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The Impact of Primary Literature-Based, Critical Thinking Activities on Competency Enhancement for Pre-Health Students

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Abstract: Thinking and reasoning competencies are crucial for the success of future healthcare professionals and are noted as pre-professional competencies for medical school admissions. At Agnes Scott College, our graduate-level Medical Cell Biology class focuses on cellular structure and function in human disease. In this course, students complete assignments meant to foster critical thinking competencies, wherein they analyze primary articles on the cellular pathogenesis of disease and relevant drug therapies. To assess student perspectives on these assignments, we developed a survey to gauge student attitudes toward the effectiveness of these assignments in supporting their learning and preparing them as applicants to various health professions programs. Attitudinal data shows that these assignments have helped students think critically when evaluating scientific literature and bolstered their understanding of cell biology in the progression and treatment of human pathologies, better preparing them for their future careers in the health professions.

Keywords: competency; critical thinking; STEM; primary literature; pre-health

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1. Introduction

Critical thinking in the classroom can help students navigate various real-world situations. Admissions committees for health professions programs, such as medical schools, evaluate various applicant competencies, including critical thinking and reasoning skills as described by the American Association of Medical Colleges (AAMC) [1]. We sought to analyze the impact of assignments that promote higher-level thinking and the integration of knowledge by utilizing primary literature to relate content to real-world applications. These assignments help guide students using primary literature to address topics including the application of drug therapies and disease treatment strategies. These assignments were specifically designed to support student learning as they progress through programs aimed at helping them transition into careers in healthcare.

To promote career readiness, programs invested in working with students entering the health professions should support students through experiences that promote the acquisition or enhancement of pre-medical core competencies [1]. Enhancement of these core competencies aligns with the goal of many medical schools, which is to matriculate students who demonstrate the specific skills and attributes that will be enhanced in medical school and throughout their profession in healthcare [2].

Instructional strategies that focus on problem-solving and real-world situations that promote understanding have a positive impact on student learning gains [3]. In STEM classrooms, learning the core content for a class can develop scientific competencies. These scientific competencies include applying their knowledge related to topics including biomolecules, cells, organs, and organ systems [1]. Furthermore, certain pedagogical methods can help students enhance their thinking and reasoning competencies, including critical thinking. Critical thinking-focused teaching practices can promote higher-level thinking and encourage students to ask questions and delve deeper as they process and analyze information, while also enhancing student engagement in the learning process [4].

Other studies have shown that designing courses that encourage students to regularly use higher-order thinking and problem-solving can improve academic performance and reduce the achievement gap between historically served and historically underserved student populations [5].

It can be difficult to conceptualize critical thinking; however, it has been described as having the intellectual resources, including conceptual knowledge and strategies, to approach a task or problem [6]. Others postulate that critical thinking can be demonstrated by utilizing knowledge and different ways of thinking at the appropriate time [7]. Studies have shown a need to have students utilize critical thinking throughout an entire curriculum to develop and strengthen their ability to solve complex problems for future use in a clinical setting [8,9]. The important need for critical thinking during the training of healthcare professionals can be addressed at various stages of their learning, from the undergraduate classroom through their medical training [10].

Analysis of primary literature prompts students to analyze and interpret data. Additionally, primary literature analysis can contextualize the importance of student learning in real-world scenarios. Previous work has shown that this teaching methodology promotes student gains in data interpretation and improves their self-efficacy regarding the understanding of primary literature [11]. Primary literature analysis can be implemented in various ways, depending on factors such as classroom size and course level, to promote learning gains in written and oral competencies [12]. The selection of specific literature for a class or project should be based on criteria that map to course learning outcomes [13]. Primary literature analysis as a teaching tool in STEM classes has been studied in many types of courses and has been shown to engage learners to promote scientific understanding [14–21]. For example, primary literature analysis has been utilized in an Immunology course to introduce new advances and drug therapies that may not be included in a textbook [19].

According to the AAMC applicant and matriculant data table (2022), students applying to health professions programs face an extremely competitive application process. Medical school admissions committees consider both the academic accomplishments and the premedical core competencies of each applicant [1]. Many graduate and post-baccalaureate programs help define a path to professional program acceptance, including medical school, dental school, and physician assistant programs [22]. The inclusion of primary literature analysis and other critical thinking-centered pedagogies may positively impact the matriculation of students from undergraduate to professional programs. This was demonstrated in the study by Kozeracki et al., in which an undergraduate program with a primary literature-based curriculum increased student acceptance into M.D., Ph.D., and M.D./Ph.D. programs [23].

Agnes Scott College (ASC) launched Master of Science in Medical Sciences (MDS) programs starting in 2022. These programs are designed to help students enhance their applications for acceptance into health professions programs. Our courses and advising models are intended to promote student gains in competencies related to academic performance, as well as to help them develop the skills, attributes, and attitudes necessary to succeed as healthcare professionals. Medical Cell Biology is a graduate-level course that is required for all students enrolled in MDS programs at ASC. In this course, students explore human disease, diagnostics, and therapeutics at the cellular level. The course utilizes a textbook and various active learning strategies to teach the scientific content. Medical Cell Biology assignments were developed wherein students analyze peer-reviewed manuscripts on relevant molecular pathologies and drug therapies. In this study, we sought to determine if these assignments enhanced critical thinking competencies among MDS students. To assess this possibility, we surveyed students about the impact of these assignments on their thinking and reasoning and their preparedness for application to health professional programs.

2. Materials and Methods

Design and Materials: A mixed methods study was conducted for graduate students in the Master of Science in Medical Sciences program at Agnes Scott College who were enrolled in Medical Cell Biology. The survey was administered to students at the end of the semester. There were two cohorts of the study. In the first cohort (fall 2022 and summer 2023 semesters), data were collected using a Likert-scale attitude measurement consisting of seven items on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). In the second cohort, fall 2023, the identical Likert-scale survey was given, but with corresponding open-ended questions. The open-ended questions prompted students to expand on the impact of the individual assignments related to the Likert-scale survey questions (1 through 7). The open-ended questions were aligned with the American Association of Medical Colleges Competencies [1] (Table 1). Additionally, demographic data (Table 2) were collected in both cohorts of the study. The survey in its entirety can be found in Supplementary File S1. The instrument and research methodology were approved by the Agnes Scott College Institutional Review Board Committee.

Table 1. Alignment of attitudinal survey questions with American Association of Medical Colleges (AAMC) Competencies. Survey questions administered (left column) were aligned with selected AAMC competencies including science competencies, thinking and reasoning competencies, and professional competencies. (x) indicates alignments between the assessment question and competency.

	Science Competencies: Human Behavior, Living Systems	**Thinking and Reasoning Competencies: Critical Thinking, Scientific Inquiry, Written Communication**	**Professional Competencies: Commitment to Growth and Learning**
Q1: The assignments given in this course helped my understanding of the course content.	x		
Q2: The assignments given in this course increased my ability to relate cellular components to their functions	x		
Q3: The assignments given in this course helped me to learn and understand complex relationships in cell biology.	x		
Q4: The assignments given in this course helped me to integrate information from multiple sources to understand the impact of various drug treatments and therapies.	x	x	x
Q5: The assignments given in this course helped me to use critical thinking skills to interpret and analyze data	x	x	x
Q6: The assignments given in this course increased my ability to examine scientific research in cell biology as it relates to real-world problems	x	x	x
Q7: Based on the critical thinking skills that I gained in this course, I feel more prepared to apply to my health career program of interest.		x	x

Table 2. Self-Reported Student Demographics. In addition to the attitudinal questions, the end-of-course survey comprised demographic questions (Table 2) with the following response options: (1) Ethnicity: Hispanic or Non-Hispanic; Race: Asian American or Pacific Islander, Black or African American, White or Caucasian. Alaskan Native, American Indian, Two or more races, or another race/ethnicity not listed above; Gender: Female, Male, Non-binary/Third gender, Prefer not to say.

Race and Ethnicity	***Number***	***Percentage***
Black or African-American, Non-Hispanic	45	78.9%
White, Non-Hispanic	5	8.8%
Asian-American or Pacific Islander, Non-Hispanic	4	7%
Hispanic, Any Race	2	3.5%
Alaskan Native, American Indian, Two or More Races, Non-Hispanic	1	1.8%
Gender	***Number***	***Percentage***
Female	55	96.5%
Male	2	3.5%

Data Collection: Data were first collected in the first cohort of the study during the fall 2022 and summer 2023 semesters, with 42 respondents out of 53 enrolled students, a ~79% response rate. During the second cohort of the study in fall 2023, additional data from 15 students were collected out of 17 enrolled students, a ~88% response rate. One student in the fall 2023 cohort responded to the survey twice. This student's second response to the survey, which was similar to her first response, was removed from the data set before analysis. Collectively, this yielded a total of 57 participants across both cohorts of the study.

Analysis: Descriptive statistics were first conducted across all Likert-scale and demographic questions. Questions were analyzed using the statistical software IBM SPSS Statistics (Version 29). Open-ended questions were analyzed using a qualitative thematic exploratory approach [24]. Questions were grouped by AAMC competencies (Table 1). Two researchers independently created themes, and then themes were compared between researchers. Differences were discussed and negotiated until both researchers agreed on final themes [24].

3. Results

Quantitative and qualitative approaches were used to assess the impact of the Medical Cell Biology primary literature assignments on the MDS students' critical thinking. Study finding analyses are presented below, in two sections:

Quantitative Findings: Across both cohorts of the study, students completed seven Likert-scale items (Q1–Q7). Students rated their agreement with each statement on a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). These questions were designed to investigate whether students supported the assertion that the assignments designed to promote critical thinking using primary literature were effective. The questions prompted students to address whether these assignments helped them to understand and integrate course content and to apply critical thinking competencies when analyzing data and researching drug therapies to help prepare them for careers in healthcare. Additionally, these questions were directly related to several AAMC competencies, including science, thinking and reasoning, and professional competencies (Table 1).

In response to questions about whether assignments positively promoted their understanding of course content (Q1), their ability to relate cellular components to cellular function (Q2), and their understanding of complex relationships (Q3) in cell biology, 90–95% of students strongly agreed or agreed with each statement. For questions related to whether assignments positively impacted their ability to integrate information (Q4), utilize critical thinking skills (Q5), and relate research to real-world problems (Q6), more than 90% of

students strongly agreed or agreed with each statement. Lastly, 96% of students strongly agreed or agreed that the critical thinking skills gained in the course better prepared them to apply to their health career of interest (Q7). Overall, these results indicate that the assignments, activities, and course content promoted student competencies, including critical thinking and reasoning skills.

Qualitative Findings: As previously discussed in Section 2, during the second cohort of the study, students were prompted to respond to open-ended questions that corresponded with each Likert-scale question (Q1–Q7). These open-ended questions prompted students to give an example of a specific assignment from the class that was linked to their responses to Q1–Q7. The questions were grouped into two categories: (1) content and application of knowledge (Q1, Q2, Q3) and (2) critical thinking and application (Q4, Q5, Q6). See Table 3 below for themes and student quotes.

Table 3. Thematic Coding. Student responses (Fall 2023 cohort; n = 15) to open-ended survey questions were analyzed for themes. Attitudinal questions were grouped into two categories: (1) content and application of knowledge (open-ended questions related to attitudinal questions Q1–Q3) and (2) critical thinking and application (open-ended questions related to attitudinal questions Q4–Q6).

Content and Application of Knowledge: Open-Ended Questions Related to (Q1–Q3)	
Theme	**Representative, Supporting Student Quotes**
Synthesis	*"The chapter 8 assignment especially helped me understand the complex relationship between small cellular processes and large processes such as reflex and movement."* *"I was able to understand how many different proteins can be produced from one gene expression"*
Explicit Reflection	*"Worksheets given to us to test whether or not we can completely understand the learning objectives"* *"in-class assignments related to the ppt we just finished. The assignment always reflected the material."*
Application; Purpose	*"Analyzing and understanding related diseases and real world implications of the raw content we learned in class was helpful for me in every chapter."* *"Though I think that all of the assignments increased my understanding, the chapter 8 assignment especially helped me understand the complex relationship between small cellular processes and large processes such as reflex and movement."*
Drug Therapies and Disease at the Cellular Level	*"This assignment really helped me to understand the implications of mitochondrial dysfunction and how different types impact different functions of the cell."* *"The assignment going over Sotorasib better helped me to understand the Ras protein function better."*
Critical Thinking and Application: Open-Ended Questions Related to (Q4–Q6)	
Theme	**Representative, Supporting Student Quotes**
Intentional linkage between drug therapies and disease	*"Chapter 4 Botox Assignment increased my ability of how botox can be a form of treatment or therapy for various diseases and come to an understanding of how it can positively impact a variety of patients."* *"The chapter 11 assignment was very helpful in understanding the impact of different drug therapies and the clinical trial process that goes into developing them."* *"The chapter 10 worksheet on Palbociclib in Hormone-Receptor–Positive Advanced Breast Cancer and Chapter 8 assignment on Diazepam [sic] were beneficial to understand how drug therapies work."*
Understanding Research Processes and Methodologies	*"Almost every assignment asked us to analyze and describe a figure, which I thought was an invaluable skill to learn and it really sharpened my ability to analyze and interpret data and graphs."* *"End of Chapter Assignments, specifically Ch. 11 Assignment really tested my critical thinking skills and my ability to interpret and analyze data between different figures presented in the scientific research and come to conclusions based on the data."*
Transfer of to Real-World Application	*"the assignments related questions about pathways and cell functions to actual medications being used for ailments people suffer from today. I think they all showed me how to examine scientific research as it relates to real world problems."* *"The chapter 4 assignment relating to botox was a real world examples about how botox can be used to help people with muscle spasms rather than [sic] just beauty treatment."*

During data analysis, specific themes in student open-ended responses were identified. These themes demonstrate key features from the Medical Cell Biology course, which affected students' learning in this course regardless of what assignments they identified. Responses were grouped into these themes to capture trends in the data. For the first category of questions (Q1–Q3) related to content and application of knowledge, the four themes that were identified as follows:

1. *Synthesis*: The students express how activities in the course aligned with how they understood the content overall.
2. *Explicit reflection*: Students describe how assignments in the course led them to consistently and intentionally reflect on the course content.
3. *Application/purpose*: Students recognize the larger, real-world application of what they are learning about cellular biology.
4. *Drug therapies and disease at the cellular level*: Students' ability to understand the relationship between the two concepts.

For the second category of questions (Q4–Q6) related to critical thinking and application, a total of three themes were identifiedas follows:

5. *Intentional linkage between drug therapies and disease*: Students describing the relationships between drug therapies and disease.
6. *Understanding research processes and methodologies*: This describes the various skills gained through continued exposure to primary literature, including synthesis, analysis, and understanding visual representation of data
7. *Transfer to real-world application*: Students explain how case studies and primary literature from this course also apply to problems in the everyday lives of possible future patients.

These qualitative results indicate features of the course in which students self-identify their engagement with real-world problems in conjunction with exposure to primary literature (Table 3).

4. Discussion

The Master of Science in Medical Sciences curriculum at Agnes Scott College incorporates classroom and experiential-learning opportunities that allow students to gain competencies associated with admission to professional programs rooted in healthcare [1]. In many STEM courses within health professions-related programs, the science competency attainment is addressed by teaching content that health professionals will utilize throughout their careers. To enhance competencies related to thinking and reasoning, as well as professional competencies such as a commitment to growth and learning, competency attainment should be intentionally integrated throughout the curriculum.

In this study, we sought to investigate whether course assignments that utilize primary literature and incorporate real-world, clinical scenarios would help promote critical thinking in our students. These assignments, implemented in Medical Cell Biology, used primary literature to relate the science of cell biology to disease, disorders, and clinical therapies. These assignments were designed to help students integrate and apply class content and promote competencies that health professions programs evaluate in their applicants (Table 1).

To gauge student perspectives on the impact of the primary literature assignments on acquiring their science, thinking and reasoning, and professional competencies (Table 1), we collected attitudinal data from students via an end-of-semester survey across two cohorts. Quantitative data from the first and second cohorts showed that students overwhelmingly had positive responses (agree or strongly agree) to questions asking about the impact the assignments had on their learning and application of knowledge (Figure 1). These attitudinal data suggest positive student perceptions of the impact of the primary literature assignments on their critical thinking. However, further, targeted analyses are needed to determine the impact of these assignments on specific thinking and reasoning competencies.

Student participants in the second cohort had additional open-ended questions about the assignments, allowing for qualitative analysis of their perceptions of their learning and the relevance of associated assignments. Two groupings of themes were identified that aligned with the student experience related to (1) the acquisition of content knowledge or (2) the application, integration, and real-world relevance when applying that knowledge using critical thinking and reasoning skills (Table 3). Themes arising from student responses include synthesis, the intentional linkage between drug therapies and disease, and the transfer of knowledge to real-world applications, among many others. Quotes from Q1–Q3 display how students felt when interacting with the different assignments. Explicit instruction with these activities by the faculty created a learning environment that made the content relevant and engaging for students. This intentional connection between course content, instruction, and in-class activities has been supported in science education and pedagogical research to help with learning [25–28]. Quotes from Q4–Q6 highlight how our assignments designed to promote critical thinking, including reading primary literature and working through case studies, have prompted these students to recognize that they have transformed their classroom knowledge into real-world application. Taken together, these qualitative data suggest that students are developing practices to assess and evaluate information within the context of course content, which aligns with the Bailin et al. definition of teaching critical thinking [6]. Previous studies yielded similar findings, demonstrating that primary literature in the classroom enhances many skills such as creating links between topics, understanding the broader implications of science, and analyzing processes [12,21,29]. Collectively, our findings suggest that most students see the value of the various features of the Medical Cell Biology course, especially the enhancement of their understanding of drug therapies and diseases by examining challenging real-world problems in primary literature.

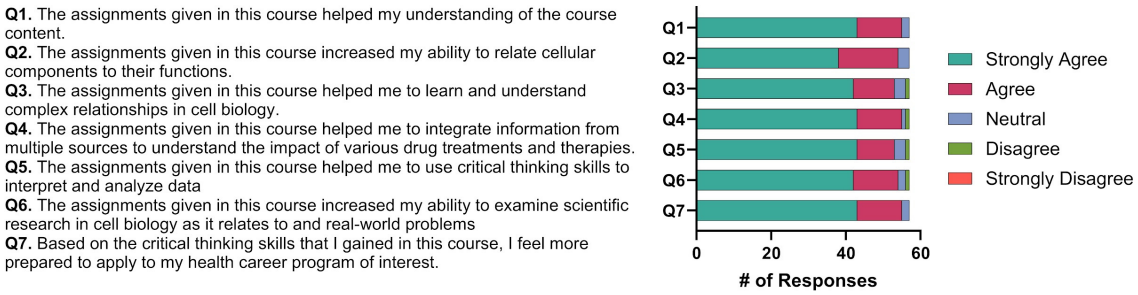

Figure 1. Attitudinal Assessment. Medical Cell Biology students (combined fall 2022, summer 2023, and fall 2023 student responses, n = 57) were given an end-of-course attitudinal survey (Q1–Q7, **left**)) with Likert-scale responses (strongly disagree; disagree; neutral, agree, strongly agree) about the primary literature assignments. Student responses were aggregated and frequencies for each Likert-scale response were determined (**right**).

Taken together, our quantitative and qualitative data suggest that students feel that the primary literature assignments in Medical Cell Biology positively impact their learning and help them gain specific competencies that are evaluated by admissions committees. It is important to note that students within this master's program also take a biostatistics course that utilizes primary research articles covered in Medical Cell Biology. This is important, as the curricular experiences aim to ensure that not only do students utilize their critical thinking competencies but have the training to help their analytic skills when reading and interpreting primary literature. It has been demonstrated that integrating critical thinking and problem-solving skills throughout all stages of their training is integral for future healthcare professionals [8–10]. While others have found critical thinking-focused assignments improve attitudes and content gains among K-12 and undergraduate students [12–16,18–21], little has been studied regarding the impact of such pedagogical methods on healthcare profession-focused graduate students. Our current

study supports the use of assignments specifically designed to enhance AAMC competencies in pre-health professional programs. Enhancement of these competencies has been shown to correlate with student matriculation to professional programs [23]. Overall, this study suggests that primary literature, critical thinking-focused assignments help graduate students obtain competencies needed for admission to medical school and related health profession programs. Our findings broadly support the implementation of curricula to enhance specific AAMC competencies in pre-health programs at both the undergraduate and graduate levels.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/higheredu3030041/s1, Supplementary File S1 contains the survey questions administered to students in both cohorts of the studies.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Agnes Scott College (protocol code C2022-23-01 and date of approval 26 October 2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: Data is contained within the article or Supplementary Materials. The original contributions presented in the study are included in the article/Supplementary Materials. Further inquiries can be directed to the corresponding authors.

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