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REVIEW

Developing Critical Thinking Skills in Pharmacy Students

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Objective. To review the importance of and barriers to critical thinking and provide evidence-based recommendations to encourage development of these skills in pharmacy students.
Findings. Critical thinking (CT) is one of the most desired skills of a pharmacy graduate but there are many challenges to students thinking critically including their own perceptions, poor metacognitive skills, a fixed mindset, a non-automated skillset, heuristics, biases and the fact that thinking is effortful. Though difficult, developing CT skills is not impossible. Research and practice suggest several factors that can improve one's thinking ability: a thoughtful learning environment, seeing or hearing what is done to executive cognitive operations that students can emulate, and guidance and support of their efforts until they can perform on their own.
Summary. Teaching CT requires coordination at the curricular level and further to the more discrete level of a lesson and a course. Instructor training is imperative to this process since this intervention has been found to be the most effective in developing CT skills.

Keywords: critical thinking, metacognition, course design, problem solving, clinical decision making

INTRODUCTION

Critical Thinking (CT) is one of the most desired skills of a pharmacy graduate because pharmacists need to think for themselves, question claims, use good judgment, and make decisions.[1,2] It is needed in almost every facet of pharmacy practice because pharmacy students need to evaluate claims made in the literature, manage and resolve patients' medication problems, and assess treatment outcomes.[3] While pharmacy educators may agree that CT is an essential skill for pharmacy students to develop, it must be consistently defined because the definition determines how it is taught and assessed.[4] While many definitions of CT exist,[5] it is most commonly defined as automatically questioning if the information presented is factual, reliable, evidence-based, and unbiased.[2] In simpler terms, it is reflecting on what to believe or do.[6]

To operationalize the CT definition, six core CT skills have been proposed: interpretation, analysis, evaluation, inference, explanation, and self-regulation (directing one's actions automatically).[7,8] Interpretation includes understanding and communicating the meaning of information to others. Analysis includes connecting pieces of information together to determine the intended meaning. Inference is recognizing elements of information one has and using those elements to reach reasonable conclusions or hypotheses. Evaluation involves making a judgment about the credibility of a statement or information. Explanation includes adding clarity to information one shares so it can be fully understood by another person. Self-regulation is the ability to control one's own thoughts, behavior and emotions.

Besides the six core skills, CT is more than a stepwise process. It is a summation of attitude, knowledge, and knowledge of the CT process (Attitude + Knowledge + Thinking Skills = Critical Thinking).[9] All three components are necessary. First, individuals need an attitude that aligns with CT. This attitude includes a willingness to plan, being flexible, being persistent, willingness to self-correct, being mindful and a desire to reconcile information.[9] If the attitude is not there, it is unlikely that the individual will engage in the actual process. Second, CT requires knowledge or something to think about. The more knowledge the individual has, the better their process and answer. Thus, acquiring foundational, requisite knowledge is important in CT. The final part is the knowledge of the CT process. Knowing the steps and following them is key to success. Not following

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the steps can lead to incorrect answers. Skipping steps is one of the barriers to CT. When these three components are present, CT can occur at a deep level.

While CT is used often, it is important to differentiate CT from other processes. Problem solving, clinical reasoning and clinical decision-making are related higher-order CT skills and while the terms may be used interchangeably, there are distinguishing features. Problem solving is a general skill that involves the application of knowledge and skills to achieve certain goals. Problem solving can rely on CT but it does not have to.[10,11] The steps of identifying a problem, defining the goals, exploring multiple solutions, anticipating outcomes and acting, looking at the effects, and learning from the experience are all steps that can benefit from eliminating assumptions or guesses during the problem-solving process.[12] In comparison to general thinking skills, clinical reasoning and clinical decision-making depend on a CT mindset and are domain-specific skills that are used within pharmacy and other health sciences.[4] Clinical reasoning is the ability to consider if one's evidence-based knowledge is relevant for a particular patient during the diagnosis, treatment, and management process.[4,13] Clinical decision-making happens after the clinical reasoning process and is focused on compiling data and constructing an argument for treatment based on the interpretation of the facts/evidence about the patient.[14] Overall, the process of thinking like an expert by considering the evidence and making correct decisions about a patient to solve a patient's problems is a skillset that students should practice so it becomes automatic. See Figure 1 for a visual representation.

Barriers to Critical Thinking

There are several challenges to students thinking critically: perceptions, poor metacognitive skills, a fixed mindset, heuristics, biases and because thinking is effortful. The first barrier is students' perceptual problem – students believe they know how to solve problems, so often, they do not understand why they are being re-taught this skill. Educators teach students how to monitor their thinking and become better problem solvers by giving them a framework to be more thoughtful thinkers.

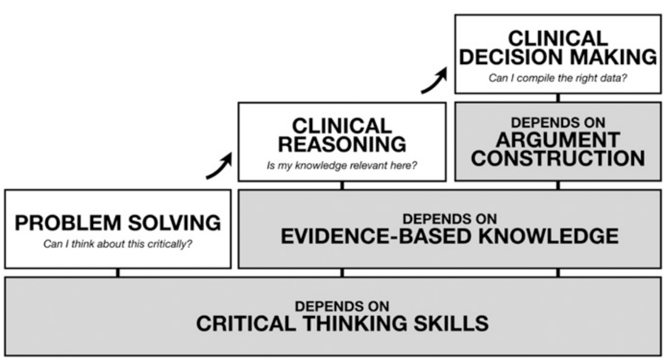

Figure 1. Schematic of Critical Thinking and its Relationship to Other Types of Thinking
White boxes represent the thinking type while gray boxes provide descriptions of each type and show how the skills build upon each other

The next challenge is students' weak metacognitive skills. The relationship between CT and metacognitive skills has been noted in the literature.[15] Metacognition refers to an individual's ability to assess his/her own thinking and actual level of skill or understanding in an area. Metacognition helps critical thinkers be more aware of and control their thinking processes.[15] Students who are weak at metacognition jump to conclusions without evaluating the evidence, thinking they know the answer, which ultimately interferes with CT.

A third reason CT is difficult for students is that they may have a fixed mindset or a belief that their intelligence cannot change.[16] If students believe CT is an innate skillset that occurs naturally, they may not invest the effort to develop it because they believe that no matter how hard they try, they will never get it.

Heuristics can get in the way of CT. Heuristics are our shortcuts to thinking – they are a strategy applied implicitly or deliberately during decision-making where we use only part of the information we might otherwise want or need. This results in decisions that are quicker and less effortful because the individual may be using the best single piece of data to make a more frugal approach.[17-19] In a classic study, participants were asked, "If a ball and bat cost $1.10, and the bat is $1 more than the ball, what was the cost of the ball?"[20] The most popular answer is $0.10, which is incorrect (the correct answer is the ball costs $0.05, the bat then is $1.05 or $1 more. If the ball was $0.10, the bat is only $0.90 more than the ball). We take cognitive shortcuts because thinking is effortful and if we can get a quick response that fits our current needs, we will do it. Kahneman referred to two systems of thought: System 1 and System 2.[19,21] System 1 is a fast decision-making system responsible for intuitive decision-making based on emotions, vivid imagery, and associative memory. System 2 thought processes is a slow system that observes System 1's outputs, and intervenes when "intuition" is insufficient.[21]

Another challenge that makes CT difficult for students is their inherent biases. One major bias is confirmation bias or the tendency to search for information in a way that confirms our ideas or beliefs.[22] Confirmation bias happens because of an eagerness to arrive at a conclusion, so students may assume they are questioning their assumptions when they are only searching for enough information to confirm their beliefs.[22] When we want to think critically, we want the evidence against our view to better inform our decision. See Appendix 1 for a list of cognitive biases that may affect our thinking.

CT is difficult and does not develop automatically. It takes practice and effort. Experts think critically without conscious thought, which makes it effortless. However, developing expertise is estimated to take 10 years or 10,000 hours (or more) of deliberate practice, so it is a time consuming activity.[14,23] In a study of thinking using the game Tetris, it was shown that initial game learning resulted in higher brain glucose consumption compared to individuals with experience playing and those watching someone play.[24] Similar results are seen when comparing experts to novices. Functional MRI studies show that experts use less of their brain to solve a problem than novices, partly because a problem for a novice is not a problem for an expert.[25] It is experience that has led to muscle memory and heuristics. Students do not have a lot of experience thinking critically and therefore, do not want to do it because it is difficult and time consuming; they would rather do things that are automatic and effortless.

Developing Critical Thinking Skills

Developing CT skills is difficult but not impossible. CT is a teachable skill and is often discipline-specific because it relies on discipline-specific knowledge. Research and practice suggest several factors that improve thinking: a thoughtful learning environment (eg, integration), seeing or hearing what is actually done to executive cognitive operations one is trying to improve (eg, model behavior), guidance and support of one's efforts until he or she can perform on their own (eg, scaffolding);[26] and prompting to question what is thought to be known (eg, challenging assumptions).[27] These are general, key points that instructors can do to help students develop CT skills.

Creating a thoughtful learning environment is not limited to just letting students make mistakes. Table 1 compares features of thoughtful classrooms to traditional classrooms that do not emphasize CT. The first piece of this thoughtful learning environment is helping students to integrate their knowledge. Integration allows students to build on previous experiences, provide developmentally appropriate opportunities for the individual to produce optimal performance, and lay a foundation for further development. By intentionally creating an environment that allows students to integrate previous and current knowledge, they can begin to evaluate how the

Table 1. Major Features of Thoughtful and Traditional Classrooms[26]

Behavior or Condition	Thoughtful Classroom	Traditional Classroom
Student	Ask and answer questions Remember and report information Collect, analyze, evaluate and synthesize information and ideas Produce and construct knowledge Accept and take thinking risks Work in groups and individually Engage in sustained discussion, deliberation, and inquiry Interact with each other and the instructor	Answers questions Remember, repeat and report information Collect and arrange information Reproduce information Avoid thinking risks Work individually Engage in recitation and drill Respond to the instructor
Instructor	Guide student use of information Seek clarification, elaboration, evaluation, and justification Stimulate, encourage, facilitate, and support learning Model complex thinking Join with students in learning	Provide information to be learned Seek correct answers Direct and referee learning Model reporting, recording, remembering Stand above students
Curriculum	In-depth study of limited number of topics Incremental, conceptual, integrated learning Integrates learning with student experience Uses multiple sources of information	Superficial coverage of many topics Fragmentary, episodic, entity learning Information learning an end of itself Uses single source of information
Class	Considerable student talk Considerable student-to-student interaction Builds knowledge as a group and individually Requires considerable mental inquiry and effort	Considerable teacher talk Limited to no student-to-student interaction Accumulate information individually Requires limited mental inquiry and effort

concepts are related and make decisions on how to apply that knowledge to future, and likely different, situations. Integration can take many forms and does not necessarily mean courses need to be integrated or aligned in time. Integration can take the form of integrating the cumulative knowledge gained over the curriculum.

Modeling expert thinking is another way to help students see CT in action and begin to use these steps themselves. Instructors should verbalize their executive cognitive operations for students to hear or see when addressing a problem or issue that requires CT. No single step is too insignificant to point out. Learners are novice and assumptions should not be made that they understand or know how to perform a seemingly simple set in the thinking process. By watching the experts process information, learners begin to form those thinking skills as well.

Scaffolding is another general method that can facilitate development of CT skills. Scaffolding is a temporary support mechanism. Students receive assistance early on to complete tasks, then as their proficiency increases, that support is gradually removed. In this way, the student takes on more and more responsibility for his or her own learning. To provide scaffolding, instructors should provide clear directions and the purpose of the activity, keep students on task, direct students to worthy sources, and offer periodic assessments to clarify expectations. This process helps to reduce uncertainty, surprise and disappointment while creating momentum and efficiency for the student.

Thinking begins when our assumptions are violated. Driving to work requires little effort. We do it all the time and sometimes we may wonder how we got to work because our thoughts were elsewhere. On a daily basis, you assume your drive will be normal and unimpeded. Now imagine there is traffic. You move from auto-pilot to thinking mode because your assumptions were violated. When our assumptions are violated, we start to think and we see this thought process as early as a few weeks from birth.[28] In the classroom, we must identify and challenge students' assumptions. As an example from self-care instructors, when students are asked to recommend a product for cough associated with the common cold, any student pharmacist with community pharmacy experience may answer "dextromethorphan." This may be what they have seen in practice or what they received as a child from their parents. They have experience in this context. However, this answer is not supported by the guidelines,[29,30] but the students will argue it is correct because of their experience. The cognitive dissonance – not expecting something to happen that you thought would – starts the cognitive thinking process. From an instructional standpoint, it may be important to initiate the critical thinking process by having students make predictions on outcomes and showing how their predictions may be correct or incorrect.

Developing CT requires a 4-step approach.[9] The first step is explicitly learning the skills of CT. The second is developing the disposition for effortful thinking. The third step is directing the learner to activities to increase the probability of application and transfer of skills. The final step is making the CT process visible by instructors making the metacognitive monitoring process explicit and overt. These four steps should be included both at the broad curricular level and down to the more discrete level of a lesson and a course.

Curriculum. College has shown to increase CT skills when CT is measured through standardized assessments of CT skills (four years of college = effect size of 0.6).[31] While part of this growth in college may be due to maturation and increase in knowledge, developing CT skills requires curriculum-level coordination. Just like a military action will fail if the individual units do not play their role, CT development will fail if individual units do not play their respective roles. One way to develop CT skills is to use a two-fold approach.[1,32] The first step is to have a course in the curriculum that teaches the general thinking skill process and starts to develop the dispositions. The second step is to have individual courses reflect that process within the context of the subject matter. Ideally courses have explicit learning objectives and make the thinking process equally as explicit; this is called the infusion method. Table 2 shows the effect sizes (difference in performance relative to the standard deviation) of these types of interventions. Typically effect sizes under 0.2 are considered small, over 0.4 are considered educationally significant, and over 0.7 are considered large.[33,34] To note, these effect sizes come from a variety of study types, durations and outcome measures. For example, one study in nursing used a standardized assessment of CT (California Critical Thinking Skills Test) to compare lecture to problem-based learning (PBL) in a pre/post design.[35] Examining pre-to-post changes, PBL showed an effect size of 0.42 whereas lecture was 0.010. When comparing the post-scores from PBL to lecture, the effect size was 0.44. Alternatively, undergraduates were placed in dyads across four different conditions outlined in Table 2: general, infusion, immersion and control.[36] The outcome was a rubric developed by the instructor and research team. Compared to control, the general (.46), infusion (1.1) and immersion (.97) all showed positive and moderate-to-large effect sizes. Relatively, infusion was better than general (.60) as was immersion (.49) with very little difference between infusion and immersion (.12). Although

Table 2. Effect Size and 95% Confidence Intervals for Types of Interventions to Develop Critical Thinking.[1,32] (Effect sizes may include: pre-post design, quasi experimental design, or true experimental design. Outcome measures may include standardized critical thinking tests, instructor-developed critical thinking assessments, researcher-developed critical thinking assessments or some combination thereof. Study durations range from short – 1 hour to 2 days – to greater than 1 semester.)

Intervention	Definition	Effect Size (g^+)
General thinking skills	CT abilities and dispositions taught separately from content of existing subject matter.	.38 (.31, .45)
Infusion	Deep, thoughtful and well-understood subject matter instruction and general CT principles are made explicit.	.54 (.49, .59)
Immersion	Subject matter instruction is thought provoking and students do get immersed in the subject. However, general CT principles are not made explicit.	.09 (.05, .13)
Mixed	General approach with either infusion or immersion: students are involved in subject specific CT but also a separate thread or course aimed at teaching general principles.	.94 (.82, 1.05)
Authentic Instruction	Effort to present students with genuine problems that make sense to them, engage them and stimulate them to inquire.	.25 (.05, .46)
Applied problem-solving		.35
Role-playing		.61
Dialogue	Learning through discussion.	.23 (.07, .39)
Teacher poses questions		.42
Class discussion led by teacher		.42
Small group discussion led by teacher		.41
Authentic+Dialogue		.32 (.17, 47)
Authentic+Dialogue+Mentoring	Mentoring is one-on-one interaction between an expert (or someone with more expertise) and a novice where the mentor models and error corrects based on a critical analysis.	.57 (.38, .77)

the effect sizes in Tables 2 and 3 should be interpreted with some caution as the context varies, they represent effects across a variety of disciplines, outcome measures and study designs, thus suggesting a more generalizable effect.

Courses. Within a course structure, collaborative learning (ie, peer teaching, cooperative learning) helps develop CT more than other activities. One meta-synthesis that attempted to integrate results from different but interrelated qualitative studies on critical thinking found an effect size of 0.41 for promoting CT skills when collaborative learning was used.[1,32] Collaborative learning provides feedback to learners and puts learners in a setting that challenges their assumptions and engages them in deeper learning to solve a problem. However, if learners receive minimal guidance, they may become lost and frustrated or develop misunderstandings and alternative understandings.[32,36] Students' CT improves most in environments where learning is mediated by someone who confronts their beliefs and alternative conceptions, encourages them to reflect on their own thinking, creates cognitive dissonance or puzzlement, and challenges and guides their thinking when they are actively involved in problem solving. This guided participation role may be implemented by learners in structured activities with the guidance, support, and challenge of companions.[26]

Lessons. Individual lessons should be designed with CT in mind by intentionally providing learners opportunities to engage in complex thinking. Appendix 2 offers a guide to developing these types of opportunities for students. The goals of the activities should be made clear and instructors should acknowledge that effortful thinking is required while recognizing that the learning environment allows students to make mistakes. Instructors should explicitly model their expert thinking and actively monitor how students are learning. Adjustments to teaching should be made reactively as instructors notice trends in student thinking. Providing enough time to think and learn during these activities is crucial. Expect novice students to take at least double the time it would take you as an expert to complete the activity. Appendix 3) provides a worksheet that students can use to develop their CT skills during an activity.

Instructors. While the curriculum structure can have a large effect, it relies heavily on the individual instructor. Instructor training has been found to be the most effective intervention in developing CT skills (Table 3). This training, however, must go beyond having students observe others think critically. This facilitation requires the appropriate material (eg, cases), facilitation skills and mentoring skills.[32] Appendix 4 provides a rubric to help

Table 3. Effect Size for Pedagogical Grounding of Intervention.[1] (Effect sizes may include: pre-post design, quasi experimental design, or true experimental design. Outcome measures may include standardized critical thinking tests, instructor-developed critical thinking assessments, researcher-developed critical thinking assessments or some combination thereof. Study durations range from short – 1 hour to 2 days – to greater than 1 semester.

Type of Intervention	Effect Size (g^+)
Instructor training	1.0 (.92, 1.07)
Extensive observations (observing others do it)	.58 (.51, .65)
Detailed curriculum description	.31 (.22, .40)
Critical thinking among course objectives	.13 (.09, .17)

instructors assess students' problem-solving skills on a problem-solving activity. Though difficult, instructors should often remain silent during the activity. When necessary, instructors can ask probing questions that require students to clarify, elaborate, explain in more depth or ask more questions, which are related to metacognition. Instructors can signal acceptance of the student's assertions by paraphrasing, providing a friendly facial expression, or writing responses for all to see. The key is to facilitate learning and not "do" the learning for the students.

Recommendations

A common model for the process of CT should be used in each pharmacy school curriculum. Ideally, a course should be required for all students early in the curriculum that addresses the definition, common model, and dispositions of CT and then provides an opportunity for students to actively practice these skills on general subject matter content. As students' knowledge of pharmacy specific content grows, courses need to explicitly use the process outlined in the general course with application to the subject specific content. The repetition of these skills in multiple courses or course series will help students practice this skill. Additionally, all instructors should learn the model taught to students and learn how to create and facilitate activities to encourage CT in their content areas.

While there may be many templates for CT, we propose a 4-step cycle: generation, conceptualization, optimization and implementation.[37,38] In the generation phase, learners identify the problem and find facts. This is followed by the conceptualization phase when learners define the problem and draft ideas that could explain the defined problem. In the optimization phase, learners evaluate and select an idea then design a plan. Finally, the implementation phase involves accepting the plan and taking action. The cycle restarts with finding a new problem. For example, during a patient encounter, a learner would enter the generation phase, find all the problems and facts (laboratory values, past medical history, etc.). Then the learner would define the problem(s) and generate ideas as to why the problems are occurring. For example, the patient is complaining of fatigue and the learner would have to come up with reasons why fatigue might occur (anemia, lack of sleep, pregnancy, poor diet). The learner then uses the facts to evaluate each potential cause and consider what further tests may be necessary to exclude some of the potential causes. After selecting the cause, the learner formulates a plan and decides his or her next action. Once the learner discovers the patient is anemic, the cycle restarts with treatment options. This cycle can be used along with the Joint Commission of Pharmacy Practitioners Pharmacists' Patient Care Process.[39]

CONCLUSION

Critical thinking skills (interpretation, analysis, evaluation, inference, explanation, and self-regulation) are important for health care providers, including pharmacists. While some students and instructors may think that CT skills are fixed, CT can be developed and augmented through a process of attitude alignment, absorption of knowledge, and learning new thinking skills. CT is also developed when one learns to combat potentially hazardous CT roadblocks such as bias, heuristics (thinking shortcuts), and simply not wanting to go through the effort of thinking on a higher level. Pharmacy educators can foster the development of CT skills in the wide scope of curricular design, in the narrowest interactions between professor and student, and everywhere in between. It is important to note that the methods described in this paper do not have to be added to an already compressed curriculum but rather can be used with existing materials to cover the content in a deeper and more meaningful way. By modeling expert thinking and using scaffolding techniques to support students' CT development, pharmacy educators can instill both the desire and the drive for students to begin thinking critically. Regardless, it is noteworthy to point out that teaching CT skills requires time and effort at the potential expense of other skills. Thus, gains in critical thinking during a PharmD curriculum may be a function of our need to develop a multitude of other skills like teamwork, empathy, adaptability, communication, and initiative.White boxes represent the thinking type while gray boxes provide descriptions of each type and show how the skills build upon each other.

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Appendix 1. List of Biases That May Impact Critical Thinking[40]

Bias	Definition
Affective bias	Occurs when emotions about the situation intervene with objective reasoning and decision-making.
Ambiguity effect	Tendency to avoid options for which missing information makes the probability unknown.
Anchoring	The over reliance on an initial single piece of information or experience to make subsequent judgments. Once an anchor is set, other judgments are made by adjusting away from that anchor, which can limitone's ability to accurately interpret new, potentially relevant information.
Authority bias	The tendency to attribute greater accuracy to the opinion of an authority figure (unrelated to its content) and be more influenced by that opinion.
Availability bias	Attributing cause based on what readily comes to mind either because the latter is common or was recently encountered.
Availability heuristic	People overestimate the importance of information that is available to them. Example: a person might argue that smoking is not unhealthy because they know someone who lived to 100 and smoked three packs a day.
Bandwagon effect	The probability of one person adopting a belief increases based on the number of people who hold that belief (a form of group think).
Base-rate fallacy	Tendency to ignore the base rate information and focus on specific information.
Blind-spot bias	Failing to recognize your own cognitive biases. People notice cognitive and motivational biases much more in others than in themselves.
Choice-supportive bias	When you choose something, you tend to feel positive about it even if that choice has flaws.
Clustering illusion	Tendency to see patterns in random event.
Confirmation bias	Occurs when decision makers seek out evidence that confirms their previously held beliefs, while discounting or diminishing the impact of evidence in support of differing conclusions.
Conservatism bias	People favor prior evidence over new evidence or information that has merged.
Focusing effect	Tendency to place too much importance on one aspect of the event or problem.
Framing effect	Drawing different conclusions to form the same information depending on how that information is presented.
Gambler's fallacy	Expect past events to influence the future.
Halo effect	An observer's overall impression of a person, company, brand, or product. Overall impression influences the observer's feelings and thoughts about that entity's overall character or properties. It is the perception, for example, that if someone does well in a certain area, then they will automatically perform well at something else regardless of whether those tasks are related.
Information bias	Tendency to seek information when it does not affect the action.
Ostrich effect	Decision to ignore dangerous or negative information by burying one's head in the sand like an ostrich.
Outcome bias	Judging a decision based on the outcome rather than how exactly the decision was made in the moment.
Overconfidence bias	Occurs when a person overestimates the reliability of their judgments. This can include the certainty one feels in her own ability, performance, level of control, or chance of success. Experts are more prone to this bias than laypeople.
Pro-innovation bias	When a proponent of an innovation tends to overvalue its usefulness and undervalue its limitations.
Recency	Tendency to weigh the latest information more heavily than older data.
Salience	Tendency to focus on the most easily recognizable feature of a person or concept.
Satisfaction of search	Tendency to end a search after one has led to a finding, despite the lack of a thorough examination of the factors in a particular case.
Selective perception	Allowing one's expectation to influence how he or she perceives the world.
Stereotyping	Expecting a group or person to have certain qualities without having real information about the person.
Survivorship bias	An error that comes from focusing only on surviving examples causing a misjudgment. Example: we might think that being a doctor is easy because we have not heard of those who failed as a doctor.
Sutton's slip	Tendency to evaluate the obvious problem and address it immediately without a thorough examination of other helpful information.
Zero-risk bias	The love of certainty and elimination of risk.

Appendix 2. Generating Thoughtful Questions to Engage Students in Critical Thinking[26]

Select a topic

a. Rich enough detail, depth of detail, implications and interconnections and relationships inside and outside of area.
b. Open to diverse interpretation and methods of inquiry.
c. Capable of being entered at any variety of points.
d. Requires guidance of an instructor.
e. Is one that instructors are likely to spend lots of time on instead of rushing through it.
f. Contributes to the development of meaningful and significant key ideas, explanation, principles, concepts, and generalizations.
g. Can be learned about in the context of realistic problems.
h. Fits into the overall curriculum and course

Begin at the global level

i. Focuses on big picture.
j. Focuses on ill-defined rather than precisely delineated topics.
k. Requires students to pose and then answer numerous subordinate questions as they seek to define and probe the initial question and implications.

Word the question provocatively

l. Helps invite student engagement; questions that present unusual, unanticipated, or unconventional points of view bother people, agitate thinking, spark curiosity, and demand response.

Engage the students

m. Focus on the "non-present" – predicting or planning future conditions or events, reconstructing past events.
n. Have students reflect about questions before they attempt to answer them or before examining the answers they generate.

Appendix 3. Critical Thinking/Making an Argument Worksheet

Adapted from Halpern's *Thought and Knowledge: An Introduction to Critical Thinking*.[9]

1. State your conclusion.
2. Give 3 reasons (or some other number) that support your conclusion. Rate each reason (weak, moderate, strong, very strong).
3. Give 3 counterarguments (or some other number) that weaken your conclusion. Rate how much each counterargument weakens the conclusion (little, moderate, much, very much).
4. List any qualifiers (limitations on the reasons for or against).
5. List any assumptions.
6. Are your reasons and counterarguments directly related to your conclusion?
7. What is the overall strength of your argument? Weak, moderate, strong, very strong

Appendix 4. University of Oklahoma College of Pharmacy Problem Solving Rubric
Created by Dr. Melissa Medina

Part 1: Prioritizing Answers (Explicit ranking/numbering of multiple-choice (MC) options)	**Points Earned**
Each MC answer was numbered in order of priority (1=best answer to 4=least desirable).	2
Only the best answer was numbered (eg, #1 or the best answer/first choice is).	1
More than one MC answer/option was numbered but not all four answers were numbered.	1
The order of priority for the MC answers/options was implied but not explicitly stated.	0.5
None of the MC answers/options were numbered in order of priority.	0
The "best" answer is selected (as determined by the problem's answer key).	1
An acceptable answer is selected (as determined by the problem's answer key).	0.5
A wrong answer is selected (as determined by the problem's answer key).	0

Part 2: Defending Answers with Evidence (Type/strength/quality of evidence used)	**Points Earned**
The "best" answer selected is explicitly justified by ≥1 strong reason that uses evidence-based literature (eg, medical literature, referenced journal article, explicitly named medical guidelines, or stated patient data).	2
The "best" answer selected is explicitly justified by ≥1 moderate reason using other data (eg, class notes or data not directly referenced in medical literature or guidelines).	1
The "best" answer selected uses ≥1 weak reason (eg, opinion or vague statements such as per guidelines or literature) to defend why it is believed to be the best answer.	0.5
The "best" answer selected has no reasons or wrong reasons defending why it is believed to be the best answer (eg, wrong patient data, wrong guidelines).	0
The other MC options are explicitly justified (≥ 1 strong reason for each option) using the medical literature, referenced journal article, explicitly named medical guidelines, or stated patient data (if majority of reasons are strong, give full credit, if not, subtract 0.5 for each).	2
The other MC options are explicitly justified (1 moderate reason for each option) using other data (eg, class notes or data not directly referenced in medical literature or guidelines) (if majority of reasons are moderate, give full credit, if not, subtract 0.5 for each).	1
The other MC options are explicitly justified (1 weak reason for each option or majority of reasons) using opinion (or vague statements eg, per guidelines or literature).	0.5
The other MC options (each option) have no reasons or wrong reasons as support.	0
Each MC answer (each option) has at least 1 exclusive reason that does not overlap with the other reasons (eg, writing "not first line choice for all other options").	2
Some of the MC answers (each option) have at least 1 exclusive reason that don't overlap with other reasons (eg, writing "not first line choice for some options").	1
None of the MC answers (each option) has at least 1 exclusive reason that does not overlap with other reasons, eg, not first line choice).	0

Part 3: Organization of the Answers	**Points Earned**
The written answers (reasons justifying each choice) are well-organized and concise (it is clear which answer matches each choice).	1
Answers are generally well-organized; occasionally skipped around, slightly unclear or wordy.	0.5
Answers are difficult to follow, more logical flow needed, mostly unclear and wordy.	0

TOTAL SCORE	Points Earned
Part 1. Answer Prioritization Subtotal	_____/3 points
Part 2. Evidence Subtotal	_____/6 points
Part 3. Organization Subtotal	_____/1 point
Total Overall Score	_____/10 points

Strengths:
Areas for improvement:
Goal(s) for Next Session: