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Screen-based digital learning methods in radiation oncology and medical education

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ABSTRACT

The field of radiation oncology is rapidly advancing through technological and biomedical innovation backed by robust research evidence. In addition, cancer professionals are notoriously time-poor, meaning there is a need for high quality, accessible and tailored oncological education programs. Digital learning (DL) is well-placed to cater to these needs, as it provides teaching options that can be delivered flexibly and on-demand from anywhere in the world. The evidence for usage of these techniques in medical education has expanded rapidly in recent years. However, there remains many reservations in the oncological community to adopting and developing DL, largely due to a poor familiarity with the pedagogical evidence base.

This article will review the application of the screen-based DL tools that are at educators' disposal. It will summarize best-practice in developing tailored, made-for-screen videos, gamification, and infographics. It also reviews data behind the following practical tips of 1) strategically combining text with graphics to decrease cognitive load, 2) engaging users through use of interactive elements in digital content, and 3) maximizing impact through thoughtful organization of animations/images.

Overall, the digital space evolving is well placed to cater to the evolving educational needs of oncology learners. This review and its practical tips aim to inspire further development in this arena, production of high-yield educational products, use of engaging delivery methods and programs that are tailored to individual learning needs.

Introduction

The field of radiation oncology is rapidly advancing through technological and biomedical innovation backed by robust research evidence. With the volume of new knowledge being generated daily, it is increasingly difficult for cancer professionals to stay up to date on clinically relevant happenings [1]. Education programs are the crucial link that bridge this gap, ensuring that the latest research findings are being conveyed to the front-line clinicians to be applied in daily practice. Unfortunately, such programs aimed specifically for radiation oncology (RO) trainees or practitioners have not been available, with many of the present options including annual seminars or expert panel discussions. However, the evolution of digital learning (DL), that is learning delivered by technological means, is expanding the opportunity to fulfill this need [2]. Additionally, one of the inequities specific to RO education has been the historical reliance of learning from instructors and mentors physically proximate to them, leading to high volume centres with large residency cohorts or special equipment perceived as

Abbreviations: RO, Radiation Oncology; RT, Radiotherapy; DL, Digital Learning; IMRT, Intensity Modulated Radiotherapy; VR, Virtual Reality; AR, Augmented Reality.

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"best educated." However, DL tools have broadened the scope of who can be a trainee's educator, and in some capacities levels the playing field.

Over the past decade there has been a trend of oncology learners turning to DL to fulfil their educational needs, which has mirrored a larger societal shift towards online education (Fig. 1) [3–5]. Importantly, This transition had already begun prior to Covid-19, but the onset of the pandemic in 2020 accelerated this change [6–8].

Covid aside, the major drivers that have fuelled this migration have been the convenience of DL and the great breadth of offerings available in this format [9,10]. The convenience factor is particularly important for cancer professionals, given that most already find it difficult to find the time to complete even their core clinical duties and as-such have found the on-demand conveniene of asynchronous learning to be particularly compelling [11].

While uptake of DL has been strong, it is at times accompanied by a perception of offering a poorer learning experience than face-to-face education. Some learners may see it as a choice between convenience and quality when deciding on what to undertake [9,12]. However, this perception is primarily reflective of early forays into the digital teaching space when the educational tools available, and ability to use them, were still nascent.

As time has progressed, there has been an ongoing evolution in the methods at educators' disposal and their comfort in applying them. Increasingly sophisticated, engaging and pedagogically-driven solutions are coming into play, providing a quality of learning experience that was previously impossible. This is being underpinned by simultaneous significant advances in educational research to better inform the implementation of these learning techniques to be effective and high-yield learning experiences.

However, given the recency of these developments, most cancer educators remain unfamiliar with their application. Furthermore, there is a notable paucity of discipline-specific research into the design and best-practice use of technology in radiotherapy education. As such, radiotherapy educators are largely being left to navigate the vast educational literature base on their own.

This article looks to specifically fill this gap in the literature by providing a succinct and curated summary of the pertinent evidence on screen-based DL methods. In addition, it will discuss the practical application of these screen-based learning techniques and give advice for educators who are looking to implement (or refine) these in their own learning contexts. It is the first in a two-part series, with the companion piece being on Virtual Reality and Augmented Reality in Radiation Oncology Education [13] and will be focused on the setting of healthcare provider education.

Screen-Based digital learning

In recent years Covid-19 had major ramifications for radiation oncology education. While there had already been notable cases of oncological educational programming moving online prior to this [14,15] they were in the minority until 2020. At this point, online delivery became a necessity and there was a rapid global shift of educational activities from in-person to online. Radiation oncology residency and specialty training programs became heavily screen-based [7,16] and educational conferences and symposia transitioned to screen-based online formats [7,16].

This is consistent with a large-scale trend of adults globally spending a significant portion of their day in front of screens. In 2021, the average time spent online each day was 6 h and 58 min, with the majority of that being on personal devices – the phone, tablet, laptop or desktop computer [3,12,17]. The ubiquity of these devices means that they allow flexible access to online materials at any time or place that is convenient for the individual. As such, screen-based digital learning techniques have become a dominant educational method.

There are a number of ways to sub-categorise screen-based digital learning techniques, without universally accepted nomenclature to define these. Here we will use the term *Delivery methods* to refer to the specific ways in which learning materials can be depicted on screen. This is a relatively short list [18,19], comprising:

(1) Text on screen
(2) Static images (visuals/infographics)
(3) Moving images (videos),

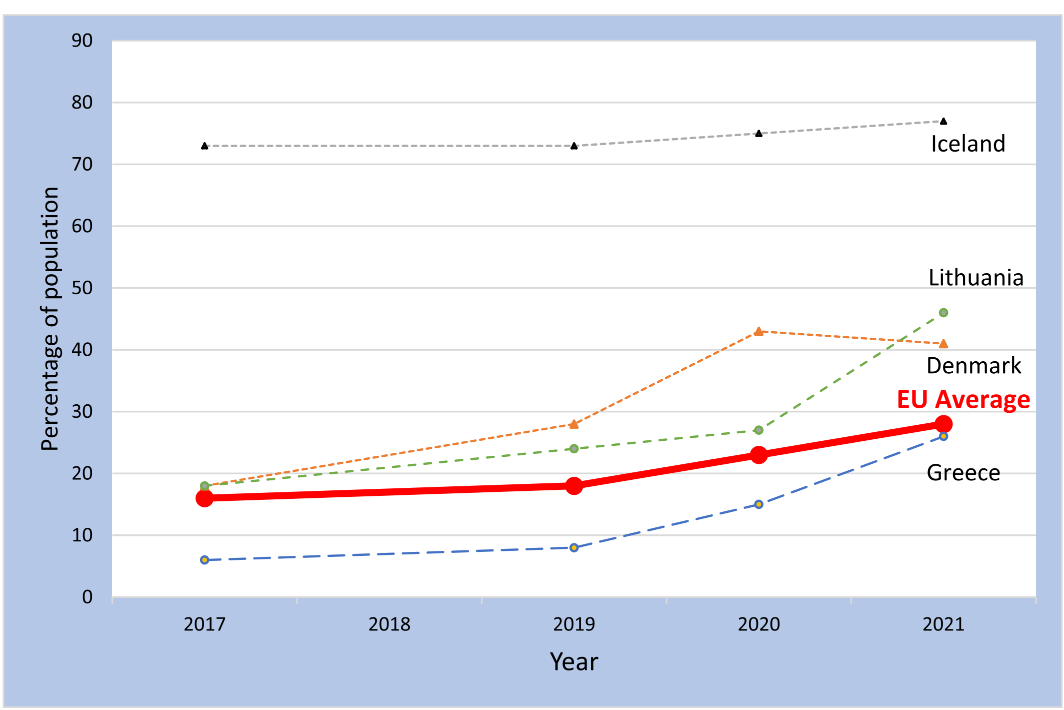

Fig. 1. Percent of individuals who are doing an online course or using online learning material in Europe 2017–2021, including highest (Iceland), lowest (Greece) and EU average (Source data from Eurostat [4]).

(4) Heavily interactive methods (gamification)

We will explore the best practice use of each of these, with the exception of 'text on screen' which is pedagogically no different to any written text format and thus requires no introduction. While non-screen-based learning materials are outside the scope of this article, they include virtual or augmented reality (VR/AR), podcasts, and audiobooks all of which have unique roles in medical education [13].

Of note, digital learning can also be categorised by its *learning context* [20,21]– this is the wider context in which an education experience is delivered; for instance, via social media, microlearning or even an online degree. A learning context generally comprises a variety of constituent smaller educational pieces, each of which may have been delivered using a different tool. For example, a microlearning module on Intensity Modulated Radiotherapy (IMRT) could be a combination of '*text on screen*' describing the principles of IMRT, an *infographic* showing possible beam angles, and a *video* demonstrating how dynamic MLC movement sculpts the dose distribution. Discussing the optimal design of these amalgam learning contextsis beyond the scope of this article.

Visual graphics & infographics

There has been a significant increase in the use of infographics for education. This includes education of the general public, of patients [22,23], of learners [24–26] and for research dissemination [27,28]. Infographics are visual representations of information, which combine the use of data, charts, icons, and illustrations, with the key aspect of comparatively minimal text [29]. They are particularly useful as a means to distil large amounts of complex information into a format that is easily digestible learners.

Infographics are particularly relevant in oncological education, which involves vast amounts of interconnected information across the biomedical and technological. As such, many large institutions such as the Cancer Research UK, International Atomic Energy Agency, Cancer Council of Australia, WHO, and others have adopted the use of infographics to depict complex data and concepts, while journals such as Cancer Cell and the British Medical Journal have adopted graphical abstracts for representing and disseminating new research findings [30,31].

Learners engage, process and retain information from illustrations/diagrams significantly better than from text alone [32–34] and, in certain situations, an order of magnitude better [34] Fig. 2.

This is because visual formats support learners to digest and interpret complex concepts in a more efficient and effective manner, than simply text alone. This is explained by the 'dual coding theory', which describes how the human brain processes information using two channels: a verbal channel for processing language and a non-verbal channel for processing other stimuli, such as images or sounds [42]. When a picture is seen, the brain categorizes this information both as a 'visual image' and also as a 'word' in the language center, thus providing dual avenues to both store and retrieve that information in the future and thus increasing the chances of successful recall at a later date [42,43].

Other, additional ways that visual images can assist with learning is by simplifying the information – certain information is inherently better suited to being presented in an image, with anatomy being an obvious example [41] – and also because images may often tell a 'narrative' which assists learners by progressively adding new details to an underlying mental framework, thus scaffolding their learning [29].

This leads to several core principles that can be applied to creating infographics, including:

- The multimedia principle – people learn better when presented with words and pictures than pictures alone; the spatial contiguity principle – when words are placed near graphics;
- The signal principle – cues are used to highlight essential material; and
- The coherence principle – extraneous words and pictures should be eliminated [29].

Thus, by carefully organising information within visual materials, we

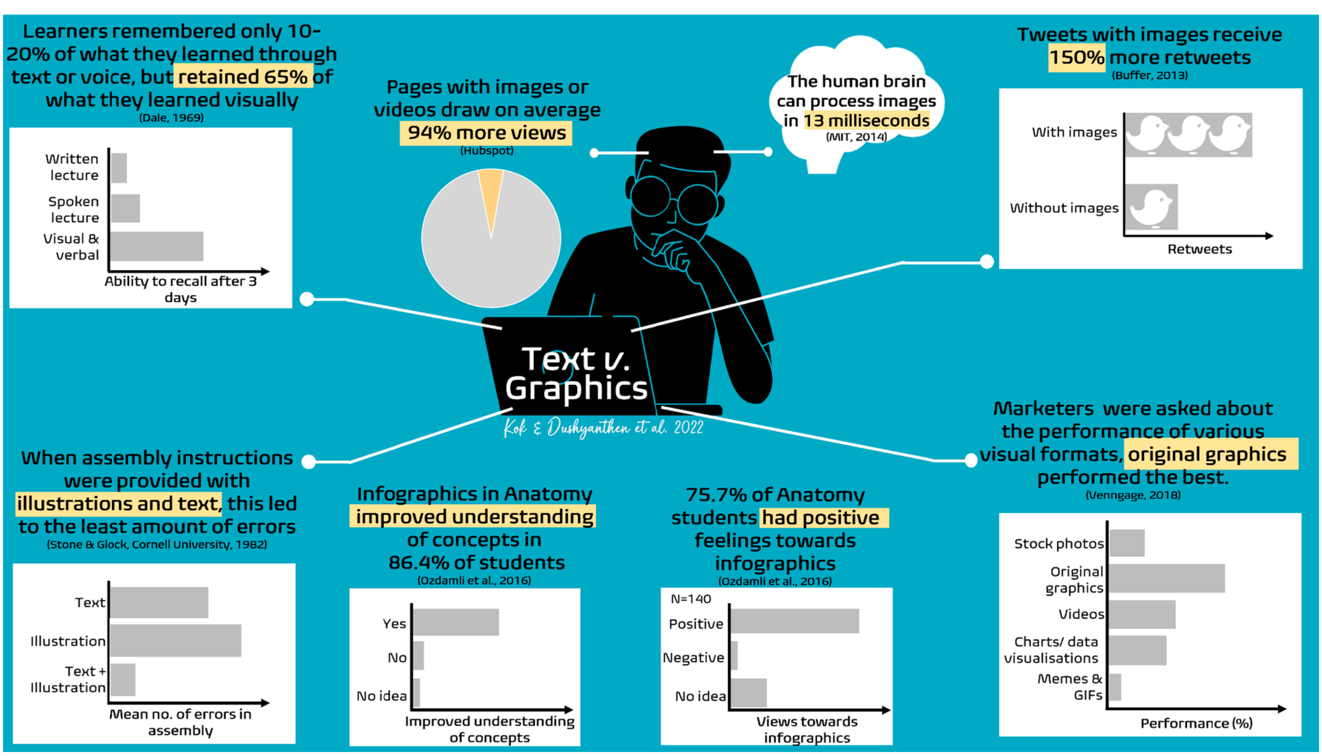

Fig. 2. Summary of data comparing the use of text versus graphics to convey complex information and education [35–41]. Current evidence for the value of a combination of illustrations and text in education, as opposed to either medium alone.

can facilitate better comprehension and enhance learning.

In addition, there are four key contexts in which infographics can be used:

1. To summarise a topic (eg. treatments available for radiation therapy);
2. To display a series of statistics on a topic (eg. proportions of infectious diseases that lead to cancer);
3. To compare two or more topics (eg. diseases, diagnostic tests, treatments); or,
4. To describe a process (eg. the COVID-19 vaccine development pipeline) [29,44].

Learners themselves can also benefit from creating infographics to facilitate their own learning. For example, tasking learners to create a visual abstract of a recent journal article to present at journal club assists them identifying, summarising and synthesising the pertinent information, thus aiding learning and enhancing retention [45]. When undertaking the process of creating visual summaries of information, learners organise and build connections between subjects, and this elaboration on their knowledge facilitates information retention [45] and ultimately, students learn how to communicate scientific information more effectively [46].

There is no single correct method for producing an infographic, as all visual compositions have some level of subjectivity in how they are perceived by the viewer. With that in mind, Fig. 3 summarizes our key tips, considerations and multimedia principles that can be used when designing visual educational material.

Educational videos

At this stage, the data comparing the educational benefit of video over static illustrations is still maturing. However, empirical consumption data shows that video is unequivocally emerging as the preferred screen-based presentation format in educational (as well as social and professional) spheres. Globally, 46 % of adults report watching any educational video on a weekly basis [3]. While there was variation in time spent consuming video between age-groups, even in 55–64 year old age group, the lowest consumption demographic, 35.9 % of females and 37.0 % of males reported watching an educational video in the past week. See Fig. 4 for a summary of current evidence and trend of video usage in education.

This high level of learner uptake has been reflected in usage of videos by educators. A recent survey of 680 international educational institutions revealed that 79 % were using some form of instructional video [48]. However, despite this high level of uptake, the level of sophistication with which digital learning videos have been delivered remains relatively basic [52]. The most common implementation remains the 'recorded lecture' where a conventional presentation is delivered and a video-recording focused on the presenter is made and matched to an accompanying slide deck concurrently displayed on screen [48,53]. While this does include all the basic elements of an educational experience, its execution is essentially a transposition of a live event onto screen, and is driven by expediency rather than any specific pedagogical or learning design theory [54].

With increasing use, familiarity, and dependence on video learning there has been a greater focus on optimal learning design that has led to a re-examination of how the video is used in education. A review of the radiation oncology educational landscape and published literature clearly shows a significant amount of online video learning material being made available in recent years [44,55–60], although many of these are still utilising the recorded lecture format [55–57]. With wider usage, educators are increasingly seeking better understanding and application of best-practice design frameworks to maximize the natural strengths of the video medium, while mitigating its limitations [52,61–63]. This has led to some recent successes with oncology education videos winning international awards [64].

The first axiomatic principle of educational video is to value your learners' time. Videos should be tightly-edited so as to be short and extremely high-yield [54]. Oncology professionals are extremely time-pressured individuals [65,66] meaning educational materials are often accessed in short intervals between other obligations. This is on top of

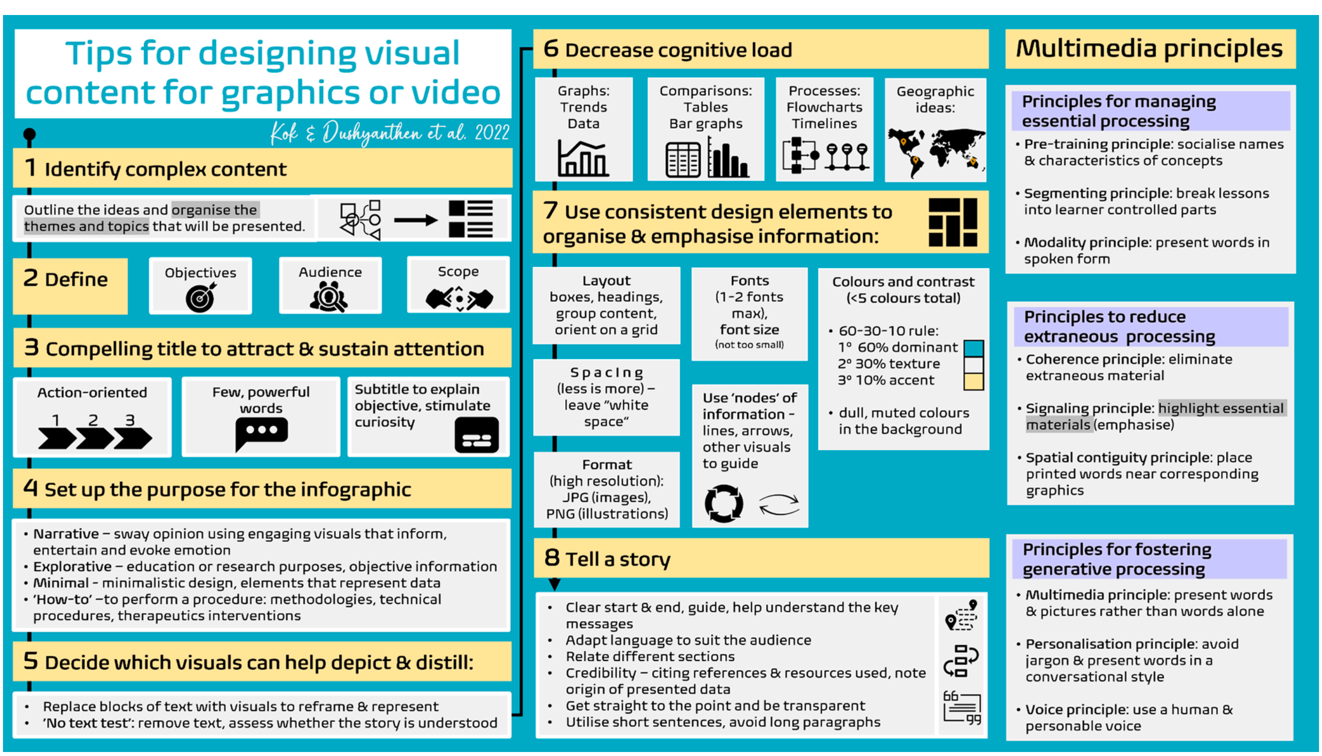

Fig. 3. Tips, steps and mutimedia principles for designing visuals fo r text or video.

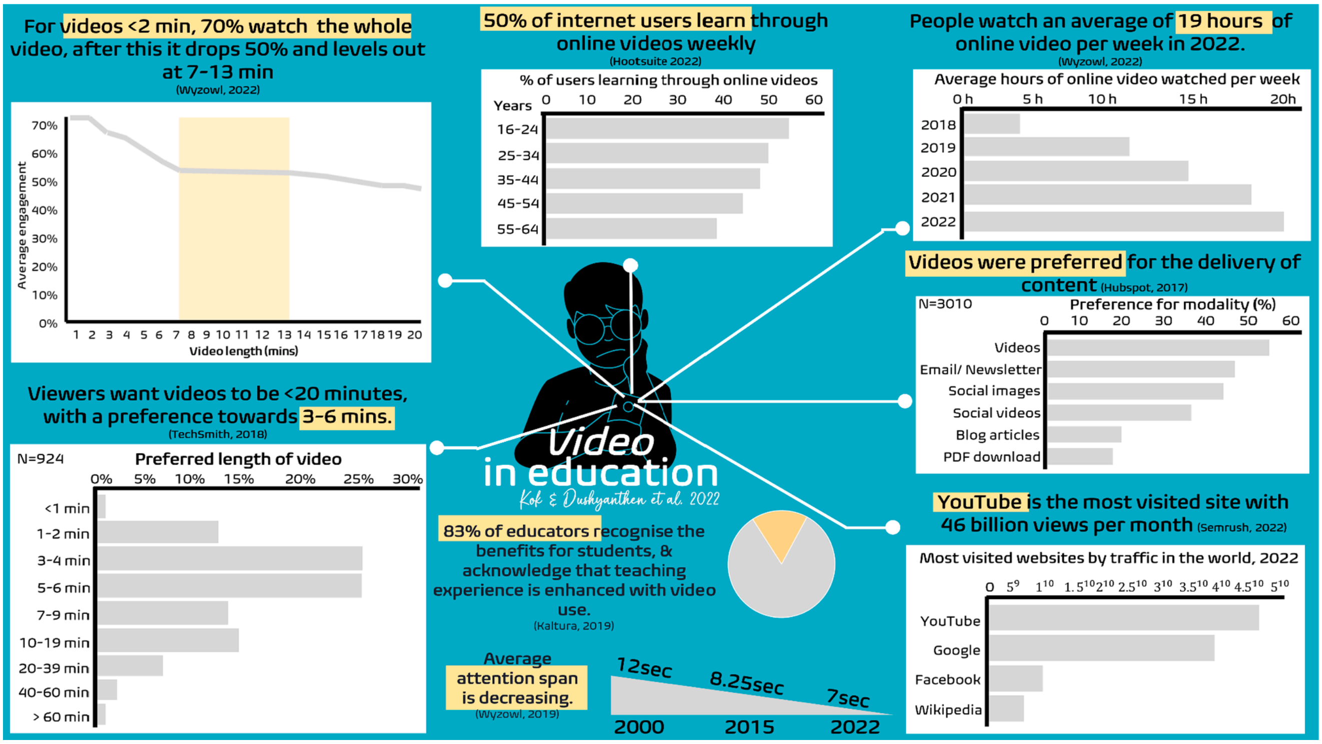

Fig. 4. Current evidence and trends of video usage in education [47–51].

the inherent risks the online environment carries with the many hundreds of distractions only a click away. As a result, the longer a videos duration, the more likely a distraction occurs or focus shifts elsewhere – for example to check emails [67,68].

While the learning task will ultimately dictate the necessary length of the video, undoubtedly shorter is better as data from general education videos [69] and radiation oncology specific educational videos [60,70] demonstrate a sharp drop off of viewership that occurs after 6–7 min. This may not just be due to viewer inattention, but also because the human brain can only retain and process a finite volume of information in a single sitting before experiencing cognitive overload [71]. Therefore, one must consider the necessity of any video that goes above this length of time, and the use of segmenting or chapterisation as a way to mitigate this inattention [71,72].

Video is also an highly effective application of the multimedia learning principle (discussed previously)[42]. Once again, it draws upon the dual learning channels of verbal and non-verbal to maximize cognitive processing [71]. On top of this, it adds another dimension – the dimension of time. Videos allow you to regulate the speed at which a learner is moving material. Paced appropriately, it allows time for processing of information before delivery of further new information or concepts.

It is also clear that learners are highly discerning in where they choose to apportion their attention in multimedia environments. It's been known for years that visual embellishment with no educational purpose does not improve learning outcomes [73] and in fact may reduce it, probably due to splitting of the students attention [74]. More recent studies have shown that web users eyes do not even track over what they perceive to be a 'stock' image – that is, images that are not directly related to the material at hand [75]. In effect, students appear to be filtering the information they consume to try and reserve cognitive capacity for important memory processing tasks. However, in doing so some cognitive capacity is used in the filtering activity itself and can actively reduce student retention. Therefore, optimal learning design spares students this mental capacity by selectively choosing what is displayed on screen and removing all extraneous or redundant information – a process known as weeding [76].

Weeding has become even more important in the mobile era, with increasing proportions of students using small-screen devices (smartphones, ultra-portable tablets) to access information [17]. The limited amount of visual real estate which is available to display information has meant there have been significant student concerns about screen clutter when viewing educational material on their phones [77]. In combination with attention and eye-tracking studies (which verifiably show that viewers' point of focus is linear, and highly vulnerable to selective inattention [78]), it is prudent to display on screen only the material which is most relevant to what is currently being explained. Another useful tool is to cut visually between views/angles to enable students to allow the student to experience the learning material from multiple angles [79].

Finally, there is the question of whether the instructor should be displayed on screen, or whether their presence in a video is purely visual clutter that is unnecessary to learning. It is true that their presence is often unnecessary and there for no other purpose than to be seen. However, when the instructor visually navigates students through material with dynamic on-screen drawing, eye-contact and purposeful visual-cuing (to draw attention to relevant on screen information) this has been shown to enhance learning [80,81]. Therefore, optimal learning design presents the screen in such a way that the presenter can authentically interact with the content.

Gamification

Gamification incorporates elements of gameplay into real-word activities and behaviours for the purpose of learning [82] and is increasingly being used in a medical education context. It can make learning engaging, memorable and motivating, while being pedagogically effective. Gamification enhances collaboration and offers the possibility of providing swift feedback, with a level of detail and quantitative analysis of performance typically not available through other learning methods [83]. They often utilise reward systems (eg. leaderboards/ badges/levels) and encourage incremental player development in a narrative structure, all of which incentivizes ongoing engagement.

Pedagogically, a key principle underlying gamification is active learning, where learners are active participants in the learning process. This may involve practicing, reinforcing, reviewing, applying knowledge, troubleshooting and problem solving; rather than passively absorbing information. Appropriate gamification can also improve learners' metacognitive strategies which in turn has the potential to improve student learning and promote deep learning [82]. Interestingly, a recent systematic review reported moderate evidence for the use of serious games with a pedagogical purpose, as an adjunct to traditional methods, using the Medical Education Research Study Quality Instrument (MERSQI) scale [84].

There are many examples of the successful implementation of gamification in a variety of fields [85] including medical education [83,86,87] with the most successful being that of the game 'Foldit', a game released by the University of Washington [88,89]. The public was given access to a protein-folding exercise to elucidate structures of various proteins; within 10 days, the players had unlocked the crystal structure of a monomeric retroviral protease that causes AIDS in rhesus monkeys, an accomplishment which scientists had struggled with for 15 years [88].

Oncology education has a small, but growing, number of notable examples where gamification is utilised. One of the well-known examples is the Cancer Research UK's Citizen Science project, which involves 5 publicly available web-based games that teaches key cancer principles and promotes active engagement with biological research questions [90,91]. Another patient application in oncology is re-Mission, a video game which improved medication compliance in adolescent cancer patients by obliquely reinforcing the effect of the treatment [92]. For health care professionals, the University of Melbourne's Master of Cancer Science degree, includes gamified learning elements that are distributed throughout the course material [15].

In terms of the cognitive engagement science behind gamification, it is known that games activate pleasure centers in the brain and causes increased dopamine levels [93]. Cognitive scientists recommend that games should be fast and include an element of unpredictability. In the absence of predictability, distributed attention is activated, leading to errors, alerting students that adjustments in behaviours are needed [93]. In healthcare, team-based collaboration is essential and game-based learning provides learning with the opportunity to discuss, strategise, cooperate and scaffold understanding based on peer-to-peer learning. Well-designed games are challenging; they facilitate progression through tasks of increasing difficulty and complexity where learners engage in strategising, decision making, evidence gathering, reviewing feedback, and reflecting on their learning.

Unfortunately, cost remains a barrier for production of good gamified learning experiences, with few oncological educational organisations having the outlay to produce these experiences. In addition, experience with gamified learning design is relatively limited, meaning in many cases there is a reliance on non-oncological third parties to provide this.

Ultimately, the success of gamified learning ultimately depends on whether the design features of the gamified learning experience and its implementation align with the intended learning outcome [94–96]. As such, it is important to be judicious in utilising gamification when the learning material being taught is inherently suited to its strengths [96].

The pedagogical scenarios where gamification has unique qualitative strengths compared to other learning techniques are:

- Teaching a transferable skill - Where the gamified activity can replicate/be-analogous-to the skill you wish the learner to learn (eg. flight simulation) and allow it to be repeatedly practiced
- Iterative Construction of Knowledge – Allows students to experience the step-wise creation of knowledge in an Active and Self-Directed Manner, at a self-paced speed. This helps the student to learn it more thoroughly and have greater insight into the learning material.
- Engagement - Reduce likelihood of distraction/mind-wandering through stimulation of curiosity, excitement and utilisation of reward mechanics

For a more detailed discussion on how best to map digital learning techniques to learning materials, see Section 4 of the companion article [13].

Re-thinking the screen-environment entirely

Given digital learning is being strongly driven by its on-demand nature, the entire screen environment which digital education is presented within has been increasingly re-considered. In the past, the possible layouts were somewhat constrained by the learning management systems upon which the learning materials were delivered.

Pleasingly, as learning management systems evolve, they are increasingly allowing for more flexible screen environments. Once again, the key principles of maximizing screen space utilisation; streamlining what is being placed in view of the learner to only the subject matter being currently discussed; and designing material to be as intuitive as possible apply. Therefore, long screens of text that require scrolling with only the occasional interspersed table or diagram are becoming less and less common. In its place are arising far more tailored screen layouts that have a greater degree of customisability, allowing the learner to have information presented to them in the format that they prefer, rather than a laundry list of what the educator is attempting to teach.

Finally, as digital learning techniques evolve, the capabilities and possibilities of the medium are evolving beyond the constraints of 2-Dimensional depictions. The companion piece to this article reviews the immersive, 3-Dimensional teaching tools that are starting to enter the radiation oncology education space as well presenting a horizon scan of what the future of digital education holds for radiation oncology [13].

Practical considerations when producing digital learning materials

Resource constraints in the cancer education sector have often prevented educators from having access to the requisite technological infrastructure to develop and deliver quality digital learning experiences [97]. However, COVID-19 provided an unexpected boost in this regard, as it compelled educational institutions to rapidly migrate their activities into the online space [98]. As such, it drove significant widespread upgrades in digital delivery infrastructure [99]. Web-cameras, online learning management systems, video-conferencing software and digital authoring tools have all became commonplace, essentially overnight [100].

Of course, the production of high-quality educational content requires not just good technological infrastructure, but also appropriately skilled and knowledgeable staff who can effectively utilise this equipment. Such individuals remain relatively uncommon in the both the tertiary and clinical education space [98] in part due to a heavy reliance on voluntary/casual teaching staff who tend to have little, if any, technical training [101–103] and extremely limited time resourcing [104,105]. Nevertheless, individuals with the composite clinical and educational skillset will likely become increasingly desirable, if not expected, in coming years.

While it may seem that asking clinical educators to utilise digital authoring tools is an unrealistic expectation, one only needs to consider the uptake of Microsoft Powerpoint to realise that this is already occurring. The convergence of a qualitatively superior technology, 'critical mass' and an easy-to-use interface has resulted in Powerpoint's ubiquitous use at the expense of older analogue technologies (such as overhead projectors and whiteboards). These same three factors have a high likelihood of driving an analogous uptick in the ability to produce educational videos and images in forthcoming years. In addition, there may be first-mover advantages to be had for those individuals and institutions willing to move expeditiously into the space.

Like other novel, or emerging, skillsets there are both formal and informal pathways that can be utilised by individuals looking to upskill themselves. Enrolment in formal training events and courses should be encouraged where individuals have the time and financial resources to do so. Alternatively, or as an adjunct to this, exposure to other professionals who have expertise in the domain remains a surprisingly effective methods of upskilling individuals, even in the absence of formal training. This has been clearly demonstrated with digital learning techniques in the secondary education sector [106].

Overall, there is likely to be an ongoing evolution in the culture of cancer education that progressively acknowledges and accepts the necessity of acquiring the capabilities to produce digital educational materials. A base level of proficiency in these techniques is reasonably attainable for any clinical educator. Undoubtedly, even after upskilling, there will still be a range of proficiency and quality in the final educational experiences produced, but this is no different to the current educational landscape.

Conclusion

The digital space is well-placed to cater to the evolving educational needs of oncology learners. Further digital uptake over the next decade is likely to be driven by the desire for flexible on demand delivery, high-yield products and more engaging delivery methods. Screen-based learning methods are the most common method of digital delivery and typically require little or no additional outlay for the user given the ubiquity of screen-based devices in the modern era. They can provide excellent learning experiences with clear qualitative and pedagogical benefits over traditional teaching methods if selected and designed appropriately. Educational programs that embrace these principles will have unique opportunities to thrive in this space.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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