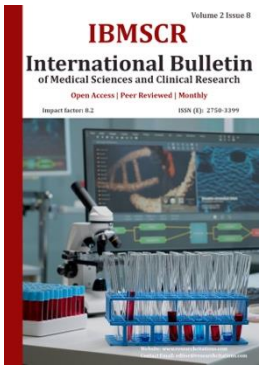

INVESTIGATING THE MOLECULAR GENETIC FUNDAMENTALS OF CANCER BIOLOGY AND THE PROCESS OF BIOMEDICAL ADVANCEMENTS WITHIN AN UPPER-LEVEL UNDERGRADUATE COURSE.

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Abstract

We outline an advanced undergraduate course in Cancer Biology characterized by an inquiry-driven approach, blending faculty lectures typical of undergraduate settings with literature-based discussions akin to those in graduate courses. Serving as a capstone course, its primary objectives include synthesizing knowledge from preceding coursework in physiology, cell and molecular biology, genetics, and chemistry to foster a contemporary comprehension of cancer and its treatment modalities. Another key aim is to familiarize students with scientific inquiry through primary literature exploration, elucidating how scientific advancements translate into enhanced cancer therapies. We detail the course's development and the strategies employed to meet its objectives. Additionally, we present findings from a 5-year survey that offers insights into class demographics and highlights noticeable enhancements in students' grasp of cancer biology and scientific methodology. Feedback from students strongly advocates for the integration of original literature as a pedagogical tool, underscoring its efficacy in promoting scientific literacy within advanced undergraduate science education.

Introduction

There has been a significant transition in university-level teaching methodologies, moving away from lecture-centric formats towards approaches that foster increased student engagement in the classroom. This paradigm shift was catalyzed by the American Association for the Advancement of Science (AAAS) "Vision and Change – A Call to Action" conference and its resulting report, advocating for heightened student involvement to enhance comprehension, satisfaction, and provide insight into scientific advancements. The report highlighted students' desire for more exposure to primary literature to grasp current scientific topics. Subsequently, the "Vision and Change in Undergraduate Biology Education – Chronicling Change, Inspiring the Future" conference, sponsored by AAAS, outlined efforts to fulfill the objectives outlined in the initial report. Various teaching strategies and programs, including capstone courses and initiatives like the CREATE program, which focuses on primary literature analysis to demystify science, were introduced to achieve these goals.

In this context, we present a capstone course in Cancer Biology that prioritizes primary literature readings to align with the objectives articulated in the AAAS "Vision and Change" reports. Harold Varmus' introduction to the inaugural volume of the Annual Review of Cancer Biology in 2019 provides a contextual backdrop, illustrating the evolution of Cancer Biology as a field and its increasing significance in scientific discourse. Despite substantial progress in

cancer research and treatment, the development of undergraduate courses in cancer biology has not kept pace with these advancements.

Our journey in developing a graduate-level "Cancer Biology" course nearly two decades ago eventually evolved into a popular inquiry-driven capstone course for advanced undergraduates. Rooted in principles of genetics, cell biology, and biochemistry, our course equips students with a comprehensive understanding of the molecular mechanisms underlying tumor genesis and treatment. Through assigned readings from primary literature, students gain insights into contemporary scientific methodologies.

Surprisingly, our exploration revealed a dearth of literature on teaching cancer biology at both undergraduate and graduate levels. To enhance the learning experience, we devised a survey instrument administered to students at the beginning and end of each semester, yielding valuable insights over a five-year period from 2017 to 2022. The survey findings indicate that prior coursework in biochemistry and molecular biology significantly correlates with success in our course. Moreover, students reported increased understanding in cancer biology and related disciplines, along with a heightened appreciation for the scientific process.

Overall, our findings underscore the efficacy of our course format, comprising structured lectures complemented by substantial literature analysis. We propose that this approach serves as a model for enhancing discipline-specific knowledge and fostering scientific literacy among undergraduate students across various disciplines.

Methods

The Study and Questionnaire

We had two primary motivations for creating a survey instrument. Firstly, we noticed a significant dropout rate among students after completing the initial section of the course, which delved into the historical origins of cancer research. This section emphasized the pivotal role of tumor virology and molecular genetics in uncovering oncogenes. Therefore, one aim was to discern why some students struggled with the foundational concept that cancer arises from mutations in genes with normal cellular functions. Secondly, for students who persevered through the entire semester, we sought to gauge how their engagement with primary research articles throughout the course influenced their comprehension of cancer research and their perception of scientific inquiry in general.

Collaborating with colleagues from the College of Education specializing in College Teaching, we crafted the survey, and obtained IRB approval. The survey, available in Supplement 1, was designed to be concise yet yield quantifiable data without consuming excessive class time. It was not an assessment of instructors but aimed to grasp students' demographics, academic background, and self-assessment of knowledge acquisition over the semester. Questions covered students' science background, including coursework and laboratory experience, and their perceived proficiency in disciplines relevant to cancer.

Certain questions, such as those regarding gender, departmental major, and previous courses, lent themselves to straightforward quantification. However, queries like "what is cancer" necessitated assigning numerical scores based on our evaluation of written responses.

Survey data were recorded in Excel spreadsheets, with names removed after pairing pre-course and post-course surveys for participants who completed both. Responses from students who finished the course but did not submit the post-course survey were included

only in the pre-course survey data. The analysis presented herein pertains solely to responses from undergraduate students.

To compare proportions in two samples, we employed a z-test and two-sided significance testing (e.g., investigating if gender influences attrition rates). Probit analysis was utilized for binary outcome analyses (e.g., "Do you know what an oncogene is?"), while a two-tailed paired t-test was employed for comparing pre- and post-course responses from students.

Results

History and Structure of Course

This course initially commenced at the graduate level, adhering to a traditional format common in graduate courses, wherein readings from contemporary literature formed the basis of study, with students tasked with presenting papers and leading discussions. However, given that many students lacked formal background knowledge in Cancer Biology as undergraduates, they often struggled to fully comprehend how individual papers contributed to the evolution of Cancer Biology as a discipline. Consequently, we introduced background lectures on specific topics preceding each set of papers to provide context. For instance, lectures on oncogenes and tumor suppressors, apoptosis, telomeres, and rational drug design preceded student-led discussions on a series of recent papers addressing the respective topics.

After several years of teaching, we received requests to include undergraduates in the course, prompted by the University's capstone course requirement. These capstone courses aim to challenge students to apply and integrate knowledge acquired in previous coursework. In the case of Cancer Biology, undergraduates were expected to utilize their foundational understanding gained from coursework in genetics and cell biology to grasp the principles of contemporary Cancer Biology. Additionally, they were encouraged to discern the connection between basic research in Cancer Biology and breakthroughs revolutionizing cancer therapy, with active participation in literature-based components integral to achieving these objectives.

Over subsequent years, the undergraduate enrollment in the course expanded significantly. Upon the publication of Robert Weinberg's comprehensive textbook "The Biology of Cancer" in 2015, we incorporated it to complement and enrich both lecture and literature components. We focused on selected topics covered in the Weinberg textbook, purposefully rearranging the sequence of various topics. Furthermore, we introduced three introductory lectures at the course's outset to review essential concepts in genetics and molecular/cell biology, which students were expected to be familiar with from prior coursework. The course syllabus for 2022 can be found in Supplement 2.

The course integrates readings from primary literature as a pivotal element, dedicating one class period per week, termed "Beyond the Book," to in-class discussions of assigned papers. Students are required to prepare by reading the paper beforehand and come prepared to engage in discussions during class. To aid in developing the skill of independently reading and comprehending primary research articles, a set of study questions accompanies each paper. These questions encompass specific aspects of the paper as well as background inquiries on techniques and concepts. Additionally, brief "News and Views" style reviews are often provided to contextualize the current work. Led by one of the instructors, the in-class discussions aim to involve as many students as possible, ensuring active participation. Before delving into the paper's discussion, students are given a brief quiz derived from the study

questions provided with the assigned article. This approach fosters accountability among students for reading the paper and enhances their willingness to engage in class discussions. The quizzes are graded and collectively contribute to 25% of the final grade, with quiz questions frequently serving as discussion starters.

The literature discussion in class spans from addressing the study questions to conducting a detailed analysis of experimental techniques and data presented in selected figures from the paper. Emphasis is placed on the historical context of the work and its impact on the evolution of cancer biology and cancer treatment. While there is no expectation for students to always provide the "correct" answers, they are encouraged to synthesize responses based on their knowledge base. Students are also encouraged to pose questions, and class discussions often evolve based on student inquiries. Both instructors are present for all class sessions and contribute to all aspects of the course, including literature discussions. The diverse perspectives offered by the instructors help students understand that science is not merely a collection of memorized facts but a dynamic and multifaceted discipline.

Selection and Integration of Primary Research Articles into the Course

The fundamental requirement for students to engage with and comprehend primary research articles sets this course apart from many other capstone offerings. A key challenge lies in the selection of primary research papers that (a) have significantly contributed to advancing our understanding of cancer, (b) clearly delineate the research questions posed and the experimental methodologies employed to address them, and (c) serve as effective tools for students to grasp how scientists present and analyze data. Recognizing that the ability to read and comprehend primary research articles is a skill honed through iterative practice, students in our course undertake the reading and discussion of 15 papers throughout the semester. The reading lists spanning the years 2017–2022 are appended in Supplement 3, with study questions from 2022 provided in Supplement 4.

The initial segment of the course offers a historical overview of the underpinnings of modern Cancer Biology. Papers selected for this section detail the discovery of proto-oncogenes, elucidate genetic mechanisms underlying the conversion of proto-oncogenes to oncogenes, and explore biochemical mechanisms driving cancer cell proliferation. These seminal papers present a challenge for students, necessitating comprehension of molecular techniques such as nucleic acid hybridization and gene cloning, along with cell biological approaches like subcellular fractionation. Despite encountering these techniques in their genetics and cell biology coursework, engaging with papers utilizing these methods compels students to articulate how these technologies have facilitated the acquisition of novel knowledge.

The central portion of the course delves into intracellular signaling pathways governing various facets of cell cycle progression and apoptosis. Introduction of tumor suppressor genes underscores the intricate interplay between oncogenes and tumor suppressor genes. Papers in this segment center on apoptosis, pivotal in understanding cancer biology and treatment. A curated selection of papers elucidating critical aspects of how dysregulation of apoptosis contributes to cancer, alongside how a nuanced understanding of apoptosis has spurred innovative cancer therapies, is presented. Notably, this section incorporates several papers from the laboratory of Anthony Letai, renowned for their clarity and ability to elucidate central concepts driving cancer research in this domain.

During the final segment of the course, significant emphasis is placed on the evolution of targeted drug therapies for cancer and the mechanisms underlying tumor resistance to treatment. Additionally, attention is drawn to the development of therapies targeting non-tumor cells. The selection of papers for this portion of the course varies annually, with a focus on recent research articles that underscore the impact of fundamental science on the clinical management of cancer. Notably, papers addressing topics such as cancer stem cells, genetic heterogeneity of tumors, and immunotherapy are frequently incorporated into this segment. Furthermore, this part of the course serves as a platform to showcase examples of how advancements in experimentation have challenged previously entrenched beliefs, such as revising perspectives on the role of epithelial-to-mesenchymal transition in metastasis.

Examinations

Our examinations are designed to underscore the paramount concepts in cancer biology while necessitating an understanding of how these concepts are substantiated through experimentation. Specific questions pertaining to the weekly readings are included, along with inquiries that integrate these papers with the lectures delivered throughout the course. Moreover, we present questions where additional data from related papers are provided for students to analyze and interpret. To further enhance comprehension, we furnish news reports on recent cancer studies and prompt students to elucidate the experiments or techniques likely employed to arrive at the study's conclusions. Examinations and corresponding answer keys from 2015 are available in Supplement 5.

To facilitate preparation, two out-of-class review sessions precede each examination, drawing participation from the majority of students. We have also explored post-examination review sessions with the intention of reinforcing covered concepts. However, we observed that post-review sessions were not favorably received by students.

Portrait of the Classes: 2017–2022

Table 1 illustrates the breakdown of students enrolled in this rigorous and advanced course, delineated by year. Notably, the demographic composition of the course remained relatively stable throughout the five-year survey period. At the outset of each semester, a total of 176 undergraduate students were surveyed in August. It is noteworthy that 52% of the students identified as male, while 48% identified as female. Regarding academic majors, 74% were pursuing degrees in Biological Sciences, 20% were Biochemistry majors, and 5% were enrolled in other disciplines.

Table 1. Demographics of registered students. UGs = undergraduates; Biology = Biology major; Biochem = Biochemistry major; Other = all other majors

Year	Total UGs	Males	Females	Biology	Biochem	Other	Complete	Did not complete	Males (did not complete)			Females (did not complete)		
									Biology	Biochem	Other	Biology	Biochem	Other
2017	29	16	13	20	7	2	23	6	2	1	0	3	0	0

Year	Total UGs	Males	Females	Biology	Biochem	Other	Complete	Did not complete	Males (did not complete)			Females (did not complete)		
									Biology	Biochem	Other	Biology	Biochem	Other
2019	29	16	13	20	6	3	23	6	0	2	2	2	0	0
2020	36	21	15	29	5	2	22	14	7	1	0	5	0	1
2021	39	17	22	27	11	1	29	10	3	0	1	5	1	0
2022	43	21	22	35	7	1	36	7	5	0	0	2	0	0
5 yr total	176	91 (52%)	85 (48%)	131 (74%)	36 (20%)	9 (5%)	133 (76%)	43 (24%)	17	4	3	17	1	1
5 yr Av.	35	18	17	26	7	2	27	9	3	< 1	< 1	3	< 1	< 1

Table 1 also shows year-by-year breakdown of the students who complete the course or drop the course, typically after the first examination. Over 5 years, 133 students (76%) completed the course and 43 students (24%) dropped the course. Of those students who dropped the course, 24 were male (56%) and 19 were female (44%). Thus, there was no substantial gender bias compared to the initial enrollments of 52% and 48%, respectively ($p = 0.553$). Of the students who dropped the course, 79% (34 students) were Biological Sciences majors, 12% (5 students) were majoring in Biochemistry, and 9% from other majors. Thus, Biological Science majors dropped the class commensurate with their representation in the class (79% compared to 78% total in the class), whereas Biochemistry majors dropped less frequently (12% compared to 20% total in the class), but there was no significant difference between the groups ($p = 0.142$). The remainder of the students who dropped the course were students from the other majors.

For a deeper understanding of why 24% (43 out of 176) of initially enrolled students did not complete the course, an investigation was conducted to determine if prior coursework could predict course completion. The prerequisites for enrollment in Cancer Biology mandated only

sophomore/junior-level courses in Genetics and Cell Biology. However, some students had undertaken additional upper-level coursework in Biochemistry and/or Molecular Biology (refer to Table 2).

In total, 101 students (comprising 56 males and 45 females) had previously completed either Biochemistry or Molecular Biology courses, while 75 students had not undertaken either of these advanced courses. Among the 101 students who had taken either Biochemistry or Molecular Biology, only 18 students (18 out of 101; 18%) dropped the course. In contrast, among the 75 students who had not taken either Biochemistry or Molecular Biology, 25 students (25 out of 75; 33%) dropped the course.

Analysis of these findings indicates a significant difference ($p = 0.017$) in dropout rates between students who had previously taken Biochemistry or Molecular Biology courses and those who had not. Consequently, it is evident that students who had completed coursework in Biochemistry or Molecular Biology were notably less likely to drop the course, underscoring the advantage of prior exposure to these subjects for success in the course.

Table 2. Prior coursework in Biochemistry and Molecular Biology contributes to success in the course. BC = taken Biochemistry; MB = taken Molecular Biology

	Completed the course (5 yr total = 133)					**Did not complete the course (5 yr total = 43)**				
	Male		**Female**			**Male**		**Female**		
Year	**BC**	**MB**	**BC**	**MB**	**Total (BC or MB)***	**BC**	**MB**	**BC**	**MB**	**Total (BC or MB)***
2017	7	1	5	4	15*	2	0	0	2	4*
2019	5	1	7	4	12*	3	0	0	0	3*
2020	7	3	1	4	14*	2	1	0	0	3*
2021	10	2	9	2	18*	1	0	3	0	4*
2022	10	4	17	4	24*	2	1	1	0	4*
5 yr total	39	11	39	18	83†	10	2	4	2	18†

* These values indicate students who took Biochemistry or Molecular Biology. Students who took both Biochemistry and Molecular Biology are only counted once. Of the 176 students who registered for the course, 101 had previously taken either Biochemistry or Molecular Biology, whereas 75 had not taken either of these advanced science courses. Of the 43 students who did not complete the course (see Table 1), 25 had not taken either of these advanced science courses.

† A *z*-test and two-sided test of significance showed that students who took BC or MB were more likely to complete the course (*p*-value of 0.017).

We examined whether prior familiarity with cancer concepts correlated with course completion. The survey comprised two binary questions, asking students if they were

acquainted with oncogenes and tumor suppressor genes, foundational concepts in cancer biology (refer to Table 3). The majority of respondents answered affirmatively to both questions, with 146 out of 176 total responses (83%) affirming familiarity with oncogenes and 151 out of 176 (86%) affirming familiarity with tumor suppressor genes.

Among the 30 students who indicated unfamiliarity with oncogenes, 13 did not complete the course (13 out of 30; 43%). In contrast, among the 146 students who claimed to be familiar with oncogenes, 30 did not complete the course (30 out of 146; 21%). Therefore, lack of familiarity with the term "oncogene" emerged as a significant predictor of non-completion of the course ($p = 0.008$).

Table 3. Self-reported understanding of “oncogene” and “tumor suppressor”

Question (5 yr total = 176)		**Completed the course (5 yr total = 133)**	**Did not complete the course (5 yr total = 43)**	
Do you know what an Oncogene is?	Yes	No	Yes	No
	116 (87%)	17 (13%)	30 (70%)	13 (30%)
Do you know what a Tumor Suppressor is?	Yes	No	Yes	No
	116 (87%)	17 (13%)	35 (81%)	8 (19%)

Among the 25 students who indicated unfamiliarity with tumor suppressors, eight did not complete the course (8 out of 25; 32%). Conversely, among the 151 students who claimed to be familiar with tumor suppressors, 35 did not complete the course (35 out of 151; 23%). Thus, lack of familiarity with the term "tumor suppressor" did not emerge as a predictor of non-completion of the course ($p = 0.342$). This disparity could stem from students potentially overestimating their comprehension of the lay language term "tumor suppressor" compared to its strictly scientific counterpart "oncogene."

We explored the involvement of students in undergraduate research in faculty laboratories, hypothesizing that prior research experience might influence student success in the course. Students were asked to indicate the number of semesters they had spent working in a research laboratory. The reported durations of research involvement varied widely, ranging from 0 to 7 semesters. However, there was no discernible correlation between student participation in research and their performance in the course (data not presented).

The Learning Experience

Examination of the survey data has yielded valuable insights into the educational benefits accrued by students through the course's learning endeavors. We sought to ascertain both the acquisition of discipline-specific knowledge and the students' broader comprehension of scientific methodologies. For these analyses, we focused on data obtained from the 118 students who successfully completed the course and provided responses to both the pre- and post-course surveys. While recognizing the inherent limitations of relying on self-reported

assessments of mastery in a given subject, we believe that this approach offers valuable insights into the students' learning journey.

Students were queried about their proficiency in Genetics, Cell Biology, and Molecular Biology. The collective responses over the five-year period from these 118 students are detailed in Table 4. Notably, the self-reported enhancements in understanding across these subjects were statistically significant (p values <0.001). This finding underscores the efficacy of teaching Cancer Biology with a robust emphasis on fundamental experimental biology principles, thus bolstering comprehension in core disciplines.

Table 4. Evaluation of the learning experience. Five-year cumulative responses from 118 students who completed the course and provided answers on both the pre-course and post-course surveys. The average and standard deviation (in parentheses) are provided. A two-tailed paired t-test was used to determine the p-value

Questions	Pre	Post	*p*-value
Rate your working knowledge of Genetics	3.67 (0.69)	3.93 (0.65)	1.21E-04
Rate your working knowledge of Cell Biology	3.71 (0.68)	3.99 (0.65)	1.82E-05
Rate your working knowledge of Molecular Biology	3.14 (1.09)	3.73 (0.86)	6.15E-11
Rate your overall understanding of what cancer is	3.03 (0.65)	4.20 (0.61)	6.58E-29
Briefly explain what you think cancer is	3.91 (1.11)	4.16 (0.79)	4.00E-02
Assess your skill and experience to explain to your parents why the “War on Cancer” has not provided a cure for cancer	2.56 (1.17)	4.17 (0.84)	2.02E-26
Assess your skill and experience to read, understand and explain a scientific paper	3.68 (0.74)	4.15 (0.70)	9.67E-10
Assess your skill and experience to design an experiment to test a hypothesis	3.38 (0.76)	3.45 (0.77)	0.4

Students responded to three questions aimed at evaluating their overall comprehension of cancer biology (refer to Table 4). For the query "Rate your overall understanding of what cancer is," students were requested to evaluate their own comprehension using a scale ranging from 1 (low) to 5 (high). Their responses revealed a significant increase from 3.03 to 4.2 ($p < 0.001$), indicating a substantial enhancement in their grasp of cancer. In a related question, students were tasked with providing a concise explanation of "Briefly explain what you think cancer is." Course instructors then rated their responses on a scale from 1 (poor) to

5 (excellent). Comparison of pre-course and post-course answers showed an improvement in response quality from 3.91 to 4.19 ($p = 0.004$). Furthermore, students were asked to assess their ability to "explain to your parents why the 'War on Cancer' which was started in the 1970s has not provided a cure for cancer" using a 1–5 scale. Notably, responses exhibited a substantial increase for this question, rising from 2.56 in the pre-course survey to 4.17 in the post-course survey ($p < 0.001$). These findings collectively suggest that students perceived a significant enhancement in both their scientific understanding of cancer and their proficiency in articulating cancer-related concepts to non-scientific audiences as a result of completing this course.

We posed two questions aimed at gauging the impact of primary research articles in this course on students' broader comprehension of how science operates (refer to Table 4). In response to a query asking students to evaluate, using a 1–5 scale, their "skill and experience to read, understand and explain a scientific paper," their self-assessed proficiency increased from 3.68 in the pre-course survey to 4.15 in the post-course survey ($p < 0.001$). Conversely, regarding a question prompting students to assess, using the 1–5 scale, their "skill and experience to design an experiment to test a hypothesis," there was no significant variance between pre-course and post-course scores (3.38 vs 3.45; $p = 0.40$).

The post-course survey incorporated two additional questions absent in the pre-course survey to provide deeper insight into the significance of incorporating primary literature into the course curriculum. Students were required to provide written responses describing how reading primary research articles enhanced their understanding of cancer and their comprehension of scientific methodology (refer to Table 5). All responses were evaluated by the instructors, with "no" responses scored as 1, simple "yes" responses scored as 2, and "yes" responses with further justification scored as 3. The average score for the query "Was reading and discussing the original research papers useful for developing your understanding of Cancer?" was 2.56, while the average score for "Was reading and discussing the original research papers useful for developing your understanding of how science is performed?" was 2.61. Selected excerpts from the 2014 and 2015 post-surveys are included in Table 5 to provide context for our scoring method. Student responses to these inquiries indicate that engaging with primary research articles proved beneficial for enhancing both their comprehension of cancer and their grasp of the scientific inquiry process.

Discussion

One of our primary objectives is to cultivate a deeper understanding of the scientific process among students, a goal underscored in the AAAS Vision and Change reports 1, 2 but often overlooked in undergraduate curricula. To achieve this aim, we have crafted an advanced, inquiry-driven curriculum that blends structured background lectures typical of undergraduate courses with a literature-focused component akin to graduate-level studies. A significant portion of class time, one-third to be precise, is dedicated to guided discussions led by instructors on assigned original literature.

This literature-centric aspect of the course is profoundly iterative, providing students with multiple opportunities to dissect primary research articles and scrutinize the process by which data is acquired, presented, and interpreted by scientists. The data presented in our study unequivocally demonstrates that selected readings from primary literature serve as an effective vehicle for imparting an understanding of scientific methodology. Notably, our findings, coupled with informal conversations with former students and feedback obtained

through university-mandated post-course evaluations, underscore the high value students place on the literature component of the course.

Our findings align with previous studies indicating that primary literature can serve as a potent pedagogical tool in undergraduate science education. For instance, the CREATE (Consider, Read, Elucidate hypotheses, Analyze and interpret data, and Think of the next Experiment) method has been shown to enhance critical thinking skills and overall perceptions of science among students 5, 7. Echoing the sentiments of students who engaged with the CREATE approach, participants in our course report an enhanced ability to "read, understand, and explain a scientific paper."

However, when gauged on their proficiency in "designing an experiment to test a hypothesis," our students did not demonstrate significant improvement in this skill. Our findings suggest that while students may develop proficiency in comprehending and analyzing scientific papers, this alone may not necessarily translate into increased confidence in hypothesis formulation and experimental design. This observation may underscore an inherent limitation of course-based research experiences. Future investigations comparing course-based research experiences with more open-ended laboratory research may shed light on the acquisition of hypothesis development skills among students.

Another objective of our course is to elucidate how insights derived from foundational research contribute to advancements in healthcare, particularly in the development of novel diagnostic and therapeutic modalities. We utilize primary research literature in our curriculum to impart fundamental scientific concepts, such as nucleic acid hybridization and sequencing, alongside relevant contextual understanding, such as the identification of genes exhibiting differential expression in normal versus cancerous cells. The significance of delivering both content and context has been underscored in the CREATE project 14. Additionally, we purposefully integrate research articles with clear translational implications, with approximately one-third of the selected papers focusing on recent strides in cancer therapy, including rational drug design and immunotherapy. Our findings affirm that engaging with primary literature equips students with insights into the progression of basic research findings into tangible therapeutic and diagnostic innovations.

Cancer, a pervasive ailment, profoundly impacts numerous individuals' lives. The quest for effective cancer therapies remains a formidable challenge in biomedicine, driving much of contemporary cellular and molecular biology research. Given the keen interest in cancer among our undergraduate cohort, many of whom aspire to careers in medicine or allied health professions, we have established a semester-long course in Cancer Biology. Leveraging both structured lectures and extensive engagement with primary research literature, our curriculum effectively imparts comprehensive knowledge of cancer as a significant health concern while enhancing scientific literacy among students.

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