Short-Term Training with Basic Science Research Literature Advances Medical Students' Skills for Adaptive Expertise

Journal of Medical Education and Curricular Development
Volume 11: 1–11

DOI: 10.1177/23821205241227328

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ABSTRACT: Physicians must adapt their learning and expertise to the rapid evolution of healthcare. To train for the innovation-efficient demands of adaptive expertise, medical students need to acquire the skill of adaptive self-regulated learning, which includes accessing, interpreting, and synthesizing emerging basic and translational research to support patient care. In response, we developed the course Medical Student Grand Rounds (MSGR). It engages all pre-clerkship students at our institution with self-regulated learning from translational basic research literature. In this report, we describe MSGR's methodology and important outcomes. Students found, interpreted, critically assessed, and presented basic research literature about self-selected clinically relevant topics. In less than one semester and mentored by basic science researchers, they completed eight milestones: (a) search research literature databases; (b) choose a clinical topic using searching skills; (c) outline the topic's background; (d) outline a presentation based on the topic's mechanistic research literature; (e) attend translational research-oriented grand rounds by faculty; (f) learn to prepare oral presentations; (g) write an abstract; and (h) present at Grand Rounds Day, emphasizing their topic's research literature. Graded milestones and end-of-course self-assessments indicated students became proficient in interpreting research articles, preparing and delivering presentations, understanding links among basic and translational research and clinical applications, and pursuing self-regulated learning. Qualitative analysis of self-assessment surveys found most students thought they progressed toward the learning objectives: find scientific information about a research topic (56% positive responses), interpret and critically assess scientific information (64%), and prepare and deliver a scientific presentation (50%). Milestones improve time management and provide a scaffolded method for presenting focused research topics. MSGR equips students with critical thinking skills for lifelong, adaptive, self-regulated learning—a foundation for adaptive expertise. The master adaptive learner cycle of planning, learning, assessing, and adjusting is a conceptual framework for understanding students' MSGR learning experiences.

KEYWORDS: grand rounds presentation, research faculty mentoring, translational basic science research literature, scaffolded learning, professional identity

RECEIVED: February 27, 2023. **ACCEPTED:** November 28, 2023

TYPE: Methodology

FUNDING: The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Dr Huston is supported in part by a Burroughs Wellcome Fund Physician Scientist Institutional Award for the Texas A&M University Academy of Physician Scientists.

DECLARATION OF CONFLICTING INTERESTS: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Introduction

Unlike routine clinical cases for which a physician already has the knowledge and skills to respond rapidly, some cases require innovation-efficient adaptive expertise.[1-7] Physicians can improve patient care in these exceptional cases by critically applying new or emerging approaches arising from current research for disease prevention, diagnosis, prognosis, and treatment. Therefore, they need to find and assess basic science research articles that can shape new approaches to patient care. They must also explain these approaches to patients, colleagues, and trainees.[8,9] However, medical school learning limited to well-established basic medical science does not prepare students to meet these needs. Thus, to prepare for these domains of adaptive learning and expertise, students should develop skills for finding, critically assessing and synthesizing, and explaining clinically relevant scientific research literature.[10,11] Training students early in their education with these skills helps them develop the adaptive self-regulated learning that is a foundation of adaptive expertise.[12]

Although most students learn and practice evidence-based medicine during medical school,[13,14] they commonly acquire little skill in applying basic research literature to clinical settings and problems. Moreover, they often know little about how basic science researchers help pioneer new methods to treat and diagnose patients. Although research experiences are increasingly viewed as assets in competing for residencies,[15] many students view basic research as irrelevant to their learning and career plans.[16] In our experience, most medical students show at least one of these gaps in skill, knowledge, and attitude.

We established the course Medical Student Grand Rounds (MSGR) to address these gaps. With mentoring from basic science researchers,[17] all pre-clerkship students conduct in-depth scientific literature studies on self-selected basic research topics related to clinical medicine. MSGR's goal is to help students develop critical and innovative thinking, equipping them to integrate basic science advances and the scientific method into clinical practice and decision-making throughout their careers to enhance patient care.[18] According to the constructivist theory of learning,[19] a practical, self-regulated learning experience that is based on a basic research topic the learner derives from a clinical topic facilitates a student's acquisition of these skills.[20] Such a learning experience with mentoring from basic science researchers promotes self-regulated learning that integrates basic science and clinical medicine—an ongoing challenge for medical education.[21,22] An additional benefit is acquainting future physicians with their roles in the biomedical research enterprise and with basic science researchers' mindsets, helping establish a foundation for effective communication between physicians and researchers to advance healthcare.[23] The course does not focus students on finding currently recognized or unrecognized links between translational basic research and clinical care. Instead, and to help simulate and stimulate discovery, the course encourages students to speculate how their research topics might contribute to patient care in the future.

Medical educators' opinions vary about the research skills medical students should learn.[24-26] For instance, brief training experiences (including those on evidence-based medicine approaches) focus on single skills such as searching the literature,[10] analyzing and appraising articles,[27,28] or presenting research findings.[29,30] Longer training experiences last a year or more[25,31,32] or even all years of medical school.[33] As a distinctive intermediate option in this research skills training spectrum, MSGR is a short-term, moderate-intensity experience for all first-year students across about 4 months of the second semester, concurrent with other courses. This article describes how we delivered MSGR to 129 students during the spring term of the academic year 2018–2019 (AY2019) and presents outcomes. After 12 years of varied course designs, we implemented this curriculum method with scaffolded milestones that engage pre-clerkship students with basic research literature.

The master adaptive learner model describes adaptive expertise as applying innovative problem-solving to an unresolved clinical problem through self-regulated learning skills.[1] Although the master adaptive learner framework, first published in 2017, did not intentionally guide the development of MSGR, it is useful as a conceptual model describing how students learn in MSGR through planning, learning, assessing, and adjusting cycles as they work through course milestones and gain skills for adaptive expertise.

Here, we provide a detailed enough description of MSGR to permit other institutions to implement MSGR-like training focusing on basic research literature. This description can also guide the development of analogous courses focusing on other literature domains (eg, behavioral and social sciences, health systems science, and medical education) using a milestone-guided, scaffolded learning paradigm.[34]

Methods

Evolution of MSGR—lessons over time

During a decade, MSGR evolved from an exercise in a medical biochemistry course for 70 students to a stand-alone course in 2013 for 200 students. In 2013, the introduction to MSGR consisted primarily of training about PubMed searching. Students chose general topics from an assigned list, independently conducted literature research, and completed training about preparing a scientific presentation. Students developed presentations largely without formative feedback. Grading by faculty was limited to students' final presentations. This design lacked milestones, ongoing mentoring, and student interactions in mentoring groups. Students often struggled to understand research articles, had little experience with oral presentations, and found MSGR's purpose unclear. Procrastination in developing presentations undermined MSGR's impact.

In 2014, the course directors started revamping the design by including milestones. In AY2019, students completed eight milestones, which increased interactions with mentors and divided the tasks leading to presentations into more understandable and attainable steps. MSGR demonstrated that first-year students who had completed only some basic science courses could learn to search, critique, and synthesize basic research literature. In addition, students' choosing topics, a feature of self-regulated learning, enhanced enthusiasm for the learning activities.

The mentoring component, implemented in 2016, guided students in developing the adaptive learning skills of finding, assessing, and communicating clinically relevant scientific information and allowed students to learn from experts. The increase in student satisfaction in the course from 2014 to 2021 can be attributed in part to the milestone organization of the course and implementing and optimizing the faculty mentoring component. Optimizing included providing a mentor training session and having the course directors monitor feedback and grades as MSGR progressed, thus helping address student criticisms about variability in grading among mentors and leading to more equitable mentoring.

Curricular context and prerequisite knowledge for students and faculty

The 19.5-week, second-semester, two-credit hour course was intended to develop skills in scientific literature navigation, analysis and synthesis, and presentation. The training was designed to build proficiency and establish processes for reviewing scientific literature throughout students' careers. At MSGR's start, students had completed courses in gross anatomy, histology, biochemistry, genetics, cell biology, pharmacology, physiology, and neuroscience. MSGR ran concurrently with microbiology, immunology, pathology, and cardiovascular and respiratory systems courses. Each mentor had research experience in at least one of the following areas: cancer, the cardiovascular system, genetics, immunology, neuroscience, regenerative medicine, pathology, or microbiology. The course had these four learning objectives:

1. Identify, from within a broad domain of current biomedical research literature, a highly focused research topic that is clinically relevant, is founded in mechanisms of pathogenesis, and engages the student's curiosity.
2. Outline pertinent background information on the focused research topic and prominent concepts from primary mechanistic research articles published within the previous five years.
3. Annotate primary research articles on the focused topic from high-impact journals.
4. Create, present, and defend a 15-min analysis and synthesis of the current research on the topic, focusing on state-of-the-art investigations that elucidate underlying mechanisms of pathogenesis and might lead to new approaches for prevention, diagnosis, prognosis, or treatment.

Implementation

In the 2018–2019 version (AY2019) of MSGR described in this report, students completed eight milestones (Figure 1). Through an online learning management system, students received course materials, including the course syllabus (Supplemental Material 1—Course Syllabus), and submitted assignments for grading. Students and faculty mentors also completed assessment and evaluation activities online. All course materials and evaluation instruments are publicly available for download in an editable form in a data repository (https://doi.org/10.6084/m9.figshare.23739459).

Mentor training. The course faculty consisted of 24 mentors. They attended an orientation and training session before MSGR began (Supplemental Material 2—Guidelines for Mentors). Although many mentoring activities with students occurred asynchronously, each mentor met with their mentoring group at least twice during MSGR. Group interactions helped answer students' questions and stimulated discussion about research topics. Each mentor worked with no more than seven students.

Student orientation. During the course orientation, students received information about MSGR's purpose and goals, the course expectations, the eight milestones, and grading policies (Supplemental Material 3—Orientation to the Course). To highlight MSGR's relevance to clinical practice, a physician described a clinical experience applying the skills and knowledge MSGR develops. Medical librarians demonstrated how to search literature databases to find research articles and evaluate and cite sources.

Milestone I (due week 1, day 3)—finding scientific information. Students acquired skills for finding high-quality review articles and primary research articles with training from librarians (Supplemental Material 4—Literature Search Training Developed by Librarians) and then completing the self-guided database-searching exercise "Effective PubMed Searching" (Supplemental Material 5—Milestone I – Effective PubMed Searching Exercise) and receiving feedback from librarians.

Milestone II (due week 3, day 5)—choosing a subject. Students selected research-related clinical subjects from a list reflecting mentors' expertise, which ensured mentors could provide suitable guidance (Supplemental Material 6—Milestone II – Choosing a Subject Area). Mentors' clinical subjects were intentionally broad (eg, diet and breast cancer susceptibility). Before choosing a subject, a student preliminarily assessed research literature published within the previous 5 years on clinical topics engaging the student's interests. The restriction to recent publications helped direct students to active research areas. As MSGR progressed, each student focused on one specific mechanistic subtopic (eg, reprograming breast cancer stem cells by glycolysis gatekeeper PDK1) within their clinical topic.

Milestone III (events throughout the semester)—Clinical Science & Translational Research grand rounds. Clinical Science & Translational Research (CST☆R) Grand Rounds is a monthly interdisciplinary forum where experts educate students and faculty about recent advances translating basic research into clinical investigations and patient care. These presentations modeled Grand Rounds Day presentations for students. Students attended two CST☆R Grand Rounds of their choice.

Milestone IV (due week 7, day 5)—Outline A—clinical background & significance. In Outline A, students presented clinical and pathophysiological background information on the selected subject (Supplemental Material 7—Milestone IV – Outline A – Clinical Background and Significance). This

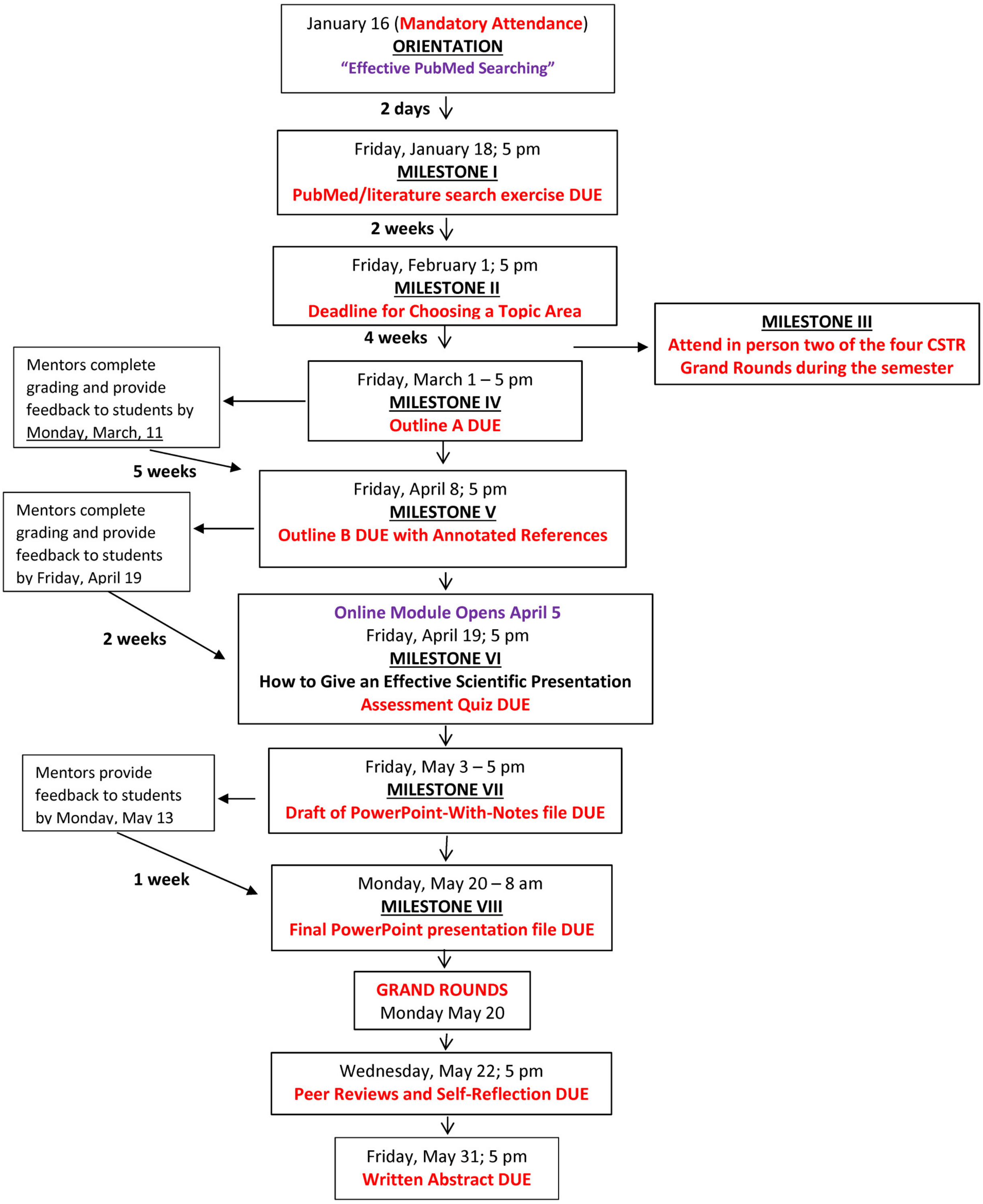

Figure 1. The flow of the eight MSGR milestones through the course in 2019. In this version of MSGR, 129 first-semester pre-clerkship students completed, with mentoring from basic science researchers, eight milestones over 19.5 weeks, culminating in a 15-min oral presentation. MSGR, Medical Student Grand Rounds.

outline also identified the research area and a primary research article on which later milestones would focus. Mentors helped students understand the mechanistic research and assessed the outline. Librarians and mentors helped students with research literature searching.

Milestone V (due week 12, day 5)—Outline B with annotated references—mechanistic research results and translation. Students identified four primary basic research articles that would become the focus of their Grand Rounds presentation (Supplemental Material 8—Milestone V – Outline B –

Mechanistic Research Results and Translation). Students' annotations detailed the research articles' purpose, hypothesis, experimental strategy, and significant findings. With mentors' contributions, this milestone showed how basic research and the scientific method help identify new approaches for prevention, diagnosis, prognosis, or treatment.

Milestone VI (due week 13, day 5)—mandatory online lecture—giving an effective scientific presentation. "Giving an Effective Scientific Presentation" (Supplemental Material 9—Milestone VI – Giving an Effective Scientific Presentation) and the accompanying quiz (Supplemental Material 10—Milestone VI – Quiz: Giving an Effective Scientific Presentation) helped students prepare their Grand Rounds presentations.

Milestone VII (due week 15, day 5)—draft presentation files with notes. The draft versions of presentation files included the students' speaker notes (Supplemental Material 11—Milestone VII – Draft PowerPoint). Mentors suggested improvements but did not grade the draft presentation files.

Milestone VIII (due week 17, day 1)—final presentation files. Students gave their final presentation files to facilitators before Grand Rounds Day (Supplemental Material 12—Milestone VIII – MSGR Day).

Capstone: Grand Rounds Day oral presentations (week 17, day 1). Each of the 24 presentation groups consisted of about five students and a facilitator/grader. Each facilitator/grader also had served as a mentor. To minimize the potential for grading bias, a facilitator/grader's group did not include any of the facilitator/grader's mentees.

Peer reviews and self-assessment (due week 17, day 3). Students critiqued peers' presentations within their presentation groups and completed self-assessments (Supplemental Material 13—Student Peer Assessment & Self-Assessment Instruments).

Written abstract (due week 18, day 5). Using guidelines for writing abstracts,[35,36] students submitted Grand Rounds presentation abstracts (Supplemental Material 14—Abstract).

Grading. The grades from the eight milestones composed the numerical course grade.

Evaluation strategy. Following institutional policy, all MSGR students completed Likert-type evaluations and provided free-text comments about MSGR and their mentors (Supplemental Material 15—Course Evaluation Instruments) after the course ended. Mentors evaluated MSGR. Qualitative analysis of student free-text comments was conducted using QDQ Miner Lite (Provalis Research). Descriptions of the content and hybrid deductive and inductive qualitative data analysis methods[37,38] are in Supplemental Material 16—Content Analysis of Course Strengths 2019, Supplemental Material 17—Content Analysis of Course Weaknesses 2019, and Supplemental Material 18—Qualitative Analysis of Student Self-Assessments 2019.

Results

Implementation

The mean (median) course grade for the 129 students in the course was 91.4% + 3.1 (SD) (91.9%). The 124 abstracts from students earning a course grade of at least 85 were published online in *Proceedings of the Medical Student Grand Rounds* (https://jmsgr.tamhsc.edu/).

Evaluation

Students generally rated MSGR and their mentors favorably. The means for 12 of the 15 evaluation items were ≥3.00 out of a 4-point scale, with the exceptions being the peer review and self-assessment activities and the course's overall quality (Figure 2). The overall effectiveness means of mentors was 3.5 (Figure 3), and that of facilitators/graders was 3.6 (Figure 2).

In their comments, students indicated they enjoyed exploring and presenting research topics and thought the milestone organization was effective (Supplemental Material 16—Content Analysis of Course Strengths 2019 and Supplemental Material 19—MSGR Course Student Evaluations 2019). They also wrote that they appreciated having frequent interactions with mentors (Supplemental Material 20—Student Evaluations of Mentors 2019). For weaknesses, a recurring theme was that limiting the scope of topics to mechanistic research at the molecular or cellular level was too constraining (Supplemental Material 17—Content Analysis of Course Weaknesses 2019). Behavioral and social sciences topics would have better suited some students' interests. Students also perceived inconsistencies in feedback and grading across mentors. Sample quotes in Table 1 illustrate these themes.

According to mentors' survey responses (Figure 4), the mean for overall course quality was 3.8 out of 4 points (N = 8; response rate = 33%). The faculty agreed that MSGR integrated basic and clinical science effectively (mean = 3.5).

Student self-assessments

Students assessed their learning by completing narrative self-assessment surveys addressing three questions about their presentation experiences (Student Self-Assessment section of Supplemental Material 13—Student Peer Assessment & Self-Assessment Instruments). A preliminary deductive

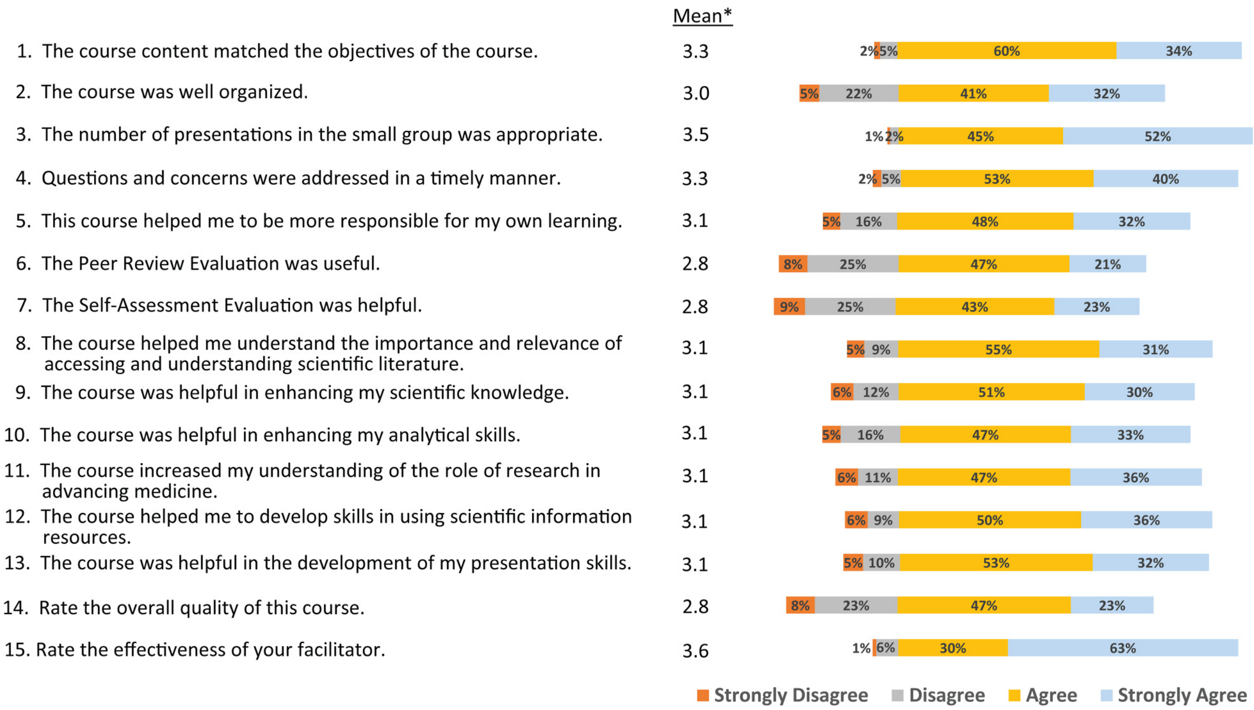

Figure 2. Student-generated evaluations of MSGR in 2019. N = 129 students (mandatory evaluation; response rate 100%). *Mean values of items 1–13 are derived from a 4-point scale where 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree. Mean values of items 14-15 are derived from a 4-point scale where 1 = poor, 2 = fair, 3 = good, and 4 = outstanding. Percentages shown in the stacked Likert bar graph are derived from the number of responses for each Likert point scale divided by N. MSGR, Medical Student Grand Rounds.

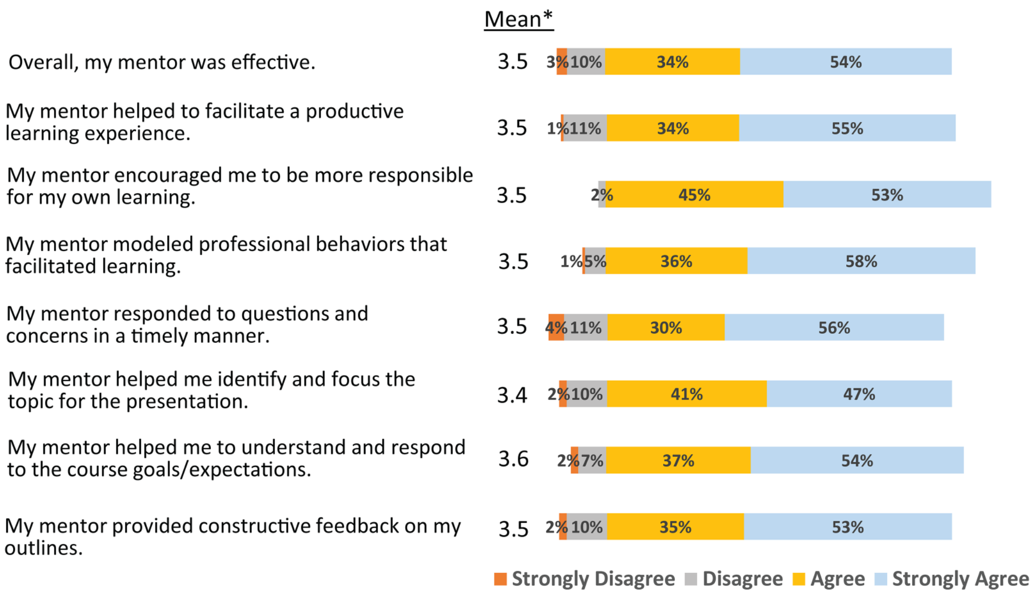

Figure 3. Quantitative results from student-generated evaluations of mentors in 2019. *N* = 129 students (mandatory evaluation; response rate 100%). *Mean values of items are derived from a 4-point Likert-type scale where 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree. Percentages shown in the stacked Likert bar graph are derived from the number of responses for each Likert point scale divided by *N*.

qualitative data analysis of the open-ended questions (Supplemental Material 18—Qualitative Analysis of Student Self-Assessments 2019, N = 128) indicated that most respondents thought they progressed toward one or more of the four learning objectives: find scientific information about a specific research topic (Objective 1; 72 [56%]) students with positive responses), interpret and critically assess scientific information (Objectives 2 and 3; 82 [64%]), and prepare and deliver an

Table 1. Sample quotes from students' course evaluation comments about MSGR (Supplemental material 15—course evaluation instruments).

Exploring and presenting research topics
• "I learned how to effectively research publications on PubMed and condense complex literature and information to present to my peers." • "I liked that we were able to research a topic of our interest and explore current research around the topic. I learned a lot from this course and appreciated getting to present our findings at the end. I think communicating research is vital and appreciated getting to practice that."
Milestone organization
• "This course was very effective because it spaced out smaller goals throughout the semester. This made it easier for students to understand their topics of presentation well and didn't drown students in too much work at any given moment." • "The length of the course was appropriate for full understanding of the subject matter, and the outlines did a good job in making preparation of the final presentation much easier."
Frequent interactions with mentors
• "My mentor was so helpful. Anytime that I had a question she addressed it quickly and she spent lots of time with me developing my presentation and outlines and highlighting areas that I need to address. " • "My mentor was always willing to work with the mentees even with his busy schedule. He was excellent at providing constructive feedback and I felt I learned a lot about the research process from him."
Limiting research topics to mechanistic research
• "The only thing is I wish we could have made it more clinical, as many of us will not be going into mechanistic research." • "I wish we could have not had to do research over molecular mechanisms. Many students are interested in public health or other research, so that really limited what we were allowed to research."
Feedback and grading disparities across mentors
• "I think that there was some variance with regards to the feedback that students received from their mentors as well as to the grading process as well." • "I would recommend ensuring objectivity and standardized grading across the assigned mentors and facilitators as it seemed to vary in what we were told, how we were graded, and what was expected from us."

MSGR, Medical Student Grand Rounds.

effective scientific presentation (Objective 4; 64 [50%]). In addition, 28 (22%) students expressed greater awareness of and appreciation for the significance of basic science research to patient care—a domain relevant to students' awareness of physicians' responsibilities and professional identity within the broad-based biomedical research community. Sample quotes in Table 2 illustrate these themes.

A preliminary inductive qualitative data analysis of the same open-ended questions (Supplemental Material 18—Qualitative Analysis of Student Self-Assessments 2019, N = 128) revealed similar themes as in the deductive analysis, although at different frequencies: finding scientific information (30%), assessing scientific information (26%), presenting information (14%), and greater awareness of the relevance of research to medicine (30%). The inductive analysis identified two additional themes: facilitating factors for better learning (positive role for mentors; 8%) and improved personal skills (confidence, focusing, improved audience engagement, learning from mentor feedback; 25%).

Mentor-generated evaluation

In 2021, with a version of the course like the 2019 version, mentors evaluated whether students had attained the learning objectives (Figure 4). Most indicated that the MSGR experience successfully produced the intended learning outcomes and that MSGR effectively integrated basic and clinical science. In a recent survey (Supplemental Material 21—Mentor Survey), mentors reported that seven students/mentor was the maximum feasible number for quality mentoring and that three or four would be ideal. Mentors indicated they gave 10 ± 3.4 h of mentoring per student. Moreover, mentors thought the total mentoring time commitment per student was feasible and sustainable for a basic science mentor with an active research program.

Discussion

Value of the experience

MSGR's value emerged in several domains of training adaptive expertise. First, students experienced training in self-regulated learning and master adaptive learner model's cycles while (a) choosing and developing the background for a clinical topic, (b) choosing and developing a research focus related to the clinical topic, and (c) developing a unique presentation story by synthesizing and critiquing basic research articles of their research focus. Second, the mechanistic research context connected students with basic research literature that can deepen learning about pathogenesis, informs clinical practice, and helps advise patients. Third, the emphasis on mechanistic research allowed basic science researchers to mentor students. The mentoring extended students' learning to critical scientific thinking

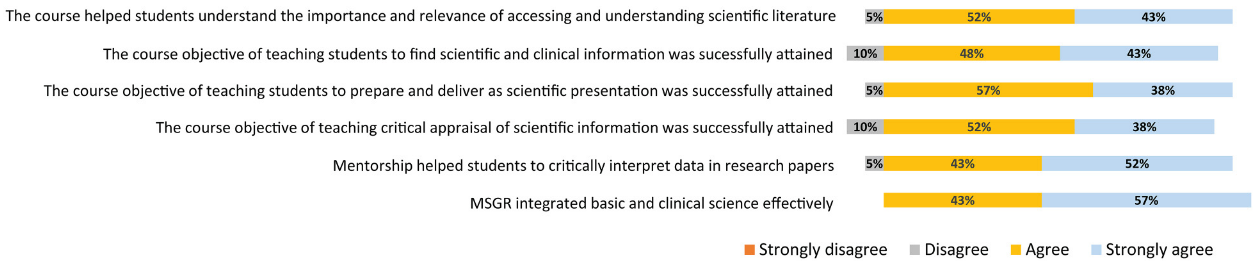

Figure 4. Quantitative results from mentor-generated evaluations of student outcomes in 2021. $N = 21$ mentors (response rate 62%). *Mean values of items are derived from a 4-point Likert-type scale where 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree. Percentages shown in the stacked Likert bar graph are derived from the number of responses for each Likert point scale divided by N.

Table 2. Sample quotes from students' self-assessment comments (supplemental material 13—student peer assessment & self-assessment instruments).

Choose a research topic and explore its literature (Objective 1)
• "I learned how one article could lead to several others, in terms of leading you to other mechanisms or pathways. I also learned how to effectively search articles that pertain to your topic." • "I also learned a lot about my specific topic, and I may continue research into the topic in the future."
Interpret and critically assess scientific information (Objectives 2 and 3)
• "Prior to this course, I was not good at reading and understanding research papers, and this course taught me how to extract relevant information and critically evaluate research papers." • "I learned how to read scientific articles and gather important data from them and how that research translates into clinical practice to improve patient outcomes."
Prepare and deliver scientific presentations (Objective 4)
• "I learned how to better communicate scientific findings and condense it into more understandable information for my peers." • "I learned to create an effective scientific presentation and was able to practice presentation skills needed for future endeavors in the medical field."
Significance of basic science research to patient care and physicians' professional identity in the broad-based biomedical research community
• I also learned how important the basic science research is, the information learned directly benefits clinical medicine in surprising ways. I need to stop taking the basic science information for granted and better understand it because it really can make me a better physician in the future." • "I also learned a physician's role requires staying up to date with current clinical research in order to . . . improve patient outcomes and . . . [provide] the most competent care."

that ties medical knowledge to its research foundations. Thus, this experience helped many students perceive the relevance of basic research to their future delivery of clinical care and encouraged them to reflect on physicians' roles as members of the broad-based biomedical research community. Fourth, students honed presentation skills for use in scholarly and clinical contexts. Fifth, MSGR occurred in a short enough timeframe to be feasible to implement within a busy pre-clerkship curriculum.

Other outcomes and limitations

Students' success with the eight milestones and their evaluations of MSGR and post-presentation self-assessments using quantitative and qualitative responses indicated that students achieved MSGR's objectives. Faculty mentors also agreed that students had attained the skills required to attain the course objectives. We estimate that a typical student needed about 50 h to complete the milestones over the 19.5 weeks (~2.5 h/week) (Supplemental Material 22—Estimated Time Effort of Students). This time commitment has proved compatible with the concurrent demands on a preclinical student's time.

Scientific knowledge is a physician's professional responsibility[39] and is integral to a physician's professional identity.[40] MSGR helps pre-clerkship students experience these aspects of their profession by interacting with research literature and basic researchers.[17] Some students will pursue research careers and will generate new knowledge. Others will rarely interact first-hand with researchers but will guide patients, trainees, and colleagues in understanding cutting-edge diagnostics and therapies. Regardless of their future career path, MSGR acquainted students with physicians' professional responsibilities and professional identity in the broad domain of biomedical research.

Limitations were inherent in MSGR's design and timing. (a) The mechanistic orientation of research topics provided a context for training in self-regulated learning integral to adaptive expertise and suited MSGR's goals and mentors' expertise but excluded behavioral and social science topics, which some students preferred. (b) Students had completed only some of their basic science courses and had little clinical experience. MSGR's impact might have been greater if students could have drawn on clinical experiences to identify and develop topics. However, scheduling MSGR early in the curriculum helped shape students' thinking about the role of basic research in medical training and practice. (c) MSGR was a relatively brief experience. Its long-term impact on lifelong learning skills and the facility to apply basic research to clinical settings is uncertain. (d) Only two faculty members—the mentor and Grand Rounds Day facilitator/grader—graded a student's performance. Students perceived inconsistencies in grading among mentors and facilitators/graders. Providing assessments from more faculty members would help standardize grading but would be logistically challenging. Making the assessments pass/fail may also alleviate student concerns about potential disparities in grading across mentors. (e) A single medical school implemented MSGR. The basic science researchers and medical librarians, who were essential resources, might not be available in other settings. However, MSGR's successful delivery in this format to more than 500 students across three years supports its generalizability to other suitably equipped environments. (f) We did not compare students' baseline and end-of-course skills or determine long-term skill retention. (g) No sample size/power analysis was performed for the study. Students were required to participate in the course and submit course evaluations.

Future directions

Mentoring benefits medical students,[41,42] but their mentors typically are physicians in clinical contexts who help with career development. MSGR highlights the value of mentoring from basic science researchers early in students' educational experience. However, the effects of and optimal approaches to mentoring medical students by basic science researchers need more investigation.

We plan to survey third- and fourth-year students who have completed MSGR about perceptions of MSGR in the context of experiences later in medical school. This information will help us determine the longer term impact of MSGR and help guide future refinements in training students in skills for adaptive expertise.

Conclusion

MSGR allowed students to gain skills for adaptive expertise by choosing clinical subjects and then finding, analyzing, synthesizing, and presenting relevant translational basic research literature. The course provided students mentoring by basic science researchers, fostering critical scientific thinking, and emphasizing connections between medical practice and its research foundations. Additionally, students developed presentation skills applicable in scholarly and clinical contexts. The course's milestone structure and faculty mentoring significantly improved student satisfaction. The master adaptive learner model's cycle of planning, learning, accessing, and adjusting describes how students learn with the milestones. Despite limitations, such as the inclusion of a limited set of clinical topics from which students could choose and the course's relatively brief duration, MSGR introduced students to physicians' professional responsibilities and identity in the biomedical research field. MSGR's success at our institution suggests its potential applicability elsewhere. Future research will focus on the long-term impact of MSGR and the benefits of mentoring by basic science researchers.

Acknowledgments

We acknowledge the medical students, administrative staff, and faculty members who participated for more than 12 years in developing and refining this course. We also acknowledge the support of the School of Medicine, Texas A&M University Health Science Center, Texas A&M University Medical Sciences Library, and Texas A&M University throughout the evolution of this course.

Author contributions

Steve Maxwell has served as the MSGR course director for over 10 years and contributed to the concept and design (all milestones). He helped draft the article, revised it critically for important intellectual content, and analyzed and interpreted the data. He approved the version to be published and can take public responsibility for appropriate portions of the content.

Robin Fuchs-Young has served as the MSGR course director for 7 years and contributed to the concept and design (all milestones). She revised the article critically for important intellectual content, approved the version to be published, and can take public responsibility for appropriate portions of the content.

Gregg B. Wells helped draft and edit the article and contributed to the concept and design (all milestones), analysis and interpretation of data, approved the version to be published, and can take public responsibility for appropriate portions of the content.

Geoffrey M. Kapler contributed to the concept and design (all milestones), approved the version to be published, and can take public responsibility for appropriate portions of the content.

Sheila Green is a librarian that contributed to the concept and design, particularly milestone I, and approved the version to be published, and can take public responsibility for appropriate portions of the content.

Catherine Pepper is a librarian that contributed to the concept and design, particularly milestone I, and approved the version to be published, and can take public responsibility for appropriate portions of the content.

Barbara Gastel contributed to the concept and design, particularly milestone VI, approved the version to be published, and can take public responsibility for appropriate portions of the content.

David P Huston contributed to the concept and design, particularly milestone III, approved the version to be published, and can take public responsibility for appropriate portions of the content.

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Data Availability

MSGR course materials, supporting data, and content analysis can be viewed and downloaded at the Figshare.com data repository (https://doi.org/10.6084/m9.figshare.23739459), which contains the following:

Ethical Approval

The Texas A&M University Institutional Review Board determined on 07/10/2020 that this study meets the criteria for Exemption (waiver of informed consent) in accordance with 45 CFR 46.101(b). Therefore, the Texas A&M University Institutional Review Board's Ethics (Human Research Protection Program) Committee waived the requirement of informed consent under IRB #IRB2018-0520 M (reference number: 109774).

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