Good Drug, Bad Practice: Tackling the Ivermectin Fiasco

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Abstract

Throughout history, biomedical advancements have alleviated suffering worldwide and significantly advanced human well-being. As researchers and educators, we are well-familiar with the painstakingly slow and meticulous process of science, some of which culminates in a life-saving therapy or a revolutionary cure. Ivermectin, the drug hailed for treating river blindness and filariasis across the globe, is one such feat of scientific discovery. However, Ivermectin has lately been falsely purported to treat COVID-19, endangering the lives of millions who have taken to self-medication. Worse even, the drug has been weaponized to undermine vaccines, which are our only solution out of this pandemic. The popularity of Ivermectin among large swaths of people is a somber lesson on the need to bridge the gap between science and the public, and to incorporate science education into our curricula. In this lesson, students learn how Ivermectin treats parasitic illnesses but does not treat COVID-19, how politically-motivated scientific misinformation has jeopardized people’s lives, and how lack of proper oversight of scientific papers has fueled the Ivermectin crisis. Through active learning techniques to foster quantitative skills and critical analysis, student-driven activities and discussions, and readings and reflections, this lesson aims to empower students to apply science literacy and education in their daily lives.


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Learning Goals

Students will:

◊ recognize that drugs treat diseases by acting on existing cellular and molecular machinery of organisms.
◊ evaluate scientifically misleading content to discern the quality of the research conducted.
◊ articulate an evidence-based recommendation on whether to use Ivermectin to treat COVID-19.
◊ consider the societal costs of scientific disinformation.

Learning Objectives

Students will be able to:

◊ use the example of Ivermectin to explain why medicines are targeted to specific infectious agents.
◊ identify the mechanism by which Ivermectin causes side effects.
◊ recognize flawed data about Ivermectin’s effect on treating COVID-19.
◊ evaluate the role of primary, peer-reviewed publications in our understanding of Ivermectin’s effect on COVID-19.

These objectives will allow students to develop the following core competencies as laid out under the Vision and Change report (page 14–15) (1):

- ability to understand the relationship between science and society.
- ability to apply the process of science.
- ability to use quantitative reasoning.
- ability to tap into the interdisciplinary nature of science.
INTRODUCTION

The value of biomedical research and discovery has become especially clear during the COVID-19 pandemic. During the early stage of the pandemic when death rates were surging, vaccines were not on the horizon and antivirals were not available. Doctors and scientists tried everything they had in their arsenal to decrease death rates and treat patients who had a severe response to the infection. As researchers rushed to develop vaccines and drug treatments, the science community was confronted with yet another battle: the fight against scientific disinformation (2). Pharmaceuticals such as hydroxychloroquine and Ivermectin were touted as wonder drugs (3) based on some early preprints (articles that were not peer reviewed) and were based on incorrect conclusions. Influencers used their political power and social media to support Ivermectin, an anti-parasitic drug used as a horse dewormer, as a silver bullet against COVID-19. There were no clinical trials to support this claim, and the way Ivermectin works has no overlap with the pathogenesis of COVID-19 and had no effect on disease outcome. However, messaging on social media outlets tried to spread the incorrect information far and wide in the face of well-reasoned arguments from health care professionals and scientists to stop using Ivermectin. The surge of Ivermectin as a purported treatment drug against COVID-19 underscores the dangers of spreading scientific disinformation.

The word disinformation is critical here, because it refers to intentionally spreading harmful information, whereas misinformation is spreading information that is incorrect (2), but not necessarily with the goal of causing harm. We follow others’ argument that politicians and dishonest researchers who had rallied behind the use of Ivermectin for treating COVID have done so knowing that people would be hurt (3). While the news media moved on from Ivermectin to other affairs, the damage brought about by the Ivermectin crisis continued to hinder lives (4). Multiple states in the United States passed or were in the process of passing (as of May 2022) legislation requiring pharmacists to dispense Ivermectin (5) to COVID-19 patients, or preventing pharmacists from contacting physicians or patients to dispute the efficacy of Ivermectin in human use (6). As the world continued to grapple with the pandemic, the Ivermectin crisis highlighted the damage caused by scientific disinformation and the pressing need for science literacy in our society. With this goal in mind, we have developed a lesson on Ivermectin to teach students to critically recognize baseless claims disguised as scientific knowledge and to avoid being persuaded by the disinformation inundating their daily lives.

The drug Ivermectin is a modified form of a compound originally discovered in bacteria in the 1970s, and was found to be effective against a wide range of parasites, including pinworms, heartworms, lice, fleas, etc. As an anti-parasitic, Ivermectin has been highly effective at treating river blindness (caused by a parasitic worm, Onchocerca volvulus) and filariasis (caused by filarial worms), because it kills the parasites that cause those diseases at concentrations that do not pass the blood-brain barrier in humans (7). It is currently on the World Health Organization’s list of essential medicines (8). In 2015, two scientists won the Nobel Prize in Physiology and Medicine for saving countless lives through their discovery of Ivermectin.

How did this “wonder drug” against parasites become a contentious issue in the COVID-19 pandemic? In August 2021, the number of Google searches for the term “ivermectin” reached a peak. Among the various factors contributing to the popularity of Ivermectin was an early study performed in a petri dish suggesting that the drug prevented the replication of SARS-CoV-2, the virus that causes COVID-19 (9). It is important to understand that although Ivermectin prevented the virus from multiplying in a dish, that does not mean it is going to treat COVID-19 in human patients. In fact, a closer examination of the data revealed that Ivermectin, if effective against the virus, would be required at a greater than 10-fold dose than what was considered safe for single use in humans, making it currently impossible to use as a safe therapy (10). That such a high dose of Ivermectin could be toxic to humans did not prevent the spread of disinformation. Despite no demonstrated clinical benefit against COVID-19, the number of outpatient Ivermectin prescriptions in the US in August 2021 increased 24-fold, and Ivermectin-related poisoning calls rose five-fold compared to pre-pandemic levels (4). Not only has Ivermectin gone on to resonate with large swaths of the global populace, it has been weaponized by vaccine deniers, conspiracy theorists, politicians, and even scientists (3).

A Closer Look at the Details

Students can connect science to their everyday lives as informed citizens by exploring the fiasco around Ivermectin. Learning details of how Ivermectin works and how clinical trials are performed sets the stage for diving more deeply into behaviors by scientists that have been questionable, such as the work that was published on preprint servers found to contain fabricated and manipulated data.

The Pharmacology of Ivermectin and Dangers Associated With Its Misuse

Ivermectin works on the nervous system of multicellular eukaryotic parasites by acting on glutamate-gated chloride (GluCl) channels (11). These channels are present on the nerve cells of mostly worms and insects. Ivermectin binds to these GluCl channels which causes the nerve cells to hyperpolarize, ultimately leading to paralysis of the organism. In this way, Ivermectin works well against eukaryotic parasites such as Onchocerca volvulus which causes river blindness. Importantly, viruses do not have GluCl channels, therefore Ivermectin does not directly act on viruses. The GluCl channels are also absent in vertebrates, although some vertebrates (including humans) contain a modified version of the channel where glutamate is replaced with glycine. Ivermectin can bind to these glycine-gated channels to silence nerve cells in humans but this binding is much weaker compared to the GluCl channels (12). Notably, Ivermectin does not cross the blood-brain barrier at smaller doses, and is therefore, unable to cause serious harm in humans. Thus, when taken in low doses orally, Ivermectin is a safe anti-parasitic drug that can effectively treat conditions, such as river blindness. However, when taken in high doses, Ivermectin can penetrate the blood-brain barrier and cause severe side effects including, rash, headache, sleepiness, nausea, vomiting, abdominal pain, mild tachycardia, and in rare cases encephalopathy (13).
Note that Ivermectin works on eukaryotes—and, even more specifically, metazoans (animals) with nervous systems. There is no evidence to suggest that Ivermectin works on viruses, let alone the COVID-19-causing virus (14).

**Pharmacological Studies Relating to COVID-19: From Dish to Live Humans**

The first published study proposing Ivermectin as a treatment against SARS-CoV-2 (the virus that causes COVID-19) was performed in a dish with cells infected with the virus (9). A report published four months following this initial study pointed out that the amount of Ivermectin that would have to be administered into live humans to treat COVID-19, assuming the results of the initial study were translatable from dish to humans, was 10 times greater than the approved dose for single use (10). Given the dangers associated with high doses of Ivermectin (as discussed above), it is not a safe treatment against COVID-19.

**Clinical Trial Gone Rogue**

A paper by Elgazzar et al. (2020) purporting to demonstrate Ivermectin as an effective COVID-19 treatment is a highly problematic clinical trial that claimed to have achieved up to 99% improvement in COVID-19 symptoms following Ivermectin treatment (15). Overall, this study, published on a preprint server (preprints are covered below), contained numerous errors including, but not limited to, plagiarism and data fabrication (an extensive forensic analysis of the report is documented on this blog [16]).

**Preprints Versus Peer-Reviewed Publications**

The Elgazzar et al. study (2020; retracted months after upload) described above was published on a preprint server, Research Square. Preprints are manuscripts published online without peer-review. During rapidly-changing times like the onset of the pandemic, preprints can provide expedited access to scientific results, particularly those that might aid vaccine and drug development. Within the first six months of the COVID-19 pandemic, two leading preprint servers received as many as 3000 manuscript submissions on coronavirus research alone (17). This deluge of studies and data has allowed several scientifically vetted claims to enter the public domain, an example of which is the Elgazzar study, and generate life-threatening disinformation. Considering the rise of preprints even before the onset of the pandemic, educating students about the differences between preprints and peer-reviewed publications is critical.

**Overview**

The structure of the lesson is as follows:

- The pre-class readings include a brief background on how Ivermectin works and media articles describing the effectiveness of Ivermectin against life-threatening parasitic diseases but a lack of evidence of Ivermectin treating COVID-19.
- Part of a classroom activity focuses on weaponization of Ivermectin by media personalities and politicians to advance their own agendas and a corresponding rise in the number of Ivermectin prescriptions among the public.
- The other part of the classroom activity highlights a scientific preprint fraught with plagiarism and data fabrication claiming significant improvements in COVID-19 symptoms following treatment with Ivermectin.

**Intended Audience**

We developed this lesson for a class of third-year science majors at a public, master’s regional university. The class consisted of 21 students but this lesson can be readily used in larger class sizes. The jigsaw activity embedded within this lesson can be modified for multiple groups (see Lesson Plan: Jigsaw activity).

Given the harm caused by the increasing prevalence of scientific disinformation across social and news media, it is imperative that we cultivate science education in our students at all levels. As such, this lesson can be used in a class of science majors and non-majors, with some scaffolding (such as basic graph reading) to support learning among non-majors. In a class of non-majors or first-year students, we recommend that instructors familiarize students with graph reading and basic data interpretation. This could be done before the mini-lecture and prior to the jigsaw exercise.

**Required Learning Time**

Pre-class reading (Supporting File S2.1) takes approximately 45 minutes. The rest of the lesson was initially designed for a 2-hour class period, although we ended up splitting the lesson into one hour at the end of one class meeting, and the first hour of a second class meeting. The lesson’s flexibility allows for instructors to adapt to the class period as needed.

**Prerequisite Student Knowledge**

At the peak of the COVID-19 pandemic, the drug Ivermectin was popularized by news media and politicians alike (18). As a result, a few students are likely to be familiar with the term, Ivermectin. However, we assumed no prior experience with Ivermectin or with how the immune system works. In the PowerPoint mini-lecture (Supporting File S3), we provide a brief biology background on neuronal signaling as it pertains to the current lesson, and describe the mechanism of action of Ivermectin (slide 3). The lesson could be used in a first-year college course, or even in high school.

In order for this lesson to truly impart science education and awareness, it needs to be adaptable to non-science majors. Indeed, the jigsaw component specifically contains several important tools (for example, detecting trends and patterns in graphs, a general understanding of the scientific peer-review process, and interpreting scientific information with a critical lens) to become an informed science audience. With additional time and scaffolding, non-science majors can be readily equipped to benefit from these activities in the lesson. Therefore, while prior student knowledge of statistics is not required, instructors should familiarize science non-majors or junior students with basic data interpretation skills through graph reading, interpreting, and building exercises. Indeed, this course may serve non-science majors as an introduction to basic graph literacy. One of the jigsaw activities involves conducting a $\chi^2$ test, for which we recommend students watch a video tutorial (19) in preparation. Overall, students can
be organized into mixed groups of science majors and non-majors, where they practice basic graph-reading exercises and statistics prior to engaging in the jigsaw assignment. Such activities driven by peer scaffolding are likely to promote peer-to-peer learning while fostering dialogue and collaborations in the classroom (20).

**Prerequisite Teacher Knowledge**

Instructors should familiarize themselves with all the Supporting Materials and the lesson plan. The pre-class reading assignment is useful to both students and instructors. By completing the pre-class readings, instructors will develop an important and nuanced perspective on why Ivermectin, a life-saving and revolutionary drug against parasites, is not necessarily the right treatment against COVID-19.

To get oriented to the themes covered in the lesson, we recommend that instructors become acquainted with the primary sources that are pertinent to the activities, the Elgazzar et al. (2020) study and accompanying reports about the fraud therein (2020–2021), as well as other Ivermectin studies fraught with problems (21–23). One of the activities students complete is an analysis of a redacted study by Elgazzar and colleagues. To understand the problems with this study, instructors may want to read the investigative report (15) and a plagiarism analysis (24). These analyses discuss the extent of fraud and plagiarism, some of which include (i) data duplication as evidenced by duplication of corresponding typos, (ii) numerous patients with identical data across multiple parameters, (iii) almost half of the patients claimed to have died during the study were already deceased prior to the start of the study, (iv) texts plagiarized from multiple sources, (v) mathematically improbable numerical values, and many more. The test for fraud covered in the jigsaw activity of this lesson relates to the age distribution of patients: out of the 600 patients in the study, 410 had ages that were even numbers. The statistical probability of having such a high incidence of even-number aged participants is extremely low. For this activity, instructors would benefit from having a basic understanding of statistics and the ability to complete a χ² test (which can be done in Excel, see instructions in Supporting File S5, and reference [19]) and probability.

Instructors should also visit the reflection questions to be assigned at the beginning and end of the lesson (Supporting File S1). While the current lesson focuses on the misrepresentation and usage of Ivermectin in the public sphere, the overarching goal of the lesson is for students to acquire a critical lens and become capable of formulating their own scientifically sound conclusions when consuming scientific information in the media. Therefore, it may help instructors to be prepared to discuss other “contentious” topics (such as, vaccines, climate change, etc.) that may emerge during class discussions.

It is helpful for instructors to know the basics of the pharmacology of Ivermectin, and why the drug, while impressively effective against parasites, may not treat COVID-19 (13). It is important to conceptualize that the specificity of drugs depends on the target receptors, and that the downstream effects in one organism may not represent the effects in another organism. To help instructors provide some background on Ivermectin and the significance of the false claim that it can treat COVID-19, we have prepared a brief PowerPoint lecture to be used in the lesson (Supporting File S3).

**Scientific Teaching Themes**

**Active Learning**

This lesson plan is specifically designed for students to develop their own expertise as they draw evidence-based conclusions, rather than defaulting to the instructor’s perspective. Dispelling disinformation requires that students actively confront the reasons that disinformation is faulty (25). Misconceptions can be used as a preliminary understanding to build a more robust critical thinking student population (26). Active learning has been repeatedly shown to improve students’ knowledge retention and application (27). Thus this lesson plan is specifically designed with active learning strategies including think-pair-share (28) and jigsaw (20) in order to differentiate disinformation from information based on evidence. Students start with a pre-class quiz to self-assess their current knowledge of Ivermectin. They are then given pre-class background material and provided specific instructions on how in-class discussions will be conducted. The lesson plan is scaffolded to provide a specific framework for gathering information from these sources and drawing conclusions individually and in groups. Students are provided original scientific data reported in Elgazzar et al. (2020) and from the CDC on Ivermectin use.

Much of the class is spent in a jigsaw activity to read and discuss assigned in-class materials and understand concepts through group discussions. In a jigsaw learning experience, students are divided into groups, where each student is assigned a separate task/topic in which they become an “expert.” All students are required to complete all the tasks, however, the only way for them to learn about topics other than their own is through listening and engaging with the “experts” in those topics (32). This form of group learning has been shown to minimize bias and foster cooperation among students while promoting efficient learning through peer discussions (32). During the sharing section of the jigsaw, students present their learning, analyze the value of different pieces of evidence, and synthesize conclusions to determine whether Ivermectin could be used as a drug against COVID-19.

**Assessment**

The primary assessment in this activity is an open-ended survey administered at the beginning and end of instruction (Supporting File S1). Before beginning the homework, for example at the end of the previous class session, students answer a series of questions to assess basic knowledge about both Ivermectin and the fact that pharmaceuticals treat specific classes of pathogens. At the end of the lesson, students are asked to return to these questions and “Add to your answers by using a different color—please don’t change any of the old text, just add.” This approach helps both the students and instructors see what students learned.

**Inclusive Teaching**

In-class teaching strategies have been specifically designed to include all students in learning. Every student had a worksheet with the jigsaw prompts on it, and each was responsible for finishing the worksheet by the end of the activity. Consistent with universal design, students had the option of turning in the worksheet within 24 hours through the learning management system, in consideration of those who needed extra time for short-turnaround assignments.
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In addition to having an inclusively designed worksheet, we used inclusive practices in our whole class discussion. For example, we used inclusive practices in our whole class discussion. For example, we used unbiased call to solicit students’ answers (29), carefully scaffolding discussion to decrease anxiety about talking to the class (e.g., 30). Students had time to think and write before discussing anything. The first discussion (the first half of the jigsaw) took place in small groups with students who had studied the same material, so students built their confidence explaining their material to others. In the second half of the jigsaw, students practiced explaining their conclusions to peers who were unfamiliar with the content. Students on the virtual platform were divided into virtual breakout rooms for the first half of the jigsaw, following which they were interspersed among students in the classroom (Figure 1). Both discussions prepared students for talking to the whole class, and students could always “pass” on answering questions with no penalty. We also kept a “do not call list” for students whose anxiety about speaking in class was too overwhelming.

LESSON PLAN

Table 1 presents a summary of the lesson plan.

Activity Preceding the Lesson

In the class preceding the Ivermectin lesson, students took the survey in Supporting File S1. These questions are geared towards assessing students’ understanding of the Ivermectin crisis during the COVID-19 pandemic, and to orient students to the forthcoming lesson. Specifically, students respond to questions surrounding the history and application of Ivermectin, the scientific consensus against using Ivermectin to treat COVID, and a general knowledge of the scientific method and the peer review process. These reflection questions are posed again at the end of the lesson to allow students to synthesize their learning, and for instructors to gain insight into student learning.

Pre-Class Preparation

Students are required to complete a 1.5-page reading on the pharmacology of Ivermectin and its applications in medicine (Supporting File S2.1). Additionally, the following articles are assigned to demonstrate why Ivermectin, a life-saving drug against parasitic illnesses, has become a politically contentious topic during the COVID-19 pandemic:

- Article 1: How ivermectin became the new focus of the anti-vaccine movement
- Article 2: Ivermectin is a Nobel Prize-winning wonder drug – but not for COVID-19 (if the online link is no longer available, please refer to the PDF version of this article, Supporting File S2.2)
- Article 3: Ivermectin: How false science created a Covid ‘miracle’ drug (if the online link is no longer available, please refer to our excerpt of this article, Supporting File S2.3)

We assigned these readings in the interactive software Perusall®, which allows students to comment on the reading, asking, and answering each other’s questions. We circulated the pre-class assignment among students via the university’s learning management system. The reading materials aim to introduce students to the Ivermectin controversy, the various interest groups involved, and the scientific community’s take on the question of Ivermectin as a treatment against COVID-19. This broad background information is meant to prepare students to delve into deeper topics to be covered in the classroom.

In-Class Lesson

Instructors begin by introducing students to the learning objectives and how they relate to the homework assignment of the lesson.

Brief Introduction to Ivermectin and Its Significance

In this section, instructors provide a concise lecture on why the misuse of Ivermectin matters from a scientific and public health perspective. We have included lecture slides in Supporting File S3—the content of this lecture largely aligns with the homework reading material. This lecture and corresponding notes discuss signaling in neurons, the mechanism of action of Ivermectin, its successful track record in treating parasitic illnesses versus the dangerous consequences of using Ivermectin to treat COVID-19. Instructors are encouraged to use unbiased call to solicit student engagement and participation, thus helping students consolidate learning from their homework and fostering discussions.

Jigsaw Activity

For the jigsaw activity, instructors should devise a system for splitting students into two groups and assigning each
As the COVID-19 pandemic continues, it is time that we, as a society, learn from our experiences and educate our students to prevent future setbacks at the hands of scientific disinformation. From a broader perspective, our classroom lesson here allows students to appreciate how science plays out at the bench, at the bedside, and in policymaking spaces. More specifically, students are able to apply quantitative reasoning and critical thinking skills from this lesson to analyze scientific information and news in their daily lives.

We have taught this lesson to third-year science majors at a regional four-year public university as part of a “science process skills” class where students worked in peer groups to acquire and apply basic science literacy skills, develop hypotheses, and synthesize knowledge about the topic. The anonymous responses collected at the end of the course indicated students’ appreciation of connecting classroom learning on Ivermectin to an ongoing real-life problem.

A feature of this lesson (in fact, of the course as a whole) is its hyflex format. Students at the institution come from complex life experiences and backgrounds (working 20+ hour jobs in addition to taking classes, caregiving responsibilities, physical difficulty with commuting, etc.) that often preclude routine in-person attendance in classrooms. Moreover, the incidence of illnesses and risks associated with disease transmission during the pandemic underscored the need for an innovative classroom design. We used the university learning management system to make classroom materials electronically available and virtual attendance feasible for interested students. Thus, students were able to attend lessons in person or via the virtual platform throughout the course. This adaptability and flexibility afforded by the lesson translated into not only high student engagement but also student-driven discussions.

This lesson is focused heavily on student participation, and grades were based on discussions and activities, which appeared to have stimulated student learning. Indeed, the student responses to pre- and post-lesson reflection questions demonstrated a nuanced understanding of Ivermectin as a treatment against certain diseases and not others. Likewise, students pointed to the role of political influencers and other interest groups in falsely promoting Ivermectin as the treatment against COVID-19. Students also expressed a strong grasp of preprints versus peer-reviewed publications, and shared ideas on designing their own experiment to test efficacy of a new use for a drug. The anonymous responses demonstrated students’ ability to connect their learning to specific class activities and peer feedback. Designating each student as an “expert” in their specific Part of the jigsaw empowered students with skills and knowledge not only to solve problems but also to lead discussions and educate their peers. This design, where each student was a unique expert in their topic, likely placed the students’ developing understanding at the forefront of the activity, while reducing the effect of preconceived notions or biases about the student (32). To ensure all students benefited from the team learning experience, we required each student to complete all of the jigsaw questions in their in-class handout. Overall, we found the jigsaw activity invaluable in fostering an equitable and inclusive learning environment.

Limitations and Future Adaptations

This lesson is flexible. Although we taught this lesson to a class of biology majors, we believe it can (and should) be used in a class of non-science majors. Moreover, with student-driven
pacing and allocating additional time as needed, this lesson can be split across two classes, or covered in a single class session. Indeed, the lesson is amenable in that it can be paused at the end of Activity 1, and seamlessly resumed with Activity 2.

The jigsaw activity is amenable to having additional Parts and teams. Relevant additions, which we were unable to include in our lesson, include a deeper dive into clinical trials using publicly available databases. Additionally, students could analyze primary data from a recent study demonstrating no proven effectiveness of Ivermectin in treating COVID-19 (33). Likewise, the in vitro study where Ivermectin suppressed viral replication could be used to teach students the complexities and problems associated with translating in vitro data directly in vivo (9). Furthermore, fraudulent papers (besides the Elgazzar et al. [2020] study) asserting the beneficial effects of Ivermectin in COVID-19 could be included in future lessons (34). These additions would make the lesson significantly more compatible with larger class sizes and among students with strong biology backgrounds.

While the jigsaw activity fosters cooperative problem solving, instructors could allocate time for individual work and reflection prior to the jigsaw expert group discussion. The current lesson plan accounts for individual work and reflection time (Table 1). This reflection time allows students to orient themselves to the task at hand, and apply preexisting knowledge and skills to address the questions (28). Importantly, this additional time might also level the playing field for students with varying reading paces.

Grading in this lesson was based on student participation in class discussions and in-class handouts. Because this course used a specified grading scheme (35), students’ worksheets (Supporting File S4) were scored as complete if 80% of the content was correct.

SUPPORTING MATERIALS

- S1. Good Drug, Bad Practice – Pre- and Post-Class Reflection Questions
- S2.1 Good Drug, Bad Practice – Pre-Class Homework Article 2
- S2.2 Good Drug, Bad Practice – Pre-Class Homework Article 3
- S2.3 Good Drug, Bad Practice – Pre-Class Homework Article 3
- S3. Good Drug, Bad Practice – PowerPoint Lecture and Notes
- S4. Good Drug, Bad Practice – Jigsaw Worksheet
- S5. Good Drug, Bad Practice – Jigsaw Answer Key

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REFERENCES


### Table 1. Lesson plan.

<table>
<thead>
<tr>
<th>Activity for the preceding lesson</th>
<th>Description</th>
<th>Estimated Time (min)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-class self-reflection</td>
<td>Students respond to questions in Supporting File S1. Students should be given this survey at the end of the preceding lesson and prior to receiving the pre-class reading assignment (listed below).</td>
<td>6</td>
<td>Students work independently to answer reflection-based questions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pre-class preparation</th>
<th>Reading assignments</th>
<th>Description</th>
<th>Estimated Time (min)</th>
<th>Notes</th>
</tr>
</thead>
</table>
| Pre-class preparation | Reading assignments | The pre-class readings include (i) a 1.5-page background on the pharmacology and application of Ivermectin, and (ii) media articles describing the effectiveness of Ivermectin against life-threatening parasitic diseases but a glaring lack of evidence of Ivermectin treating COVID-19:  
  - Article 1: How ivermectin became the new focus of the anti-vaccine movement  
  - Article 2: Ivermectin is a Nobel Prize-winning wonder drug – but not for COVID-19  
  - Article 3: Ivermectin: How false science created a Covid ‘miracle’ drug  
These assignments are included in Supporting File S2. | 45 | |

| Activity 1 | Lesson introduction and learning objectives | Instructor briefly introduces the lesson and covers learning objectives. | 2 | |
| Activity 2 | Mini lecture/discussion | Instructor delivers a mini-lecture using the material provided in Supporting File S3. | 10 | This material aims to revisit homework content in a lecture format, while encouraging student-led discussions facilitated by unbiased calls. |

| Activity 2 | Pre-Jigsaw | The Jigsaw activity is included in Supporting File S4. Divide students into multiple groups of 2 or 3, because there are two Parts in the jigsaw.  
1. One Jigsaw Part focuses on weaponization of Ivermectin by media personalities and politicians to advance their own agendas, and a corresponding rise in the number of Ivermectin prescriptions among the public.  
2. The other Jigsaw Part highlights a scientific preprint fraught with plagiarism and data fabrication claiming significant improvement in COVID-19 symptoms following Ivermectin treatment. | 8 | Students individually read their respective section, and familiarize themselves with the questions prior to convening as an expert group for Jigsaw. |
<p>| Activity 2 | Jigsaw: Expert group | Students are divided into two expert groups, wherein each group overviews primary data and contextual information to interpret scientific findings and develop collective recommendations. | 20 | Large groups should be broken into smaller groups of 2 or 3 students. |</p>
<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Estimated Time (min)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jigsaw: Reshuffled group</td>
<td>Students work in reshuffled groups of 4, where each student is an expert on their designated Part. Experts take turns discussing the problem at hand and sharing their data interpretations and subsequent recommendations.</td>
<td>15</td>
<td>Instructor circulates among the groups to provide feedback and assistance. Instructor will have access to the answer key in Supporting File S5.</td>
</tr>
<tr>
<td>Quiet time</td>
<td>Each student uses this time to catch up on notes and revisit their responses to the Jigsaw questions.</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Whole class discussion</td>
<td>Instructor selects students using unbiased calls to share key takeaways from their section with the class.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Post-class activity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-class self-reflection</td>
<td>Students complete Supporting File S1.</td>
<td>5</td>
<td>Students work independently to answer reflection-based questions on the in-class worksheet.</td>
</tr>
</tbody>
</table>

Good Drug, Bad Practice: Tackling the Ivermectin Fiasco