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Research Letter

Results of a Multi-Disciplinary and Multi-Institutional Pilot Creating High-Yield Physics Educational Content (Hi-Phy)

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Purpose: The quality of medical physics education is heterogenous across training programs, despite its importance in radiation oncology (RO) residency training. We present the results of a pilot series of free high-yield physics educational videos covering 4 topics chosen from the American Society for Radiation Oncology core curriculum.

Methods and materials: Scripting and storyboarding of videos were iterative processes performed by 2 ROs and 6 medical physicists, with animations created by a university broadcasting specialist. Current RO residents and those who had graduated after 2018 were recruited through social media and e-mail with an aim of 60 participants. Two validated surveys were adapted for use and were completed after each video as well as a final overall assessment. Content was released sequentially after completion of the survey instruments for each prior video. All videos were created and released within 1 year of project initiation with a duration of 9 to 11 minutes.

Results: There were 169 enrollees for the pilot from across the world, 211% of the targeted cohort size. Of these, 154 met eligibility criteria and received the first video. One hundred eight enrollees initiated the series and 85 completed the pilot, resulting in a 78% completion rate. Participants reported improved understanding and confidence applying the knowledge learned in the videos (median score 4 out of 5). All participants reported that the use of graphic animation improved understanding across all videos. Ninety-three percent agreed with a need for additional resources geared specifically toward RO residents and 100% would recommend these videos to other residents. Use metrics revealed the average watch time was 7 minutes (range, 6:17-7:15).

Conclusions: The high-yield educational physics video pilot series was successful in developing videos that were effective in teaching RO physics concepts.

Introduction

Learning physics concepts well is a fundamental skill necessary to become a competent radiation oncologist. Although

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Data sharing statement: Research data are stored in an institutional repository and will be shared upon request to the corresponding author.

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board preparation is not the sole goal of physics education for residents, it is a crucial component to residency training, as one cannot practice independently without passing the board examination. Unfortunately, a recent survey of radiation oncology (RO) residents show a majority (76%) report they are unsatisfied with the current level of lecture content/study materials currently available.[1] Only 30% of residents found their institutional physics curriculum helpful in board examination preparation, and 44% purchased expensive national review courses to supplement their learning, leading to inter-program inequity and variability in the depth of learning in resident education.[1] Additionally, in 2018 the physics (and biology) board examination was 1 of the top 2 concerns among residents.[2] Moreover, some suggest the recent decline in applicants to RO is related to a perception that specialized education in physics is a prerequisite and the drop in board pass rates could detract from recruitment efforts.[3-5]

To meet this need, we developed a pilot series of high-yield educational physics (Hi-Phy) videos illustrating key concepts in an engaging way, offered at no cost and intended to be widely disseminated. This project was multi-institutional with a team of medical physicists, attending and resident radiation oncologists, the Poorvu Center for Teaching and Learning, and a professional broadcasting department.

The pilot objectives were: (1) develop 4 high-yield illustrative videos for the Hi-Phy initiative pilot; (2) disseminate the video content across the country using national and international organizations; and (3) evaluate the accessibility and scope of the video series to inform development of future modules.

Methods and Materials

Project design

The Hi-Phy team used 5 basic steps in this process: global design, scripting, storyboarding, editing, and evaluation. Details of the creation and development of video content have been submitted for publication separately. Briefly, these videos were created based on the 2015 American Society for Radiation Oncology core curriculum[6] and were not meant to supplant institutional physics courses but rather provide an illustrative overview to help solidify concepts that residents are expected to master in preparation for their qualifying examination and in clinical practice. To this end, graphics and animations were created and timed with voice-over to create a mental recall image for learners and demonstrate the relationship of 1 item/thought to another.

Survey creation

A protocol was created and approved by the Yale Institutional Review Board. Two survey tools were adapted for this pilot.[7,8] Each video had a corresponding survey, including retrieval practice questions created and vetted by medical physicists, as well as an adapted technology acceptance model survey assessing participant's baseline understanding of the topic and perceived benefit of the digital content.[7] The final survey also had an overall program assessment, including an adapted and validated tool assessing fitness-for-purpose, efficiency, suitability, usefulness, and perceived ease-of-use.[8] The modifications of the survey were discussed with the Center for Education and Learning. In addition, we also asked participants for feedback on video length and effect of animations on their understanding. Responses were predominantly Likert scale: (1) not at all; (2) slightly; (3) moderately; (4) quite; and (5) extremely. Examples of a video-specific survey and the overall program evaluation are available (supplemental surveys).

Participant enrollment and pilot rollout

All current RO residents (graduation date 2021-anticipated 2025) and those who had graduated after 2018 were eligible. Enrollment was open for 1 month. After accrual, the pilot lasted 1 month, during which videos and surveys were released sequentially, with the next video released upon completion of the previous video's survey. The sign-up was publicized on social media, (Fig. E1) e-mailed to all residency program coordinators and department chairs, and included in the QuadShot newsletter and in the Association of Residents in Radiation Oncology (ARRO)gram. The videos were posted as "unlisted" on YouTube such that viewing was only available by direct link. During the pilot, 2 reminders were sent to participants and there was a raffle for 2 $100 Amazon gift cards available for those who completed all surveys.

Data analysis

Descriptive statistics described participant impression and perceived benefit of the pilot. Comparisons of all eligible enrollee demographics were analyzed and compared with those who completed all 4 videos/surveys. Understanding was analyzed among all participants and specifically those with previous exposure to the content being taught. Linear regression was used for continuous outcomes (with Bonferroni correction), and for categorical outcomes χ^2 and Fisher's exact test were used. Statistical significance was defined as a probability less than 5% (α = .05).

Results

Four videos were created as part of this pilot on the following topics: (1) factors affecting dose calculations; (2)

monitor unit calculation practice; (3) photon penumbra; and (4) photon field matching (craniospinal irradiation). One hundred sixty-nine unique participants enrolled in the pilot, representing 211% of the target (60 participants). Out of 154 eligible participants (Fig. E2), 108 participants completed video 1 and its survey. All 4 video/survey pairs were completed by 85 participants, corresponding to a 79% completion rate by those who initiated the pilot (Fig. E2). Participant characteristics represented a variety of training levels, regions, and program sizes (Table 1), consistent with Association of American Medical Colleges- and ARRO-reported demographics. There was no difference in self-reported demographics between responders and nonresponders, $P > .05$ for all categories. A majority (72%) of registrants felt they were provided with insufficient access to physics educational materials, and 94% acknowledged a need for free educational resources geared specifically toward RO in-training.

Survey assessment

Video-specific feedback

Most participants had at least 1 instance of prior instruction on these concepts; however, at baseline, postgraduate year (PGY) 1 to 4 felt the topics were moderately or quite confusing before watching the Hi-Phy videos (Fig. 1). All videos were well-received, with near unanimous reporting of improved understanding of the covered topics and a median score of 4 (quite improved; Fig. 2). This persisted when analyzing only those who reported previously being taught the covered material (data not shown). Despite participants reporting relatively high baseline exposure to all topics covered in the Hi-Phy series, there was a consistent absolute improvement in self-reported confidence applying said principles (Fig. 3).

For videos 1 to 3, >90% of participants felt the videos were appropriate in length, with the remaining 5% to 9% citing they were too short. For video 4, 74% of respondents reported appropriate length, whereas 25% felt the video was too short, and several respondents desired an explanation of matching breast fields.

Overall program assessment

Overall, the videos were perceived as quite beneficial and enjoyable to watch (Fig. 4). The lowest scores for the categories of "appropriate for learning level" and "helping to understand topics that were previously confusing" were given by PGY4 and prior RO graduates (n = 9; Fig. 4). All participants would recommend these videos to other RO residents. Regarding clarity of graphics, animations, and how these contributed to an overall improvement in understanding of the covered concepts, all domains received a median score >4.

Table 1 Pilot participant self-reported demographics of those who completed all videos and surveys

Characteristic	n = 85 (%)
Sex	
Female	40 (48)
Male	42 (50)
Prefer not to answer/missing	2 (2)
Origin	
Hispanic	4 (5)
Not Hispanic	67 (79)
Other	6 (7)
Prefer not to answer/unknown	8 (9)
Race/ethnicity	
Asian	32 (38)
Black	2 (2)
White	40 (47)
Other/unknown	11 (13)
PGY level	
PGY1	2 (2)
PGY2	25 (29)
PGY3	32 (38)
PGY4	19 (22)
PGY5	6 (7)
2019-2021 graduate	1 (1)
Regions	
West	13 (15)
Southwest	5 (6)
Midwest	12 (14)
Southeast	12 (14)
Northeast	29 (34)
Outside US	14 (17)
No. Residents Median (IQR)	8 (6-12)
Medical physics board status	
Already taken	9 (11)
Actively studying	24 (28)
Will take it sometime in the future	52 (61)
Background in physics	
Prerequisites	65 (76)
Undergrad minor	6 (7)
Undergrad major	5 (6)
Doctoral degree	2 (2)
Other	7 (8)

Abbreviations: IQR = interquartile range; PGY = postgraduate year; US = United States.

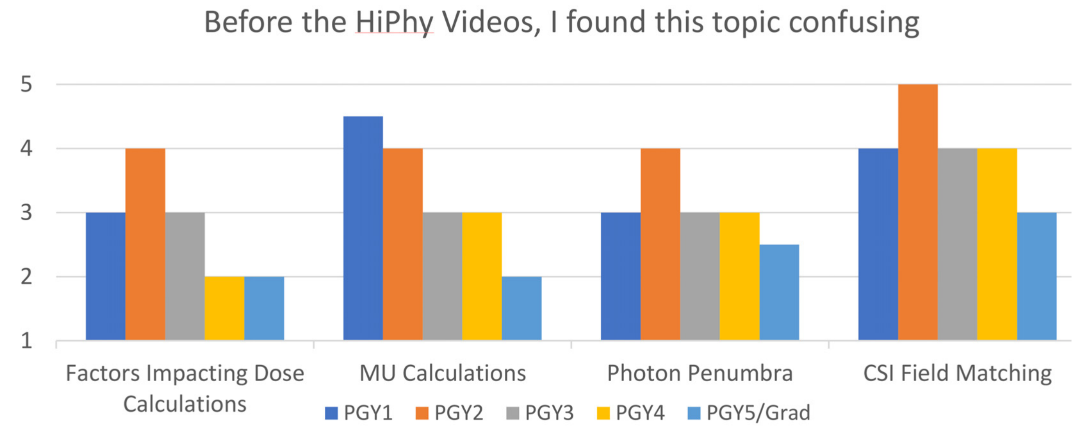

Figure 1 Video-specific question asking for pilot baseline confusion regarding the material covered in the video, based on PGY level. Likert scale: (1) not at all; (2) slightly; (3) moderately; (4) quite; and (5) extremely. *Abbreviations:* CSI = craniospinal irradiation; MU = monitor units; PGY = postgraduate year.

The videos ultimately fulfilled their fitness of purpose, accessibility, and ease of use with a multitude of positive qualitative feedback (Fig. E3).

Video-use metrics

During the 1-month pilot period, the 4 Hi-Phy pilot videos were watched 451 times through 153 unique internet protocol addresses (162, 111, 93, and 85 times for videos 1-4, respectively). Each individual video generated its own average watch time. We compiled these results and the median watch time for the 4 videos was 7 minutes per view (range, 6:17-7:15; Fig. 5). Based on our engagement graphs, it is likely that participants were watching on >1x playback speed, as the viewership never dipped below 50% during physics content despite absolute view time, 7 minutes, being less than video duration, 9 to 11 minutes. An average of 64% of viewers were still watching the video when credits began. YouTube is not able to retrieve more granular information. Additionally, participants appeared to skip some sections and rewatch others, evidenced by dips and spikes on the graphs (Fig. 5).

Discussion

The Hi-Phy pilot demonstrates the feasibility of developing illustrative physics videos geared toward resident-level learners. There was near unanimous improvement in participants' self-reported level of understanding and confidence in the RO physics topics, and participants felt that watching these videos was an effective use of their time. Participants agreed that additional RO-directed

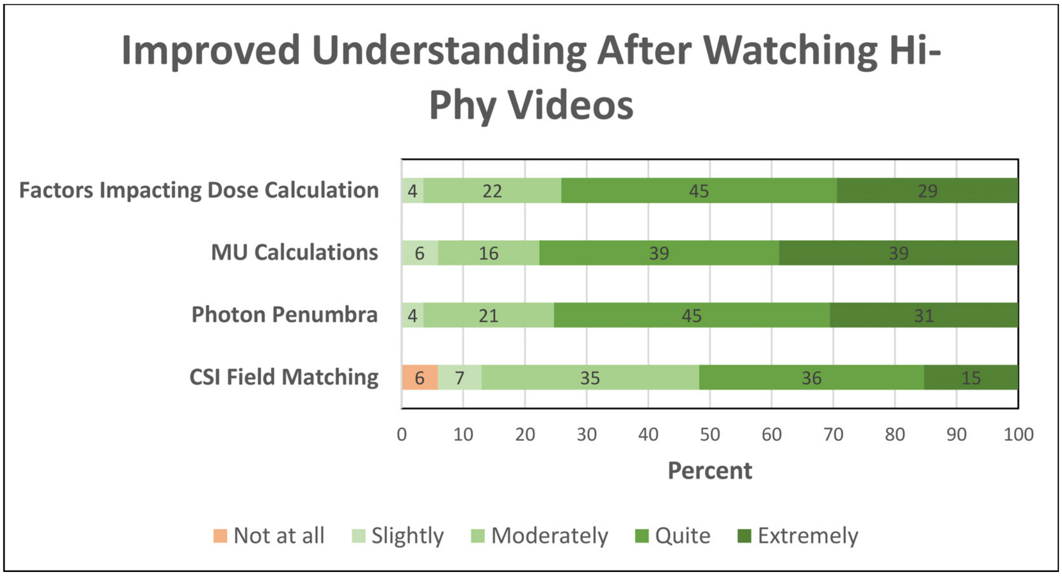

Figure 2 Video-specific question regarding self-reported improved understanding of the concepts taught in the pilot video.*Abbreviations:* CSI = craniospinal irradiation; MU = monitor units.

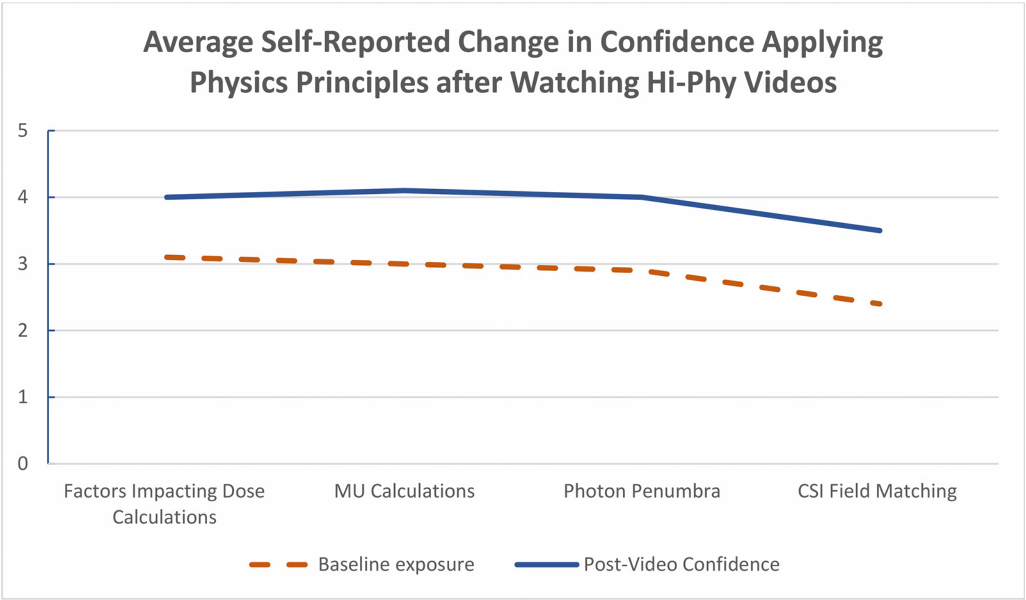

Figure 3 Comparison of self-reported, prepilot exposure to the material taught in each video (dotted line) compared with self-reported, postpilot confidence in applying the principles learned during each video (solid line). *Abbreviations:* CSI = craniospinal irradiation; MU = monitor units.

content would be valuable, and they would recommend their coresidents watch the Hi-Phy series.

The rapid accrual to our pilot supports the general interest and desire for similar content. The Hi-Phy YouTube channel will remain active to host this content indefinitely, with links listed on ARRO[9] and the Radiation Oncology Education Collaborative Study Group websites.[10] The present study underscores the importance of these efforts as supplements to standard physics didactics. It is notable that baseline level of confusion decreased as years of training increased. This may indicate that this series is most valuable in the early years of training, although it is noted that confusion remained on field matching even for PGY-5s. Of note, since the development of this pilot, an additional excellent resource has become available, including a series of videos published alongside a renowned physicist-authored textbook.[11]

One avenue for implementation of the Hi-Phy series[12] or Eric Ford series[11] includes institution of a reverse classroom approach in which, before scheduled didactic lectures, trainees watch a corresponding engaging video to become familiar with the terms and underlying principles pertinent to that topic. This allows trainees to be more engaged in the following lecture, which could be used

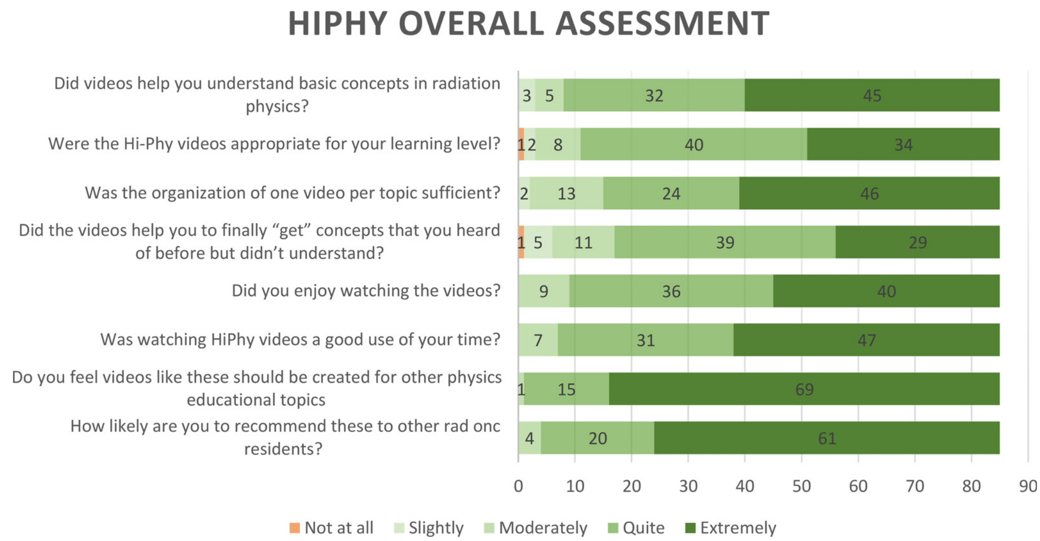

Figure 4 Overall assessment of the high-yield educational physics videos. All questions were Likert scale.

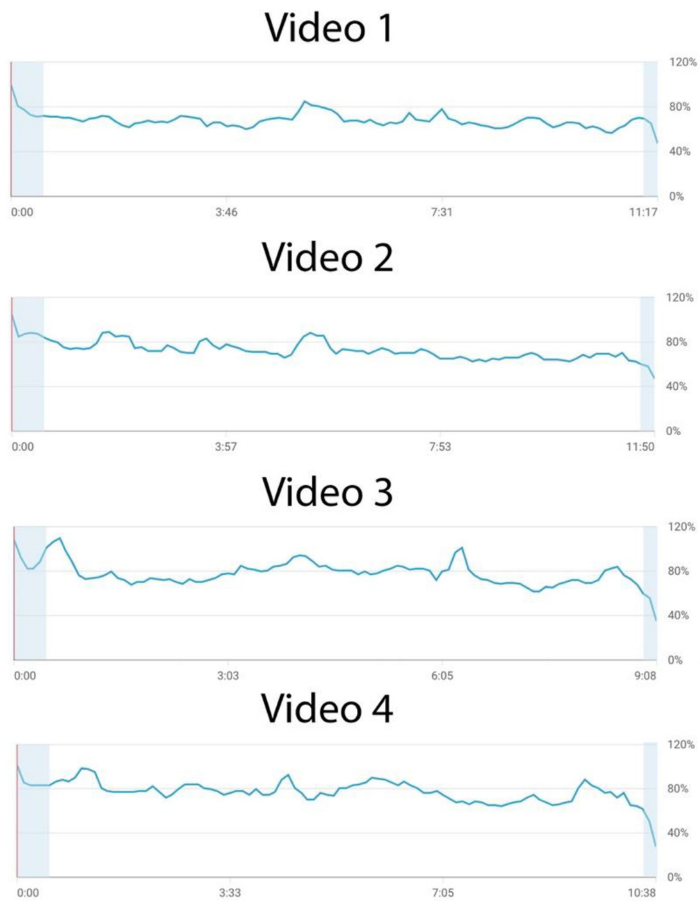

Figure 5 YouTube use metrics of each video. These line graphs represent percentages of total viewers across the running times of all 4 videos. Percentages can exceed 100% because viewers can rewind to watch a section of a video more than once (spikes) or skip over sections, such as the introduction/credits (dips). The blue shaded sections represent the first 30 seconds of introductory material and the final 15 seconds of credits (x-axis represents time within the video and y-axis represents the percentage of viewers still watching at any given time x).

partially to elaborate on the topic but also to address trainee questions and work through sample problems. This contrasts with many "typical" didactic outlines, in which the residents come to a lecture and hear about a new topic, with 60 minutes of lecture through PowerPoint slides.

Digital media medical education can take many forms; however, studies have shown that learners engage, process, and retain information from illustrations and diagrams significantly better than from text alone by taking advantage of the dual coding theory[13,14] (eg, that visual imagery adds to learning). Importantly, audiovisual media must be tightly edited to limit extraneous and distracting information.[15] In support of this existing literature, participants in our study expressed that the combination of graphics and animation aided the understanding of concepts previously difficult to visualize.

Data demonstrate that video length <10 minutes maximizes viewer attention and engagement.[16-18] Though we aimed to create videos on the order of 5 to 8 minutes, adequate explanation of complex content and accompanying animation resulted in videos ranging from 9 to 11 minutes. Our audience retention was better than the average of 45% to 50% after 5 minutes,[19,20] and our use metrics suggest that most viewers had diminishing interest or attention after approximately 6 to 7 minutes. This should be kept in mind during creation of future videos. One limitation of this study is that the videos, by nature of the platform used to deliver them, were not interactive and did not directly engage the learner to apply the lessons. Additionally, given the large number of factors that might affect performance of pilot enrollees on an assessment after these videos, this pilot relied on self-reported improvement of understanding, which may not be as reliable as rigorous assessments of these concepts through testing. However, the willingness of pilot enrollees to complete both a pre- and postvideo assessment was considered and felt to represent a significant time investment, which would have hindered participation. Finally, the phrasing of questions and lack of neutral options within the Likert scale could have caused skewed responses.

Despite these potential limitations, the participants in this pilot were very positive about the experience.

Conclusions

Based on the overwhelmingly positive feedback on these videos and the reported need for resources by Hi-Phy participants, future endeavors to create more content and cover additional topics in the American Society for Radiation Oncology physics core curriculum are encouraged. Essential components to producing similar content are securing funding, partnering with appropriate animation resources, and assembling a motivated team, as well as collaborating with other educational study groups in RO to avoid duplicate resources and material.

Disclosures

Todd F. Atwood and Derek Brown receive honoraria from Varian (outside scope of this work), Derek Brown receives grant funding from the US Trade and Development Agency (outside scope of this work), Eric Ford is on the American Society for Radiation Oncology Board of Directors, and Titania Juang holds leadership roles through the AAPM.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.adro.2023.101262.

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