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A Summer Course in Cancer for High School Students - Lessons Taught and Lessons Learned

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Abstract

In this discussion we present a course in cancer biology and therapeutics that we have taught for high school students the past five summers. Course content as well as data quantifying student learning are presented. Our hope is to provide guidance to those teaching similar courses or a template to teach the same course elsewhere.

Introduction

The Student Science Training Program (SSTP) is sponsored by the Center for Precollegiate Education and Training at the University of Florida. For the past fifty-five years, more than 4,000 rising high school juniors and seniors have spent two months of their summer at the University of Florida as part of the program. The students gain lab experience working in an academic research lab and also attend scientific lectures and participate in a class chosen by them from a list of offerings. These courses are created and organized by graduate students and postdoctoral associates at the university, focusing on their areas of expertise.

For the past five summers, a small group of five graduate students, some of which have continued to participate after transitioning to a postdoctoral position, have hosted a "Cancer Biology and Therapeutics" course as part of the program. Having limited prior teaching experience, teaching this course has been just as influential on the instructors as it has been on the students. In an effort to maximize the student benefit, the lesson plan has evolved over the years.

This paper aims to analyze and discuss the changes that occurred as well as the effects that they had on student learning. It is the authors' hope that this discussion will aid others in their efforts to educate highly motivated high school students about complex scientific and medical topics as well as serve as a template for others teaching about cancer.

Methods

Course Material

This course met eleven times with biweekly 1.5 hour sessions, for a total of 16.5 contact hours, with class size ranging between 10 and 13 students. The lesson material

consisted of two main parts: the first focusing on the biology of cancer and the second examining the current treatment options. As a guide to the basics of cancer biology, Hanahan and Weinberg's Hallmarks of Cancer [1] were used. After students were made familiar with the concept of cancer, its molecular basis, and tumor biology, the process of carcinogenesis (cancer initiation) and the current procedures used in the clinic to diagnose cancer prior to its treatment were introduced.

The current options available for cancer treatment were grouped into five main types: gene therapy, chemotherapy, targeted therapy, biological therapy, and radiation therapy. In addition, the course also included a class focusing on mechanisms of resistance that cancers use to avoid the previously discussed treatment modalities. The diverse cancer background of the instructors allowed each topic to be presented by someone with a deep understanding of the material. The course concluded with first-hand accounts and data presentations from the instructors regarding their own research, illustrating the role laboratory research plays in the fight against cancer. The course topics are shown in Figure 1.

Course Period	Topic
1	Introduction to the course Cancer in society
2	Hallmark 1: Self-sufficiency in growth signals Hallmark 2: Insensitivity to anti-growth signals Hallmark 3: Genome instability and mutation Hallmark 4: Tissue invasion and metastasis
3	Hallmark 5: Evading apoptosis Hallmark 6: Deregulated metabolism Hallmark 7: Sustained angiogenesis Hallmark 8: Inflammation
4	Hallmark 9: Limitless reproductive potential Hallmark 10: Evading the immune system Gene Therapy
5	Carcinogenesis Cancer Diagnosis/Staging
6	Classic chemotherapy
7	Biological therapeutics
8	Targeted therapy
9	Radiation therapy
10	Mechanisms of resistance
11	What is cancer research?

Figure 1.
Sample course schedule.

Course Format

While the topics covered remained constant between the five years the course was taught, the format changed slightly each year. The first year consisted of primarily formal lecture. In addition, each student, in pairs, gave a 15 – 20 minute presentation giving a more in-depth look into a specific treatment regimen that had been discussed that day. For example, after an instructor lectured on chemotherapeutic drugs, students may have presented about the drug Taxol. These presentations were generally more clinically focused, examining the current use of the treatment, including the benefits and limitations. Students' overall grade in the class was based on attendance, participation, and their presentation. There were no assessments of the students' knowledge throughout the course.

The second year the course was held, quizzes were added to the beginning of each class period, testing knowledge and comprehension of the material from the previous meeting. Student presentations maintained the same format. The third year reduced the number of quizzes from nine to four, testing students on multiple topics for each quiz. This allowed enough time to introduce group discussions and activities into the curriculum to promote student interaction. Additionally, the student presentation format was changed to a short, 10-minute presentation on a relevant current-events topic followed by a group discussion facilitated by the student presenters.

Group Discussions

In addition to student driven discussions, the third year curriculum and beyond also included a number of instructor-led group discussions. A brief synopsis of these activities is included below.

Acting on Information about Cancer

This discussion was adapted from a larger activity published by the National Cancer Institute [2]. It presented students with a proposed law requiring additional clothing be worn by minors to protect against sun exposure and skin cancer. Students were broken into two groups: one supporting the law and the other opposing it. They were then given a handout presenting comments from their "constituents" about the proposed law and were given a chance to ask for additional information from their science advisors, the course instructors. The two groups debated the law before bringing it to a vote.

The Ethics of Germ Line Gene Therapy

To coincide with the lecture regarding gene therapy and its use in cancer treatment, a discussion was had about germ line gene therapy. Currently, gene therapy techniques are used only on somatic cells, thus producing results that are not inheritable, but in theory could be employed on germ cells to produce permanent changes that would be passed on to the next generation. This student discussion looked at whether research in this area, currently banned in most countries of the world, should be allowed presently as well as the ethics of using the procedure on humans should it be perfected in the future.

Testing your Cancer IQ

On the first day of class, students were presented with cancer terminologies and asked to define the terms with their relation to cancer. This allowed us to understand how much the students knew about the field, and allowed the students to confirm certain concepts they already had, as well as open the door to new ones. Students had a good knowledge of most of the terminologies that were put forth on the screen, such as "chemotherapy", "UV rays", and "carcinogenesis", except for certain arcane terminologies, such as "angiogenesis" and "apoptosis". All incomplete definitions were aided by the instructors.

Are You Smarter than Cancer?

After the Mechanisms of Drug Resistance class, students were divided into groups of 4. Each group was presented with two case studies and asked to analyze the data at hand (fabricated Western blot data) to determine potential mechanisms of drug resistance for each case. In addition, they were also expected to propose strategies to overcome drug resistance.

What's the Diagnosis?

The students were broken into teams of three or four, and provided with a list several different types of cancers. A scenario was presented to them, and they were asked to diagnose the patient based on symptoms and the age and gender of the patient. The first group to raise their hands were allowed to answer the question. A correct answer earned them one point, while an incorrect answer eliminated from any further guesses that round.

Identify the Target and Get the Grant

Following the targeted therapy lecture, students were divided into two groups and each given the same summary write-up of how cells undergo DNA segregation and cytokinesis during mitosis, including how this process is different in cancer cells. They were tasked with identifying an appropriate protein from this process that, when it is targeted by a therapy, will preferentially kill cancer cells. After identifying their target, they needed to develop a research plan to discover the corresponding therapy. Students then pitched their ideas to the instructors, who posed as a review panel, in order to be the group that was awarded the fictional grant money to carry out their research.

Cumulative Exam

At the conclusion of each course year, students were given the same identical test on all topics that had been covered in the class. The exam consisted of 24 multiple choice and true/false questions, with the number of questions on each topic proportional to the time spent discussing it. Questions were presented in Microsoft PowerPoint format on a screen in front of the classroom and each question was visible for 40 seconds before proceeding to the next.

Results

Cumulative Exam

The results of this comprehensive exam served as a comparison point between

years. While differences in the educational background and overall aptitude of the students between years cannot be accounted for, the participants in the program largely come from the same areas year after year. Therefore, changes in class performance can likely be attributed to the slightly different teaching approaches and increased experience of the instructors. An upward trend in the class average was observed from year 1 to year 5, with an increased average each year (Figure 2). This value increased from 16.46 in year 1 to 19.83 in year 5. Analyzing these data with GraphPad Prism software (GraphPad Software, Inc., La Jolla, CA) identified a positive slope of 0.89 ± 0.10 points/year (where points are questions correct out of 24). The p value of this slope was 0.0034, indicating a significantly non-zero value and an increase in student performance year-over-year.

Pre and Post Test

The third year the class was held, the students were given a simple test on the first and last meeting. This test served to gauge their general knowledge of cancer, their opinions about cancer research, and expectations for the course. The questions and results were as follows and the data are presented in Figure 3.

Give a one sentence definition of cancer.

Instructors assigned a number grade to each definition between 1 – 10. The average score increased from 5.73 to 7.82 over the course of the class. The results were statistically significant ($p \leq 0.05$) using a paired Student's t-test.

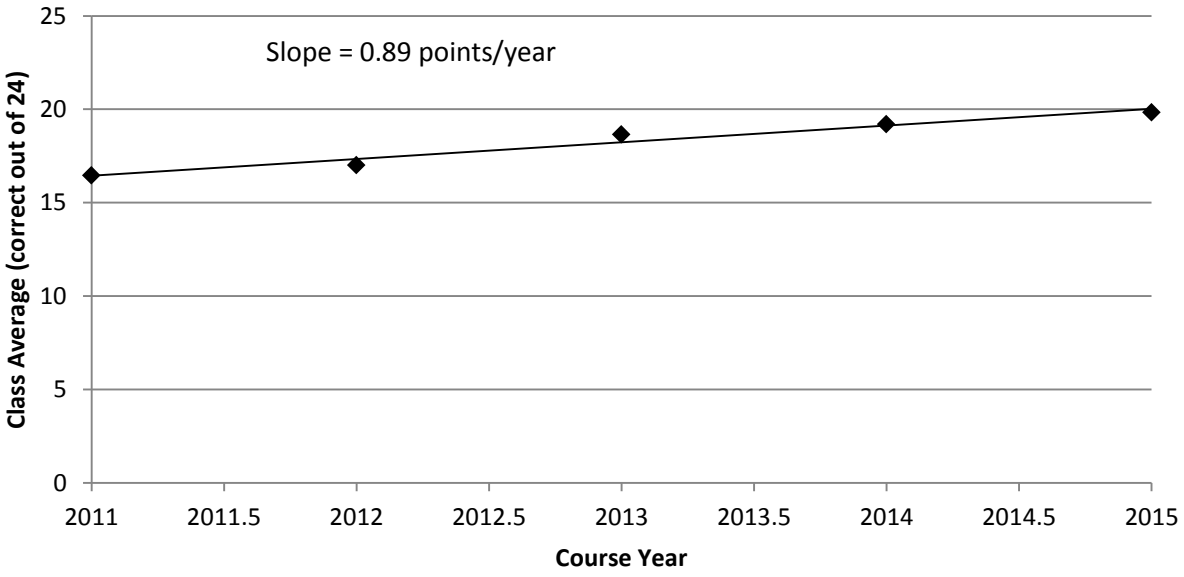

Figure 2. Comparison of cumulative exam performance. Values denote the average score out of a possible 24. Error bars represent the standard deviation. The exam was identical across years.

Name as many types of cancer therapy as you can (i.e. chemotherapy).

Similar therapies were counted as only one. The average number listed increased from 2.09 to 3.18. The results were statistically significant ($p \leq 0.05$) using a paired Student's t-test.

On a scale of 1 – 10 (10 being extremely close), how close do you think scientists are to curing cancer?

The average rating saw a statistically insignificant drop from 5.41 to 5.18.

On a scale of 1 – 10 (10 being very likely), how likely do you think you will pursue a career in lab-based medical research?

The average reported score decreased from 5.68 to 5.59 and was statistically insignificant.

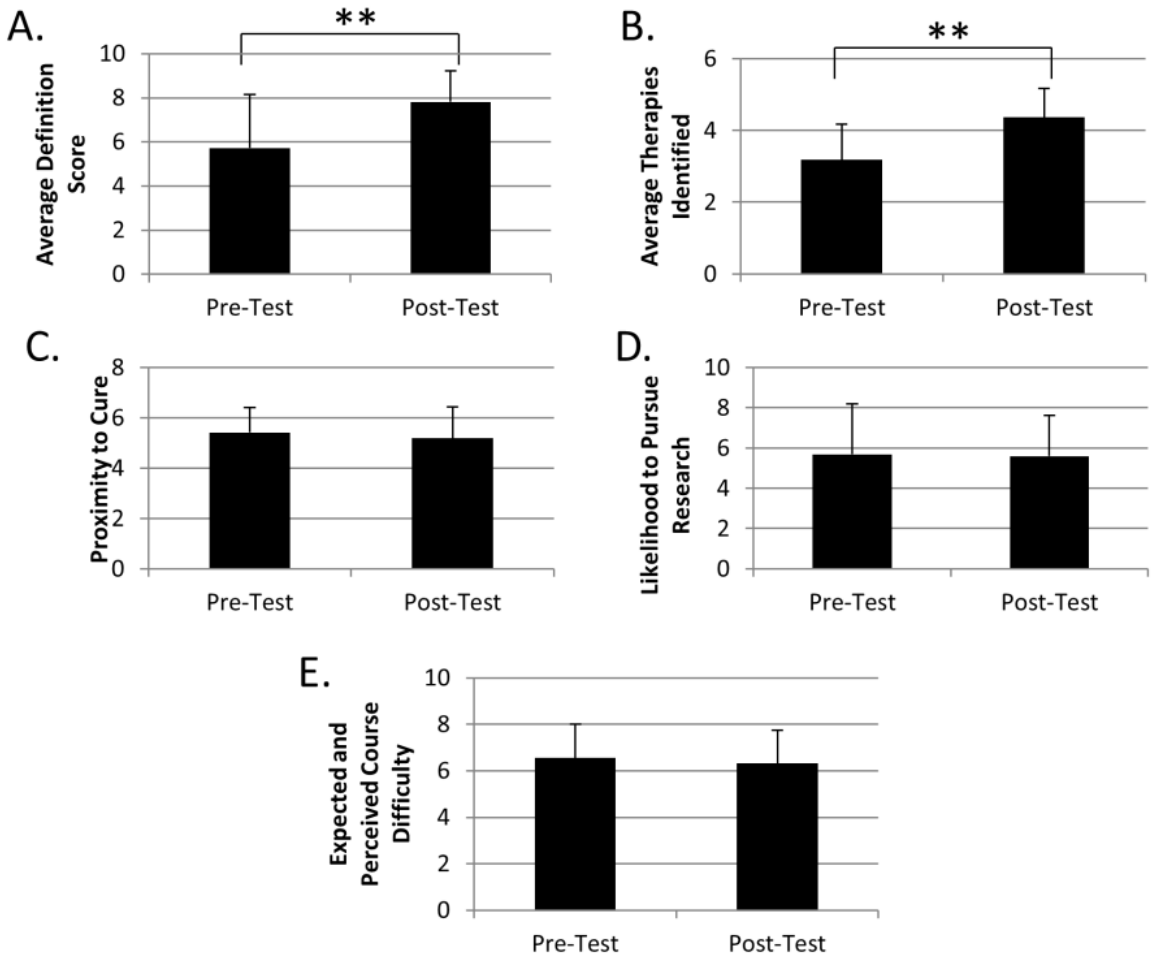

Figure 3. Results of the pre- and post-tests. A.) The average score given to a one sentence definition of cancer. B.) The average number of cancer therapies listed. C.) Average students' rating as to how close scientists are to a cure for cancer. D.) Average self-reported likelihood of pursuing a career in lab-based research. E.) The average expected and perceived difficulty of the course. All values show the average value of the third-year class. Error bars represent the standard deviation. ** denotes $p \leq 0.05$ All values are n = 11.

On a scale of 1 – 10 (10 being the most difficult), how difficult do you expect this class to be/how difficult was this class?
The average difficulty reported decreased from 6.55 to 6.32 and was not statistically significant.

Discussion

Over the past five summers, this course has been a joy for those instructors involved. They have continued to teach the course as they find it rewarding to share their knowledge and it is clear that they are having an impact in the lives of the students. Multiple times, the class has been suggested to incoming students from other students at their high school who have taken it in prior years. While it continues to be a wonderful experience, the instructors have been able to increase the effectiveness of their teaching methods through experience.

We find the general course structure, teaching the Hallmarks of Cancer prior to the treatment options, to be successful. Students oftentimes have widely variable knowledge of cancer prior to taking the course, and the knowledge they do possess is not at the level needed to understand the treatments that are discussed in this class. By the time the Hallmarks are finished, all students are on relatively equal footing, allowing a deeper comprehension of the course material that follows.

That comprehension is further boosted by the addition of student-led group discussions in the third year and beyond that allowed students to delve deeper into the subject, which might also have enhanced their understanding, interaction, and test scores. Students readily take ownership of their assigned topic, conducting online research and asking questions of the instructors. It also provides an opportunity for the rest of the class to receive the information from a different angle that may increase their amount of understanding.

Similarly, the addition of group discussions seems to have boosted the amount of information retained by the students, illustrated by an increase in test scores as discussed below, but also noticeably improved student participation. The group discussions outlined above generally produced lively discussions and debates. Once started, these discussions received such participation that they required little effort by the instructors other than to keep discussion on topic and to ensure factual correctness. Many times these discussions generated so much interest that they needed to be stopped by the instructors due to time constraints.

While the majority of the course structure remained unchanged between the second and third year, the increased emphasis on these group discussions led to a marked increase in scores on the cumulative exam given at the end of each summer. Each class was given the identical exam in order to provide a means of comparison between them. The class average in third year increased to 18.64 out of 24 from 17.00 in year 2 and 16.46 in year 1. It is our belief that this is due to the application of knowledge gained during the group discussions.

A lesser change in class average on the cumulative exam was seen the first two years. The most significant change between these two years was the addition of quizzes

at the beginning of each class period. While the change in class scores was minor, we observed a very large shift in student demeanor between these two years. The first year, students largely did not come into the classroom until it was time to start class, sometimes necessitating a late start. However, with the addition of quizzes, many students arrived to class early in order to study their notes, discuss them amongst themselves, and to ask questions of the instructors.

The course format did not change dramatically for the fourth or fifth years, but class performance did indeed continue to increase. The most likely cause of this increase is the additional teaching experience brought by the instructors. With the passing of each year, the instructors are able to subtly change presentation styles and content to better suit the students.

The third year, a pre- and post-test was introduced to the course for the purpose of monitoring the progress made by one class over the summer. The questions included on this test not only examined the students' general knowledge of the material covered in the course, but also judged their perception of cancer, their career path, and the course itself. As would be expected, a significant increase in the students' comprehension of "cancer," as determined by a subjective grading of a one word definition, increased, as did the number of cancer therapies that students were able to recite.

Interestingly, no statistical difference was seen in the students' perception of how close researchers are to "curing cancer" or in their reported likelihood of pursuing a career in laboratory-based research. While this was a small cohort of students out of the much larger program, the lack of change in interest in lab science is interesting since exposure to this work is the main component of the SSTP program. One possible explanation is that a number of the students in this course report as wanting to enter clinical practice and are not very open-minded about other career options. It is our belief that their experiences in the SSTP program will have a more measureable impact on their career choices, in either direction, later in their lives as they are exposed to other opportunities and begin making life-decisions.

We feel that this course provides an excellent opportunity for both the instructors and the students. The authors very much look forward to teaching this course each summer and hope to continue in the future. Cancer is a disease that touches us all, yet most of the population has a very poor understanding of even the basics of what cancer is and how it is treated. Even if the students that take this course do not pursue cancer research or treatment in their careers, they leave with invaluable information. One former student, now an undergraduate, has remained in contact with the instructors, seeking advice in deciding what he should focus on in his studies and future career. This student continues to mention how much this class influenced them and how much they appreciated us teaching them that summer. If students enjoy a class, learn information relevant to their lives and the lives of their family and friends, and the instructors find the course individually rewarding and fulfilling, it is certainly worth the time and effort put into it.

References

1. Hanahan D, Weinberg RA (2011) Hallmarks of cancer: the next generation. Cell 144: 646-674.

2. National Institutes of Health (1999) Cell Biology and Cancer http://science.education.nih.gov/supplements/nih1/cancer/default.htm.