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A New Philosophy for 21st Century Postgraduate Education

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Abstract: To confront the major challenges of the 21st century, doctoral students need to be able to think and work across disciplinary boundaries. I have been inspired by the *Interdisciplinary Research: Process and Theory (*2017) textbook, by Allen Repko and Rick Szostak, to reform an interdisciplinary doctoral curriculum in Singapore. For example, in coursework for the degree, I have combined the "Broad Model" of interdisciplinary research, a framework designed to encourage students to articulate and integrate disciplinary insights, with "blended learning" to promote collaboration amongst students from different STEM disciplines. In an interdisciplinary Journal Club, the Broad Model has helped me to demonstrate how an interdisciplinary approach has generated testable hypotheses that transcend disciplinary boundaries. Both in coursework and beyond I have shown how students need to integrate both scientific and philosophical insights to address complex moral dilemmas in STEM research and choose the right course of action. As integration of disciplinary insights is a hallmark of the Broad Model, I have argued that the Model can be used to support ethical decision-making in doctoral courses on research ethics and scientific integrity where such diverse insights need to be integrated. Drawing on these examples and experiences, I recently contributed to major curricular reforms at my institution to align our doctoral program with evolving national educational and research policies. In this article, I will elaborate on how the use of *Interdisciplinary Research* has guided interdisciplinary education and curricular reform at my institution and inspired a new philosophy for postgraduate education in the 21st century.

Keywords: interdisciplinarity, graduate education, curricular reform, holistic learning, wicked problems, Massive Open Online Course (MOOC)

Introduction

Doctoral education is in dire need of reform for several reasons. Firstly, the partitioning of academia and degree programs into traditional academic disciplines is not consonant with the complexity of current global challenges,

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for example, climate change, environmental pollution, sustainability, and the COVID-19 pandemic. The remedy to this inherent reductionism is to offer programming that emphasizes holistic approaches in which disciplinary insights are integrated to generate effective solutions to 21st-century problems. Our doctoral students need to be trained to leave the comfort of their own disciplines to conduct research that transcends one or more disciplinary borders (Bosch & Casadevall, 2017; Rashid, 2019, 2021).

Secondly, it has been argued that poor experimental reproducibility and a rise in the number of retracted scientific publications are due to doctoral students not receiving sufficient training in critical thinking (Bosch & Casadevall, 2017). Overspecialization in a single discipline tends to downplay the critical thinking skills that are essential for working across disciplines. Advocates for doctoral educational reform believe that PhD programs should be training students to be critical thinkers as well as specialists by giving them opportunities to challenge assumptions and engage in creative problem-solving and meaning-making within active learning contexts. In a word, the "Philosophy" needs to be put back into "Doctor of Philosophy" (Bosch, 2018).

Thirdly, doctoral curricula have traditionally relied upon didactic instruction and assessment modes that primarily test a student's content knowledge. Traditional or exposition-centered instructional approaches (in which instructors rely on "teaching by telling") fail to engage doctoral students in the learning process. In the Singapore context, this general problem is compounded by the tendency of students here to be reserved. To address this challenge, active learning strategies are needed, which Bonwell and Eison (1991) define as "instructional activities involving students in doing things and thinking about what they are doing." According to Freeman et al. (2014), active learning "engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes critical thinking and often involves group work." Active learning strategies focus on developing students' skills rather than on transmitting information, and require that students do something, for example, read, write, or discuss, that requires higher-order thinking.

To meet these various challenges in doctoral education, I have been experimenting with curricular and instructional strategies for cultivating the understanding of and capacity for practicing interdisciplinarity at the doctoral level. The strategies that I have developed were inspired by the interdisciplinary education literature, advances in the use of technology in education, and my own interdisciplinary research practice, and are the subject of a self-study that I recently undertook to reflect on and improve my teaching practice. I have synthesized these strategies into a unified framework for developing competencies in interdisciplinarity at the doctoral level (Rashid, 2021). One such strategy has involved combining Repko and Szostak's Interdisciplinary Research Process or "Broad Model," a framework designed to encourage students to articulate and integrate disciplinary insights, with "blended learning" (discussed below) to promote collaboration amongst students from a variety of STEM disciplines. To improve the quality of blended learning, I have adapted Eigenbrode et al.'s (2007) "Toolbox Project," a set of questions designed to elicit students' views on the philosophical aspects of research in an interdisciplinary context so as to promote face-to-face and online interdisciplinary discussions. Furthermore, to "role-model" the interdisciplinary collaborative process, I have incorporated examples of my own interdisciplinary research into my teaching in order, for example, to demonstrate how being interdisciplinary can generate novelty for a doctoral thesis.

Here, I will elaborate on how the *Interdisciplinary Research: Process and Theory* textbook (Repko & Szostak, 2017), in which the authors present their Broad Model, has helped me to design new interdisciplinary academic modules, topics, and instructional approaches at the National University of Singapore, and how the consequent positive experiences have inspired and guided major reforms in curriculum and pedagogy at the doctoral level. Collectively, these experiences have inspired a new philosophy for 21st century doctoral education at my university.

The Integrative Sciences and Engineering Programme at the National University of Singapore

The context for this article is the Integrative Sciences and Engineering Programme (ISEP) of the National University of Singapore's newly established Graduate School. At ISEP we believe that interdisciplinary approaches are required to solve challenging problems. Our full-time research-intensive PhD program lasts four years and is home to approximately 400 students from a variety of STEM disciplines, for example, biology, chemistry, computing, mathematics, and physics, as well as various engineering disciplines. During the first two years, students are required to complete three credit-bearing academic modules: (1) Research Ethics and Scientific Integrity, (2) Academic Professional Skills and Techniques, and (3) Integrative Sciences and Engineering. Our curriculum is meant to cultivate a keen interest in interdisciplinary research amongst its PhD students, where a typical class has a range of students from several of the above disciplines. Given the nature of its courses and the diverse composition of each class, ISEP is uniquely positioned to adopt new practices to enhance interdisciplinary doctoral training.

Integrative Sciences and Engineering: The "Microbiomes and Sustainability" Example

To encourage students to think about the complex problems facing society, I introduced "Microbiomes and Sustainability" into the Integrative Sciences and Engineering module as a new topic. The relevance of microbes and their communities (microbiomes) to sustainability is due to the fact that for more than 3.5 billion years, microbiomes have shaped the Earth and its inhabitants. Various discoveries have led scientists to believe that a holistic understanding of the role of our planet's microbiomes is key to addressing the challenges that we face to supply food, energy, and clean water while maintaining and improving the health of our population and ecosystems—actions which are crucial to achieving sustainability.

As sustainability is a complex topic that no single discipline can adequately address, I wanted students to think in an interdisciplinary manner about how we might harness microbiomes to achieve sustainability. The definition of interdisciplinarity that I provided to my class was that of Repko and Szostak (2017), who define interdisciplinarity as

> a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline, and that draws on the disciplines with the goal of integrating their insights to construct a more comprehensive understanding. (p. 21)

Complementing this definition is their Broad Model (Table 1), which is designed to facilitate integration of disciplinary insights (Repko & Szostak, 2017). Relevant materials from the text (definitions, the Broad Model, key concepts) were provided to students via lecture notes (the text itself was not required reading for the course).

Table 1. Steps of the Integrated Model of the Interdisciplinary Research Process/Broad Model (Repko, 2006, p. 123)

A. Drawing on disciplinary insights
1. Define the problem or state the research question
2. Justify using an interdisciplinary approach
3. Identify relevant disciplines
4. Conduct the literature search
5. Develop adequacy in each relevant discipline
6. Analyze the problem and evaluate each insight or theory
B. Integrating disciplinary insights
7. Identify conflicts between insights and their sources
8. Create common ground between insights
9. Create a more comprehensive understanding
10. Reflect on, test, and communicate the understanding

In an article on the module I published in 2019, I argued that this Broad Model promoted interdisciplinary thinking and collaboration amongst our students by making both the definition and process of interdisciplinarity explicit (Rashid, 2019). In a subsequent article (Rashid & Lim, 2020), my co-author and I showed that the Broad Model, when implemented in blended learning modes, promoted interdisciplinary thinking, collaboration, and problem-solving. "Blended learning" is defined as the "organic integration of thoughtfully selected and complementary face-to-face and online approaches and technologies" (Garrison & Vaughan, 2008). The use of blended learning in our Integrative Science and Engineering Module was inspired by advice from colleagues at our Centre for the Development of Teaching and Learning as well as an internal blended learning training course and an external course on Open Networked Learning (https://www.opennetworkedlearning.se/). This was the first implementation of blended learning in our curriculum.

To further promote higher-order thinking and encourage interdisciplinary collaborations, I used micro-lectures, online discussions, peer feedback, and instructor feedback (Rashid, 2021; Rashid & Lim, 2020; Repko & Szostak, 2017). My teaching assistant and I were pleased to see the Broad Model and blended learning working together via these various pedagogies to help students think and collaborate across disciplines. Certain Broad Model-related themes were evident in both face-to-face and online forum discussions—namely stating the research question, recognizing that a problem is complex, identifying relevant disciplines, integrating disciplinary insights, and collaborating—themes that clearly indicated that students had understood the definition of interdisciplinarity. Students put the Broad Model into practice by suggesting how their own disciplines would be relevant to their assigned United Nations' Sustainable Development Goal (SDG). And, in the process, they learned how to explain disciplinary jargon to classmates from other disciplines. Using the Broad Model as a guide, students exchanged and integrated various disciplinary perspectives via their in-person and online discussions, and this integration culminated in solutions that they subsequently articulated in face-to-face group presentations (Rashid & Lim, 2020). Forum discussions and peer/instructor feedback resulted in final presentations that were better than initial outlines. Given our limited face-to-face contact time (due to course design), the online discussion forum allowed students to continue their in-person discussions and build on each other's ideas, and allowed me to prompt them to elaborate on good ideas, provide additional information, and/or demonstrate real-world applications. The peer feedback exercise increased the classroom participation rate over the rate of earlier versions of the class from 20% to 90%. Giving and receiving feedback is a form of "social reflection" and "articulation" (Herrington & Herrington, 2006), which are two features of authentic learning. Through surveys and interviews we ascertained that students responded positively to the module topic and format (Rashid &

Lim, 2020). The end-of-semester evaluations showed most students agreed that the new topic served to demonstrate the nature of interdisciplinarity, the approach to teaching interdisciplinarity was appropriate, the topic was suitable for learning about interdisciplinarity, and the sessions were engaging.

To enhance the quality of collaborative discussions occurring within the online forum, I drew on Eigenbrode et al.'s (2007) "Toolbox Project" to construct a series of questions designed to elicit students' views on the philosophical aspects of research in an interdisciplinary context—questions that students would answer prior to lectures in face-to-face sessions. Using the Community of Inquiry (CoI) framework (Vaughan et al., 2013), I devised questions to trigger cognitive presence in each class group comprising a mix of scientists and engineers. (See the "Trigger Questions" in Table 2.) During the lecture, students were instructed to share their answers with their group mates in their respective groups. After the lecture, group members would collaborate to choose a real-world problem, propose an interdisciplinary approach to solve it, and summarize their work in a two-page report that had to be based on discussions carried out in an online forum.

Table 2. "Trigger Questions" inspired by the Toolbox Project (Eigenbrode et al., 2007)

Trigger Questions
1. Are you a scientist or an engineer? What do you think it means to be a scientist or an engineer?
2. What is your research about? Would you describe it as applied research or basic research?
3. What is your discipline? How would you describe your discipline?
4. What does "interdisciplinary" mean to you? Can you think of any problems that require an interdisciplinary approach?

These four "Trigger Questions" helped to set the stage for subsequent online discussions where students used their respective disciplinary perspectives to devise a solution to their chosen problem. Students suggested how their own disciplines might contribute to the project, and some students also felt confident enough to suggest how other students' disciplines might be relevant. It seemed that our questions were helping them to understand disciplines different from their own and that they were comfortable interacting online as a result. This observation is consistent with Repko and Szostak's theory of perspective taking, which refers to a particular issue, phenomenon, or problem being analyzed from a standpoint or perspective different from one's own (Repko & Szostak, 2017, p. 58). Students were able to articulate ideas from various disciplinary standpoints, select and integrate the most relevant ones, and eventually synthesize a solution that they could report. In short, in achieving a deeper understanding of their own discipline and recognising the relevance of other disciplines, students were able to appreciate the value of interdisciplinary collaborations in addressing complex problems.

From Module to MOOC: Designing an Interdisciplinary Massive Open Online Course

Given the positive response from our students to the "Microbiomes and Sustainability" topic, and the urgent need to raise awareness about the topic on a global scale, I decided to collaborate with colleagues from other departments to develop the topic into a Massive Open Online Course (MOOC) on the same theme. This MOOC was also inspired by an entirely new area of microbiology research on the lipid biology of *Enterococcus faecalis*, a bacterial species that resides in everyone's gut and is thus a member of the normal gut microbiome.

We used our tried-and-tested interdisciplinary framework that promotes collaboration and creative problem-solving as a basis for the MOOC design. As fragmentation in academia makes it difficult to view sustainability holistically, I needed to provide MOOC learners with an interdisciplinary framework that would help them understand our proposed microbiome-based solutions. The Repko and Szostak (2017) text helped me to define the MOOC's intended learning outcomes: define microbe, microbiome, and sustainability; produce an interdisciplinary understanding of the role(s) of microbiomes in sustainable development; integrate insights and modes of thinking from two or more disciplines; and articulate a microbiome-based innovation for a sustainable future. To my knowledge, this is the first time that the text has supported the development of an interdisciplinary MOOC. Relevant material from the text (definitions, the Broad Model, brief descriptions) was provided via video lectures. The MOOC is organized into four sections, each of which takes three hours to complete: (1) Sustainability; (2) Threshold Concepts: Bridging Sustainability and Microbiomes; (3) Which Global Problems Can Be Addressed with Microbiomes; and (4) What Microbiome-based Solutions Can We Develop.

I concluded the MOOC emphasizing several points relevant to my field and to interdisciplinary education. Firstly, rapid advances in the microbiome field have been made possible by interdisciplinary research. Secondly, given the complexity of sustainability as a global challenge, we require an interdisciplinary approach to understand, predict, and harness microbiome function. Lastly, if we are to harness microbiome function to achieve sustainability, we need to promote integrative thinking. We who developed and offered the MOOC emerged with valuable take-homes, too. Developing the MOOC gave us an opportunity to improve upon the content of the module that inspired the MOOC, providing ideas that we subsequently used to enhance future iterations of the module.

A post-MOOC survey revealed that students rated the MOOC from very good to excellent; students reported that they had learned a lot from the MOOC—in particular, the need for disciplines to work together through a holistic approach—and that the MOOC had met their expectations, the MOOC was well worth their time, and they would recommend the MOOC to other people.

Interdisciplinary Journal Club on Tackling Antibiotic Resistance

The Broad Model of the Repko and Szostak text has also proved useful for a Journal Club that I conduct whose theme is my current research on tackling antimicrobial resistance (AMR) in bacteria. The overall goal is to help teach our PhD students to appreciate how an interdisciplinary approach generates productive novelty, with the following intended learning outcomes: to describe the elements of a well-constructed journal article; to analyze the experimental strategies and data reported in the assigned journal articles; to evaluate the claims made and conclusions drawn in the assigned journal articles; and to examine how a scientific investigation into mechanisms of antibiotic resistance was enabled by an interdisciplinary approach. To make our Journal Club theme more interesting, I tell them the interdisciplinary "backstory" behind my research for a manuscript currently under preparation. Role-modeling and storytelling, for example, by sharing personal experiences from one's own scientific practice, are powerful active learning strategies (Bosch & Casadevall, 2017).

I use my research into the role of bacterial lipids in AMR as a real-life example to help students in the club appreciate how an interdisciplinary approach is distinct from a disciplinary approach. While a disciplinary approach to AMR would be to study it through the narrow lens of say, microbiology or genetics, an interdisciplinary approach would be to study the same problem by also drawing on biology and other disciplines relevant to the problem, for example, analytical chemistry and biophysics, as in the case of my research on the AMR mechanisms of *Enterococcus faecalis*. I explain that, as AMR is determined partly by the bacterial membrane's chemical composition and physical properties, we need to integrate insights from at least three disciplines (biology, chemistry, and physics) to fully understand the AMR mechanism.

Given the complexity of the topic, I introduce Journal Club members to Repko and Szostak's (2017) definition of interdisciplinarity and their description of the steps in the Broad Model. Students are required to read three journal articles that examine the problem from the three aforementioned disciplinary perspectives and then submit critical reviews and deliver presentations, in the process learning the Journal Club's key take-home message: Interdisciplinarity in research is a process in which data generated with methodologies and/or technologies from discipline 1, 2, . . . n, may lead to the formulation and testing of hypotheses in discipline X that would not have been conceivable within discipline X alone. This take-home message is consistent with the philosophy of science that emphasizes falsifiability as a core feature of the scientific method, and is also the product of a cross-fertilization between interdisciplinary theory and practice, the ideal I always hope to achieve as an interdisciplinary practitioner.

When surveyed, students in the Journal Club reported the sessions were engaging and the learning activities were well-designed; the research made the Journal Club more meaningful; the interdisciplinary teaching approach was appropriate; and the Journal Club inspired them to take a module outside of their primary discipline, cross disciplines in their research, and read articles from outside their research area. In addition, I can attest that all students had provided detailed critiques and contributed well to roundtable discussions. Overall, it would seem that the Journal Club succeeds in making students appreciate the role of interdisciplinarity in contemporary research, and students participating have been able to appreciate how an interdisciplinary approach to a complex problem is distinct from and often more useful than disciplinary approaches.

Enhancing Ethics Training for STEM Doctoral Students

In earlier work, I have argued that the Broad Model (as presented in Repko and Szostak) may be useful when dealing with moral dilemmas requiring insights from both scientific and philosophical disciplines (Rashid, 2020b). This view was inspired by an observation I had made in teaching the Integrative Science and Engineering module. During their small-group presentations on the relevance of global microbiomes to the United Nations' 17 Sustainable Development Goals (SDGs), the students addressed the ethical and social dimensions of the problems they were investigating, even though they were not explicitly required to do so. Given the fact that they managed to recall and apply ethical concepts that I had taught them in a previous semester in the Research Ethics and Scientific Integrity module of our program, we were able to ascertain that the interdisciplinary approach (applying the Broad Model plus blended learning) had inspired them to consider the ethical and social ramifications of their proposed solutions.

Teaching ethics to STEM students is inherently challenging given their limited exposure to moral philosophy as an academic discipline. So I employed several strategies to cultivate their interest when I taught them the Research Ethics and Scientific Integrity module of our program. In my first lecture on moral reasoning, I presented them with an example of an everyday moral dilemma so as to ease them into the subject and encourage them to engage in discussion. I usually devoted 15–20 minutes to an exposition of the dilemma and a discussion of the students' responses. They were very eager to express themselves when invited to do so. Next, I challenged them with the classic Trolley Problem (Dilemma 1) and its "Fat Man" variant (Dilemma 2). I used the Poll Everywhere app to display students' responses live in class. For Dilemma 1, the majority of the class favored the consequentialist (utilitarian) option, while for Dilemma 2, the majority favored the categorical (deontological) option. These thought experiments helped students to differentiate between consequentialist and categorical moral reasoning. This demonstration allowed me to show them how their responses tended to change when particular details of the dilemma were changed. In my subsequent lectures on the ethics of human subjects in research and the ethics of dual-use research of concern—defined as well-intentioned scientific research that may be misused for nefarious purposes (Office of Science Policy, 2019)—I taught each topic by presenting the scientific and ethical insights individually before integrating them with the help of relevant case studies. This two-step approach is akin to using Parts A and B of the Broad Model ("drawing on disciplinary insights" and "integrating disciplinary insights," respectively).

Based on these experiences, I have argued in an opinion article that the task of dealing with moral dilemmas in STEM research (which requires input from both scientific and philosophical disciplines) should be explicitly handled as an interdisciplinary process (Rashid, 2020a). However, students are ill-prepared to address complex moral dilemmas in this way whenever "interdisciplinary" has been vaguely defined and the process of integrating disciplinary insights has not been articulated clearly. Thus, in the context of complex problems that simultaneously raise deep moral dilemmas (such as antimicrobial resistance, sustainability, dual-use research of concern, and human cloning), I propose, in this as in previous writings, using the Repko and Szostak Broad Model as a tool to support ethical decision-making in research ethics and integrity courses for doctoral students. Its clarity on the subjects of interdisciplinarity and integration can well prepare STEM doctoral students for ethical analyses, while also helping them to develop key communication and collaboration skills, and develop the intellectual flexibility and confidence that are needed to deal with current global challenges.

Conclusions and Future Directions

Here I have provided an account of how I have used Repko and Szostak's (2017) textbook *Interdisciplinary Research: Process and Theory* to teach interdisciplinary doctoral modules in the Singapore context. My efforts to create interdisciplinary learning opportunities in which students are active participants rather than passive learners were inspired by the definition of interdisciplinarity and the Broad Model for the interdisciplinary research process presented in the text. In empowering students to transcend disciplinary boundaries, the Broad Model has proved useful in training doctoral students in our Integrative Sciences and Engineering Program to be critical thinkers, capable of working with those in multiple disciplines, rather than just specialists, thus encouraging the "Ph" in "PhD." In motivating students from different disciplines to work across disciplines through collaboration, the Broad Model in combination with the blended learning supports active learning. This combined strategy promotes a holistic, interdisciplinary learning philosophy and practice that are suited to the complex challenges of the 21st century, unlike the reductionistic, disciplinary programming currently favoured by most doctoral curricula.

There is a strong need to shift the focus away from content knowledge towards essential skills such as our doctoral program develops. We are, after all, living in a world of complex or "wicked" problems that defy single-discipline solutions. To address such problems, doctoral students of the 21st century need to emerge from their degree programs ready to look beyond their own areas of expertise, situate their expertise in broader contexts, and integrate knowledge and skills from different disciplines. Given the recognition of the urgent need to make doctoral education more interdisciplinary, all doctoral programs within the National University of Singapore (NUS) are to be administratively managed by a new umbrella graduate school—the NUS Graduate School—whose mission is to promote broader interdisciplinarity across campus. The School's core philosophy is closely aligned with the university's desire for more interdisciplinary education and research.

One key role of the Graduate School is to make program administration more consistent across the university's various PhD programs. As a result, it was decided that students of the Integrative Science and Engineering Program would have to complete the mandatory curriculum—consisting of the three modules of Research Ethics and Scientific Integrity, Academic Professional Skills and Techniques, and Integrative Sciences and Engineering—in one semester rather than four semesters so that, from their second semester onwards, they could follow their supervisor's departmental program requirements. As a member of the Program's curriculum committee, I played a major role in carrying out this overhaul of the Program's curriculum in the summer of 2021.

In addition, as a member of the Graduate School's curriculum committee, I am also responsible for developing a new common curriculum—distinct from the mandatory curriculum mentioned in the previous paragraph—that will introduce all PhD students within the university to interdisciplinarity. I believe that the Repko and Szostak (2017) text will be useful in creating a framework for promoting broader interdisciplinary integration across the STEM and non-STEM disciplines represented in all the degrees we offer.

I might note, though, that introducing others to the use of the text will have its challenges. It was at first a challenge for me to use the Broad Model in my teaching because the Repko and Szostak (2017) text lacks a significant number of case studies from the STEM disciplines, and the case studies provided are derived mainly from undergraduate courses. It took me a considerable amount of time to figure out how to apply the Broad Model in the ways that I have described in this article in our Singapore context. In addition, given the fact that interdisciplinary research in the STEM disciplines typically involves collaborations, suggestions as to how the Broad Model might be applied in collaborative settings would be very useful. I hope the authors will consider addressing these limitations in the next edition of the text.

I remain convinced, though, that the Repko and Szostak (2017) text that has helped me to strengthen my own teaching and that of my colleagues in our doctoral program may help other individuals and institutions do the same. Firstly, the text defines interdisciplinarity clearly and provides a student-friendly process for engaging in interdisciplinary research. Secondly, it specifies the crossing of disciplinary boundaries as the action required to access and integrate disciplinary expertise. I hope that my account of how I have used the Broad Model and other approaches to interdisciplinary instruction recommended in this text—and complementary approaches like that of blended learning—will serve as a useful guide for other educators.

Biographical Note

Rafi Rashid, PhD, is an interdisciplinary scientist who is curious about the role of bacterial lipids in antimicrobial resistance (AMR), which the World Health Organization has declared a serious global health problem. In the lab, Rafi uses mass spectrometry to study how lipids make bacteria more resistant to antibiotics. By taking an interdisciplinary approach (mass spectrometry from chemistry and AMR from microbiology/public health), Rafi is able to test hypotheses that lie beyond the reach of a single discipline. He received his PhD in Biophysics and Bioengineering and BSc (Hons) in Biomedical Science from the National University of Singapore in 2013 and 2007, respectively. Since 2016, Rafi has been a Lecturer at the National University of Singapore Graduate School's Integrative Sciences and Engineering Programme (ISEP), where he teaches modules on interdisciplinary research, research ethics and scientific integrity, and scientific communication. From 2013 to 2016 he was a Research Fellow at the Singapore Centre for Environmental Life Sciences Engineering (SCELSE), where he developed an entirely new area of microbiology research on the lipid biology of *Enterococcus faecalis*, a bacterial species that resides in everyone's gut. This research inspired him to take his teaching to a global audience via a Massive Open Online Course (MOOC) called "Microbiomes and Sustainability." He is deeply passionate about educating undergraduates and postgraduates about the norms of good scientific practice and science's philosophical foundations. At the NUS Graduate School, he is on a mission to put the "Ph" back into "PhD." He pursues his other passion—science for society—with the students of NUS's Tembusu College, a residential college that emphasizes interdisciplinary and active small-group learning. He may be reached at ngsrr@nus.edu.sg.

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