Published in final edited form as:

Acad Med. 2019 February ; 94(2): 213–216. doi:10.1097/ACM.0000000000002470.

Case-Based Learning in Translational Biomedical Research Education Provides More Realistic and Adaptive Skills for Early-Career Scientists Than Didactic Sessions

Alexandra J. Greenberg-Worisek, PhD, MPH [Assistant professor],
epidemiology, Mayo Clinic College of Medicine, Mayo Clinic, Rochester, Minnesota.

Katherine A. Campbell, PhD [Assistant professor],
molecular pharmacology and experimental therapeutics, Mayo Clinic College of Medicine, Mayo Clinic, Rochester, Minnesota.

Eric W. Klee, PhD [Assistant professor],
biomedical informatics, Mayo Clinic College of Medicine, Mayo Clinic, Rochester, Minnesota.

Nathan P. Staff, MD, PhD [Assistant professor],
neurology, Mayo Clinic College of Medicine, Mayo Clinic, Rochester, Minnesota.

Lisa A. Schimmenti, MD [professor],
pediatrics, Mayo Clinic College of Medicine, Mayo Clinic, Rochester, Minnesota.

Karen M. Weavers, MEd [manager],
research operations, Center for Clinical and Translational Science, Mayo Clinic, Rochester, Minnesota.

Stephen C. Ekker, PhD [professor], and
biochemistry and molecular biology, Mayo Clinic College of Medicine, Mayo Clinic, Rochester, Minnesota.

Anthony J. Windebank, MD [professor]
neurology, Mayo Clinic College of Medicine, Mayo Clinic, Rochester, Minnesota.

Abstract

Problem—Case-based learning is an established means of educating students in law, business, and medicine; however, this methodology is not often applied to educating translational biomedical researchers. The application of case-based learning to translational biomedical research education allows scholars to actively engage with real-world material and apply their newfound knowledge as it is acquired.

Approach—Through the Mayo Clinic Center for Clinical and Translational Science (CCaTS), three courses were delivered in 2009–2017 which emphasized case-based learning in clinical and

Correspondence should be addressed to Anthony J. Windebank, Mayo Clinic, 200 First Street SW, Rochester, MN, 55905; telephone: (507) 284-4716; Windebank.anthony@mayo.edu.

Other disclosures: None reported.

Ethical approval: Reported as not applicable.

translational science, entrepreneurship, and individualized medicine. Quantitative measures collected in student course reviews upon course completion were analyzed. Additionally, products arising from each course were identified, including publications and startups pitched.

Outcomes—Analyses demonstrate that case-based learning techniques are well suited to graduate biomedical research education. Furthermore, case studies can be employed throughout the entire clinical and translational spectrum, from basic and preclinical work through to clinical and population-based learning.

Next Steps—Within CCaTS, next steps include creating case-based courses in regulatory and team science to continue to allow scholars to learn and apply these critical skills to real-world material. The goal is to continue to provide immersive training opportunities in areas of clinical and translational science that cannot be readily learned in a traditional lecture-based class setting.

Problem

Biomedical research attracts students and faculty who are innately curious and thrive on hands-on learning. Traditionally the majority of didactic training is conducted using lecture-based delivery methods involving a faculty member at the front of the hall and students passively taking in knowledge. Although such training has been employed for generations in medical school classrooms and in the training of other health care professions for which there is a clearly outlined, proscribed program of study, lecture-based learning is not ideal for those in highly tailored biomedical research training programs. In the field of clinical and translational science, the use of the lecture-based format is antithetical to the objectives of the training programs, in which students are encouraged to apply their newfound knowledge in “real time” to better facilitate safe, evidence-based, and rapid translation of biomedical discoveries into clinical use. With this in mind, the Mayo Clinic Center for Clinical and Translational Science (CCaTS) has designed key courses that utilize case-based learning methodologies to address this challenge. The curriculum delivered through CCaTS targets a diverse group of learners across predoctoral, master’s, and certificate programs; learners earn the associated degrees and certificates in Clinical and Translational Science from CCaTS and/or Mayo Clinic Graduate School of Biomedical Sciences, depending on where the broader program is housed. The objectives of these programs vary as to level of mastery, but all aim to equip investigators and clinicians to actively participate in translational biomedical research across the clinical and translational spectrum. Scholars include recent undergraduates, medical students, postdoctoral fellows, and established clinicians and scientists. The purpose of this report is to describe how case-based learning methods have been used in three different courses in the Mayo Clinic CCaTS to better equip scholars to apply content to their personal areas of research to improve human health.

Approach

Though there are many definitions of a “case study” in the educational context, the general consensus is that a case study allows trainees to critically analyze an event, topic, or issue through a multi- or transdisciplinary lens. The use of case studies is not novel in graduate education in the fields of law, business, public policy, and clinical medicine, but their use is novel in biomedical research education.

Course 1: Case Studies in Translation

The first course established in our series was “Case Studies in Translation,” which is required for CCaTS predoctoral students and an elective option for scholars in other programs. This course was first delivered in 2009, and has been delivered annually since that time. Classes meet weekly for two hours at a time throughout one academic quarter for blended presentation and discussion. The primary aim of this course is to explore the process by which discoveries and inventions move from first discovery in the laboratory to widespread use in clinical care and public health. While it takes an average of 17 years for a new discovery or innovation to be used in routine patient care, this can vary greatly based on the scientific and sociopolitical forces surrounding the discovery. To that end, “Case Studies in Translation” was created to provide trainees the opportunity to investigate and critically evaluate selected cases, identify relevant social and political factors that influenced the speed of translation in these cases, and to create a definition of “successful” clinical translation (Table 1).

“Case Studies in Translation” is delivered in a blended format of in-person presentations and discussion and online readings and assessments. During the course, each student is assigned a case study to research, develop, and present from initial discovery or invention through to clinical adoption. Cases are representative of as broad a spectrum of translated discoveries and inventions as possible, including drugs, devices, in vitro diagnostics, and biologics. Although some cases are repeated from one year to the next, the majority are chosen as current examples based on recent scientific developments.

Assigned topics are purposefully outside the expertise of the student presenter. This encourages presenters to think critically about the science in the context of translation and to push them to learn how to evaluate the translational barriers and facilitators. Additionally, each student is paired with a faculty content expert for the case. The student can work with the faculty expert to develop their project. We were able to identify within our institution faculty partners representing the broad array of expertise needed to deliver these courses. These content experts attend the student presentations to assist with questions that arise during the class session. Although the assigned student presentations provide a scaffold for the class session, the course and content are heavily driven by student interest and discussion.

Course 2: Case Studies in Entrepreneurship

The second course is “Case Studies in Entrepreneurship” (Table 1). Modeled after the National Science Foundation’s Innovation Corps (I-Corps) Programs, “Case Studies in Entrepreneurship” aims to teach students to identify potential product ideas based on their academic research and to employ valuable entrepreneurship skills, including creation of a business canvas and customer discovery. This course serves as an elective for scholars in the certificate, master’s, and predoctoral programs. Although this course employs some case-based learning techniques, including examination of exemplar cases, the primary focus is on learning through development of biotech startup ideas and pitches in small-group settings; that is, the students’ ideas ultimately serve as case studies themselves as they present and discuss them with their colleagues. Regardless of whether the final startup pitches are

successful, the course aims to foster entrepreneurial mindsets among budding scientists and clinicians.

This course relies on a blended format involving in-class discussion, group work, and out-of-class experiences. Class meets each week for one hour throughout an academic quarter, with additional meetings scheduled as needed outside of class for additional immersion experiences. These experiences involve customer interviews and two immersion experiences with entrepreneurs outside of Mayo Clinic. The first immersion experience occurs early in the course, and is designed as a "field trip" to give participants an understanding of real-world entrepreneurship and to begin to build their network. The second immersion experience is selected later on, once students have identified any "missing pieces" in their business canvas and/or pitches. Specific group assignments include the development of a business canvas to assess key partners, activities, and resources; value propositions; customer relationships and segments; cost structure and revenue stream; and distribution channels. Final group projects include a 120-second business pitch in the qualifying round of "Walleye Tank," a Minnesota Biotech Business Pitch Competition in the style of the popular television show "Shark Tank," and a formal application to the Minnesota Cup business accelerator.

Course 3: Case Studies in Precision Medicine

The newest course in the case studies series is "Case Studies in Precision Medicine." This course also serves as an elective for scholars in the certificate, master's, and predoctoral programs. The course is predicated on the fact that the use of whole exome sequencing (WES) to achieve a diagnosis in a patient with an undiagnosed disease is an important skillset for both clinicians and investigators. Interpretation of genomic data is highly complex and requires a unique series of clinical and bioinformatics steps to identify putatively causal genomic variation.

Each student is assigned a "medical mystery" case at the start of the course, which includes phenotypic and raw WES sequencing data and/or first-degree relative genomic data. Students are led stepwise through the analysis of their sequence data over each week of the course, allowing real-time development and application of genomic bioinformatics skills. Students work independently on various portions of the analyses, but they are also expected to share results and collaborate to come to a consensus regarding diagnosis.

Course delivery is a blend of didactic lectures and hands-on workshop sessions delivered throughout one academic quarter, with two one-hour classes per week. Students are also exposed to Mayo Clinic's Center for Individualized Medicine "Genomic Odyssey Board" by attending two meetings. The Genomic Odyssey Board is a multi-disciplinary team of physicians, genetic counselors, laboratory-based geneticists, bioinformaticists, and bioethicists that meets weekly to discuss cases where WES has been performed. At the meeting, the patient's results are reviewed at a level of detail that exceeds what is provided on the clinical report, enabling the board to discuss the findings and render an opinion on whether the reported results are likely pathogenic for each patient. By the end of the course, students have performed a phenotypic analysis, used bioinformatics tools to mine existing databases for genes already associated with the identified phenotype(s), performed an

analyses of the WES data for potentially disease-causing gene variants in the genes previously identified, and conducted an analysis to look for autosomal dominant *de novo* or recessive genes which may be associated with the patient's condition.

Outcomes

Course 1: Case Studies in Translation

Results of course satisfaction surveys (Supplemental Digital Appendix 1) collected over the past five course administrations (2013–2017) indicate overwhelmingly positive experiences in the class (response rate: 37/52, 71.2%). This course survey is administered within a week of completion of the course for all courses in CCaTS. Across nine years of course deliveries, all participants indicated that they "somewhat agreed," "agreed," or "strongly agreed" that the "course assignments were worth doing." Similarly, all respondents "agreed" or "strongly agreed" that the course was "well integrated" and that "discussion was well facilitated." Over the past five years of course delivery, 94% of 36 students who responded to the survey gave the course a grade of A. Many wrote positive comments, including "Easily my favorite CCaTS course. Really pushed me out of my comfort zone," and "A real eye-opener into the workings of the [Food and Drug Administration], lobbying, patient care, and clinical trials."

In addition to student feedback, students are given the opportunity to further develop their presentation into a commentary or letter to the editor for journal submission. Several students have taken advantage of this opportunity, with 5 publications over as many years, including several in *The Journal of Clinical and Translational Science* and one in *Science Translational Medicine* (Table 1).[–]

Course 2: Case Studies in Entrepreneurship

Of the 23 students who responded to the course satisfaction survey delivered after completion of the class, all responded that they "agreed" or "strongly agreed" that the "course assignments were worth doing"; 60.5% (23/38) "agreed" or "strongly agreed" that the course was "well worth the effort". Although the feedback in these structured assessments was overwhelmingly positive, student outcomes that truly speak to the success of the course are the progress each group has made towards making their startup biotech company a reality. Several teams' pitches have made headway over the past year. This has included initiating IRB-approved clinical testing and validation, identifying external partners and CEOs for launches, and further developing business models and products. Notable student business start-ups are listed in Table 1; video footage of some of the students' final pitches can be found at www.walleyetank.com.

Course 3: Case Studies in Precision Medicine

This new case-based learning course has only been delivered twice. Because of its intensity, class sizes were limited. However, feedback from the two offerings has been positive (response rate: 2/10, 20%). Comments from participants were that "there is a clear significance and urgency of solving the mystery assigned to each group because each case is a real patient case," and "It is one of the rare courses that we realize that our learning and skillset are directly related to changes in patients' and other peoples' lives."

Next Steps

Utilizing case-based learning in these three CCaTS course offerings has demonstrated that these techniques are well suited to translational science education. While defining translational science can be challenging, these case-based approaches afford trainees an experiential knowledge of translational science across multiple disciplines. The variety of methods of delivering case material, including discussion, teamwork, and problem-solving, can be applied to many of the transdisciplinary and multidisciplinary areas unique to translational educational programing. This novel application of case-based learning methods helps to address the gap in the literature regarding how best to teach translational science concepts to early-career scholars. Given the applied nature of biomedical research, little additional faculty development and training was needed to equip educators to develop and implement these courses effectively. Furthermore, case studies can be employed throughout the entire clinical translational spectrum, from basic and preclinical work through to clinical and population-based learning. Finally, the spirit of case-based learning—learning through doing—fits well with the application-driven philosophy of clinical and translational science. Courses in regulatory science and team science emphasizing the use of case-based learning are forthcoming, with the goal of providing additional immersive learning opportunities in areas of clinical and translational science that are difficult to teach in a traditional didactic manner.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

The authors would like to acknowledge the support of Katherine Cornelius, MPH, in gathering data from post-course surveys for inclusion in this manuscript.

Funding/Support: This project was supported by Clinical and Translational Science Award Grant Number UL1 TR000135 from the National Center for Advancing Translational Science (NCATS). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the National Institutes of Health.

References

1. National Center for Case Study Teaching in Science. About Us. 2017 http://sciencecases.lib.buffalo.edu/cs/about/. August 24, 2018.
2. Crowe S, Cresswell K, Robertson A, Huby G, Avery A, Sheikh A. The case study approach. BMC Med Res Methodol. 2011;11:100. [PubMed: 21707982]
3. Ahlfeldt S, Mehta S, Sellnow T. Measurement and analysis of student engagement in university classes where varying levels of PBL methods of instruction are in use. Higher Ed Res Dev. 2005;24:5–20.
4. Cornell University Center for Teaching Innovation. Problem-Based Learning. 2017 https://teaching.cornell.edu/teaching-resources/engaging-students/problem-based-learning. August 24, 2018.
5. Balas EA, Boren SA. Managing clinical knowledge for health care improvement. Yearb Med Inform. 2000;(1):65–70. [PubMed: 27699347]
6. National Science Foundation. NSF Innovation Corps (I-Corps). 2017 https://www.nsf.gov/news/special_reports/i-corps/. August 24, 2018.

7. Greenberg AJ, McCormick J, Tapia CJ, Windebank AJ. Translating gene transfer: a stalled effort. Clin Trans Sci. 2011;4:279–281.

8. Juskewitch JE, Tapia CJ, Windebank AJ. Lessons from the Salk polio vaccine: methods for and risks of rapid translation. Clin Trans Sci. 2010;3:182–185.

9. Staff NP, Runge BK, Windebank AJ. Breaking Down Translation Barriers: Investigator's Perspective. Sci Transl Med. 2014;6:252cm257.

10. Miettinen R The concept of experiential learning and John Dewey's theory of reflective thought and action. International Journal of Lifelong Education. 2000;19:54–72.

Table 1

Characteristics of Courses Delivered Through the Mayo Clinic Center for Clinical and Translational Sciences Using Case-Based Methods, 2009–2017

Characteristic	Case Studies in Translation	Case Studies in Entrepreneurship	Case Studies in Precision Medicine
Years delivered	2009–2017	2016–2017	2016–2017
No. of quarters offered	9	4	2
Total no. of scholars completing the course	98	38	10
Post-course survey response rate	71.2% (2013–2017; 37/52)	60.5% (2016–2017; 23/38)	20% (2016–2017; 2/10)
Case delivery approach	Discussion-based learning	Team learning	Problem-centered learning
Intended learning objectives	At the end of this course, students will be able to: • *Define* the clinical translational spectrum • *Explain* how fundamental discoveries have improved the health of the community using specific examples • *Identify* the scientific and societal forces that either drive a discovery to implementation or stand in its way • *Analyze* the role of these scientific and societal forces in successful translation of a discovery to the clinic/population • *Construct* a framework for successful translation of a discovering using conclusions fromt the different modules • *Propose* new policies or practices that will accelerate the speed of implementation of discovery	At the end of this course, students will be able to: • *Identify* business models within life sciences • *Explain* the difference between an inventor and an entrepreneur • *Prioritize* research goals based on scientific impact with a focus on translational potential • *Explain* the roles of the founder scientist and leadership team in entrepreneurial activities • *Utilize* free and easily accessible virtual collaboration tools to enhance team culture	At the completion of the course, students should be able to: • *Review* and understand medical summaries for “unsolved” medical odyssey patients • *Identify* and *interpret* the medical outcomes of identifying a pathogenic sequencing variant that leads to a diagnosis in the context of personalized medicine • *Ability* to access and utilize human genetic disease databases to interpret genetic variants • *Create* and *execute* a systematic and thorough analysis plan of whole exome data for an individual patient • *Integrate* multiple data sources and synthesize an explanation of the genetic underpinnings of the odyssey patient(s) • *Demonstrate* the ability to work in teams and use team-based science principles in the analysis of sequence data
Samples of previous cases and projects	• Gene therapy • Polio vaccine • Rituximab • Deep brain stimulation	• Go!Audio • Gene Coach • Outpatience • C^2 Solutions	• *RUNX1* gene-mutated thrombocytopenia