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Developing Sustainable Critical Thinking Skills in First-Year Medical Students: Explicit Fallacy Detection

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ABSTRACT

Critical thinking is a core competency in medical education, yet structured methods for fostering it remain limited. This study evaluates an explicit fallacy-detection module embedded within a 45-hour English for Health Sciences course designed for first-year medical students in Thailand (N = 97).The intervention targeted six fallacies—false cause, hasty generalization, confirmation bias, appeal to authority, false analogy, and appeal to nature, through scaffolded instruction, guided practice, and application with authentic medical texts. A mixed-methods design was used: pretest–posttest scores were analyzed with paired-sample t tests, and semi-structured interviews with 15 students were thematically analyzed. Results showed significant improvement ($t(96) = 20.15, p < .001$, Cohen's $d = 2.42$), with the strongest gains in false cause and hasty generalization. Thematic analysis highlighted three developmental shifts: adopting a systematic "critical lens," balancing respect with skepticism, and applying skills to patient-centered scenarios. Findings suggest that explicit fallacy instruction in ESL medical curricula strengthens analytical ability and cultivates sustainable critical thinking skills.

KEYWORDS: sustainable critical thinking skills; fallacy detection; English for Specific Purposes (ESP); ESL pedagogy.

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INTRODUCTION

Critical thinking, the ability to analyze arguments, evaluate evidence, and make logical, well-reasoned judgments, is a foundational skill in medical education, particularly during the demanding early stages of undergraduate training. First-year medical students encounter a vast and complex body of biomedical knowledge, and while traditional curricula often prioritize content memorization and technical proficiency, they tend to underemphasize the cultivation of analytical and reflective skills. Educators have increasingly advocated for a pedagogical shift toward critical thinking integration within medical training. For instance, systematic reviews highlight that strategies such as literature exposure, visual representation, simulation, and team-based learning can effectively foster critical thinking and clinical reasoning skills among medical students (Arau jo *et al.*, 2024; Tian, Hemchua & Wang, 2023), problem-based learning (PBL) has been repeatedly shown to enhance critical thinking, with meta-analyses affirming its favorable impact on critical reasoning across diverse health professions contexts (Su *et al.*, 2025). Despite these advancements, there remains a shortage of instructional materials and strategies designed for ESL contexts. In Thailand, ESL teaching is characterized by a dearth of structured materials, such as reading and writing exercises using authentic medical literature, aimed at explicitly developing critical thinking skills in early medical schooling. This study aims to fill that gap by investigating the effectiveness of a structured, classroombased intervention designed to improve critical thinking skills among first-year medical students at a university in Thailand. The intervention specifically targeted the identification of six common logical fallacies: false Cause, hasty generalization, confirmation bias, appeal to authority, false analogy, appeal to nature. This approach is grounded in the view that deconstructing arguments to identify flawed logic is a core component of critical thinking (Facione, 1990). Such training therefore fosters the default skepticism and analytical mindset essential for learning in general and in particular for scientific inquiry. Engaging with fallacies in authentic medical literature trains students to move beyond superficial acceptance of claims, encouraging them to scrutinize the underlying structure of evidence and reasoning. This method aligns with pedagogical research showing that explicit instruction in argument analysis significantly improves critical thinking outcomes (Bensley et al., 2010). This process cultivates a healthy intellectual attitude, questioning assumptions, demanding robust evidence, and considering alternative explanations. Such an attitude serves as a prerequisite for the rigorous evidence-based practice required in medicine (Jenicek & Hitchcock, 2005). To evaluate the intervention's effectiveness, we employed a mixed-methods approach. Quantitative data were collected using a pretest– posttest design that assessed students' ability to identify and explain six types of logical fallacies in items (2–6 sentences) modeled on medical discourse. Qualitative insights were obtained through open-ended interviews with a selected subgroup of 15 participants offered richer perceptions of their learning experience and development as critical thinkers. Triangulating test results with interview data provides a robust evidence base confirming that the explicit instruction model effectively develops both the measurable skills and the underlying habits of mind essential for critical thinking. By illustrating how critical thinking can be explicitly taught through medical texts and writing exercises, these findings provide ESL teachers with a model for integrating higher-order cognitive skills into ESL curricula.

Theoretical Framework

This study is grounded in an integrated theoretical perspective that conceptualizes critical thinking as a complex skill developed through scaffolded practice with authentic disciplinary tasks. The foundation is a constructivist approach (Piaget, 1954), which posits that learners actively build knowledge through experience. For first-year medical students, this means critical thinking is not acquired by memorizing facts but by actively engaging with and deconstructing the arguments found in real medical literature, thereby constructing their own understanding of what constitutes sound evidence and logical reasoning. To systematically target the development of higher-order cognitive skills, the intervention is structured around Bloom's Taxonomy (Bloom *et al*., 1956). The specific task of identifying logical fallacies is an act of *analysis*, which breaks down an argument into its components to examine its structure and validity. Subsequently, composing a coherent, evidence-based written response requires *synthesis* (combining ideas into a new argument) and *evaluation* (judging the strength of evidence and making a reasoned judgment). Thus, the pre-test/post-test measure of fallacy detection directly assesses a key analytical skill at the heart of the taxonomy. The pedagogical design is deeply informed by Vygotsky's (1978) sociocultural theory, particularly the concept of the Zone of Proximal Development (ZPD).

For ESL students grappling with both a new language and sophisticated cognitive
skills, support or "scaffolding" is essential. The use of authentic medical texts places students within a realistic but challenging ZPD. The classroom instruction and structured exercises then act as the necessary scaffolding, guiding them to decode complex language, identify rhetorical moves, and apply logical criteria they could not yet apply independently. This scaffolding is gradually removed as their skills develop, moving them toward autonomous critical appraisal. This process is facilitated by fostering metacognition (Flavell, 1979), which is the awareness of one's own thinking. The intervention prompts metacognition by requiring students to articulate not just *what* a fallacy is, but *why* it is logically unsound, thereby regulating their own comprehension and evaluation processes. Furthermore, we aim to cultivate a positive disposition toward critical thinking (Facione, 1990), characterized by inquisitiveness and skepticism, which is essential for students to consistently apply these skills throughout their life-long learning.

By integrating these theoretical frameworks, our pedagogy uses scaffolded engagement with authentic medical texts through explicit fallacy detection to move students from lower-order learning to higher-order analysis and evaluation. This framework provides a robust rationale for predicting that explicit instruction in fallacy detection and argumentation will lead to measurable gains in the critical thinking skills.

Related Studies

The imperative to integrate critical thinking (CT) instruction into higher education is widely acknowledged; however, a significant gap persists in understanding its effective application within English as a Second Language (ESL) or English as a Foreign Language (EFL) contexts at the university level. A systematic review by El Soufi and See (2019) directly addresses this evidential void, synthesizing international causal evidence on explicit CT instruction for English language learners. Their findings are critical for contextualizing the present study, as they concluded that while various approaches claim positive effects, the overall evidence base is remarkably weak, with studies suffering from methodological flaws such as small sample sizes and high attrition. Notably, explicit instruction in general CT skills emerged as the most promising approach, yet the authors caution that the evidence is not yet conclusive, underscoring a clear need for more robust, large-scale studies. This review not only confirms the identified gap but also validates the current study's focus on explicit instruction based on detecting fallacies.

Additionally, research by McLaughlin and McGill (2017) demonstrates explicit instruction efficacy in cultivating skepticism and reducing epistemically unwarranted beliefs. In their study, a history course explicitly designed to debunk myths using tools like a "baloney detection kit" significantly reduced students' belief in pseudoscientific claims, with the most substantial decline observed in an honors section with higher academic preparedness. This challenges the assumption that CT is solely the domain of science education and highlights the role of individual differences in skill transfer, reinforcing the importance of active application and interdisciplinary approaches.

A key pedagogical strategy for such active application is the integration of writing assignments that force students to apply theory to real-world contexts. Malcom (2006) provides a highly applicable model through a "point of divergence" (POD) task, where students analyze news articles by identifying how a real-world event differs from an ideal-type sociological concept. This forces students into a critical, evaluative space, arguing against their initial assumptions. Malcom's model is directly relevant for its use of authentic texts, its explicit CT task, and its framework for assessment, offering a transferable blueprint for designing discipline-specific critical analysis exercises. Beyond specific techniques, a profound philosophical framework for teaching CT is offered by Wells (2009), who draws on the pragmatist philosophy of Charles Sanders Peirce. This perspective conceptualizes CT not as a mere skill set but as a fundamental habit of mind rooted in the psychological "dynamic of belief and doubt." The critical insight for medical education is that the goal is not to eliminate doubt but to manage it effectively, a process that directly mirrors clinical reasoning. Peirce's methods of "fixing belief" provide a powerful diagnostic tool for understanding flawed reasoning, while the framework argues that effective teaching must address the underlying "habits of belief" to foster a true critical thinker.

A significant challenge, however, lies in effectively embedding these abstract CT habits into the dense, content-heavy curriculum of specialized fields like medicine, especially for diverse cohorts including ESL students. The work of Melles (2009) provides a highly relevant case study, demonstrating the successful integration of critical appraisal skills for postgraduate ESL engineering students through a sustained, content-based instructional model. Rejecting the stereotype that ESL students lack CT ability, Melles highlights that the obstacle is often a lack of exposure to Western academic conventions. His findings reveal that while students can develop a strong understanding of critical evaluation, they often face significant cultural barriers (e.g., unease critiquing authority) and practical hurdles in synthesizing sources. This study offers key insights for medical education: the necessity of disciplinary integration, the effectiveness of scaffolded tasks, and the importance of continuous formative feedback. The application of CT is a clinical imperative, as flawed reasoning can directly impact patient care. This is powerfully illustrated by Triposkiadis *et al*. (2021), who use the debate over RAAS inhibitors and COVID-19 as a paradigm for how logical fallacies can permeate medical discourse during crises. The authors systematically categorize formal and informal fallacies, such as "*argument from ignorance*" and "*appeal to authority*", that appeared in statements from major scientific societies. Furthermore, the article reinforces the hierarchy of evidence, a cornerstone of evidence-based medicine. This work provides a tool for teaching medical students to deconstruct arguments, cultivate intellectual humility, and examine evidence with critical thinking.

While these studies provide frameworks for *what* to teach, the article by van Gelder (2005) offers crucial, evidence-based insights from cognitive science on *how* to teach it effectively. His central argument is that "*critical thinking is hard*" and requires deliberate practice where students actively do the thinking themselves with focused feedback. To overcome the notorious problem of transfer failure, he advises educators to explicitly "*teach for transfer*". Two of his most impactful recommendations are to teach the theoretical vocabulary of logic to reveal the underlying structure of arguments and to use argument mapping to accelerate skill development. Finally, he addresses cognitive biases like belief preservation, advocating for metacognitive strategies to combat them. These lessons suggest a CT curriculum that is practice-based, explicit, and metacognitive. This relates directly to a central pedagogical debate analyzed by Robinson (2011); that is whether CT is best taught as a general skill or as a set of discipline-specific practices. Robinson critiques the strongly "*specifist*" position, arguing that while CT is applied within a discipline, generic courses can provide the foundational language and tools for argument analysis as a necessary first step. For medical education, this analysis suggests a hybrid or "infusion" approach, where students receive explicit instruction in generic reasoning skills (the *how*) that are immediately practiced using authentic, discipline-specific materials (the *what*). This model validates a curriculum that teaches general CT principles through the context of medical literature and cases.

However, implementing any such approach first requires confronting a significant obstacle: the broad and often ambiguous definition of CT itself. Schmaltz *et al*. (2017) argue the term has become so expansive it "*can encompass nearly anything and everything*", leading to inconsistent pedagogy. They propose a stronger focus on teaching students to "*think like scientists*," defined as "the ability to generate, test, and evaluate claims, data, and theories." This provides the essential tools to distinguish sound information from unsound by applying foundational principles such as ruling out rival hypotheses and differentiating correlation from causation. Their suggested skeptical inquiry toolkit offers a practical framework for tailoring critical appraisal to medical contexts, such as evaluating clinical trials and deconstructing misinformation.

The question of *how* to teach most effectively is addressed empirically by Orhan and Çeviker Ay (2023). Their quasi-experimental study compared three approaches: general (explicit stand-alone instruction), immersion (implicit within content), and mixed. The results demonstrated that while all three improved CT, the general approach was the most effective for improving both CT skills. The authors suggest the immersion approach's relative weakness stems from students' difficulty in transferring implicitly learned skills to novel contexts. This finding is highly significant for medical students, who must apply CT across diverse domains, and strongly supports integrating a dedicated, explicit CT course to provide a universal "thinking toolkit" before encountering complex medical content. An equally important challenge, once the approach is determined, is how to communicate the intent and process of CT to students effectively. The action research by Gamble Blakey et al. (2022) found the abstract term "critical thinking" itself to be a "distracting and useless" barrier in the classroom. Their solution is a pragmatic strategy: avoid the term critical thinking altogether. Instead, instructors should use short, specific phrases like evaluative thinking and offer concrete linguistic scaffolds, such as sentence starters, to model the desired cognitive process. This is vital in medicine, where clinical reasoning must be articulated clearly, and provides a practical method for reducing cognitive load and semantic confusion while developing sophisticated thinking skills.

Finally, a crucial component of CT in medicine is making robust decisions based on uncertain quantitative data. Holmes *et al*. (2015) provide an evidence-based framework for cultivating this quantitative critical thinking through a cyclical process: make quantitative comparisons using statistical tools, decide how to act based on those comparisons (e.g., improve data quality), and iterate. This approach counters the tendency to distrust data and attribute discrepancies to human error. The results were striking: students trained with this method were far more likely to improve their methods and explain model limitations. For medical education, this suggests structuring activities around iterative cycles of acting on data, such as comparing lab results to decide on further tests, thereby transforming students from passive collectors into active, critical evaluators of evidence.

MATERIALS AND METHODS

2.1 Research Design

This study employed a mixed-methods, pretest-posttest design to evaluate the effectiveness of a structured classroom intervention on first-year medical students' ability to identify logical fallacies. Quantitative data were collected through identical fallacy detection tests administered before and after the intervention. Qualitative data were gathered through semi-structured interviews to provide deeper insight into the students' learning experiences and self-perceived development of critical thinking skills.

2.2 Participants

Participants consisted of 97 first-year undergraduate medical students at a university in Thailand. They were drawn from four consecutive annual cohorts (Cohort 1: n=24; Cohort 2: n=23; Cohort 3: n=30; Cohort 4: n=20). Participation was integrated into a mandatory English for Health Science course. This course, henceforth referred to as ESAP, was a required component of the curriculum. All students in each cohort participated in the intervention as part of their regular curriculum.

2.3 Instructional Content and Pedagogy

The critical thinking intervention was embedded within a mandatory 45-hour English for Health Science course, delivered over a single semester at a rate of three hours per week. The course's main objectives were to develop students' proficiency in reading health science texts, along with incidental listening, writing, and speaking skills. A dedicated module focused on detecting and explaining logical fallacies was integrated into the curriculum to support these goals. The selected six fallacies were systematically incorporated into the learning materials and operationalized primarily through reading comprehension exercises based on authentic medical texts, including journal abstracts, public health reports, and pharmaceutical advertisements. Following each text, students were required to answer short-answer questions designed to assess comprehension and, crucially, to identify and explain instances of flawed reasoning using the taught fallacies.

2.3.1 Selected six fallacies

The six fallacies were selected for their direct relevance to medical reasoning and scientific inquiry (Facione, 1990; Jenicek & Hitchcock, 2005). "*False cause*" addresses the challenge of establishing causality, central to diagnosis and treatment decisions. "*Hasty generalization*" and "*confirmation bias*" target errors in evaluating evidence, such as drawing conclusions from inadequate samples or selectively favoring information that supports pre-existing hypotheses (Bensley et al., 2010; Norman & Eva, 2010). "*Appeal to authority*" and "*appeal to nature*" train students to scrutinize the source of claims rather than accepting them based on perceived expertise or a naturalistic halo effect. Finally, "*false* analogy" develops students' ability to evaluate the validity of comparisons, crucial for applying basic science research to clinical contexts, understanding pharmacological mechanisms, and communicating complex information to patients without oversimplification (Timmermans & Tavory, 2012). Together, these fallacies provide a foundational toolkit for deconstructing arguments and fostering the analytical skepticism required for evidence-based practice.

2.3.2 Instruction followed a structured pedagogy

Explicit Instruction: Each fallacy was defined and illustrated with multiple clear examples from both general and medical contexts. *Guided Practice*: Instructors and students collaboratively analyzed text excerpts to identify instances of each fallacy, discussing their impact on the argument's validity. *Application and Production*: Students worked in small groups to identify fallacies in new, unseen texts and composed short written critiques explaining the reasoning errors they detected. **2.4 Data Collection Instruments and Procedures**

2.4.1 Quantitative Data: Fallacy Detection Test

The identical test was administered as a pretest in the first class of the module and as a posttest in the final class. Students were asked to identify the specific fallacy present in each statement from a provided list. Each item was scored on a nuanced two-point scale to separate the skill of identification from explanation. 0.5 points were awarded for the correct identification of the fallacy type, and 0.5 points were awarded for a correct written justification of the reasoning error, yielding a maximum possible score of 18. This approach allowed for a more granular analysis of specific gains in diagnostic versus explanatory skills. The use of a precise rubric ensured scoring consistency, which was validated through an inter-rater reliability check in which a second researcher independently graded a portion of the assessments. The strong alignment between raters confirmed that the rubric was clear and easy to follow, and any scoring disagreements were discussed to align interpretation, reinforcing the consistent application of the criteria across the dataset.

2.4.2 Qualitative Data: Semi-Structured Interviews

A semi-structured interview protocol was developed with open-ended questions designed to explore students' perceptions of their own critical thinking development. The protocol focused on probing how the intervention influenced their approach to deconstructing arguments in medical literature and constructing their own evidence-based responses. Following the posttest, a purposive sample of 15 students was selected from across the four cohorts using a strategy of maximum variation sampling.This sample was stratified to ensure it included 5 high performers, 5 medium performers, and 5 low performers based on their posttest scores. This sampling strategy was employed to ensure a diversity of perspectives and learning experiences, capturing both positive and negative cases to provide a comprehensive understanding of the intervention's impact. The interviews were conducted by the primary researcher, audio-recorded, and transcribed verbatim to ensure accuracy for analysis.

Data Analysis

A mixed-methods approach to data analysis was employed to integrate quantitative and qualitative findings. To measure the effectiveness of the intervention in improving fallacy detection skills, pretest and posttest scores were analyzed using a paired-sample t-test. This statistical test was selected to determine if a statistically significant improvement in scores occurred within subjects over the duration of the intervention. Descriptive statistics (e.g., means, standard deviations) were calculated for both the overall scores and the scores for each specific fallacy type to provide a detailed overview of performance and identify patterns of strength and difficulty. For the qualitative analysis, thematic analysis, following the six-phase framework outlined by Braun and Clarke (2006), was employed to analyze the interview transcripts. This involved a process of familiarization with the data, generating initial codes inductively based on the participants' responses, searching for themes by collating relevant codes, reviewing potential themes, defining and naming themes, and finally producing the report. The analysis focused on generating themes related to key areas of inquiry, such as participants' metacognitive awareness, their approach to analyzing medical text, and the perceived application of critical thinking skills to medical contexts.

RESULTS

3.1 Quantitative Findings and Discussion

The quantitative results demonstrate a statistically significant and substantial improvement in students' ability to correctly identify and explain logical fallacies following the intervention. A paired-samples *t*-test comparing pre-test (M = 7.2, SD = 2.8) and post-test (M = 14.1, SD = 2.9) scores revealed a dramatic increase, $t(96) = 20.15$, $p < .001$, with a large effect size (Cohen's $d = 2.42$). This provides strong evidence that the explicit instruction within the ESAP curriculum was effective in enhancing students' critical thinking skills, as operationalized by fallacy detection (Table 1).

Table 1

Descriptive Statistics for Pre-test and Post-test Scores

Measure	Mean	SD	Min	Max
Pre-test Score	7.2	2.8	2	14
Post-test Score	14.1	2.9	6	18

This dramatic gain empirically validates the study's integrated theoretical framework. The success of the explicit, scaffolded instructional model aligns with van Gelder's (2005) core argument that critical thinking is hard and requires deliberate practice with focused feedback. It demonstrates the constructivist principle (Piaget, 1954) that students actively constructed their understanding of logical reasoning through engagement with authentic tasks. The intervention's structure, which moved students from identifying fallacies (*analysis*) to composing critiques (*synthesis* and *evaluation*), directly operationalized Bloom's Taxonomy (*Bloom et al*., 1956**)** and was supported by the scaffolding informed by Vygotsky's (1978) Zone of Proximal Development, effectively guiding students from assisted to more autonomous performance. A more nuanced analysis by fallacy type, however, revealed important variations within this overall success (Table 2). The greatest improvements were observed for "*false cause*" and "*hasty generalization*", fallacies directly tied to core scientific concepts of causality and evidence sampling. This suggests students successfully transferred their foundational scientific knowledge to the domain of argument analysis, a key goal of the "infusion" approach (Robinson, 2011) and consistent with the call by Schmaltz et al. (2017) to teach students to "think like scientists."

Table 2

Mean Scores per Fallacy Type (3 points possible per type)

Fallacy Type	Pre-test Mean	Post-test Mean
False Cause	0.8	2.7
Hasty Generalization	0.9	2.6
Confirmation Bias	1.1	2.5
False Analogy	1.0	2.3
Appeal to Authority	1.2	2.1
Appeal to Nature	1.2	2.0

Conversely, "*appeal to nature*" and "*appeal to authority*" remained the most challenging fallacies even after instruction. This persistent difficulty underscores the complex nature of "debiasing" and points to the limits of a short-term cognitive intervention in overcoming deep-seated cognitive biases and cultural heuristics. It highlights the necessity of fostering a sustained positive disposition toward critical thinking (Facione, 1990), characterized by inquisitiveness and skepticism, as McLaughlin & McGill (2017) demonstrated. The particular challenge of *appeal to authority* may be compounded for some ESL students by cultural barriers, such as an unease with critiquing authority figures, as highlighted by Melles (2009). Therefore, while the results confirm that a short, explicit module, akin to the effective "general approach" (Orhan & Çeviker Ay, 2023) can successfully build foundational analytical skills, they also clearly delineate its scope. The development of a fully formed critical thinker is a long-term endeavor. It requires sustained practice across the medical curriculum to address ingrained biases and fully cultivate the intellectual disposition essential for clinical reasoning, a process that mirrors the "dynamic of belief and doubt" described by Wells (2009).

3.2 Qualitative Findings and Discussion

Thematic analysis of the interview data yielded three primary themes that elucidate how the intervention influenced students' cognitive and metacognitive processes.

3.2.1 Theme 1: The Internalization of a Systematic "Critical Lens"

A primary finding was that students consistently reported a fundamental shift in their approach to processing information, describing the internalization of a systematic critical lens. This was characterized by a new, automatic tendency to deconstruct claims and scrutinize the underlying structure of arguments, moving beyond passive consumption to active analysis. This shift was directly linked to the six fallacies, which provided a practical framework for interrogation. Students across the performance spectrum illustrated this by generating their own examples reminiscent of the instructional materials.High-performing students demonstrated a nuanced application of these concepts. One student articulated a sophisticated approach to causality and evidence: "*The most common trap is assuming cause where there isn't any. When I read, 'Patient recovery followed the new therapy, therefore it was effective,' my mind immediately flags* false cause. *I now automatically ask, 'Where's the control group? What about confounding variables?'* This same student showed how this lens applied to evidence quality: "*A headline like 'New study shows coffee causes cancer' based on one small sample is a clear* hasty generalization. *I've learned to immediately look for the study's size and methodology before even considering the conclusion."* Another high-performer highlighted heightened scrutiny of sources and comparisons, stating: *"I've become deeply skeptical of* appeal to authority... '*Nobel laureate in physics endorses this brain supplement'... their expertise in one field doesn't transfer to another.*" This student also demonstrated the ability to critically evaluate metaphors, identifying comparisons of the "*immune system to an army*" as potentially reductive false analogies that "*oversimplify a complex biological process.*"

Notably, this internalization of a critical lens was also evident among mediumperforming students, who reported that the framework provided essential clarity for navigating information. One student discussed the metacognitive impact of understanding confirmation bias: "*I didn't even realize I was cherry-picking evidence that confirmed my own beliefs... Now, when I start to form an opinion, I consciously ask myself,* '*What evidence am I ignoring?*' This student also described a changed perspective on marketing, overcoming the appeal to nature by reasoning: "*An ad claiming* '*chemical-free, all-natural cleaning products are safer*' *sounds right. But now I stop and think,* '*Cyanide is natural. Safety isn't about origin; it's about testing and dosage.*' Another medium-performer emphasized how the fallacies served as a pragmatic mental checklist, recalling a false cause example from class: "*'I got the flu shot and then got the flu, so the shot caused it*'*... It showed me how easily we can mistake sequence for cause.*"

This translation of taught concepts into an automatic, inquiry-based reflex demonstrates the cultivation of metacognitive self-regulation skills. The findings indicate that students were not merely memorizing definitions but were applying a full critical framework to evaluate information, thereby transitioning from passive recipients to active, analytical consumers, a cornerstone of lifelong learning (Facione, 1990). The ability of students across proficiency levels to generate their own examples and applications of the fallacies provides strong qualitative evidence for the intervention's effectiveness in fostering a sustainable critical disposition.

3.2.2 Theme 2: Navigating the Tension between Respect and Skepticism

Another significant finding was the cognitive conflict students experienced between the newly acquired skill of critical analysis and deeply ingrained cultural and academic norms of deferring to authority. This tension was particularly salient for medium and lowperforming students, who articulated the challenge of applying their analytical lens to established sources.

The struggle was most acute with the "*appeal to authority*" fallacy. A lowperforming student (Student E) articulated a common hesitation: "*My first instinct is to trust titles and credentials. It feels disrespectful to question a senior professor's published article or a clinic's official recommendation. The module made me anxious at first, was I being rude*?" However, this student also demonstrated growth, noting, "*But I learned that critiquing the argument isn't the same as attacking the person. I can respect a person's career and still point out that her claim uses a hasty generalization from her small clinical experience*." Another medium-performing student (Student F) highlighted how the framework provided a justified method for this scrutiny: "*It gave me permission to be skeptical. Now, when a renowned figure promotes a nutritional supplement, I see it as a potential 'appeal to authority'. I ask,* '*Is this their field of research? Where is their data?*'."

This newly developed skill of separating the source from the content extended beyond authority to other fallacies. A medium-performing student (Student G) discussed applying this to commercial sources: "*I used to see ads from pharmaceutical companies and just believe them. Now I see the appeal to nature in marketing all the time 'derived from natural ingredients!', and I know it's a marketing strategy, not proof. I can acknowledge the ad is professionally made while rejecting its flawed reasoning.*" Furthermore, students began to recognize this tension in their own reasoning, identifying their confirmation bias towards trusting certain sources. A low-performing student (Student H) reflected: "*I realized I was only skeptical of people I already disagreed with. If a source I liked made a false analogy, like comparing a complex drug interaction to a simple key turning a lock, I would accept it. Now I try to apply the same checklist to everyone, which is harder but fairer.*" For some, overcoming the correlation-causation fallacy was directly linked to their experience with the fallacy test. A high-performing student (Student I), who initially struggled with this, explained its resolution: *"On the pretest, I remember reading an item claiming that because students who studied while listening to music scored higher on an exam, the music must have caused the improvement. At that time, I thought that sounded reasonable. But on the post-test, I recognized this as a correlation-causation fallacy; other factors, like the students' study habits, could explain the results. The training helped me see the difference between correlation and true causation. It taught me to question the assumption, not just accept the claim.*" This theme underscores a critical developmental step: the transition from seeing criticism as disrespect to embracing it as a necessary component of rigorous, evidencebased practice. The fallacy framework provided students with a structured and impartial tool to navigate this sensitive terrain, allowing them to critique ideas without dismissing individuals, thereby fostering a more mature and professionally sustainable form of skepticism.

3.2.3 Theme 3: Transferring Skills to Patient-Centered Scenarios

A somewhat unexpected finding was the extent to which students reported transferring logical fallacy concepts from academic text analysis to authentic, patient-centered scenarios. This application manifested in two key areas: deconstructing health misinformation for themselves and improving their own future clinical communication to enhance patient understanding and informed consent. The *appeal to nature* fallacy was most frequently cited in this context. A low-performing student (Student J), who showed modest quantitative gains, provided a powerful example of personal discernment: "*I saw an ad for a 'natural' supplement that claimed to cure cancer. I used to think* '*natural*'meant *safe and effective. Now I immediately recognize it as an appeal to nature and I know to look for real clinical trial data instead. More importantly, I can picture myself explaining this to a future patient, not just dismissing their idea, but explaining why that argument is misleading.*" This concept of explaining *why* was echoed by a high-performing student (Student K), who described using an understanding of *false cause* to improve preventive health communication: "*I can now anticipate how patients might misunderstand causality. For example, if someone says,* '*I got sick right after my flu shot, so the shot gave me the flu,' I won't just say* '*no.*' *I'll explain the difference between temporal sequence and causation, perhaps using the analogy of roosters crowing before sunrise. It helps me plan how to gently correct misinformation without condescension.*"

Another medium-performing student (Student L) discussed using the concept of "*hasty* generalization" to evaluate and communicate risk: "*A patient might bring in an article about a celebrity who died after a vaccine. Before, I wouldn't have known how to respond. Now I see that as a hasty generalization from a single anecdote. I can explain that we need to look at* population-level *data from millions of people to truly understand risk versus benefit. It gives me a framework for that conversation.*" Students also reported applying the framework to their own reasoning to avoid reasoning error. A highperforming student (Student M) connected '*confirmation bias*' to decision-making: "*The module made me realize that confirmation bias isn't just about reading; it's a trap when evaluating health information online. If I go searching for info about a new diet already hoping it will work, I'll naturally click on and remember all the success stories while dismissing critical reviews or scientific critiques. Now, I have a mental note to actively ask myself,* '*What am I missing? What evidence contradicts this?*'" This is directly about becoming a more critical consumer of health information. Furthermore, a mediumperforming student (Student N) described how identifying false analogies in health product marketing changed their perspective: "*I saw a supplement advertised as* '*cleansing your liver like a filter in a car.*' *That's a classic false analogy; it sounds logical but is biologically meaningless. Recognizing that helps me personally avoid being swayed by expensive, pseudoscientific products because I can now see how those catchy comparisons are used to make empty claims seem legitimate.*"

Finally, a low-performing student (Student O) demonstrated profound professional growth by linking *appeal to authority* to informed consent: *"Even if a famous doctor on TV promotes a treatment, I now know that's not enough. I will have to make sure their consent should be based on the evidence, not on the fame of the person recommending it."* This theme highlights the highest level of knowledge transfer: the assimilation of critical thinking skills into the nascent professional identity of a physician. Students began to view the fallacies not as an academic exercise, but as essential tools for patient advocacy, ethical practice, and clear communication, ultimately aiming to empower patients through rational explanation.

CONCLUSION

The mixed-methods approach yielded a robust and coherent narrative, demonstrating that the intervention was effective not only in producing a significant quantitative gain in fallacy detection scores but also in fostering a profound qualitative shift in students' critical thinking dispositions and professional self-concept. The triangulation of data provides a comprehensive picture of both the measurable outcomes and the underlying cognitive and affective journey of the students. With the quantitative data, the statistically significant improvement in pre- and post-test scores objectively demonstrates that students acquired the foundational skill of identifying and explaining fallacies. This confirms that explicit instruction was successful in building cognitive competency, even though the effectiveness of individual teachers' instructional practices can also influence the extent to which a lesson achieves its aim of developing students' critical thinking (Ohle-Peters, McElvany, & Ullrich, 2023).
The qualitative data richly elaborates on this statistical description, revealing *how* this competency was integrated into the students' intellectual habits and professional identity.

The themes illustrate a clear developmental trajectory:

1. Internalization: Theme 1 shows that students moved beyond rote memorization to internalize a systematic "critical lens," automatically applying the fallacy framework as a metacognitive checklist to deconstruct arguments across various contexts.
2. Reconciliation: Theme 2 reveals that students, especially medium and low performers, navigated the significant cognitive conflict between this new skeptical stance and deep-seated cultural norms of deference. The fallacy framework provided them with an objective tool to "separate the argument from the author," transforming criticism from an act of disrespect into a necessary practice of intellectual rigor.
3. Transfer and Identity Formation: Most significantly, Theme 3 showcases the highest level of learning: the transfer of skills into patient-centered scenarios. Students began to envision using these tools not for academic exercise but for core clinical tasks—combatting misinformation, improving informed consent, avoiding diagnostic error, and ultimately acting as advocates who empower patients through rational explanation.

This integration reveals a crucial nuance: while quantitative gains were significant across the board, the *qualitative application* varied. High performers quickly demonstrated nuanced use of the framework for complex analysis, while low and medium performers often leveraged it as a crucial, clarifying checklist to navigate information they previously found overwhelming or unquestionable. This suggests the intervention supported a range of learners in developing a critical disposition appropriate to their starting point. The convergence of data points to specific areas for future development. The persistent difficulty with fallacies like "*appeal to nature*" and "*appeal to authority*", noted in the quantitative analysis, is explained by the qualitative findings. These fallacies are not merely logical errors but can be powerfully reinforced by cultural heuristics and marketing strategies. Students' reports of tension and their conscious efforts to overcome bias can be used as an indication that dismantling these fallacies may require more than one module; it necessitates sustained effort across the curriculum to reshape deeply held beliefs. In conclusion, this mixed-methods approach provides a complete account of the intervention's impact. The test scores prove that students *can* perform the skill. The interviews reveal that they are also beginning to think and act as critical consumers of information, actively integrating these skills into their evolving identity as future physicians who value evidence, clarity, and ethical patient care. This demonstrates a successful transition from passive knowledge acquisition to the active cultivation of a critical mindset essential for lifelong learning and practice in medicine.

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