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OPINION/EDITORIAL

Training STEM Ph.D. Students to Deal with Moral Dilemmas

Rafi Rashid[1]

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Abstract

Research in science, technology, engineering, and mathematics (STEM) fields has become much more complex in the twenty-first century. As a result, the students of our Graduate School, who are all Ph.D. candidates, need to be trained in essential skills and processes that are crucial for success in academia and beyond. Some research problems are inherently complex in that they raise deep moral dilemmas, such as antimicrobial resistance, sustainability, dual-use research of concern (defined as well-intentioned scientific research that may be misused for nefarious purposes), and human cloning. Dealing with moral dilemmas is one of several core competencies that twenty-first-century Ph.D. students must acquire. However, this might prove difficult for STEM Ph.D. students who have had limited exposure to moral philosophy. Since the task of dealing with moral dilemmas in STEM research requires input from both scientific and philosophical disciplines, it is argued with the help of the 4 examples above that this task be explicitly modelled as an interdisciplinary process. Furthermore, it is argued that a particular model from the interdisciplinary education literature could serve as a learning tool to support ethical decision-making in research ethics and integrity courses for doctoral students.

Keywords Applied ethics · Responsible conduct of research (RCR) · Critical thinking · Broad Model · Collaboration · Doctoral education

Introduction

The Doctor of Philosophy (Ph.D.) is the highest attainable degree in science, technology, engineering, and mathematics (STEM), and typically takes 4–7 years to complete (National Academies of Sciences, Engineering, and Medicine 2018). Traditionally, many Ph.D. students are monodisciplinary, meaning that they tend

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✉ Rafi Rashid
ngsrr@nus.edu.sg

[1] NUS Graduate School for Integrative Sciences and Engineering (NGS), National University of Singapore, University Hall, Tan Chin Tuan Wing, #04-02, 21 Lower Kent Ridge Road, Singapore 119077, Singapore

to specialize very deeply in a single discipline. However, twenty-first-century problems are frequently too complex for any one discipline to handle. Highly specialized STEM Ph.D. students may thus lack the breadth required to deal with modern-day research problems whose solutions necessitate an interdisciplinary approach (Brown et al. 2015). Given the pressing needs of the real world, the time is ripe for initiating reform in traditional doctoral curricula worldwide so that students are better prepared to address such problems (Bosch 2018).

This initiative would be in line with recent calls to overhaul doctoral programmes such that students are trained to be critical thinkers rather than mere specialists (Bosch 2018; National Academies of Sciences, Engineering, and Medicine 2018). The new curriculum would retain what is still essential in current training, such as a Ph.D. thesis that generates new knowledge. In addition, first-authored publications may be required and would reinforce the core skills and processes necessary for achieving originality. Major changes would consist in offering new courses that either complement or replace specialized courses; placing greater emphasis on scientific rigour, responsibility, and reproducibility; and developing key skills such as critical thinking, effective communication, teamwork, interdisciplinarity, and commitment to high ethical standards (Bosch and Casadevall 2017).

At an interdisciplinary graduate school of the National University of Singapore, efforts are underway to shift the focus away from content knowledge towards essential doctoral skills and processes in the curriculum. Aside from the didactic nature of the courses, another problem is that the curriculum does not make the interdisciplinary process explicit. What this means is that although the term “interdisciplinary” is often invoked in education and research, it is often defined vaguely and the process by which it may be achieved is not spelled out clearly enough. As a result, students are ill-prepared to address complex problems, including the moral dilemmas that arise in STEM research. Motivated by these challenges as well as the above calls for curricular reform, research to develop pedagogical strategies that would mould our students into interdisciplinary critical thinkers and practitioners was recently initiated. In a recent Reflection on Practice, it was proposed that a new strategy based on an interdisciplinary learning model and blended learning techniques would help train students to “critically think and do interdisciplinary research” (Rashid 2019). As for the definition of interdisciplinarity itself, it is a process of enhancing one’s understanding of a real-world challenge through the integration of multiple disciplinary insights so as to answer questions, solve problems, or address topics that are too complex to be handled by a single discipline (Repko and Szostak 2017, p. 8).

When the interdisciplinary learning model was introduced into a separate course on integrative sciences and engineering, it was found to promote collaboration, communication, and reflection amongst our Ph.D. students who had been assigned complex problems to work on in small groups. Group presentation scores were higher for the topic where the model was applied compared to another topic where it was not. Enhanced collaboration and content were found to have contributed to the improved scores. Surveys and interviews revealed that one of the factors that contributed to this enhanced performance was the fact that the model encouraged students to think across disciplines, give peer feedback more effectively, and, once feedback was received, to reflect on it with an integrative mindset.

In fact, the inspiration for the current article was an observation that the author had made in the above course (which students are required to attend after completing a mandatory research ethics and scientific integrity course). In the former course, students attended a lecture on microbiomes, sustainability, and the interdisciplinary approach that will be the focus of this article. A week later, they were required to deliver small-group presentations on the role of global microbiomes in achieving any of the United Nations' seventeen Sustainable Development Goals (SDGs). Surprisingly, most of the presenting groups included a section on the ethical dimensions of the problems they were investigating even though this was not a requirement of the assignment. It was clear that they were inspired to do so by the interdisciplinary approach that they had learnt in lecture. Upon reflection it was realized that the same interdisciplinary approach might prove useful in the ethics and integrity course itself, which, like the course described above, is also made up of students from a variety of STEM disciplines. The ethics and integrity course presents moral dilemmas as complex problems and includes topics such as introduction to moral reasoning, research involving human subjects and human materials, and environmentally sensitive research. These topics involve some of the more complex moral dilemmas in STEM research, namely reproductive and therapeutic cloning, dual-use research of concern, antimicrobial resistance, and sustainability. These four dilemmas were chosen for this article because they are the particular topics taught by the author in the ethics and integrity course. Moreover, because of their especially complex nature, each one necessitates an interdisciplinary approach.

These dilemmas raise deep ethical questions: What is the moral status of the embryo? To what extent is a scientist responsible for the harm resulting from research that has been misused by unscrupulous third parties? How should we relate to animals and the rest of nature? However, our students sometimes find it very challenging to integrate scientific or technical knowledge with philosophical knowledge because they tend to view moral philosophy as being distant, irrelevant, or "alien". This is particularly evident when they attempt to use moral theories in their moral reasoning, either during class or on asynchronous online discussion forums. In the author's experience, students seem to be less comfortable discussing the moral aspects of a dilemma than the scientific or technical aspects. One other particularly striking observation is that STEM students struggle with the very notion of a moral theory and the role that theory plays in moral reasoning. As a result, they have a tendency to ask which of the three theories that they are taught in class, namely utilitarianism, deontology, and virtue ethics, is the "correct" one. This common observation further demonstrates the need to bridge the disciplinary divide between STEM and philosophy.

In the integrative sciences and engineering course, the interdisciplinary learning model formed the basis on which face-to-face and online learning activities were designed. Through surveys and interviews, it was ascertained that the model guided students when they gave feedback to their peers and when they reflected on the feedback that they had received from their peers and the instructor. This reflection, in turn, allowed them to draw explicit interdisciplinary connections during the group presentations and thus improved their overall score. Encouraged by the recent success of the new strategy to cultivate complex problem-solving skills, the objective of this Opinion is to consider how this interdisciplinary learning model might facilitate resolution of moral dilemmas by modeling the task as essentially an interdisciplinary process.

The Need for Ethics in STEM Research

Moral dilemmas involve conflicts between moral rules or norms in particular situations. Conflicts arise when we have moral reasons to do each of two actions but doing both actions is not possible. A moral dilemma occurs when a moral agent is required to do each of two (or more) actions and is capable of performing each of the actions, but cannot do both (or all) of the actions. No matter what action is taken, the agent will either do something wrong or fail to do something right (McConnell 2018).

To deal with moral dilemmas there is a need to turn to ethics, the sub-discipline of moral philosophy that provides a practical and systematic way of reasoning through moral dilemmas and deciding on the right course of action when there are conflicting choices (Talbot 2012). It is concerned with what is right or wrong, good or bad, or virtuous or vicious (Chrisman 2016), and answers questions like: How should we live? Which actions are right? Which actions are wrong? How can we know whether actions are right or wrong? Is moral truth absolute or relative? Unlike science, which is concerned with how the world *does* work, ethics is about how the world *ought to* work. STEM Ph.D. students need to be able to evaluate relevant ethical insights when confronted with moral dilemmas in research. Although this author believes that other graduate and undergraduate students should, in general, be trained in this essential skill, this article focuses on the doctoral level because all the students at our institution are Ph.D. candidates. The ability to deal with complex dilemmas in STEM research has been recognized as an essential competency for the twenty-first century Ph.D. student (Bosch and Casadevall 2017; National Academies of Sciences, Engineering, and Medicine 2018). As these types of dilemmas concern a multitude of disciplines, an interdisciplinary strategy is needed.

Examples of moral dilemmas included in the course are antimicrobial resistance, sustainability, dual-use research of concern (DURC), and human cloning. Each dilemma is presented to the class, which consists of 15–20 STEM Ph.D. students, as an inherently complex problem because of the need for input from both the STEM disciplines and moral philosophy. The relevant disciplines are identified and how each one illuminates some aspect of the problem is briefly explained. The class is then asked to consider serious ethical questions, e.g. Do animals have rights? Does the embryo have the right to life? Is the non-human–environment intrinsically or instrumentally valuable? With the help of arguments where the premises and conclusions are explicitly stated, the lecturer proceeds to explain that both scientific and moral premises are needed to reach a conclusion that has moral force.

Reflecting on how ethics might be relevant to research into antimicrobial resistance (AMR) culminated in the realization that an interdisciplinary strategy could generally be quite useful when attempting to negotiate ethical issues associated with STEM research. AMR is defined by the World Health Organization (WHO) as “when microorganisms such as bacteria, viruses, fungi and parasites change in ways that render the medications used to cure the infections they cause ineffective” (World Health Organization 2018). The huge burden imposed on individuals and society is due to the fact that AMR, which in some cases can have fatal consequences, can easily spread from person to person. AMR is thus a major healthcare concern worldwide (World Health Organization 2018).

In class, the case is made to students that AMR is a truly interdisciplinary problem because of its complexity and that the Broad Model (Table 1) could help them reach a more comprehensive understanding of the problem. As with any research project, the first step is to state the research problem (Step 1 of the Broad Model), which helps to emphasize the importance of framing the problem or question clearly at the outset. Then, the use of an interdisciplinary approach needs to be justified by indicating that several disciplines are relevant to this problem rather than a single one (Steps 2 and 3). Many disciplines are potentially relevant to AMR, e.g. biology, biotechnology, economics, ethics, and political science. This step would broaden students’ thinking about the problem and make them realize that the problem is more complex than they might have imagined. The next 3 steps involve delving into literature from across various disciplines in order to aid comprehension and analysis of the problem in the light of various disciplinary insights (Steps 4–6). The purpose of the literature search at this stage is to help students discover that the problem is recognized as needing research. The last four steps promote interdisciplinary integration by identifying and creating common ground between conflicting insights (Steps 7 and 8) so as to achieve and communicate a more comprehensive understanding (Steps 9 and 10). It is through these last 4 steps in particular that students will be able to integrate their scientific/technical knowledge with their moral knowledge in order to achieve an integrated understanding of a moral dilemma, thus improving their moral reasoning skills. In addition to making the interdisciplinary process explicit, the Broad Model will reinforce the essential components of the methodology of research, i.e. the need to state the research problem clearly; conduct a literature review to summarize current knowledge; identify a gap in knowledge, provide a statement of need and the consequences of not meeting that need; and design a study that would fill that gap and thereby advance the field.

Table 1 The Broad Model. Steps of the integrated model of the interdisciplinary research process/Broad Model (Repko 2006) Reproduced with permission

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. Analyse 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

Sustainability is a topic of global importance that is used as a classroom example to stimulate moral reasoning. The definition of sustainability or sustainable development is “development that meets the needs of the present without compromising the needs of future generations to meet their needs” (The World Commission on Environment and Development 1987, p. 41). For the STEM researcher, a moral dilemma arises when research that is considered to be vital for the present may end up despoiling the environment and compromising it for future human inhabitants of the planet. On this account of morality, certain research interests, e.g. recombinant DNA technology, nuclear energy, genetically modified crops/organisms, infectious microorganisms, nanotechnology, may be morally questionable or even reprehensible. The dilemma becomes even more challenging if the scientist regards the environment and animals as intrinsically (rather than instrumentally) valuable. Historically, ethics has been omitted from the sustainability discourse. Failing to address the ethical dimension, however, will have serious consequences for achieving sustainability (Nelson and Vucetich 2012). The disciplines most relevant to the complex issue of sustainability would be the natural sciences, engineering, environmental studies, economics, ethics, philosophy, the social sciences (Thompson 2012).

The question that is posed in class is, Do we have a responsibility to future generations to pass on to them the earth’s life-support systems in as healthy condition as they exist in now? The class is then guided through a discussion of a moral argument about climate change that consists of both scientific and moral premises. The exercise involves convincing them that the argument is valid and that it generates a categorical imperative that rationally binds us (STEM practitioners in particular) to mitigate the negative effects of climate change by leveraging on our expert knowledge.

The next classroom example is dual-use research of concern (DURC), another challenging moral dilemma with implications for both society and the environment. DURC is defined as knowledge, products, or technologies arising from life sciences research that, if acquired by a third party with malicious intent, would pose a threat so significant as to have far-reaching consequences for public health and safety, agriculture and other plants, animals, the environment, material, or national security (Office of Science Policy 2019). For example, genetic engineering of bacteria is routine in microbiology research but the worry is that if a resulting bacterial strain is hypervirulent or resistant to multiple drugs, it could be used for nefarious purposes by unscrupulous individuals or groups. A moral dilemma thus arises because it is not possible to guarantee that the results of well-intentioned research would not be misused by unscrupulous third parties to inflict harm. DURC is not restricted to the life sciences, however, as one of the earliest examples was nuclear energy, which has served as an alternative to fossil fuels in many countries for several decades but nonetheless has the potential to be weaponized by anyone with evil intent. The natural sciences, engineering, law, and ethics are the disciplines most relevant to DURC. The question that students are asked is to what extent is a researcher with good intentions responsible for the harm caused by a third party with evil intentions?

The last example that is examined in class is human cloning, one of the most challenging moral dilemmas that biomedical scientists have to contend with. Therapeutic cloning refers to “the cloning of embryonic cells to obtain organs for transplantation or for treating injured nerve cells and other health purposes". Reproductive cloning involves "the use of somatic cell nuclear transfer (SCNT) to obtain eggs that could develop into adult individuals" (Ayala 2015). Therapeutic cloning presents a moral dilemma because it would violate the moral rule "do not kill" as it is not possible to harvest stem cells from the early embryo for research or therapeutic purposes without simultaneously killing it in the process. The idea of reproductive cloning triggers a feeling of intense disgust for most people. This kind of reaction is predicted by the "Boo/Hooray" theory of ethics which says that moral judgements are guided by feelings of approbation or disapprobation rather than reason (Talbot 2012, p. 76). Because of their complexity, both therapeutic and reproductive cloning present moral dilemmas requiring input from multiple disciplines, including biology, psychology, political science, philosophy, religion, law, and bioethics (Repko and Szostak 2017).

In the author's own class, the learning objectives are first stated, namely to appreciate the usefulness of embryonic stem cells (hESCs) and to recognize ethical issues arising from hESC research. Cloning is presented as a complex question or problem which, in its broadest sense, requires input from the above seven disciplines, each of which could potentially illuminate some aspect of the problem. Given the limitations of the class, the disciplines most relevant to the needs of the course are selected—bioethics, biology, and philosophy. With reference to three moral theories (utilitarianism, deontology, and virtue ethics) introduced earlier in the course, the class is asked to consider the fundamental question, Does the embryo have the right to life? The instructor then walks the students through a series of arguments about conditions necessary and/or sufficient for possessing the right to life. The point is that addressing such a complex problem involves considering both the moral status of the embryo and the scientific/medical aspects of therapeutic cloning, an exercise that requires that knowledge from multiple disciplines be integrated.

A Theoretical Framework to Help Resolve Complex Dilemmas in STEM Research

To address such complex moral dilemmas, Ph.D. students will need to think broadly so that they can first identify the disciplines most relevant to a particular moral dilemma, and then go about using knowledge from these disciplines to reach a holistic understanding and propose a solution. Given the fact that AMR, sustainability, DURC, and human cloning each involve multiple disciplines, there is a need to provide students with a decision-making process that would facilitate the knowledge integration required to model the task of resolving moral dilemmas as an interdisciplinary project.

The Integrated Model of the Interdisciplinary Research Process or Broad Model (Table 1) has been recognized as a potentially useful instructional tool for students who need to integrate across science and engineering disciplines (Rashid 2019). Since the Model's ten steps are designed to promote knowledge creation, meaning-making, and interdisciplinary research, in particular when these problems span the natural sciences, social sciences, humanities, and applied fields (Repko and Szostak 2017; Repko et al. 2017), it makes sense to use it in the research ethics and scientific integrity course. The cited references provide numerous examples of interdisciplinary work, such as human cloning, freshwater scarcity, organized environmentalism, globalization and its effects on the environment, and the practice of cultural analysis. The authors expect that this range of explicitly interdisciplinary case studies would strongly contribute to interdisciplinary curricular development. These case studies may prove relevant to a particular course problem, topic, or theme, and will reveal to students how interdisciplinarians have used the steps in the Broad Model to address complex problems. The overall goal is for the students to reach a "more comprehensive understanding", based upon which they would attempt to resolve complex moral dilemmas. Applying the Broad Model to ethical decision making will help students achieve a more comprehensive understanding of the dilemma by rendering the exercise explicitly interdisciplinary.

The Broad Model's ten steps reveal the decision points that are undertaken in almost any interdisciplinary project, thus enabling students to proceed from a problem to an understanding of the problem to a tentative solution. It is heuristic, i.e. serves as an aid to understanding, discovery, or learning. In making the interdisciplinary process explicit, the Model encourages greater reflexivity. By this it is meant that students become more conscious or aware of any disciplinary or personal biases that may influence the way they view a particular problem or dilemma, and help them resist the temptation to ignore disciplines simply because they are unfamiliar to them (Repko and Szostak 2017). Students within my ethics class initially seem reluctant to engage in moral reasoning with the help of moral theories and principles. This is not too surprising since they are science and engineering students who have had little or no prior exposure to moral philosophy. When presented with case studies in class, they tend to focus more on the scientific or engineering aspects of the dilemma than on the moral aspects.

They are also slow to initiate discussions in their online discussion forum. Hopefully, by promoting reflexivity, students will develop sufficient adequacy in applied ethics to incorporate relevant moral theories and/or principles in their decision-making procedure, a task which STEM students might be reluctant to undertake for various reasons, e.g. lack familiarity with moral philosophy, an aversion to anything outside of science and engineering, and a preference for "objective" answers. Students' proficiency in moral reasoning could be assessed with the help of, for example, in-class polls that would solicit their responses to moral dilemmas over the course of a semester. This information could be triangulated with other outcome measures, e.g. presentation scores and final exam grades, as well as pre/post-surveys and interviews to determine their proficiency level in applied ethics. Unlike disciplinary approaches which prioritize a single discipline's phenomena, epistemologies, assumptions, concepts, theories, methods, and data, the Model encourages researchers to cast their gaze across the defining elements of *all* relevant disciplines, which is the approach that I believe should be adopted for complex moral dilemmas in STEM research, in particular AMR, sustainability, DURC, and human cloning.

According to Repko and Szostak (2017), each step entails certain strategies. For example, to perform Step 1 (Table 1), the 3 tendencies of personal bias, disciplinary bias, and disciplinary jargon need to be avoided. To justify using an interdisciplinary approach in Step 2, it must be demonstrated that the problem under consideration is complex and therefore requires input from more than one discipline. To perform Step 6, one needs to, *inter alia,* be receptive to every disciplinary perspective but being dominated by none, preserve intellectual flexibility, think inclusively, and practice both deductive and inductive reasoning. Step 8 involves establishing common ground between disciplinary insights at the level of concepts, assumptions, and/or theories. The first step in creating common ground between conflicting *concepts or assumptions* is deciding how to proceed, i.e. knowing when to establish common ground (e.g. after the problem has been mapped), determining how comprehensive the research will be (which depends on how many disciplines are drawn upon), and ascertaining what common ground will be created from (concepts or assumptions). The next step involves selecting, from a range of techniques (namely, redefinition, extension, transformation, or organization), the one that would be most appropriate for modifying the concepts or assumptions. In the case of establishing common ground between *theories,* modification would entail one or more of the same four strategies depending on whether (a) one or more of the chosen theories already have a broader range of applicability than do other theories (extension), (b) none of the chosen theories borrows from other disciplines (redefinition, extension, or transformation), or (c) the chosen theories focus on complementary parts of the research question (organization).

Lastly, the Model is iterative because it is non-linear, i.e. students may find it necessary to repeat earlier steps after reaching later steps. This need may arise for any number of reasons, e.g. students may have defined the problem/question too broadly or too narrowly; they may not have correctly identified the parts of the problem; they may need to narrow down the disciplines most relevant to the problem; they may not have gathered the most important insights concerning the problem; they may have realized that they had been privileging one discipline's perspective over another's because they happen to be working in the former discipline; or they may have allowed their personal bias to influence the project's direction. For example, selecting the most relevant disciplines in Step 3 may require that the problem be restated in Step 1 (Repko and Szostak 2017).

In particular it is worth noting that ethical evaluations have to be made in *at least* two steps of the Model: When conducting the literature search (Step 4) and when analysing the problem and evaluating each disciplinary insight or theory (Step 6). At Step 4, students should strive to prevent their personal opinions from skewing the selection of insights relevant to the issue. Such skewing is typical of disciplinary research. At Step 6, students should strive to prevent their personal opinions from skewing the evaluation of these insights, some of which they may happen to disagree with (Repko and Szostak 2017, p. 288).

Conclusions

In this Opinion it has been argued that complex moral dilemmas in STEM research should be treated as interdisciplinary problems, and that the Broad Model of interdisciplinarity would provide Ph.D. students with an explicit process for dealing with such dilemmas. Key areas of research where ethical considerations are urgently needed, namely human cloning, DURC, AMR, and sustainability, have been identified. Ethics is an essential discipline for STEM researchers not only because it will cultivate a sense of responsibility towards the environment and society, but also because it will also make individuals realize the limits of their own perspectives and encourage them to look for value in the claims of others (Harris and Pritchard 2018), whatever their professional backgrounds happen to be.

The above four examples all require insights from multiple disciplines and are therefore inherently much more complex than the dilemmas that students are likely to encounter as a matter of routine, e.g. responsible laboratory conduct, authorship, conflicts of interest or commitment, and relationship with one's mentor(s). In the absence of guidelines for dealing with complex dilemmas, students need to develop adequacy in primary moral theories and/or principles. The Model will be useful, for example, in emphasizing the ethical dimension of sustainability that defines the "end goals of sustainability", in contrast with the scientific dimension that defines the "means by which to achieve sustainability" (Vucetich and Nelson 2010). An interdisciplinary approach that highlights sustainability's ethical aspects would motivate scientists and engineers to venture beyond their own disciplinary comfort zones to engage societal and environmental challenges more directly (Nelson and Vucetich 2012).

The Model presents a process that is analogous to research methodology in general but also extends it by including additional steps for achieving interdisciplinarity. Research methodology generally involves stating a research problem, designing the research strategy, selecting or constructing a data collection instrument, choosing a sample(s), submitting a research proposal, collecting, processing, and analyzing data, and publishing a research report. In short, the research journey is about deciding "*what,* planning *how,* and actually doing" (Kumar 2005, p. 19). Using the Broad Model in the classroom would not only reinforce this core methodology, which would in itself be beneficial to our students who would be nearing their Ph.D. qualifying examination, but it would also go a step further by promoting interdisciplinarity, which in the long-term might help them achieve the originality required for a doctoral thesis. As interdisciplinarity is one possible source of originality (Phillips and Pugh 2010), the Model is likely to be practically relevant beyond the classroom.

Another anticipated benefit of the Broad Model is that it would promote critical thinking, which needs more emphasis in postgraduate education (Bosch and Casadevall 2017). Known by many different names, e.g. high-order thinking, problem solving, evaluation, analytical thinking, or metacognition, critical thinking essentially depends on cognitive skills and strategies to promote thinking that is "reasoned, purposeful, and goal-directed" (Halpern 2007; Mayer and Alexander 2016). This approach promotes the "outside-the-box" thinking and adaptability that our students would need for diverse careers in academia, industry, administration, science communication, advocacy, government, and social work (Bosch and Casadevall 2017; National Academies of Sciences, Engineering, and Medicine 2018; Rashid 2019). Modernizing the Ph.D. would involve formalizing training in critical thinking throughout the curriculum so as to motivate students to challenge assumptions, solve problems, and find meaning in their research.

The interdisciplinary strategy described herein will (1) sensitize STEM doctoral students to the ethical aspects of their research, (2) inspire them to address moral dilemmas by providing them with an explicit decision-making process, and (3) cultivate key skills such as communication and collaboration between disciplines, and (4) develop the confidence and intellectual dexterity needed to confront twenty-first-century challenges. This new strategy will effectively put the "Philosophy" back into "Doctor of Philosophy" (Blachowicz 2009; Grayson 2006; Grune-Yanoff 2014; Prather et al. 2009). This is important because Ph.D. students need to be competent enough to deal with the increasingly complex problems of the twenty-first century, which means that traditional Ph.D. programmes need to be redesigned so as to train students to be thinkers rather than mere specialists.

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