Evolution and Evaluation of a Structured Applied Physics Course for Radiation Oncology and Radiation Physics Trainees

S. Babic1 · A. L. McNiven2 · A. Bezjak2 · J. M. Balogh3 · K. Mah2,3 · M. N. Tsao3

Accepted: 5 June 2022 / Published online: 28 June 2022
© The Author(s) under exclusive licence to American Association for Cancer Education 2022

Abstract

We sought to supplement medical physics textbook knowledge and clinical learning with case-based discussions. To our knowledge, this is the first report on a structured combined applied physics curriculum for radiation oncology (RO) and medical physics (MP) trainees. We reviewed our yearly applied physics course given from the years 2016–2021 inclusive. The number of applied physics trainees ranged from 7 to 14 per year (2–9 RO and 3–6 MP residents per year). Each session was taught by a pair of (RO and MP) faculty members. Twenty-nine case-based sessions were given yearly (2016 to 2019). Because of the COVID-19 pandemic restrictions, the course was shortened to 8 case-based sessions in 2020 and 2021. For the years 2016–2021, the mean and median teaching evaluation scores were 4.65 and 5, respectively (range 2–5), where 1 represents worse teaching quality and 5, the best teaching quality. For the year 2021, 2 questions relating to the video virtual format (implemented due to the covid-19 pandemic), revealed consistent high scores with the mean and median responses of 4.14 and 5, respectively (range 1–5). The results from the teaching evaluation scores indicate that the trainees highly valued the teaching sessions and teachers. Our experience indicates that a case-based applied physics course was delivered successfully with continued high teaching evaluation scores. A video virtual platform for an applied physics course could be useful, especially for small programs without a structured applied physics curriculum.

Keywords Applied · Physics · Education

Introduction

The practice of radiation oncology is built on a strong foundation of multi-professional interactions. A critical component for delivering high quality radiation oncology care involves applying medical physics knowledge and skills to everyday practice. In order to build on the future for radiation oncology, the curriculum for radiation oncology and medical physics trainees relies, in part, on an effective applied physics course.

Several sources of applied physics learning are obtained through textbooks [1–4] and hands-on clinical experience. This approach, however, is not structured and cannot reliably ensure that each trainee is competent in practice when applied physics knowledge and skills are crucial.

Based on the International Atomic Energy Agency (IAEA) recommendations on medical physics in Europe [5], close to 70% of medical physicists surveyed in 2015 cited lack of structured clinical training as an important issue. The International Atomic Energy Agency has also specified guidance on clinical training of medical physicists specializing in radiation oncology [6].

The American Society for Radiation Oncology’s 2015 core physics curriculum for radiation oncology residents outlined the most important medical physics topics residents are required to learn [7]. However, accredited radiation oncology training programs generally do not specifically outline detailed aspects relating to applied physics education [8–11].

We sought to supplement applied physics textbook learning and clinic learning with case-based discussions. These
case-based discussions were guided by radiation oncology and radiation physics faculty. This structure allowed for the following pedagogical approaches: collaborative, integrative and inquiry. In this collaborative approach, students worked in small teams with the recognition that the students have different levels of ability. As well, our students included both radiation oncology residents and radiation medical physics residents. Students collaborated with one another to learn together. In the integrative approach, classroom education was taught with real-world applications. In the inquiry-based approach, students were asked questions and were asked to use reasoning and problem-solving skills to reach a solution.

To our knowledge, this is the first report on a structured applied physics curriculum for radiation oncology and medical physics trainees.

**Methods and Materials**

We reviewed the recent 6 year applied physics teaching experience (2016–2021) in a university-affiliated multi-hospital site radiation oncology and medical physics accredited training program. The radiation oncology training program is accredited through the Royal College of Physicians and Surgeons of Canada. The medical physics training program is accredited through the Commission on Accreditation of Medical Physics Education Programs (CAMPEP).

The applied physics course was first developed in 1991 prior to the CAMPEP certification of the medical physics residency program. Although initially designed for radiation oncology residents, within 2 years, medical physics residents joined the course. The course has been revised regularly to incorporate evolving changes in practice, along with serial and exponential advances in radiation technology and computational power.

The applied physics course has therefore been a long-term component of the physics curriculum for the radiation oncology residency program, and a mandatory component of the medical physics residency curriculum. A unique component of the course is the intentional inter-professional education, due to the inclusion of both radiation oncology and medical physics learners and faculty.

The applied physics course was given to second year medical physics residents and PGY3 (post-graduate year 3) and in one year PGY2 and PGY3 radiation oncology residents. In 1991, the course ran from September to February, but required expansion to accommodate more complexity in treatments. In its recent format (prior to the pandemic), the course ran once a week from September to May for a total of 29 weeks. All sessions were 1 h long and case based except for 5 didactic sessions (Appendix 1).

Each session was taught by a pair of faculty members (one radiation oncologist and one medical physicist). Trainees and teaching faculty were given the course syllabus, consisting of the course schedule and cases. Each trainee was expected to prepare their answers for the cases and discuss during the class sessions. The cases in the syllabus were reviewed yearly by teaching faculty and adjusted for updated clinical management and technological changes.

The RO physics curriculum required re-development in 2019–2020 due to the introduction of the new competency-based curriculum, which necessitated completion of the physics curriculum prior to the end of the Foundations of Discipline stage of training in the Competence by Design framework. Due to excellent feedback on the applied physics course by previous residents, the importance of applied knowledge and the additional benefits of inter-professional education that the existing course offered, it was a priority to include a version of the previous applied physics course in the redesigned curriculum. The re-design included a planned reduction in the length of the applied physics course, as it transitioned to a final module in the physics curriculum focused on Review and Integration of Physics Concepts in Clinical Cases (Applied Physics). Several topics were moved into one of the other 5 modules. Another key component of the redesign was the weekly time allocated for physics, which resulted in a change from a 1 h timeslot to a maximum 3 h timeslot.

The introduction of the new version of applied physics was further complicated due to the COVID-19 pandemic which necessitated a change in teaching format. Similar to other teachers around the world [12, 13], our course coordinators needed to adapt and change the way we taught applied physics pre-pandemic by moving to a shortened virtual format that would preserve high quality education and teacher-trainee interaction. Within this shortened format, some of the cases (e.g. breast, lung, head and neck) that were typically covered over a 3 week period (1 h class per week), were revised in order to fit within a 2 h time slot. It was felt that online classes > 2 h in duration would lose the attention of trainees learning from home as well, over commit teachers as they adapted their teaching strategy to this new online system.

In 2020 and 2021, during the pandemic, the applied physics course syllabus was shortened to 8 weekly sessions (2 h class per week) and given from April to May. Classes were undertaken by video conferencing due to local hospital restrictions preventing in person learning. In order to keep class size small and encourage trainee discussion, the video conferencing sessions were repeated such that the class size was maintained to a small number of 5–6 trainees per class (Appendix 2). Trainees uploaded the answers to the case questions prior to each class session. An example of a case is shown in Appendix 3.

After each teaching session, trainees were given teaching evaluation forms consisting of 6 items (Appendix 4). The
teaching evaluation results were converted to a Likert scale from 1 (strongly disagree) to 5 (strongly agree). Open-ended comments regarding teaching quality were also sought with each teaching evaluation form.

In 2021, the teaching evaluation sheets were revised with an additional 2 items to account for virtual learning (Appendix 5). The teaching evaluation results were converted to a Likert scale from 1 (strongly disagree) to 5 (strongly agree).

A final examination was given to each trainee at the end of the course and it consisted of 3 clinical case scenarios, with written and oral questions on applied physics concepts learned throughout the course. The examination included 1 h written preparation for the cases which was then followed by a 1 h oral set of questions given by 2 faculty examiners (one medical physicist and one radiation oncologist).

During the initial height of the pandemic, in 2020, the final examination was waived, recognizing our trainees would be experiencing the stress of learning through a new virtual format while potentially coping with psychological effects such as anxiety and fear caused by the pandemic. Some of our radiation oncology residents were also redeployed to internal medicine to help with the covid-19 crisis.

In 2021, after one full year of adapting to working from home and learning through virtual formats, it was felt that trainees would have adjusted to this new way of teaching and that they would benefit from having an oral exam albeit through video conferencing. Course coordinators ensured the academic integrity of this final exam by having the trainees complete it online at their host hospitals.

This study was registered at the local institution as a quality improvement project (registration number 72).

Results

The number of trainees participating in the applied physics course ranged from 7 to 14 per year (2–9 radiation oncology residents per year and 3–6 medical physics residents per year). There were 7–12 faculty radiation oncologists who taught the course per year. Some taught more than one session. There were 7–9 faculty medical physicists who taught the course per year. Some taught more than one session. Each session was taught by one medical physicist faculty together with one radiation oncologist faculty member. Faculty teachers were chosen based on their evaluations by students for being effective teachers and for their willingness/availability.

The end of course exam was completed by all trainees. One faculty medical physicist and one faculty radiation oncologist administered the end of course examination. Ninety-four percent of trainees passed the final exam. Trainees who did not pass the final exam were given a supplemental exam (same format but different cases and questions). The supplemental exam was scheduled approximately 1 month after the first exam. Feedback was given to each trainee who did not pass the first exam. All trainees who did not pass the final exam, were successful in passing the supplemental exam.

Out of a possible 1800 teaching evaluation forms given to each trainee to score each teacher and each session taught, there were 366 teaching evaluation forms received. Although evaluation forms were given to each trainee to score each teacher for each session, return of completed evaluation forms was voluntary. These evaluation forms were received anonymously from each trainee. Open-ended written comments were welcome on each teaching evaluation form.

For the years 2016–2021, the mean and median teaching evaluation scores (for questions 1–6 Appendix 4) were 4.65 and 5, respectively (range 2–5).

In 2020–2021, due to the covid-19 pandemic, the teaching evaluations administered included 2 questions (questions 7 and 8 Appendix 5) regarding the virtual format of the course. For these 2 questions relating to the virtual format of the course, the mean and median responses were 4.14 and 5, respectively (range 1–5).

There were 49 anonymous written comments received. These were categorized as positive feedback relating to the session or faculty teacher and feedback regarding areas for improvement. No negative comments were received regarding teaching quality. There were a total of 41 positive comments relating to the high quality of teaching or the high quality of the teaching session. These comments included “Excellent course,” “Excellent teaching,” “Dr. X. is one of my favourite teachers in this course. Very knowledgeable and clear in explanations.” There were 8 comments regarding areas for improvement. Two comments for improvement related to providing slides to the trainees before or after each teaching session. Four comments related to having the answers to the case-based questions provided to the trainees after each session. One trainee commented that time management (too many questions and discussion topics) was an issue for some sessions and that at times the discussions veered off topic. One trainee commented that “virtual is fine given covid, but a mix of virtual and in person would be better.”

Discussion

This study is the first to report a structured applied physics course in an accredited radiation oncology and medical physics training program. This applied physics course is a component of a larger physics curriculum given to our radiation oncology and medical physics residents. The overall scope for physics education in radiation oncology resident
training has, for example, been detailed in The American Society for Radiation Oncology’s (ASTRO’s) 2015 core physics curriculum [7]. The ASTRO 2015 physics curriculum for residents outline suggested lecture hours on topics, learning objectives and textbook references. Site-based modules are also available listing common radiation treatment techniques based on body site. The intent of ASTRO’s physics-based learning modules is to provide an observational experience that supplements didactic education and clinical rotation experience. Our program is unique in that we have supplemented physics learning with a formal structured case–based applied physics course.

Furthermore, inter-professional education is recognized as an important component to improving healthcare delivery and patient outcomes [14]. The format of this applied physics course demonstrates inter-professional education between medical physicists and radiation oncologists. This structured opportunity provides learners an understanding of each other’s professional roles. Not only are applied physics concepts and principles learned, learners also practice and establish effective communication skills.

Each session was guided by teaching faculty (one medical physicist and one radiation oncologist). This format was well-received by the trainees. Having both a medical physicist and radiation oncologist, respectively, enabled insightful medical physics and clinical radiotherapy perspectives. The cases developed for each session were chosen based on common clinical scenarios and based on the ability of the case to highlight key physics concepts. In order to keep up to date with respect to medical physics and radiation oncology practice [15, 16], the syllabus of cases is reviewed yearly by a teaching faculty and is revised according to changes in evolving technology available and evolving clinical practice.

The applied physics examination results reveal that the initial pass rate was high at 94% and subsequently was 100% for those who took a supplemental exam (after not passing the initial exam). Because this applied physics exam was a smaller component of the overall physics and radiation oncology curriculum, we did not examine the overall pass rate for these trainees on the national specialty board certification exam. The main goal for this course was to enable residents to achieve competency with respect to applied physics principles [16]. It was not within the scope of this course to evaluate overall clinical competency.

The success of this course depends on a dedicated faculty who demonstrates excellent teaching skills. The results from the teaching evaluation scores indicate that the trainees highly valued the teaching sessions and teachers.

During 2020 and 2021, this applied physics course transitioned to a virtual teleconference format. Our experience indicated that the nature of this course (case-based discussions) was adaptable to a virtual format. In 2020–2021, due to the covid-19 pandemic, the teaching evaluations administered included 2 questions (questions 7 and 8 Appendix 5) regarding the virtual format of the course. For these 2 questions relating to the virtual format of the course, the mean and median responses were 4.14 and 5, respectively (range 1–5). One respondent preferred an in class setting or a mix of in class and virtual sessions.

The transition to virtual learning did help address programmatic feedback for the physics residency program as it has eliminated the need to travel which was quite extensive for some residents, with a 1 h course necessitating a full morning commitment of travel. Transitioning to virtual format had been discussed previously but course coordinators and lecturers were hesitant to switch the format before it was necessitated by the pandemic.

Although in person, class-based applied physics teaching may be preferred by some residents, our experience suggests that a case-based applied physics course could be delivered virtually. This could be useful, especially for small programs without a structured applied physics curriculum. For example, established applied physics courses based on clinical cases could be offered to smaller programs and offered virtually.

Future Plans

Our national radiation oncology training program has initiated a “Competence by Design” medical education framework. This involves a list of learning objectives called Entrustable Professional Activities (EPAs) and milestones.

As part of our national radiation oncology curriculum re-design, the applied physics course will be given to PGY2 radiation oncology residents and continue to be given to second year physics residents. Applied physics teaching content will be reviewed and edited yearly.

Specifically with respect to our national radiation oncology competencies, residents are expected to develop seven themed roles: Medical expert (the integrating role), communicator, collaborator, leader, health advocate, scholar, and professional. The applied physics course covers many of the radiation oncology competencies defined under these themed roles [17].

Our training program will continue to track resident performance in the physics curriculum as well as in other formal examinations such as our radiation planning exams, which incorporates core physics principles. Radiation oncology residents will continue to have weekly academic half-day teaching where physics-related concepts are incorporated into didactic teaching and case-based scenarios. These structured learning opportunities help ensure that applied physics fundamentals are integrated competently into daily practice. Our applied physics curriculum is expected to continue to evolve based on national accreditation standards,
with evolving technological changes and with feedback from
teachers and learners.

Appendix 1. 2016–2019 Applied physics

Appendix 1. 2016–2019 Applied physics

Appendix 1. 2016–2019 Applied physics

Sessions:
1. Didactic review of radiation physics
2. Case 1 Breast
3. Case 2 Breast
4. Case 3 Breast
5. Case 4 Gynecology
6. Case 5 Lung introduction
7. Case 6 Lung
8. Case 7 Lung
9. Didactic radionuclide therapy: clinical aspects
10. Case 8 Colorectal
11. Case 9 Lower GI-pancreas
12. Case 10 Prostate
13. Case 11 Head and neck
14. Case 12 Head and neck
15. Case 13 Head and neck
16. Case 14 Skin
17. Case 15 Lymphoma
18. Didactic brachytherapy physics
19. Case 16 Brachytherapy (tongue)
20. Case 17 Prostate seed implant
21. Case 18 Prostate HDR
22. Case 19 Gynecology brachytherapy
23. Case 20 Didactic radiation protection
24. Case 21 Brain stereotactic
25. Case 22 Total body irradiation
26. Case 23 Craniospinal irradiation
27. Didactic quality assurance part 1
28. Case 24 Quality assurance
29. Didactic Plan review and evaluation

Appendix 2. Pandemic 2020–2021 applied

Appendix 2. Pandemic 2020–2021 applied

Appendix 2. Pandemic 2020–2021 applied

Week Group Case
4 2 3 Lung
5 1 4 Skin
1 5 Gynecology
2 6 Colorectal
6 2 5 Gynecology
1 6 Colorectal
7 1 7 Head and Neck
2 8 Radionuclides and Radioprotection
8 2 7 Head and Neck
1 8 Radionuclides and Radioprotection

Appendix 3. Case example:

CASE 1 BREAST

Consider a 42 year old female with a T2N0 ca breast for
adjuvant radiation following a lumpectomy.

Questions:
1. Using illustrations, describe a technique (e.g. beam
arrangement, patient positioning, immobilization) that
will adequately treat all breast tissue while minimizing
dose to the critical structures. What dose would you pre-
scribe?
2. What factors contribute to a non-uniform dose distribu-
tion in the breast?
3. Describe how a physical wedge, virtual wedges and
MLC-based segments (control points) can be used to
create a “wedged distribution”.
4. Using your above illustrations, draw and describe an
acceptable isodose distribution.
5. What happens to the dose distribution as the separation
increases? Consider choice of beam energy as a function
of separation.

CASE 2 BREAST

A 50 year old female with T2N3 ca breast requires radiation
to the entire breast following a lumpectomy.

Questions:
1. Identify the GTV, CTV and PTV. What are the critical
structures and dose constraints? What dose would you
prescribe?
2. Using illustrations, describe a technique which will treat
the breast and nodal regions using photons. Consider
beam arrangement, patient positioning, immobilization,
beam junctions and dose uniformity throughout the volume.

3. What can you expect the dose across the junction to be? If gross disease is present at the level of the junction, how could you increase dose coverage?

4. How would you modify the technique if the internal mammary chain (IMC) nodes need to be included in the treatment volume? What is the impact of this modified technique on the critical structures?

5. Following her four field irradiation, the patient, whose biopsy showed positive lumpectomy margins, requires a boost to the lumpectomy site. How would you identify the CTV for the boost site? What margins would you use for the PTV boost?

6. Describe two photon beam arrangements that one might use to treat the boost volume.

Learning Objectives:

Clinical:
- Treatment volumes: GTV, CTV, PTV
- Field arrangement: tangential-opposed and 4-field
- Patient positioning and immobilization
- Photon beam junctions

Applied Physics:
- Influence of missing tissue (or lung), increasing separation and increasing energy on parallel-opposed field dose distributions
- Methods of missing tissue compensation: wedges
- Methods of creating ‘wedged’ distributions: Physical wedge, Virtual wedge, MLC-based segments (control points)

Appendix 4. Teaching evaluation surveys (2016–2019)

1. Communicated ideas
   - □ Strongly disagree □ Disagree □ Equivocal □ Agree □ Strongly agree

2. Demonstrated breadth of knowledge and ability to analyze information
   - □ Strongly disagree □ Disagree □ Equivocal □ Agree □ Strongly agree

3. Questioned and challenged students
   - □ Strongly disagree □ Disagree □ Equivocal □ Agree □ Strongly agree

4. The complexity of the material covered was appropriate to my level of training
   - □ Strongly disagree □ Disagree □ Equivocal □ Agree □ Strongly agree

5. The teacher explained ideas and concepts clearly
   - □ Strongly disagree □ Disagree □ Equivocal □ Agree □ Strongly agree

6. The session increased my knowledge
   - □ Strongly disagree □ Disagree □ Equivocal □ Agree □ Strongly agree
Appendix 5. Teaching evaluations during the pandemic

1. Communicated ideas
   - Strongly disagree  Disagree  Equivocal  Agree  Strongly agree

2. Demonstrated breadth of knowledge and ability to analyze information
   - Strongly disagree  Disagree  Equivocal  Agree  Strongly agree

3. Questioned and challenged students
   - Strongly disagree  Disagree  Equivocal  Agree  Strongly agree

4. The complexity of the material covered was appropriate to my level of training
   - Strongly disagree  Disagree  Equivocal  Agree  Strongly agree

5. The teacher explained ideas and concepts clearly
   - Strongly disagree  Disagree  Equivocal  Agree  Strongly agree

6. The session increased my knowledge
   - Strongly disagree  Disagree  Equivocal  Agree  Strongly agree

7. The virtual technology used for this applied physics session is equivalent to learning during an in-person classroom session
   - Strongly disagree  Disagree  Equivocal  Agree  Strongly agree

8. This applied physics session should continue to be given via the virtual technology used
   - Strongly disagree  Disagree  Equivocal  Agree  Strongly agree
Declarations

Conflict of interest The authors declare no competing interests.

References

1. Stanton R, Stinson D (2009) Applied physics for radiation oncology. Revised edition. Madison, WI: Medical Physics Publishing
2. Gibbons JP (2019) Khan’s The physics of radiation therapy. Sixth edition. Philadelphia, PA: Wolters Kluwer Health
3. Khan FM, Gibbons JP, Sperduto PW (2016) Khan’s Treatment planning in radiation oncology. Fourth edition. Philadelphia, PA: Wolters Kluwer Health
4. Podgorsak EB (2016) Radiation physics for medical physicists . Third edition. Cham, Switzerland: Springer
5. Casar B, do Carmo Lopes M, Drljevic A et al (2016) Medical physics in Europe following recommendations of the International Atomic Energy Agency. Radiol Oncol 50(1):64–72
6. International Atomic Energy Agency (2010) Clinical training of medical physicists specializing in radiation oncology. Training Course Series 37. IAEA, Vienna
7. Burmeister J, Chen Z, Chetty JJ et al (2016) The American Society for Radiation Oncology’s 2015 core physics curriculum for radiation oncology residents. Int J Radiat Oncol Biol Phys 95(4):1298–1303
8. Shakespeare TP, Back MF, Lu JJ et al (2004) Design of an internationally accredited radiation oncology resident training program incorporating novel education models. Int J Radiat Oncol Biol Phys 59(4):1157–1162
9. Khan RFH, Dunscombe PB (2016) Development of a residency program in radiation oncology physics: an inverse planning approach. J Appl Clin Med Phys 17(2):573–582
10. Cotter GW, Dobelbower RR (2005) Radiation oncology accreditation: the American College of Radiation Oncology, Practice Accreditation Program, guidelines and standards. Crit Rev Oncol Hematol 55(2):92–102
11. Li R, Shinde A, Novak J et al (2020) Temporal trends of resident experience in external beam radiation therapy cases: analysis of ACGME case logs from 2007 to 2018. Int J Radiat Oncol Biol Phys 106(1):37–42
12. Haworth A, Fielding AL, March S et al (2020) Will COVID-19 change the way we teach medical physics post pandemic? Phys Eng Sci Med 27:1–4
13. Azlan CA, Wong JHD, Tan LK et al (2020) Teaching and learning of postgraduate medical physics using Internet-based e-learning during the COVID-19 pandemic – a case study from Malaysia. Physica Med 80:10–16
14. Schultz O, Hight R, Chandra RA et al (2020) Qualitative study of interprofessional collaboration in radiation oncology clinics: is there a need for interprofessional education. Int J Radiat Oncol Biol Phys 108(3) suppl: E449.
15. Georg D, Thwaites D (2017) Medical physics in radiation oncology: new challenges, needs and roles (editorial). Radiother Oncol 125:375–378
16. Fiorino C, Jeraj R, Clark CH et al (2020) Grand challenges for medical physics in radiation oncology. Radiother Oncol 153:7–14
17. Burmeister JW, Domiello MM (2020) Radiation oncology resident didactic education in medical physics: evaluating residents, educators and the process. Int J Radiat Oncol Biol Phys 106(1):45–46

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.