Teaching Radiology Trainees From the Perspective of a Millennial

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The millennial generation consists of today's medical students, radiology residents, fellows, and junior staff. Millennials' comfort with immersive technology, high expectations for success, and desire for constant feedback differentiate them from previous generations. Drawing from an author's experiences through radiology residency and fellowship as a millennial, from published literature, and from the mentorship of a long-time radiology educator, this article explores educational strategies that embrace these characteristics to engage today's youngest generation both in and out of the reading room.

Key Words: Education; technology; millennials; residency; fellowship; medical student.

BACKGROUND

Most of today's radiology trainees belong to millennial or Generation Y. The term millennial generation was first used by William Strauss and Neil Howe in 1991 (1). Although precise definitions of the generation vary, demographic studies sometimes categorize Americans born between the years 1982 and 2001 as millennials (2). My[1] generation grew up with the explosion of technology in daily life, immersed in always-on notifications, social media, and memes, and my childhood memories were punctuated by the 9/11 terrorist attack, the war in Iraq, and school violence. Today, we have entered the workforce *en masse*, surpassing Generation X to become the largest employed American age group according to Pew Research Center (3). In academic radiology, my generation now comprises your medical students, residents, fellows, and junior staff.

Millennials crave active engagement, multimedia learning, and continuous feedback (2). Therefore, much published work exists on how to innovate modern education for these needs. In a flipped classroom, students prepare outside of class and focus in-class learning on critical thinking (4). An abundance of "podcast" lectures—prerecorded audio or video discussing a focused topic—and educational websites brought to life the promise of massive open online classrooms. Digitized lectures personalize learning to the speed of the learner who can repeat, fast-forward, or skip through content (5,6). The availability of low-cost personal computers and smart

devices enabled computerized simulation and gamification of learning not only in general education but also specifically in interventional and diagnostic radiology (7–10). With a myriad of these learning modalities, engaging my generation to learn would seem easier than ever.

However, an overemphasis on technology without considering the millennial learning pattern can backfire. Increasing data show teaching the millennial learner is more than deploying as many of these novel approaches and technology as possible. A survey of millennial medical students shows that when asked to identify the ideal mix of "flipped vs lecture," only 8% of respondents prefer a 100% "flipped" learning model; in contrast, a majority of the respondents prefer a predominantly lecture-based system (11). Additionally, although some prefer to watch lecture videos at 1.5× playback speed, evidence shows that higher playback speed correlates with lower knowledge retention (6).

In this manuscript, we share our experience as a millennial who was a recent resident and fellow and a long-time educator and mentor of millennials. Although we too have implemented many of these novel techniques, examples of our best educational successes come from leveraging new technology such as online resources, new software, and social media mechanics to support traditional learning approaches such as setting specific goals, teaching relevant facts, giving feedback, and others. Table 1 describes a summary of the approaches.

ENGAGING MILLENNIAL RADIOLOGY TRAINEES

Set Specific Goals

Millennials set high standards for themselves and are optimistically motivated by their abilities (12). In a meta-analysis of survey studies focused on the millennial generation, researchers find that the higher assertiveness and self-expectations of this age group come at the cost of a larger

[1]Although one of the authors (M.H.S.) technically belongs to a different generation, this article is written primarily by and in the voice of the millennial author (P.-H.C.).

TABLE 1. Summary of Our Approaches to Engage Millennial Trainee

Topic	Recommendation(s)
Set specific goals	• Leverage the ACGME requirements and milestones • Create SMART goals from broad requirements • Establish a mechanism for assessment and attestation
Leverage technology to emphasize relevance	• Use teaching moments during on-service readout to search the Internet or institutional database for similar cases, pitfalls, and related concepts • Use discrepancy detection software to show differences between final attending and preliminary trainee interpretations • Establish a safe environment to allow trainees to share missed cases • Create a teaching file of useful cases by soliciting trainees to earmark cases they find educational (ie, "crowdsource")
Give formative feedback	• Give feedback on specific actionable ways to improve during on-service readout or after a procedure
Create transparent assessments	• Give benchmarks on objective expectations such as volume of interpretation or procedure • Create mechanism to provide frequent reporting on important metrics such as MQSA
Encourage self-development	• Support academic endeavors with time and funding

ACGME, Accreditation Council for Graduate Medical Education; MQSA, Mammography Quality Standards Act; SMART, specific, measurable, attainable, realistic, and time-bound.

gap between the expectation of achievement and the effort necessary to achieve it (13,14). Therefore, explicit goal-setting may be valuable in focusing the stress of learning radiology onto specific tasks and in bridging the gap between expectations and competency. The competency-based medical education and the Accreditation Council for Graduate Medical Education (ACGME) Diagnostic Radiology Milestone Project have created broad guidelines of competency designed for resident performance (15).

Although ACGME only broadly defined the goals of Milestones because of the complexity of individual subspecialties, we have found that junior residents respond better when guidance is provided in the form of specific tasks. Specifically, we converted each ACGME Milestone to a set of SMART goals which stand for specific, measurable, attainable, realistic, and time-bound (16). SMART goals and targeted feedback have been described as best practices for millennial learners (17). In our residency program, the program director and chief residents work with ongoing junior resident input to maintain a comprehensive, itemized list of tasks that should be completed for each iteration through each subspecialty rotation. Measurability is performed either as a web-based quiz or by self-attestation. Attainable goals are frequently marked as required, whereas those requiring an in-depth dive are not. Therefore, items in the list are separated into "required" and "strongly recommended." Table 2 provides an example of expected goals for the first rotation through body computed tomography, which consists of a combination of reading material and practice quizzes either from a trusted online source or created by our faculty.

To create realistic expectations, we do not set volume-based goals by rotation but provide residents a resource to review their volumes and benchmark with the aggregate record of previous residents (discussed in the following).

TABLE 2. Example of Specific Goals for First-time Rotation Through Body CT

Required
RSNA physics radiation dose in CT
Select the protocols for 360 CT examinations
Start the Basic GU&GI online quiz (to be completed by June of R1 year)
Complete SAM on the topic: Administration of Iodinated Contrast
Complete Quiz on Contrast Reaction

Strongly Recommended
Complete RSNA physics online module: CT Image Quality and Protocols
Review the 20 Must See First Year Cases found in the Body CT rotation packet

CT, computed tomography; GI, gastrointestinal; GU, genitourinary; RSNA, Radiology Society of North America; SAM, self-assessment module.

To close the loop and provide feedback in ACGME goal-setting, we also created a low-cost, semiautomated software allowing residents to attest to their completion of a module, the details of which were published previously in this journal (18). The Milestone software also allows faculty to evaluate the state of resident performance after conducting an interventional procedure. The timely completion of these specific goals and assessments aids in the semiannual review of resident competency.

Leverage Technology to Emphasize Relevance

The millennial generation spends much of their childhood immersed in omnipresent technology. Within seconds of

accessing a computer or smartphone, a radiology trainee can mobilize a volume of knowledge that dramatically outmatches that of his or her professors. In addition to relevant results arising from an intentional search on Google, the millennial generation is immersed in curated content in their daily lives. Netflix, the online streaming video company, delivers recommendations based on users' viewing history. Amazon, the online superstore, delivers shopping recommendations based on what the customer—as well as other users with similar behavioral patterns—has purchased or has viewed but did not purchase previously. Millennials interact with peers via social media such as Facebook and Twitter, where users can give favorable endorsements to each other by pressing a button to "Like" or "Retweet" another person's shared content. Therefore, it is no surprise that millennial learners expect ready access to searchable content and peer endorsement.

However, applying imaging finding to the clinical context still requires the careful guidance of an experienced radiologist. In 2010, a trainee from our program created a search tool allowing trainees to search through prior studies in the radiology department to identify similar examples of a diagnosis seen during on-service readout, similar to the way a "Google search" can identify websites pertinent to a specific topic (19,20). Today, similar search-based tools have become commercially available. Although search-based tools are valuable for quality improvement, they can be used to improve on-service readout also (19). In addition to on-service readout and didactic lectures, our residency program deploys several mechanisms to keep trainees grounded in the relevance of their work. During independent call shifts, residents and fellow interpretations are overread by attendings using structured reporting elements. There is no formal in-person readout. Instead, standard language in attending feedback is collected on a case-by-case basis and then collated for resident review through software (21).

Although attending feedbacks vary and are subjective, digitizing trainee discrepancies has benefits both for the individual resident and for the residency program. At the individual level, our program requires residents to review all discrepancies and to share missed cases, good calls, and otherwise educational cases at resident conferences. Our residents previously published that missed cases shared through "peer learning conferences," which our program holds monthly, can decrease future discrepancy rates (22). At these conferences, residents also share "triumphs" of having identified subtle but clinically relevant abnormalities on call. At the level of the residency program, warning signs can be detected using data analytics when discrepancies are marked using structured elements. For instance, after our data trends showed higher than desired missed rates for pulmonary embolism, we were able to identify and analyze the missed cases and target faculty teaching toward these causes.

To become further engaged, one of the authors worked with co-resident peers to create a discrepancy software that incorporates mechanics seen in social media that is popular among the millennial generation such as Twitter, allowing trainees to share educational cases using short segments of free-text and hashtags. In this system, a trainee can assign short terms preceded by the pound sign (#)—or "hashtags"—to categorize cases such as "missed pneumothorax" or "edge of film." The software mines the hashtags to create teaching collections with corresponding themes. The process of creating cohesive content by aggregating contributions of multiple users may be called "crowdsourcing." By crowdsourcing a "social teaching file," a relevant and growing list of original cases can be created to include the resident report, attending insights, the post hoc resident annotation, and—in many instances—program director comments on the importance of key findings. This work has been presented in a peer-reviewed conference setting (23). Although the software utilizes social media mechanics and allows sharing of teaching cases as permitted by Health Insurance Portability and Accountability Act, it maintains strict access control to patient health information by keeping information behind the firewall. Furthermore, the teaching file is made available only after a user authenticates with approved credentials.

Give Formative Feedback

Whereas summative feedback provides an overall assessment of trainee performance and commonly is used during quarterly or semiannual reviews, formative feedback consists of ongoing guidance throughout each rotation. Summative feedback is often perceived as higher stakes, whereas formative feedback appears more collegial. The use of formative feedback has received attention in medical school education for modern students (24–26). Although individual members of the millennial generation vary widely, formative feedback may be overall more receptive for the millennial radiology trainee whose generation is characterized as simultaneously having not only high self-expectations but also higher stress and anxiety (13).

The radiology trainee of the millennial generation prefers granularity in feedback. At our institution, all 46 residents were surveyed regarding two types of end-of-rotation written feedback that contained a single question, "Which of the following type of written faculty evaluations do you prefer?" Two choices were provided: (A) each faculty anonymously submits an independent evaluation based on his or her own experience with the resident, or (B) the educational faculty for the rotation writes a balanced evaluation based on input from all faculty. An "additional comments" free-text box was provided. On this survey, 39 (84%) responded, of which 29 chose (A), and 10 chose (B).

Our surprise arises from the "additional comments" text box included at the end of the anonymous survey when we recognized we had not asked the right question at all. Whereas we asked for the preferred mode of summative feedback, residents strongly preferred formative feedback. Some comments included, "I think the daily interactions we have with the attendings is the best and most important opportunity." Another

commented, ". . . a few minutes here and there to say things like: try to be consistent with your search pattern. . . you're doing a great job making the findings, and now I want you to work on honing your own differential diagnoses." When given an opportunity to voice their opinions, in our experience, millennial trainees prefer specific, actionable feedback proximal to a learning opportunity.

Create Transparent Assessments

Outside of health care, millennials are entering the workforce and disrupting performance assessments. More than their predecessors, they expect highly accessible, on-demand, objective performance data with clearly established benchmark for achievement or promotion, with the overarching paradigm
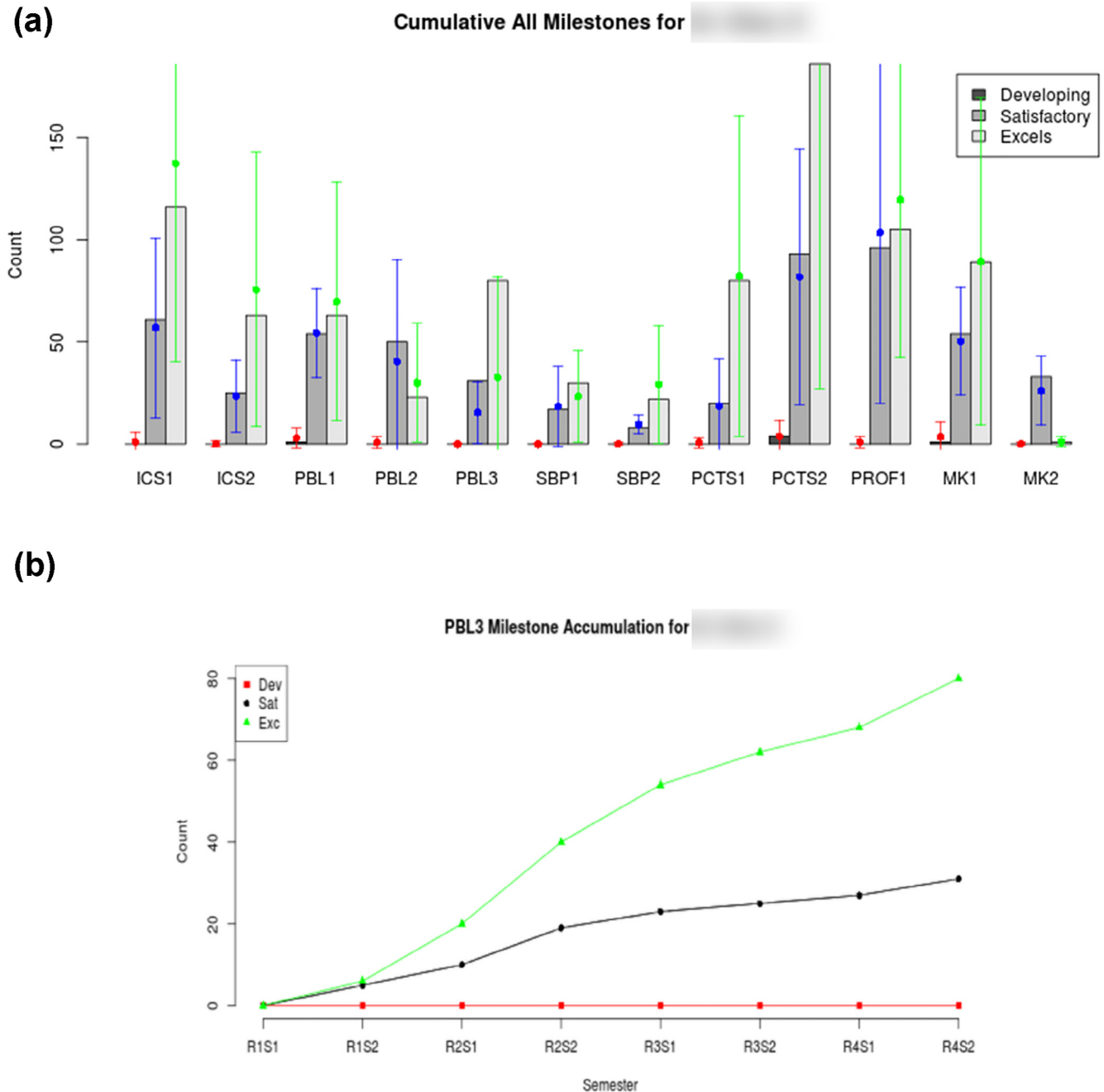

Figure 1. Example review charts from our custom-created software. Residents are reminded that the displayed data use only submissions through the software and do not include faculty assessment. **(a)** Cumulative ACGME Milestones (28). **(b)** Demonstration of resident progress in the PBL3 Milestone over time. A full description of the inspiration and software design is available in Reference (18). Dev, developing; Exc, excels; ICS, interpersonal and communication skills; MK, medical knowledge; PBL, practice-based learning and improvement; PCTS, patient care and technical skills; PROF, professionalism; R, residency year; S, semester; Sat, satisfactory; SBP, system-based practice.
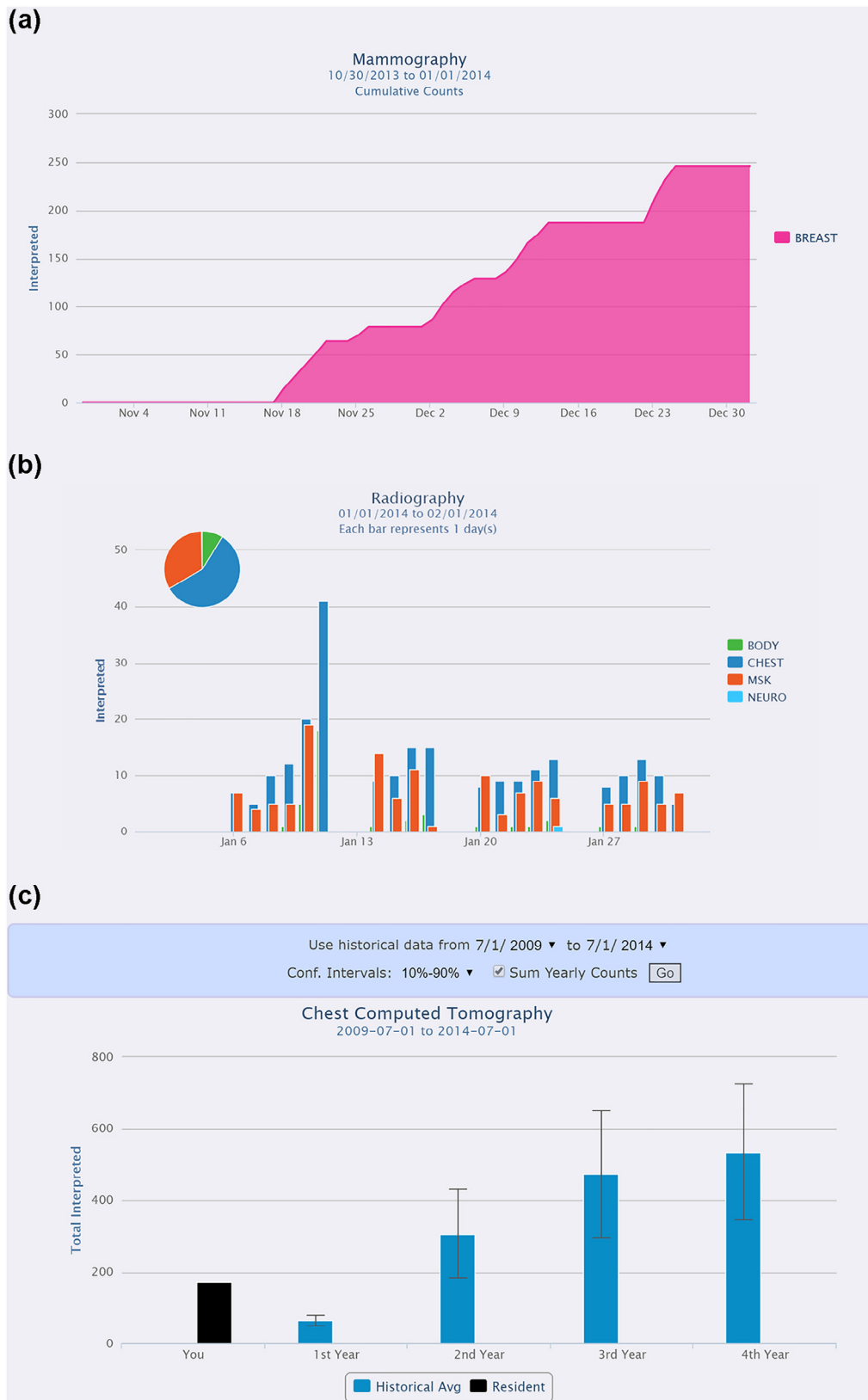
(a)

Mammography
10/30/2013 to 01/01/2014
Cumulative Counts

BREAST

(b)

Radiography
01/01/2014 to 02/01/2014
Each bar represents 1 day(s)

BODY
CHEST
MSK
NEURO

(c)

Use historical data from 7/1/ 2009 ▼ to 7/1/ 2014 ▼
Conf. Intervals: 10%-90% ▼ ☑ Sum Yearly Counts Go

Chest Computed Tomography
2009-07-01 to 2014-07-01

Historical Avg   Resident

Figure 2. Automated case log software example chart from the perspective of the trainee user, with **(a)** cumulative mammography volumes for Mammography Quality Standards Act and Program compliance, **(b)** day-to-day radiography volumes, and **(c)** an example second year resident's chest computed tomography volume at midyear, displayed alongside historical aggregate resident volumes at the end of each year of residency and associated confidence intervals. Data are available for trainee review on their own computers. Full description of the software design, capabilities, and survey of trainee reception to the software is available in Reference (29). Avg, average; MSK, musculoskeletal.

shift focusing on the increasing appreciation for open assessment or transparency (27). Where possible, our program makes the expectations clear and makes evaluative data transparent. In addition to using software to track the completion status of individual goal-directed tasks for resident rotation, the software also provides resident growth charts grouped by each of the ACGME Milestone competencies (Fig 1). Residents have access to their current milestone status by logging into the software, understanding that the actual competency depends on both the objective and faculty evaluation, which is also available for review.

We developed and implemented an open-source automated resident case log software for residents to review their current volume of interpretation, which was published in this journal previously (29). Although volume is only one of the many dimensions of competency, the software provides a useful benchmark alongside the ACGME minimum requirements as well as Mammography Quality Standards Act and Program requirements (Fig 2). Furthermore, through this software, trainees can assess their volume of interpretation alongside aggregated historical trainee volumes and calculate expected variance and confidence intervals, mining data from our radiology information system (Fig 2). Initially, we were fearful that providing specific numbers and comparisons can harm trainee morale. In practice, millennial trainees gave favorable reviews to the approach of providing aggregate averages and confidence interval and a mechanism to assess and address their performance in the privacy of their computers. This work was published in this journal previously (29).

Encourage Self-development

Millennials value time for independent development. Evidence for education in the health-care space through new models of medical student and nursing student education reveals a trend toward independent and peer-to-peer learning (16–18). With increasing availability of knowledge-based resources outside of the reading room, modern radiology trainees also benefit from the encouragement and time to develop independently. In our institution, clinical residents receive an average of one academic half-day per week, and research residents receive at least 2 weeks per year of uninterrupted research time in the first 3 years. Our department also provides travel funding for first-author conference presentations by a trainee. Residents have used their academic time to develop radiology-related skill sets in scientific research, teaching, quality improvement, information technology, and leadership. From July 1, 2016, to June 30, 2017, 44 of the 46 residents from our program (95%) published a total of 52 peer-reviewed publications and delivered 56 conference presentations. Additionally, 26 residents (57%) used their academic time to give teaching presentations.

WHAT HAS NOT CHANGED

Whereas the millennial generation's distinct upbringing and comfort with technology deserve evolving educational strategies,

one emerging theme is that technology is deployed to streamline an otherwise human learning process and not to replace learning. The epitome of careful goal-setting, constant feedback, and encouraging self-development is mentorship. Mentorship deserves a special note here as it has been and continues to be the cornerstone of an enriching radiology education. Guidance from senior clinical radiologists, educators, and researchers on personal life, professional career, and their balance remains irreplaceable. In between their web searches, likes, hashtags, and obsession with artificial intelligence and virtual reality, millennial radiology trainees and junior faculty quietly draw inspiration from role models in their work environment both explicitly and implicitly.

The millennial generation has a collaborative nature, and peer mentorship has been shown to have positive effects on the mentor and mentee alike (30–32). Therefore, in our residency program, we explicitly established a "big-sib, little-sib" program. Each first-year resident volunteers to mentor an incoming resident as his or her "big sibling." This process creates a sibling "family" because each little-sib becomes a big-sib in 1 year's time and volunteers to mentor a new incoming resident. We found that residency-wide gatherings are too large for meaningful mentorship discussions, so we also created three intermediate units of "residency houses." Each house contains three to four randomly assigned sibling lineages. Therefore, a new incoming resident immediately has a big sibling mentor and becomes a member of a "residency house." The residency program provides funding for informal "house" dinners and hosts friendly cross-house competitions to facilitate interaction between senior residents and their junior counterparts. Through this mechanism, the peer-supported program also facilitates discussions to help residents choose a faculty mentor for academic projects.

CONCLUSION

With the millennial generation's increasing prevalence in the workforce, fulfilling their unique needs for career development requires unique attention toward goal-setting, relevance, feedback, transparency, and autonomy. Radiology education plays a critical role in the training of millennial radiologists as they take our profession into a technology-laden future of medical imaging.

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