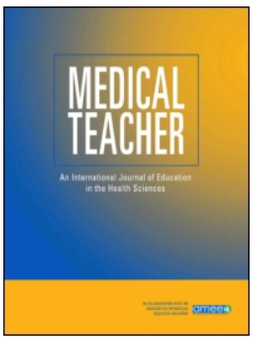

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TWELVE TIPS

Twelve tips for conducting educational design research in medical education

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ABSTRACT

Despite a steady growth in educational innovations and studies investigating the acceptance and effectiveness of these innovations, medical education has not realized sufficient improvement in practice and outcomes from these investments. In light of this lack of impact, there has been a growing call for studies that more effectively bridge the gap between research and practice. This paper introduces Educational Design Research (EDR) as a promising approach to address this challenge. Twelve tips are provided to inspire and guide medical educators to conduct EDR to achieve the dual goals of tackling a significant educational problem in a specific context while at the same time advancing the theoretical knowledge that may be used to improve practice elsewhere.

Introduction

The field of medical education research has witnessed steady growth since the 1950s (Traynor and Eva 2010). Today's healthcare professionals are increasingly invested in conducting educational research of various kinds (Eva and Lingard 2008), with efforts often supported by their institutions (Ahmed et al. 2016). Unfortunately, the impact of educational research on medical education practice is weak, just as it is in other educational contexts (Kaestle 1993; Kennedy 1997; Albert et al. 2007; Dolmans and Tigelaar 2012; van Enk and Regehr 2018). As a result, there has been a growing call for studies that more effectively bridge the gap between research and practice.

In addition to the insufficient impact on practice, few medical education research studies contribute adequately to the definition and refinement of robust theory related to teaching and learning. According to Cook et al.'s (2007) systematic review of the experimental medical education research published in leading journals between 2003 and 2004, 45% of the studies lacked a conceptual framework. The inadequacy of theoretical underpinnings and contributions in medical education research continues, with Meyer et al.'s (2018) text analysis listing failure to contribute to the body of knowledge as *Academic Medicine* editors' top (44%) rationale for denying submissions consideration for external peer review.

Responding to the demand for medical education research that is 'both theory-oriented and application-relevant, using each to inform the other' (Eva 2010, p. 4), this paper introduces Educational Design Research (EDR) as a promising approach to accomplishing this twofold objective. Figure 1 illustrates the three major phases of EDR projects (McKenney and Reeves 2019):

- 'Analysis and Exploration' involves working closely with collaborators to acquire an understanding of a significant educational problem and investigate how others have addressed it;
- 'Design and Construction' focuses on identifying or creating appropriate design principles and using these principles to develop your prototype intervention; and
- 'Evaluation and Reflection' consists of multiple iterations of data collection and analysis to test your prototype intervention and review the implications of the findings.

While only recently introduced to medical education researchers (Dolmans and Tigelaar 2012; Wolcott et al. 2019), EDR emerged in other educational settings in early 1990s and has been steadily increasing as a way of enhancing the impact of educational studies on practice while at the same time extending and refining theory (McKenney and Reeves 2019). Encompassing similar approaches such as design-based research and design-based implementation research, EDR has been featured in multiple special issues of leading educational research journals between 2003 and the present. Figure 1 illustrates the process of EDR as delineated by McKenney and Reeves (2019). The following practical tips describe how EDR can be conducted by medical educators to increase the relevance and impact of scholarly research whilst developing more effective learning environments.

Tip 1

Ensure your EDR initiative is focused on a significant problem related to learning and teaching

First and foremost, your EDR initiative should focus on a meaningful problem relevant to the practice of teaching and learning and aim to meet this identified challenge. This sharp focus on addressing a significant educational challenge distinguishes EDR from many other approaches to educational research (McKenney and Reeves 2019).

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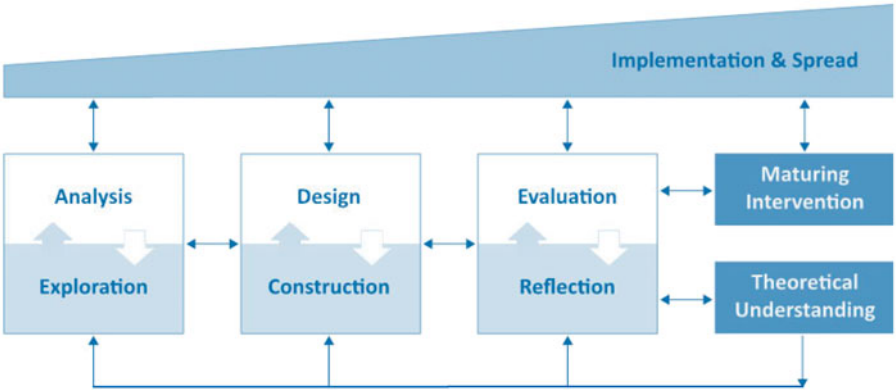

Figure 1. The process of conducting educational design research (McKenney and Reeves 2019, p. 83, used with permission).

As illustrated in Figure 1, your understanding of the problem will be informed by intensive 'Analysis and Exploration' during the first phase of your EDR initiative and subsequently enable the development of a prototype solution to the problem during the second phase, 'Design and Construction.' The solution can be characterized as an 'intervention' in the form of newly planned or enhanced educational processes (e.g. innovative pedagogical strategies), programs (e.g. enhanced faculty development efforts), or policies (e.g. changes in training sites for residents) (Gruppen et al. 2018).

What constitutes serious problems for healthcare educators today? Many educational challenges are not unlike those experienced by teachers at all levels (e.g., increasing the integration of active learning principles or the achievement of higher-order learning outcomes), but others are more specific to medical education, including:

- Develop capacities to work effectively in increasingly fluid healthcare teams.
- Cultivate skills to communicate in a culturally competent manner with patients and other healthcare professionals.
- Prepare healthcare professionals for practice in a world increasingly infused with machine learning algorithms and robots.
- Improve assessment protocols and feedback practices to promote competency-based education.
- Enhance healthcare professionals' clinical reasoning (CR).

To clarify how EDR can be conducted in medical education, a hypothetical study focused on the problem of enhancing medical students' clinical reasoning (CR) will be used in the description of the following tips. Despite the fact that CR is a core skill in medical practice with major implications for patient safety, it is rarely explicitly taught because it is assumed that these skills will be developed by observing expert practitioners during clinical rotations (Gay et al. 2013; Amey et al. 2017). Enhancing the CR of their students is clearly a serious challenge for medical teachers (Higgs et al. 2019).

Tip 2

Strive for both practical and theoretical outcomes

As delineated in McKenney and Reeves (2019), two primary outcomes are sought simultaneously in EDR projects, specifically a maturing intervention and enhanced theoretical understanding. As illustrated in Figure 1, the practical outcome of EDR is conceptualized as a maturing intervention in recognition that no problem solution is ever final because as new conditions evolve, interventions must evolve as well. Figure 1 designates the theoretical contribution of EDR as theoretical understanding. In EDR, theoretical understanding is usually represented in the form of 'design principles.' Design principles are the best practices derived from prior research that you will use to inform the creation of your prototype solution and that subsequently, you will refine through your data collection, analysis, and reflection activities.

In applying EDR to the challenge of enhancing students' CR skills, the practical outcome would be an educational intervention that improves CR skills while the theoretical outcome would be enhanced design principles for developing interventions that address other higher order outcomes. An example of a maturing intervention might be a computer-based simulation that engages students in applying CR to actual cases with interactive feedback and coaching. An example of a design principle might be that 'A case-based simulation is most effective when the formative assessment of clinical reasoning is embedded in authentic tasks and feedback is provided immediately rather than delayed.'

Tip 3

Seek theoretical understanding throughout the research and development process

Throughout an EDR initiative, various research activities such as needs assessment, literature review, and quasi-experiments are integrated into the cyclical development of a solution to the significant problem. These research and development activities are informed by and in turn yield different types of theoretical understanding (McKenney and Reeves 2019):

- *Descriptive understanding* is typically pursued during the 'Analysis and Exploration' stage, before starting the actual development of your innovative intervention. Through literature reviews or empirical exploration, you derive a better understanding of the current situation related to the target educational challenge, which subsequently informs the 'Design and Construction' stage.

- At the 'Evaluation and Reflection' stage, through the testing and refinement of your intervention, you can seek *predictive understanding* of the desired outcomes, addressing whether, and to what extent, the designed intervention addresses the target issue.
- While it is useful to assess 'if' your innovation works, it is also important to simultaneously study 'how,' 'when,' and 'what' aspects of it work and 'why' that happens (Regehr 2010). *Explanatory understanding*, therefore, explicates how and why the intervention succeeds or fails, revealing important causal relationships or influential contextual factors.
- Through multiple iterations of investigating the efficacy of your intervention during the 'Evaluation and Reflection' stage, you can derive *prescriptive understanding*, usually in the form of refined design principles. Ideally, these refined design principles will enable the design and implementation of similar interventions in new educational contexts by yourself or others.

Numerous innovations have been developed to enhance the CR of healthcare learners, such as virtual patients, interactive simulations, responsive manikins, illness scripts workshops, service learning, problem-based learning, concept mapping, blended learning, and 3-D games (among others), but none of these interventions has adequately met this challenge. At least part of this failure may be attributed to the all-too-common practice of developing interventions without a sound theoretical understanding of CR and the complexities of teaching these skills (Rencic 2011). Koivisto et al. (2016, 2017, 2018) conducted EDR to enhance nursing students' CR skills and eventually developed a 3-D simulation game to provide their students with opportunities to apply and refine CR skills. In the process of evaluating and reflecting upon the outcomes of their game design, they sought both predictive and explanatory understanding. They were not only interested in whether students learned CR through playing the game, but also how that actually happened.

Tip 4

Identify and apply conceptual frameworks

The 'Analysis and Exploration' phase (see Figure 1) includes identifying one or more conceptual frameworks as early as possible to guide your planning of both research and design activities (Yin 2014). Conceptual frameworks include theories, models, and principles of practice that are developed based on observations, validated by empirical research, or derived from other well-grounded theories. Each framework provides a lens for examining and interpreting complex educational phenomena (Bordage 2009). In other words, different frameworks bring attention to interrelated and often complex aspects of the target problem and influence the types of educational strategies that might be integrated into an innovative intervention.

If you identify a framework from learning theories (Zackoff et al. 2019), you are likely to focus on the process of how learning occurs and how to improve instructional efforts to support successful learning; on the other hand, if you derive your framework from system theories (Barr 2013), you will probably investigate factors that influence the diffusion of your innovation so as to enhance your organization's capacity to sustain it. Researchers and practitioners conducting EDR have adopted different learning theories to enhance healthcare learners' CR. For example, Ramaekers et al. (2012) adopted cognitive theories and built a curriculum with authentic examples and practice to support learners' construction of cognitive understanding whereas Leggett (2016) emphasized the importance of 'self-regulated learning' on the performance of CR and sought to enhance feedback practice to foster students' self-regulated learning skills. On the other hand, Koivisto et al. (2016, 2017, 2018) focused on the central role that experience plays in learning. In developing a 3-D game to enhance learners' CR skills, they adopted the experiential learning theory to investigate and enhance students' learning process. Within the context of medical education, additional examples of learning theories are available in Zackoff et al. (2019, p. 137–138), and Barr (2013) provided examples of system theories, such as organizational theory and activity theory. How do you select appropriate conceptual frameworks? Start by reviewing the literature on similar challenges and innovations, and look for theories that have been consistently applied.

Tip 5

Identify practitioners and researchers willing and able to collaborate on the EDR initiative

A hallmark of EDR is that it involves the close collaboration of researchers and practitioners, or more likely in medical education a group of practitioners willing to engage collaboratively in long-term efforts to improve practice and theoretical understanding. The success of any intervention in an educational ecological system is determined by the innovation's interaction with other components of the system (Zhao and Frank 2003). The following stakeholders may play an important role in the ecosystem in which your EDR project is conducted, and therefore you should seek to collaborate with them (e.g. Chen et al. 2015):

- professionals involved in teaching the core and peripheral skills related to the problem your project addresses,
- professionals with expertise in program evaluation and learning assessment,
- professionals with expertise in faculty and staff development and/or instructional design,
- administrative, academic, student, and technology support personnel, and
- representatives of the target learner population.

While you should play key roles in both instructional development and research, consider including one or more experienced educational researchers or evaluators on your team. It has become increasingly challenging for healthcare professionals to keep up with the evolution of educational research methods and tools aside from clinical duties. Including an educational researcher on the team mitigates this burden. With successful project management (Huggett et al. 2011), multidisciplinary collaboration can significantly advance the quality of scholarship (Traynor and Eva 2010).

In our hypothetical study addressing the problem of enhancing students' CR, you should seek to assemble a

team of other medical teachers plus other professionals such as creative instructional designers, highly skilled evaluators, and any relevant content experts. In addition, you might want to engage medical students themselves in the EDR initiative as they can serve as participants in small-scale evaluations and as sounding boards for design and implementation ideas.

Tip 6

Analyze the target problem and learners

To inform your construction of an intervention, you must acquire a rich descriptive understanding of the target problem and the existing innovations that others have employed to address your target problem, and you must also garner detailed information about the target population and the learning environment (Bass and Chen 2016; Hughes 2016). This kind of information is typically sought through reviewing the literature, conducting site visits and observations, and/or surveying learners and their educators. For instance, any efforts to enhance learners' CR will benefit from an understanding of the status quo of CR teaching, including the impact of healthcare professionals' CR skills on the outcomes of patient care and the effectiveness of current CR teaching methods. Higgs et al. (2019) provide a valuable and current overview of the state-of-the-art of CR innovations in health professions education.

Additionally, you should seek to clarify the following information about your target learners and their learning environment (Fink 2013):

- learner and instructor characteristics;
- the setting of the learning environment, technology, and other resources;
- external expectations from the society, professional associations, and your institute; and
- nature of the subject matter and inherent pedagogical challenges.

Tip 7

Design and construct an aligned educational design

The 'Design and Construction' phase of EDR is when you begin constructing your design plan based on the descriptive understanding acquired during the previous 'Analysis and Exploration' phase (see Figure 1). First, continue to review literature related to your conceptual framework(s) and similar solutions to derive design principles for your prototype intervention. These principles are turned into your design plan, which must include three key elements at a minimum: *educational objectives, instructional activities and materials*, and *assessment and feedback procedures* (Fink 2013). While you might be eager to start developing your innovation by identifying the content or exploring a novel teaching method or technology, instead begin by composing or reviewing your educational objectives, clearly describing what learners are expected to do at the end of the instructional intervention. When you write clear educational objectives to guide the development of your innovation, you build the foundation for the alignment of the other two major design elements (instructional activities and materials and assessment and feedback procedures) with these objectives. This alignment enhances your students' opportunities to engage in meaningful learning (Fink 2013). The International Training and Education Center for Health (2010) provides useful tools to guide the writing of specific, measurable, and appropriate objectives.

The process of specifying your educational objectives naturally prompts you to consider other key design elements, crafting instructional activities and materials to support learners' achievement of these objectives and developing relevant assessment and feedback procedures to demonstrate that the desired learning has occurred. MedBiquitous Curriculum Inventory Working Group Standardized Vocabulary Subcommittee (2016) identifies common instructional and assessment methods in medical education.

Suppose that after the 'Analysis and Exploration' phase, you and your colleagues have sketched out a design of an instructional intervention to enhance students' CR, specifically a 'flipped classroom' whereby 'didactic materials are provided to the learners prior to the scheduled lecture time [and the] face-to-face time is used to fill in knowledge gaps and further solidify understanding of the key concepts' (Morrissey and Heilbrun 2017). During the iterative design process, you will revise and revisit each of these design components to make sure that they are in alignment with each other and that the intervention is congruent with the proposed design principles. Ask questions such as:

1. To what extent does the flipped classroom model effectively address all the educational objectives and prepare students for learning assessments?
2. To what extent do the assessment activities cover all the objectives?
3. How well are your design principles reflected in your prototype flipped classroom approach?
4. Based on your understanding of the target learners, learning environment, and resources, how feasible is it to actually implement this innovation?

Tip 8

Evaluate the implementation of your prototype intervention

The third phase of EDR involves 'Evaluation and Reflection' to refine the innovative intervention and extend or enhance theoretical understanding (see Figure 1). Conduct periodic assessments to investigate the intervention's functioning in both the local and the broader institutional ecological systems and identify factors impacting its success. Recommended questions include:

1. To what extent have both teachers and learners perceived your intervention as relevant to their needs?
2. How engaged are learners in the intervention?
3. How well does your intervention address its intended goals?
4. If any unintended outcomes emerge, are they positive or negative and why have they occurred?
5. What modifications have been made of your original plan and why were these changes made?

How can you address these types of questions? There are many different data collection methods and tools that can be used in your evaluative work, including observations, interviews, and questionnaires (Reeves and Hedberg 2003). Linderman and Lipsett (2016, p. 135–137) compared the strengths and limitations of the methods commonly used to evaluate medical education initiatives. For instance, during their EDR project involving a simulation game, Koivisto et al. (2017, 2018) conducted focus group interviews and observations of learners playing the game, looking for possible areas to improve the user interface. They also asked students about their learning experience with the game and opinions about the various features. Imagine beginning to implement an instructional innovation such as a flipped classroom approach to enhance your students' CR. Plan to conduct several iterations of testing and refinement to see whether the innovation is being implemented as designed and determine how to make any needed adjustments to its design.

Tip 9

Evaluate the outcomes of your intervention

Although there is no set rule for the number of iterations of 'Evaluation and Reflection' you carry out to enhance both your practical and theoretical outcomes, most EDR studies encompass at least three iterations (McKenney and Reeves 2019). For each iteration, in addition to evaluating the implementation of the intervention, analyze the achievement of both the immediate educational objectives and the long-term ultimate goals of the EDR initiative, including unintended effects. A range of outcomes that can be evaluated are divided into four levels by Kirkpatrick and Kirkpatrick (2016):

1. learner satisfaction with their learning experience and perception of the usefulness of the intervention;
2. learning acquired from the intervention as reflected in the learning assessment outcomes;
3. behaviors changes or transference of new learning to a performance context; and
4. organizational results following the intervention such as improved patient safety outcomes.

Determine the appropriate level(s) of outcomes to evaluate based on feasibility, available resources, and your objectives, and use appropriate evaluation method(s) and instrument(s) (Cook 2010). In the case of a flipped classroom approach to improving students' CR, you will at least want to carry out evaluations of the first three levels described by Kirkpatrick and Kirkpatrick (2016). For Level 1, you could use questionnaires and observations to determine how students are reacting to the flipped classroom approach. For Level 2, seek to assess to what extent learners' CR knowledge and skills are actually improved by this innovation (Durning et al. 2012). For Level 3, use observations, interviews, and focus groups to assess the degree to which the students are using their newly acquired CR skills in their interactions with real or virtual patients.

Make sure to relate learning outcomes back to your findings about the implementation process, since most innovations are subject to differences between the intended and actual implementation (Reeves and Hedberg 2003). By conducting iterative evaluations of your educational intervention, you ensure that the information necessary to demonstrate the practical and theoretical impact of your intervention is captured. These evaluation activities should lead to the generation of predictive, explanatory, or prescriptive understanding.

Tip 10

Examine usability when adopting technologies

With the increasing use of technologies in medical education, it is necessary to incorporate usability considerations to ensure that students and teachers can easily use the technology to effectively and efficiently accomplish their instructional tasks and truly engage with their learning experience (Asarbakhsh and Sandars 2013). Usability evaluation can be conducted even before you begin constructing any technology-based intervention (Reeves and Hedberg 2003). For example, you can use PowerPoint or other graphics software to illustrate a few prototype screens and to represent the target learning system's main functionalities. You can use this prototype to interview target learners, observing their interaction with the design plan and asking for their opinion about the functions and 'look and feel' of the system. Similarly, usability evaluation can be conducted using your completed or nearly completed product, with collected feedback guiding the enhancement of the intervention.

In addition to eliciting perspectives from target users (Sandars and Lafferty 2010), you can invite others to review your learning system against usability principles, a method called heuristic evaluation (Reeves and Hedberg 2003). Compared with other usability evaluation methods, heuristic evaluation is relatively less resource consuming and yet effective. For instance, Chen et al. (2017) conducted a heuristic evaluation to improve the usability of an online Geriatrics Clerkship module. Usability evaluations are even relevant with instructional innovations such as the flipped classroom if the learning materials provided to students before lectures are computer-based.

Tip 11

Unleash the power of reflection in your iterations

The possession of a reflective mindset is a key characteristic of those who conduct EDR. Intentional reflection plays an important role in enhancing both educational research and instructional practice (Visscher-Voerman and Procee 2007; Hong and Choi 2011; Yin 2014): Thoughtful reflection enables you to bridge the gap between practice and research, facilitating the adoption of research findings to inform your practice and the transformation of acquired experience into theoretical insights. Meaningful reflection is empowering. Although reflection involves a critical examination of past experience, its focus is not on self-criticizing or simply the detection of errors. Rather, it leads you to discover new perspectives on your experiences that will help you identify opportunities to improve practice and enhance theory.

Table 1. Possible outlets.

Medical education specific	Educational technology, instructional design, and online teaching related
• Short papers summarizing early implementation outcomes: *Medical Education*'s really good stuff, *Medical Teacher*'s short communication, *Medical Science Educator*'s Innovation and Short Communication, and *Perspectives on Medical Education*'s show and tell. • Additional suggestions available at Yarris and Deiorio (2011, p. S32) and Gottlieb et al. (2018, p. 3–4).	• Journal suggestions curated by Dr. Curtis Bonk: http://www.trainingshare.com/resources/distance_ed_journals_and_online_learning_books.php • Conference suggestions curated by Dr. Clayton Wright: https://teachonline.ca/training-opportunities/upcoming-conferences

One idea is to approach your experience from different viewpoints (Visscher-Voerman and Procee 2007; Hong and Choi 2011), yielding unexpected insights. For instance, after observing learners engaging in flipped classroom activities, recall a moment when you feel surprised, confused, frustrated, or excited. From where do such feelings come? Your understanding of the situation can also be enriched through considering the interpretations by some of the key stakeholders or different research or practitioner community members. Further, you might compare the current situation with an ideal one, asking questions such as: What, if any, discrepancies are observed between the ideal and actual implementation of the flipped classroom design plan? What would I do differently during the next iteration? How might I best foster the spread of my intervention to others?

Tip 12

Strategically disseminate and diffuse outcomes through presentations or papers at different EDR stages

Some of you might be eager to build up your research profile and therefore worry that conducting EDR might mean that you have to wait to publish your work until after the innovation has achieved its goals. However, you are encouraged to seek opportunities to share your research findings from the earliest stages of your EDR project. For example, during the 'Analysis and Exploration' phase, you might write a paper describing the theoretical framework for your EDR initiative, or you might seek to publish a literature review concerning the problem the EDR is addressing. The 'Evaluation and Reflection' phase may yield several publishable papers, e.g., one for each iteration of data collection, analysis, and refinement of the intervention.

Successful dissemination of research activities and results not only helps maintain the project momentum, providing continuous motivation to your team members, but also contributes to the continuous improvement of both practical and research products as you collect feedback from like-minded colleagues, and engage yourself in meaningful reflection. These efforts of dissemination subsequently encourage the diffusion of your innovation into novel settings, extending the impact of your intervention (e.g. Chen et al. 2015). The ultimate goal of an EDR project is, therefore, not only the successful implementation of your intervention in your local context, but also successful spread of your practical ideas and theoretical insights, as you aspire to introduce your intervention to new contexts and share your theoretical understanding to inform the work of other practitioners and researchers. Ideally, other educators will relay your effort and conduct EDR to study the outcomes of implementing your intervention or theoretical findings in their institutes.

Although the concept of flipping the classroom in medical education has existed for several years (Prober and Khan 2013), there is still much scholarly work that can be reported, especially with respect to its use to improve CR. To get the publication process started during an EDR initiative, consider submitting an abstract of preliminary findings to present at the department, institutional, regional, national, or international conferences. Many journals accept shorter papers that focus on rapid dissemination of innovations. Online platforms, such as MedEdPORTAL, that disseminate peer-reviewed instructional materials can also be considered. You are encouraged to also explore other publication possibilities outside of medical education (see Table 1).

Conclusions

We present 12 tips to healthcare professionals who are interested in tackling significant instructional problems and simultaneously advancing their scholarship in teaching and learning. The 12 tips demonstrate the process of conducting EDR to address this meaningful twofold challenge (see Figure 1). We believe that with careful planning, a reflective and responsive mindset, and teamwork during the implementation, healthcare professionals can successfully conduct EDR initiatives that contribute to closing the gap between research and practice in the medical education community.

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The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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