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Future Trends in Medical Physics Education
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Adapting Graduate Education to Future Directions in the Field of Medical Physics

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Objectives

Learning Objectives:

1. Understand the ways in which graduate education is expected to change to incorporate potential changes in the science and practice of medical physics
2. Understand current trends and future directions in residency training for medical physicists
3. Understand how novel educational approaches can contribute to robust and effective teaching of medical physics

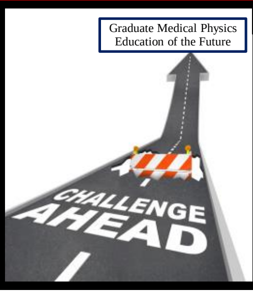
Disclaimer

- I currently serve as the
  - President and Chair of the Board for CAMPEP
  - Vice Chair of the AAPM Education Council
- The opinions expressed in this presentation *do not* necessarily reflect the recommendations (AAPM) or accreditation standards or policies & procedures (CAMPEP) of either organization.
- They may not reflect the opinions of other faculty at my current or former institutions…or anyone else.
- Overall Goal: To lead to an active dialog and, hopefully, subsequent action.

Background

Standard Medical Physics Graduate Curriculum
- AAPM TG197 defines the recommended graduate curriculum
- AAPM TG197S defines the *minimum* core topics that *must* be addressed for an alternative pathway applicant to a residency program
  - Radiological Physics and Dosimetry
  - Radiation Protection and Radiation Safety
  - Radiation Therapy Physics
  - Fundamentals of Imaging in Medicine
  - Radiobiology
  - Anatomy and Physiology
- CAMPEP *Standards for Accreditation of Graduate Educational Programs* requires these six topics, plus Professionalism and Ethics, be covered, at a minimum

Challenges

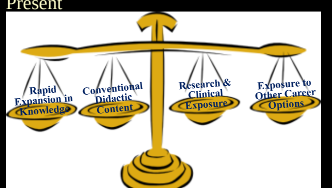


Fundamental Challenge

Balance

Past

Present



Challenges

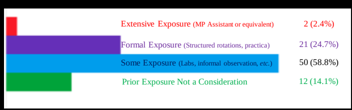
Medical Physics Graduate Program Challenge #1

- Balance of breadth and depth:
  - Number of course credits required to address CAMPEP curriculum *vs.* time allocated to research *vs.* time available for courses in increasingly important areas for the future of medical physics (computational biology, compressed sensing, bioinformatics and "big data", machine learning, optical/multiscale imaging, *etc.*)
  - Option to "Opt Out" of CAMPEP curriculum for accredited programs exists, but
    - less than 30% of accredited programs have implemented the option
    - even where implemented, most students pursue "CAMPEP track"

Challenges

Medical Physics Graduate Program Challenge #2

- Balance of didactic and research *vs.* clinical exposure:
  - Introduction of residency programs was anticipated to decrease the need for graduate programs to provide more than introductory clinical exposure.
  - A 2017 survey of residency program directors indicates >25% anticipate formal clinical rotations or practica levels of exposure (or more).



Challenges

Medical Physics Graduate Program Challenge #3

- Diversification of graduate program content – a need to:
  - identify and recruit faculty with appropriate content expertise in areas other than "conventional" medical physics
  - provide more diverse opportunities for students
    - internships, entrepreneurial training, principles of business, *etc.*
  - avoid over-emphasis on medical physics as applied to oncology (broadened curriculum as well as research opportunities)
    - surgery, targeted therapy delivery and distribution, multi-scale imaging, neuroscience, computational biology, "big data", *etc.*

Challenges

Medical Physics Graduate Program Challenge #4

- Truly valuing graduate education

  - conversion from “sage on the stage” Powerpoint lectures to active learning opportunities takes significant time and effort
  - maintaining “up-to-date” curriculum content requires time and effort
  - faculty conflicts – balance with other responsibilities, *e.g.*, clinic, research, service => strong impact on educational program time allocation
  - perceived value of educational contributions *vs.* research and clinical contributions relative to promotion and tenure and career advancement.

Challenges

Medical Physics Graduate Program Challenge #5

- Need for expanded numbers & diversity of career “role models”

  - How do we ensure our future (compete) in times of continued limited research funding? (Research mentors)
  - How do we produce the next entrepreneurs in diverse areas of medical physics? (Patent, tech transfer, startup company mentors)
  - Non-clinical medical physicists involved in the education program (or research) may be limited
    - potential lack of support if primarily in a clinical department
    - potential disparity in compensation

Challenges

Medical Physics Graduate Program Challenge #6

- Unintended consequences of the residency requirement

  - Over-emphasis on board certification impacting choices made by students who might otherwise focus on research-oriented or other non-clinical career preparation
  - Impact of students who would have pursued a terminal MS degree for a career in clinical medical physics now entering PhD degree programs to be more competitive in gaining entry to residency program
  - Need for more, and optimal design and implementation of, combined residency / post-doc programs

Challenges

Medical Physics Graduate Program Challenge #7

– Tendency for "Let's all do the same thing"

- Downside of accredited programs
- Can lead to stagnant structure and content, *e.g.*, the TG197S six core topics, silo-ed imaging *vs.* therapy content, *etc.*
- Need for "fresh start" in medical physics curriculum and education design
  – Requires significant time and energy in curriculum development (AAPM recommendations, local implementations)
  – Should ideally be aligned with CAMPEP accreditation standards

Challenges

Medical Physics Graduate Program Challenge #8

– Funding

- Shortage of fractional salary lines for education
- Research grant funding for research training is highly competitive and cuts are common
- Training grant funding is invaluable to enabling high-impact, high-risk research by students; being a training grant PI is a true act of altruism; funding is highly competitive

Balance Challenge Example

Core Curriculum *vs.* Med Phys Electives *vs.* Outside Electives

– *Mathematical & Conceptual Foundations* | *Applications: Imaging in Medicine*
– *Radiological Physics & Dosimetry* | *Radiation Physics Metrology* | *Monte Carlo Rad Transport*
– *Radiation Protection* | *Energy-Tissue Interactions*
– *Radiation Biology*

Total Available Med Phys Classes: 33 / Credits: 85

– *Physics of Medical Imaging – X-Ray* | *Principles of X-ray Computed Tomography*
– *Physics of Medical Imaging – MR & Ultrasound* | *Advanced MR Physics* | *Advanced Ultrasound Physics*
– *Radioisotopes in Medicine & Biology, including PET & SPECT*
– *Physics of Radiotherapy* | *Advanced Brachytherapy Physics* | *Advanced Treatment Planning*
– *Anatomy / Physiology* | *Patient Safety & Error Reduction*
– *Ethics & the Responsible Conduct of Research & Practice of Medical Physics*
– *Required Seminars*

Still doesn't adequately address machine learning, compressed sensing, *etc.*

Advanced Med Phys Labs | *Clinical Practica* | *Other MP Electives* | *Non-Med Phys Electives*

Common Electives

Typical Non-Med Phys Electives (UW-Madison Students)

- Oncology
- Biostatistics / Statistics (various)
- Bioinformatics
- Computational Methods for Medical Image Analysis
- Computer Science (various, including nonlinear optimization)
- Biochemistry / Organic Chemistry
- Neuroscience
- Physiology
- Introduction to Clinical Trials

Non-Med Phys Electives

Program Evolution

How should we consider evolving our programs to address future directions?

Opportunities

Medical Physics Graduate Program Evolution

- Break down artificial barriers and silos
  - Not imaging *vs.* therapy
  - Not just clinical career *vs.* academic career preparation
  - Not MR *vs.* CT *vs.* Ultrasound *vs.* Nuclear Medicine
  - Not just oncology
- Rethink the curriculum and educational environment “from ground up”, incorporating current and expanding opportunities for future medical physicists, not just what the current mentors and teachers learned and do
  - Computational biology, bioinformatics and “big data”, multiscale imaging, “non-conventional” therapies (targeted delivery and distribution of agents, minimally invasive surgery, focused ultrasound, *etc.*), business principles, entrepreneurship, …
- How would this be possible?

Opportunities

Medical Physics Graduate Program Evolution

- Reduce redundancies in the curriculum (often cited as inefficient by learners based on course evaluations)
  - Examples: production of ionizing radiation, basic interactions, attenuation coefficients and HVL, radioactive decay, counting statistics, *etc.*
- Increase communication and coordination between courses – teaching teams, not just individual teachers – integration of materials

- Implement or expand active learning environment across courses
  - Problem-based learning and peer instruction modules to reinforce and integrate content from prior courses
- Other contemporary pedagogical approaches (Montemayor presentation)


Evolution

Think outside the box…

- Modernize fundamental mathematical concepts and applications courses
  - Maintain fundamentals (Fourier theory, convolution, sampling theory, apodization, distributions, error propagation, Bayes theorem, mutual information, *etc.*)
  - Include additional concepts, including inverse problem applications: parameter estimation, singular value decomposition, penalized maximum likelihood methods (L1, L2, "compressed sensing"), optimization methods (linear *vs.* non-linear, convex *vs.* non-convex)
  - Include applications as problem-based learning modules (*e.g.*, Matlab implementations) and peer-instruction projects
  - Use multi-modality datasets, without addressing data acquisition specifics, to *demonstrate multi-application generalities, e.g.*, compressed sensing in MRI, CT, Nuclear Medicine imaging; inverse problems and optimization in therapy


Evolution

Think outside the box…

- Combine radiobiology and anatomy/physiology content
  - Cellular-level: radiobiology aspects as well as basics of cell biology important in therapeutic intervention and assessment – cell membrane transport, extracellular matrix, *etc.*
  - Organ system-level:
    - anatomy and physiology integrated with relevant radiobiology information
    - radiographic anatomy with common pathology (not just oncology)
      - use "compare and contrast" exercises to emphasize advantages of specific imaging modalities

Evolution

Think outside the box…

- Coordinate and craft content for radiological physics and dosimetry course
  - Eliminate need for repeating basic interactions, cavity theory, *etc.* content in subsequent courses in radiation therapy, diagnostic, and nuclear medicine physics
- Introduce a production and measurement of ionizing radiation course
  - Address all modalities, both radiation therapy (linacs, brachy) and imaging (x-ray, nuclear medicine – both diagnostic and therapeutic)
  - Include radionuclide production, *e.g.*, cyclotron-produced radioisotopes
  - Raise the bar on practical measurement concepts, *e.g.*, cavity theory
  - Include key metrology concepts and methodology
  - Include lab components
  - Eliminates redundant content in multiple courses

Evolution

Think outside the box…

- Harmonize and optimize content for ionizing radiation-based imaging courses
  - Eliminate redundancies across the content for each modality
  - Use peer-instruction and problem-based modules to integrate radiological physics and dosimetry course information into specific examples for each modality
  - Include "compare and contrast" assignments to force deeper understanding of common applications of each modality
  - Integrate radiobiology concepts, with examples and problems for each modality
  - Include lab components for each modality
- Harmonize content for non-ionizing radiation-based imaging courses
  - Use peer-instruction and problem-based compare-and-contrast modules
  - Include lab components for each modality

Evolution

Think outside the box…

- Optimize the radiation therapy physics course content
  - Minimize redundancy with the radiological physics and dosimetry course. Instead, use peer-instruction and problem-based modules to integrate concepts
  - Include external beam, brachytherapy, and targeted radiotherapeutics
  - Include "compare and contrast" assignments to force deeper understanding of common applications of each treatment modality
  - Integrate radiobiology concepts, with examples and problems for each treatment modality
  - Include risk analysis methods in quality management
  - Include lab components for each modality

Evolution

Think outside the box…

- Make ethics and the responsible conduct of research content relevant
  - Address topics in AAPM Report of Task Group 159, *Med Phys* 37(8):4495-4500, 2010
  - Include specific vignettes that address ethical and professional conduct and interactions and specific examples relevant to medical physics

Evolution

Think outside the box…

- Incorporate course content in bioinformatics, computational modeling/biology, and machine learning
  - "Standard" statistics material is no longer sufficient
  - "Big data" is here to stay, whether emphasizing imaging or therapy applications
- Develop or collaborate on courses to introduce relevant business concepts
  - Budgeting and business plan development
  - Project management
  - Non-disclosure agreements
  - Patents and technology transfer
  - Medical regulations
  - Note that these are important skills not only for industry, but for academic research, consulting, *etc*.

Evolution

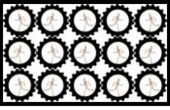
Think outside the box…

- Include options for internships and entrepreneurial experience
  - Seek out industry options for internships – some companies are eager to support and even fund such opportunities (must balance w/research grant support requirements)
  - Form "mentor bureau" and develop mentor support mechanisms
- Actually use the Individualized Development Plan (IDP) process for students

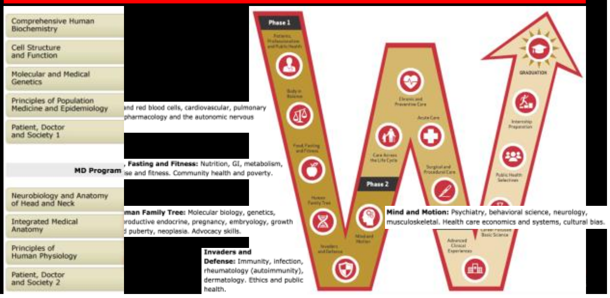
What will it take?

A whole new level of coordination and support…

- Development of a common goal and vision for curriculum transformation
  - Locally
  - Nationally / Internationally (AAPM, CAMPEP, *etc.*)
- Significant coordination of effort amongst teachers
  - Medical physics faculty
  - Interdisciplinary faculty
- Evolution of pedagogical approaches to optimize in-person educational experience
- Increased engagement of students as active learners



Curriculum Transformation



Thank you for your attention…

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