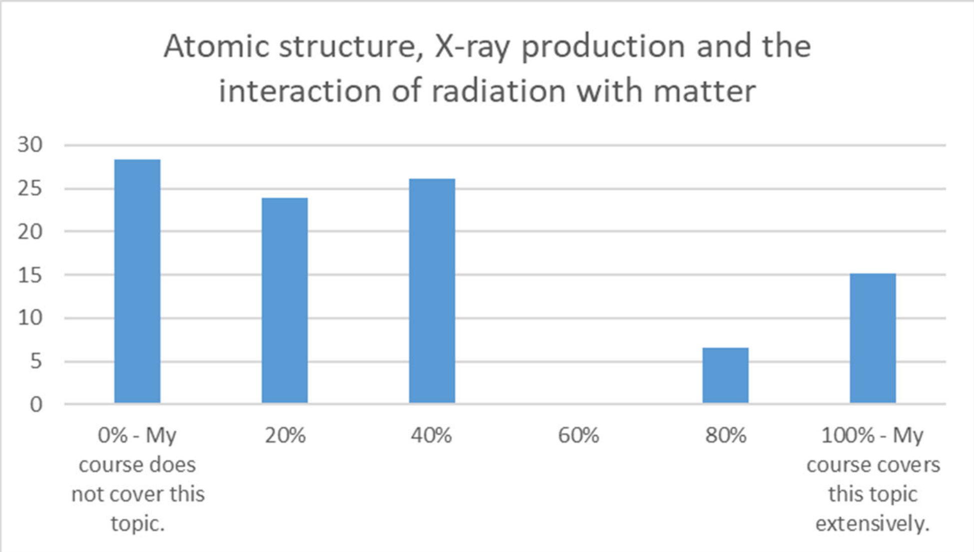


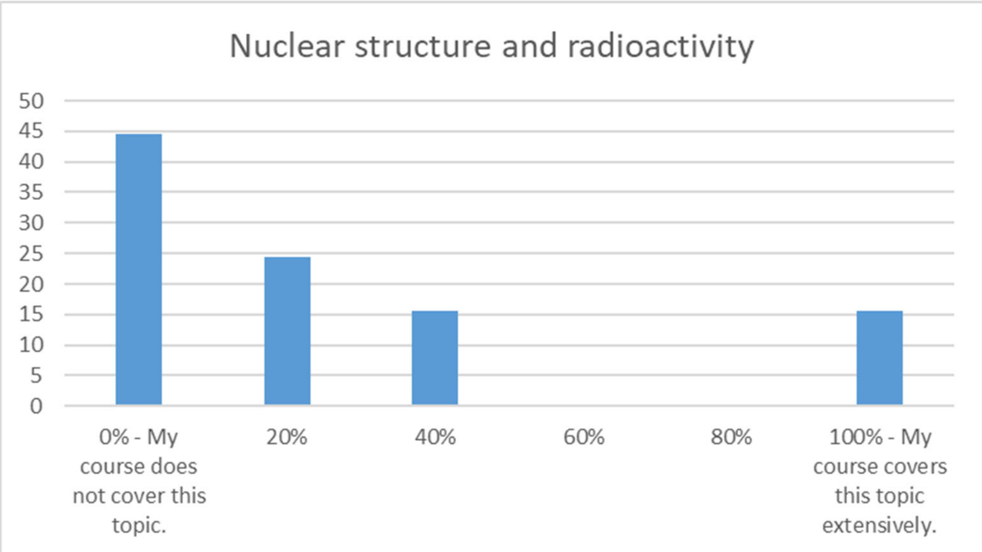


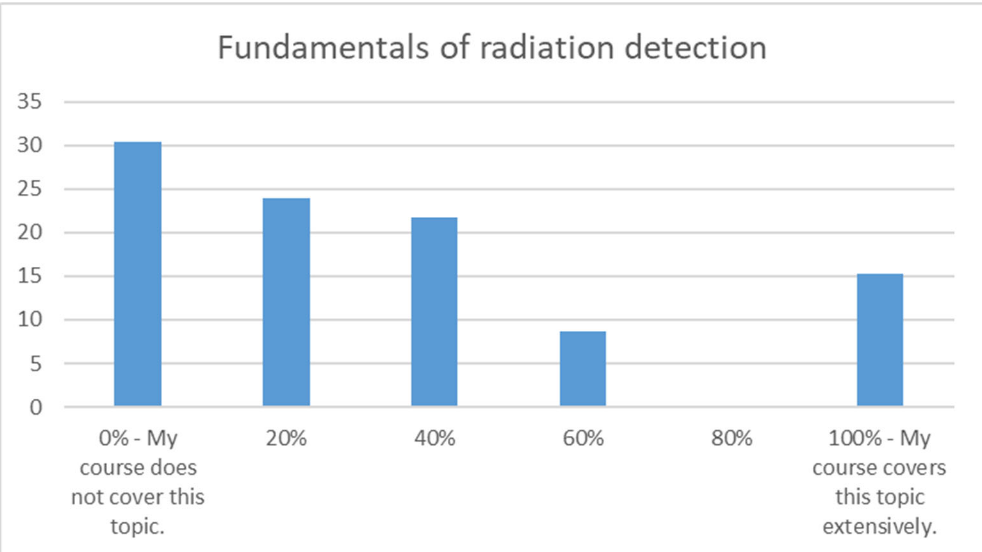

Impact of Covid-19 on the learning outcomes
Percentage (%)
120
100
80
60
40
20
0
0% - COVID 19 didn't change the learning outcomes of my course
20%
40%
60%
80%
100% - COVID 19 significantly changed the learning outcomes of my course

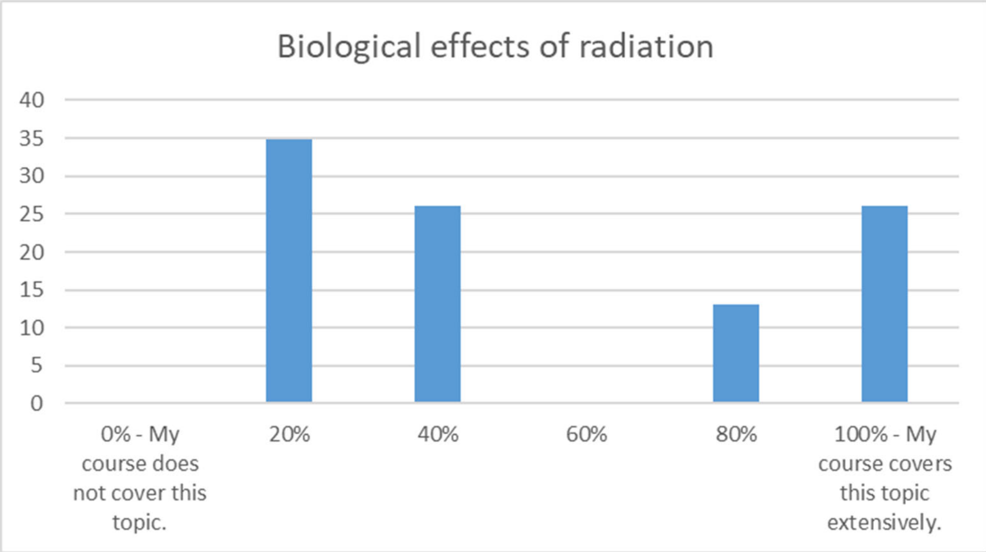

Impact of Covid-19 on the quality of the course
Percentage (%)
60
50
40
30
20
10
0
0% - COVID 19 didn't change the quality of my course
20%
40%
60%
80%
100% - COVID 19 did significantly change the quality of my course

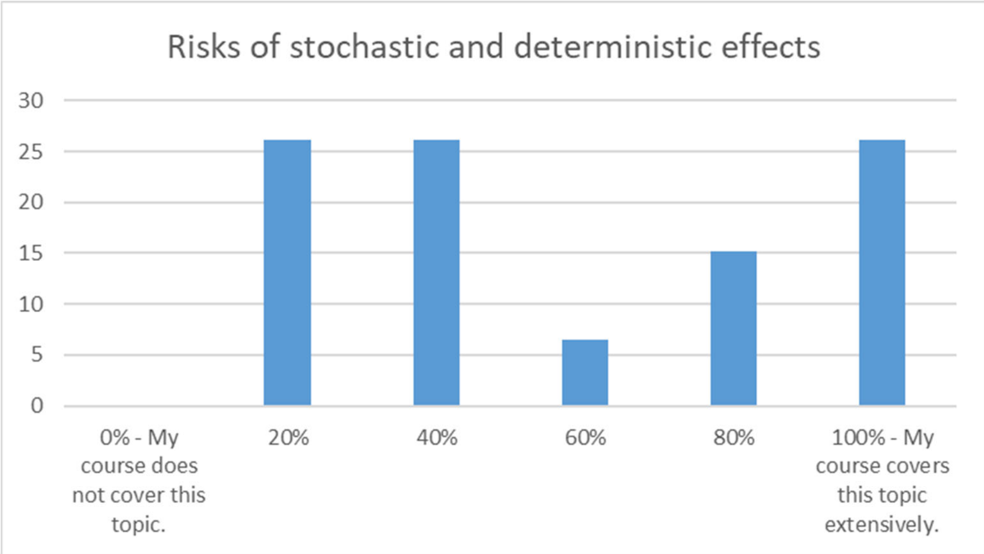
- **Course contribution to the core topics defined in RP 175** [1]

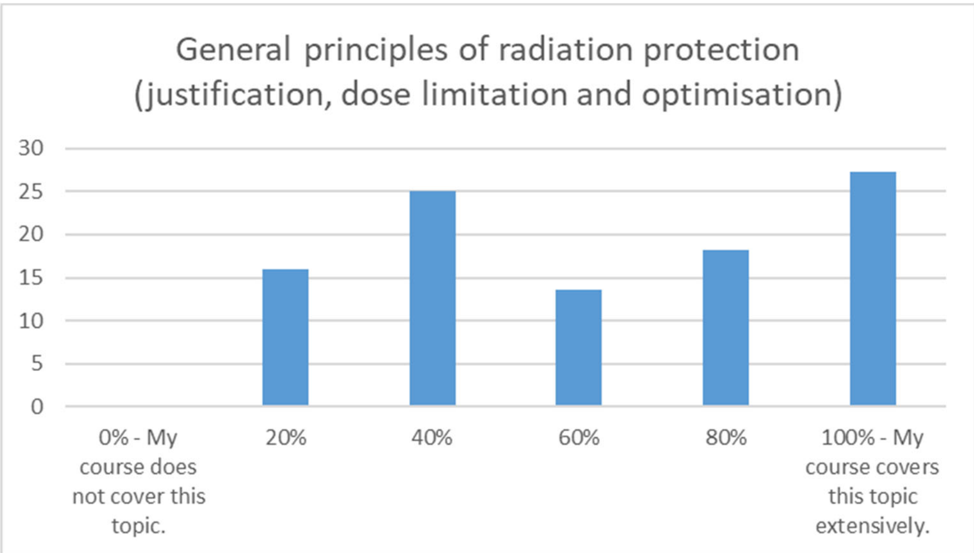


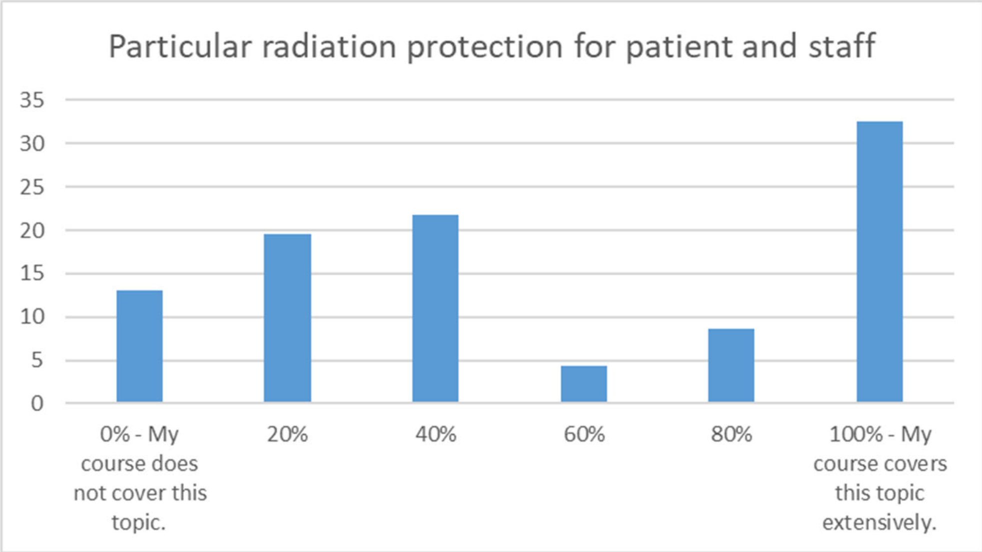


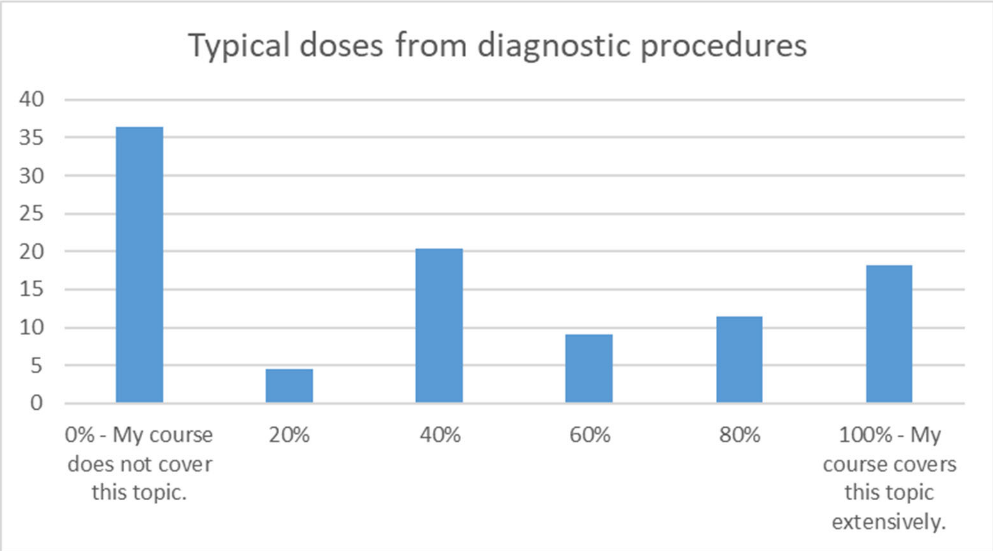


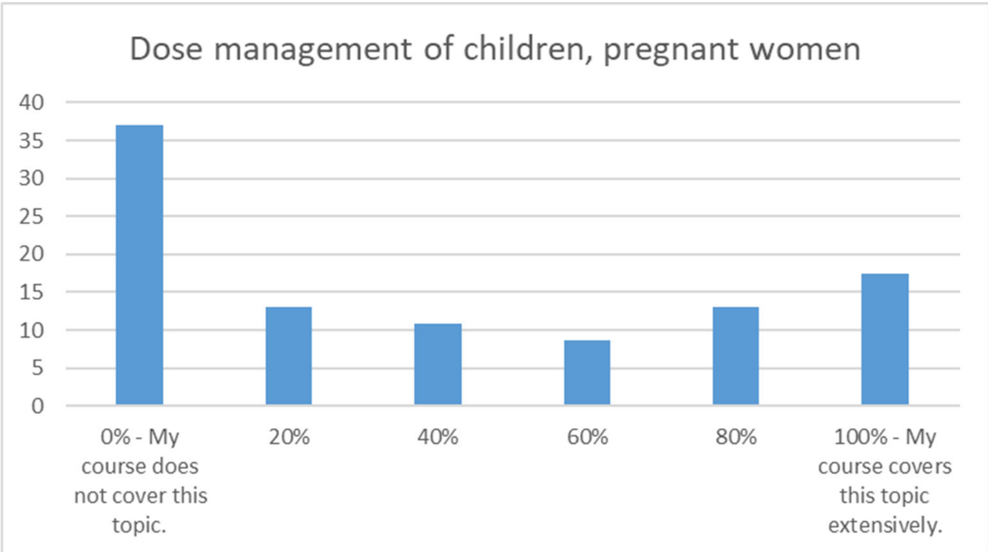

Biological effects of radiation
40
35
30
25
20
15
10
5
0
0% - My course does not cover this topic.
20%
40%
60%
80%
100% - My course covers this topic extensively.

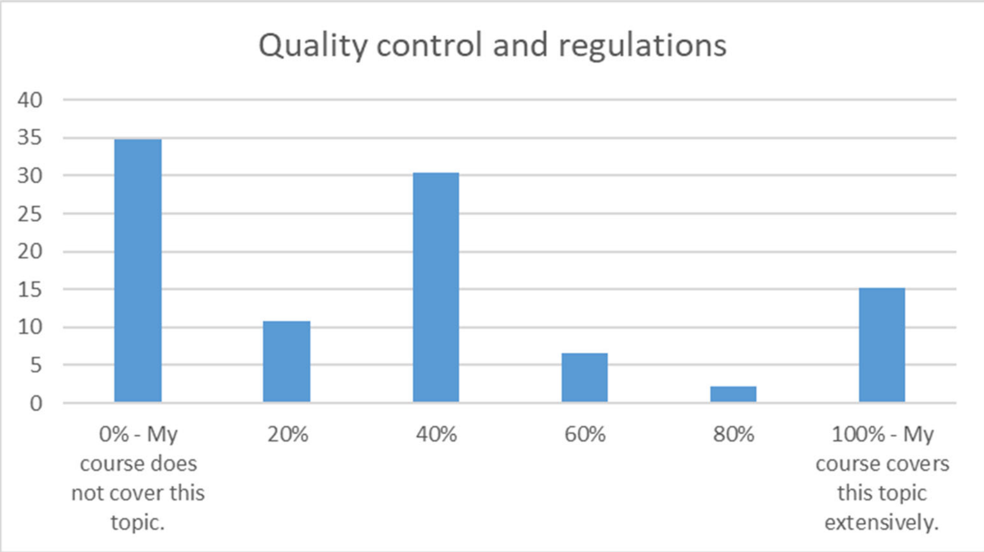

Risks of stochastic and deterministic effects
30
25
20
15
10
5
0
0% - My course does not cover this topic.
20%
40%
60%
80%
100% - My course covers this topic extensively.

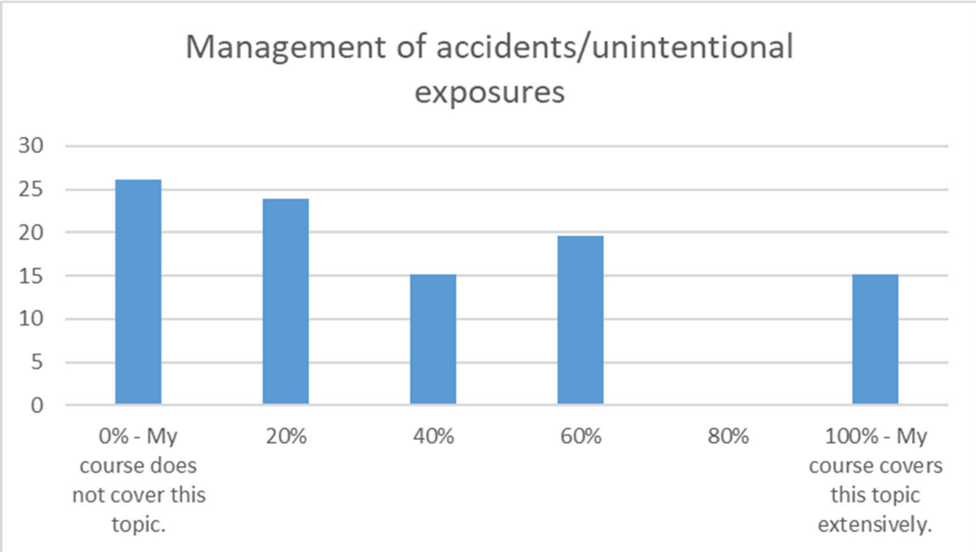

General principles of radiation protection (justification, dose limitation and optimisation)
30
25
20
15
10
5
0
0% - My course does not cover this topic.
20%
40%
60%
80%
100% - My course covers this topic extensively.


Particular radiation protection for patient and staff
35
30
25
20
15
10
5
0
0% - My course does not cover this topic.
20%
40%
60%
80%
100% - My course covers this topic extensively.


Typical doses from diagnostic procedures
40
35
30
25
20
15
10
5
0
0% - My course does not cover this topic.
20%
40%
60%
80%
100% - My course covers this topic extensively.


Dose management of children, pregnant women
40
35
30
25
20
15
10
5
0
0% - My course does not cover this topic.
20%
40%
60%
80%
100% - My course covers this topic extensively.





4. Conclusions

- Some respondents indicated that answering the questions of the survey was challenging as in some educational programs there are no stand-alone courses on "dosimetry", "radiobiology" and/or "radiation protection". Instead, the dosimetry, radiobiology and radiation protection subjects are partially treated in many courses. In the latter case, the respondent requires the knowledge of an entire study program.
- Currently, the dosimetry, radiobiology and radiation protection courses are predominantly organized using traditional teaching methods: lectures, exercises and lab sessions. Active learning concepts (such as project-based learning, microteaching…) are implemented in only a minority of the cases.
- The course material is often a mix of online material, reference books/publications and PowerPoint slides. In the majority of the cases, lecturers do not seem to compile a dedicated course syllabus. Most often, the course material is not provided as open access material.
- The evaluation of the dosimetry, radiobiology and radiation protection courses is, in the majority of the cases, based on a traditional written examination. Especially for dosimetry and radiation protection courses other evaluations (such as project and internship evaluation) are implemented as well.

- Time allocated for lectures, exercises and lab sessions widely vary among countries and institutes. However, as only a fraction of the respondents provided this data, no further conclusions can be made.
- Overall, the COVID pandemic had only a minor impact on course content (and hence learning outcomes) of the dosimetry, radiobiology and radiation protection courses. On the other hand, the pandemic forced the lecturers to implement new (online) teaching method which were not in place before the pandemic. Possibly, these newly developed online modules (both theoretical and practical), could help the further development of active learning in the field.
- Despite the online teaching efforts made during the COVID pandemic, respondents indicate a minor to significant influence of the pandemic on the quality of the courses.
- The dosimetry, radiobiology and radiation protection courses significantly contribute to all core topics as identified in the "Guidelines on Radiation Protection Education and Training of Medical Professionals in the European Union" [1]. The latter courses do not perfectly cover the full content of all core topics, as part of them will be addressed in other courses of a study curriculum.
- The learning outcomes are different for different educational programs (e.g. medical physics expert vs radiologists). Respondents were specifically asked to indicate these differences for their courses organized for different target groups. Given the relatively low number of responses in this survey, data was insufficient to accurately evaluate the compliance with the learning outcomes of the study programs of different medical and healthcare professions. We can conclude however, that dosimetry, radiobiology and radiation protection courses significantly contribute to most of the learning outcomes as defined in the "Guidelines on Radiation Protection Education and Training of Medical Professionals in the European Union" [1].

5. Reference

1. Radiation Protection Series, No 175: Guidelines on Radiation Protection Education and Training of Medical Professionals in the European Union. European Commission. February 2014.