

UCF RET Site: Research Experiences in Computer Vision and Bio-Medical Imaging Lesson/Unit Plan

200810, 200820: IB Biology 1 & 2

2018

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RET Site: Research Experiences in Computer Vision and Bio-Medical Imaging Lesson/Unit Plan

Course(s): SL IB Biology 1 or 2
Grade Level: 11-12
Suggested Length of Lesson: 270 min. (3 90 min. block sessions or 5-6 45 min. periods)

Materials/Technology Needed

- Laptop
- 3D Slicer
- MS Office or OneNote

Where this Fits

- 1.6 Cell division. Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumors.
- 3.4 Inheritance. Radiation and mutagenic chemicals increase the mutation rate and can cause genetic diseases and cancer.
- 6.4 Gas Exchange. Application: Causes and consequences of lung cancer.

Lesson Objective(s)/Learning Goal(s)

- Understand that cumulative genetic mutations result in primary and secondary tumor development.
- Understand that personal risk factors and environmental mutagens influence DNA expression and the cell cycle.
- Use biomedical image analysis to identify the presence of, and specific tumor characteristics.
- Explore the basic principles of artificial intelligence and its potential impact on biomedical technology.

Standard(s)/Benchmark(s) Addressed

- *Next Generation Sunshine State Standards:*
  - SC.912.L.16.8: Explain the relationship between mutation, cell cycle, and uncontrolled cell growth potentially resulting in cancer.
  - SC.912.L.16.14: Describe the cell cycle, including the process of mitosis. Explain the role of mitosis in the formation of new cells and its importance in maintaining chromosome number during asexual reproduction
- *Common Core Standards for Mathematics:*
  - CCSS.MATH.CONTENT.5.MD.B.2: Represent and interpret data.
  - CCSS.MATH.CONTENT.HSS.MD.B.7: Analyze decisions and strategies using probability concepts

Standards for Mathematical Practice

- CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.
- CCSS.MATH.PRACTICE.MP3 Construct viable arguments and critique the reasoning of others.
- CCSS.MATH.PRACTICE.MP4 Model with mathematics.
- CCSS.MATH.PRACTICE.MP5 Use appropriate tools strategically.

Instructional Strategies

- Think, Pair, Share
- Group Discussion
- Case Study Analysis
- Assignment Choice/Menu
- Learning Log

Evidence of Learning (Assessment Plan)

- Cancer Lecture Notes
- Meet Laura Reflection Log
- 2D-3D Diagnostic Activity
- Computer Vision Assignment Choice

Description of Lesson Activity/Experiences

The lesson(s) experiences have been developed using the 5E Model Framework to develop the daily lessons. Each learning experience within the framework of the lesson is intended to interact with other learning experience as explained in the descriptions below:

1. **Engage:** The learning experience(s) elicit student curiosity on the lesson.
2. **Explain**: The learning experience(s), primarily teacher-driven, that clarifies lesson concepts, and procedures; Or lesson experience(s), primarily student-driven, that provide students to reflect and communicate to demonstrate a conceptual understanding.
3. **Explore**: The learning experience(s) that allow students to develop necessary skills and individually investigate questions.
4. **Elaborate:** The learning experience(s) that provide opportunities for student(s) to apply a conceptual understanding and connect to a real-world setting.
5. **Evaluate:** The learning experience(s) where students have opportunities to monitor and demonstrate their understanding of the lesson goal(s) as well as the opportunities that provide for teachers to assess student understanding both as a formative and summative evaluation.

*Note: Not every lesson has all 5 components, but all 5 components are incorporated at least once.

Flipped Session (Pre-lab Homework, 60 min)

1. ***HHMI Video Lecture: Putting the Brakes on Cancer***. Students are introduced to the concepts of benign, malignant and metastatic tumor development via cumulative genetic mutations in the suppressor, repressor, and oncogenes; as well as how personal risk factors and environmental mutagens influence DNA and the cell cycle. Students also investigate and record genetic, bacterial, and viral agents of cancer. Lecture notes and investigations are recorded in guided notes.
2. ***3D Slicer download and install:*** Students download and install 3D-Slicer and patient data in preparation of in-class activities.

Day 1 (90 min)

3. ***Engage: Meet Laura*** **(15 min)** Students are introduced to Laura, a 30-year old non-smoker diagnosed with stage 4 SCLC. Laura's vlogs detail her diagnostic and treatment process. Students reflect on Laura's story in the Meet Laura reflection log.
4. ***Explain: Lung Cancer Basics Slides & Discussion*** **(45 min)** Students are provided with current statistics regarding lung cancer epidemiology and detection methods. Students think-pair-share to investigate various imaging and diagnostic procedures. Specific advantages and disadvantages with respect to lung cancer is discussed as a group. In preparation for the next activity, students learn the major characteristics used to identify and describe and stage lung nodules.
5. ***Explore: 2D Diagnostics Activity*** **(30 min)** Students simulate the X-ray screening process using static 2D LDCT scans and reference tables to characterize and stage lung cancer using real patient data from the Cancer Image Archive (cancerimagingarchive.net).

Day 2 (90 min)

6. ***Re-Engage: Check in with Laura*** **(5 min)** Students continue to watch Laura vlog about her disease and treatment progression, then reflect in the log. (may be moved to the end of Day 1 if needed)
7. ***Explain: 3D-Slicer Tutorial*** **(35 min)** Students learn how to utilize 3D Slicer software to segment and characterize lung nodules in a step-by-step tutorial using sample patient data.

8. ***Explore/Evaluate: 3D Diagnostics Activity*** **(40 min)** Students re-analyze case studies for nodule characteristics (size, margins, density, shape, est. volume) using segmentation and volume rendering in 3D Slicer and compare their results to X-ray simulation screening techniques.
9. ***Elaborate: Meet Sir Geoffrey*** **(10 min)** Students are introduced to Sir Geoffrey Hinton, the "Father of Deep Learning", and his explanation of artificial intelligence (A.I). Subsequently, students watch Sir Geoffrey speak to the possibility (probability) of radiologists being replaced by A.I. for cancer detection. (may be moved to the beginning of Day 3 if needed)

Day 3 (90 min)

10. ***Explain: Computer Vision Presentation*** **(40 min)** Via lecture and discussion, students focus on the preliminary concepts of edge detection, segmentation, deep learning, neural networks, and how these concepts are used in CAD of lung cancer nodules.
11. ***Explore/Elaborate: Computer Vision Assignment Choice*** **(35 min)** Students are given a choice of assignments to explore specific facets of computer vision in biomedical imaging. Choices include conceptualizing a neural network for use in computer aided detection of lung nodules, a position paper on the implications of deep leaning in biomedical imaging, and extended analysis of additional cancers using the 3D slicer and real patient data. This assignment may be finished at home and/or submitted later.
12. ***Evaluate: Saying Goodbye to Laura*** **(15 min)** Students read Laura's final blog posts in which she reveals her lung cancer spread after 7 years of remission. Articles provided by her family relay details of Laura's passing, and her advocacy for lung cancer awareness. Students' final reflection on Laura's story, includes how her story may be different given their new knowledge regarding computer aided diagnostics.

Recommended Assessment(s) and Steps

Note: Links for all videos are provided in the notes sections of PowerPoint slides and are embedded in actual presentations when possible.

- **Flipped Session**

  Students watch the ***HHMI Video Lecture: Putting the Brakes on Cancer*** and complete the Cancer@Home Notes.

  - EdPuzzle Video Links (2 shorter videos):
    Video 1 https://edpuzzle.com/assignments/5b16c622b6179c40a8ab8e3c/watch
    Video 2 https://edpuzzle.com/assignments/5b16ce9166e15440617c4d20/watch
  - Youtube Video Link (entire lecture): https://www.youtube.com/watch?v=2XvHVBhUqj4&t=3160s

  Students download and install 3D Slicer and Fast Grow extension using the 3D Slicer Install Tutorial.

  Assessment:

  Cancer@Home Notes (formative)

- **Day 1**

  Engage: Meet Laura (15 min)

  - Students watch Laura's vlog, and respond to reflection questions in the Meet Laura Reflection Log. Questions are centered around student's assumptions about cancer, particularly that only long-term smokers get cancer.

Explain: Lung Cancer Basics Slides & Discussion (45 min):

- Using the Day 1 PowerPoint slides, students are provided with current statistics regarding lung cancer epidemiology and detection methods.
- During the presentation, students conduct a 5-minute think-pair-share investigation into various imaging and diagnostic procedures. To assess their findings, the teacher leads a short group discussion into the specific advantages and disadvantages of each diagnostic with respect to lung cancer, paying careful attention to the concept of early detection.
- Embedded into the power point slides are additional vlogs from Laura, during which students answer additional questions in the Meet Laura Reflection Log.
- In preparation for the next activity, students learn the major characteristics used to identify and describe lung nodules (size, margins, density, shape, est. volume) and disease stage using the Lung Cancer Staging Reference Sheet. Additional statistics related to the survival rates of each stage are also included, to help remind students that early detection is the key to survival.

Explore/Evaluate: 2D Diagnostic Activity (45 min)

- Students (individually or in pairs) are assigned 1 of 13 specific case studies. These case studies were derived from real patient data, provided by the Cancer Image Archive. Patients are denoted by patient number.
- Students are asked to evaluate if a patient's tumor is malignant, and/or metastatic (stage) based on evaluation of nodule size, margins, density, shape, est. volume using three 2-dimensional images (x-axis, y-axis, and z-axis views). Students will likely discuss and debate the best formula to use to estimate nodule volume, as the shape is irregular. Students should come up with their own answer/method/justification for this step.

  (DICOM Data: https://wiki.cancerimagingarchive.net/display/Public/LungCT-Diagnosis)
- To conclude this activity, the teacher and students discuss the student's process. The lesson is concluded by viewing a segmentation video, previewing what the students will be able to do by the end of the next lesson.

Assessment:

Lung Cancer Basic Discussion (formative)
Meet Laura Reflection Log (formative)
2D Diagnostic Activity results (formative) on Patient Data Sheet

- **Day 2 (90 min)**

Re-Engage: Check in with Laura **(5-10 min)**

- Students continue to watch Laura vlog about her disease and treatment progression, then reflect in the log. ***(may be moved to the end of Day 1 if needed)***

Explain: 3D-Slicer Tutorial **(35 min)**

- Students learn how to utilize 3D Slicer software to segment and characterize lung nodules in a step-by-step tutorial using sample patient data.
- Teachers may use the tutorial PowerPoint to guide students, or, may conduct the segmentation themselves while students follow along using the tutorial slides as a reference (class set advisable).

***Explore/Evaluate: 3D Diagnostics Activity* (40 min)**

- Students work independently to re-analyze their specific case studies (from the previous activity) for nodule characteristics (size, margins, density, shape, est. volume) using segmentation and volume rendering in 3D Slicer.
- Students complete questions on the patient data sheet that focus on comparing their results to X-ray simulation screening techniques. Students must explain if and why their diagnosis changed using the 2 different methods (x-ray vs. LDCT). Precision and accuracy between the methods should be discussed and included in student answers, specifically within the context of using these two different screening methods (X-ray vs. LDCT) to advise oncologists and surgeons.
- If students would like to know the actual diagnosed stage of their patient at the time of the scan, and known survival time, that information is provided in the Lung CT Survival Data document. This document should not be provided to students prior to the completion the activity.

***Elaborate: Meet Sir Geoffrey* (10 min)**

- Students watch 2 short video clips of Sir Geoffrey Hinton, the "Godfather of Deep Learning", and his explanation of artificial intelligence (A.I). and the possibility (probability) of radiologists being replaced by A.I. for cancer detection. The teacher should ask students to predict how this relates to the activities they've completed so far. **(may be moved to the beginning of Day 3 if needed)**

Assessment:

Meet Laura Reflection Log (formative)
3D Diagnostic Activity results (formative) on Patient Data Sheet
2D-3D Comparison Questions (summative) on Patient Data Sheet

- **Day 3 (90 min)**

***Explain: Computer Vision Presentation* (40 min)**

- The teacher provides a video-guided lecture on the surficial concepts and applications of artificial intelligence and computer vision. Concepts include edge detection, region growing through splitting and merging algorithms, and semantic segmentation.
- The teacher then walks students through a video mini-lecture that explains the concept of neural networks, using digit recognition as an example. The teacher should pause regularly to discuss specific questions during the video, and to reassure students that the math is not the important component of the information; but rather the conceptual model and structure of a neural network. Students may want to take short notes.
- The presentation concludes with a brief description of recent research at UCF that uses neural networks to classify malignant and benign lung tumor models. Again, the mathematics of this process are not the focus in this activity, rather the process by which the neural network functions at a conceptual level.

***Explore/Elaborate: Computer Vision Assignment Choice* (35 min, finished at home)**

- This activity begins with a description of each (of 3) potential assignments students may choose to explore specific facets of computer vision in biomedical imaging. Assignment descriptions are provided in the Day 3 Slides, and the Computer Vision Assignment handouts. Some choices include provided resources, while some require students to find their own. Students should be allowed some time to decide which choice they'd prefer. It is advised that students be allowed to work together but should be expected to produce their own work.
- Assignment choices include:

Option 1: Targets visual/process thinkers. Students draw a conceptual schematic of how a neural network might analyze a nodule for malignancy. Students should use the Lung Cancer Staging Reference sheet to help them develop possible features by which to classify nodules, though they may also come up with their own. Student must label each feature and layer, describing the process by which the network assesses each characteristic. For this reason, their work should not look just like the UCF research slide, as no feature or label descriptions are provided in that diagram. It may also be helpful to encourage students to look up neural networks in Google images to help come up with a framework if necessary. The purpose of this exercise is to provide evidence that the student can properly apply the concept of neural networking to a visual biomedical assessment. Students should not be penalized for not understanding the mathematical details of how neural networks function.

Option 2: Targets language lovers/debaters. Students conduct research and write a short position papers (5-10 paragraphs) on the use of deep learning in medical imaging applications. Students must discuss potential advantages and disadvantages, and clearly state and defend a position. Resources may include, but are not limited to:

- Geoff Hinton (Father of Deep Learning) discusses the use of AI vs. traditional radiology (2 min video provided in Day 2 Slides)
- MIDL 2018 Panel discussion about radiology and artificial intelligence https://medium.com/@erik.ranschaert/midl-2018-panel-discussion-about-radiology-and-artificial-intelligence-2bec1d252adb
- Other video/written sources as needed (must be cited at the end of your paper). Plenty of relevant and appropriate content is available through google and YouTube searches using the search terms Radiology, Deep Learning, Biomedical imaging, and Artificial Intelligence.

Option 3: Targets analytical thinkers/computer lovers. Students work in pairs to analyze metastatic nodules 3 patients using 3D slicer, and subsequently explain discrepancies and similarities of their results. Additionally, students should explain how a neural network might analyze the same 3 patients. Students should follow the method provided in the 3D slicer tutorial but should not be limited to the lung cancer case studies provided in this lesson. Additional LDCT scans of breast, brain, pancreatic and colon cancer patients are available at cancerimagingarchive.net . Brain or breast cancer are likely the easiest to segment.

- After students choose their assignments, group students in the room such that all students working on the same option are sitting near each other. This will help students share research sources and strategize how best to complete the assignment. Assignments will likely not be completed by the end of class, so additional class time and/or homework time may be needed.

Evaluate: Saying Goodbye to Laura **(15 min)**

- Students read Laura's final blog posts in which she reveals her lung cancer spread after 7 years of remission. Articles provided by her family relay details of Laura's passing, and her advocacy for lung cancer awareness.
- Students' final reflection on Laura's story, includes how her story may be different given their new knowledge regarding computer aided diagnostics.
- Students should also be given time to share out personal experiences, and/or write additional reflections to help process emotional responses to lesson content.

Assessment:

Computer Vision Presentation Discussion (formative)
Meet Laura Reflection Log Final Question (summative) – students should incorporate as much relevant knowledge from the lesson activities and discussions as they can.
Computer Vision Assignment Choice (summative or formative)

List of Materials/Resources Used

- Flipped Session:
  - Laptop/tablet
  - Cancer@Home Notes
  - 3D Slicer Install Tutorial
- Day 1:
  - Laptop/tablet
  - Day 1 Slides (teacher)
  - Meet Laura Reflection Log
  - Patient Data Sheets
  - Lung Cancer Staging Reference Sheet
- Day 2:
  - Laptop/tablet
  - Day 2 Slides (teacher)
  - Meet Laura Reflection Log
  - 3D Slicer Tutorial
  - Patient Data Sheet
  - Patient DICOM Files
  - Lung Cancer Staging Reference Sheet
  - Lung CT Survival Data (teacher)
- Day 3:
  - Laptop/tablet
  - Day 3 Slides (teacher)
  - Meet Laura Reflection Log
  - Computer Vision Assignment Choice

Important Vocabulary

Term	Definition
Angiogenesis	The recruitment of blood vessels by a tumor
Cancer	Uncontrolled growth of cells
Cell Cycle	The series of stages associated with the replication and division of a cell.
Characterization	The evaluation of a visual and quantitative factors to determine malignancy.
Computed Tomography (CT) Scan	An imaging procedure that produces detailed black and white images (slices) of internal tissue and organs.
DNA	A molecule known as Deoxyribose Nucleic Acid, that contains the genetic information of a cell.
Genes	Segments of a hereditary information of a chromosome that is utilized by the cell to determine certain physical traits.
Lung Nodule	Small masses of tissue developed in the lungs
Metastasis	The development of abnormal cell growth originating from a primary tumor
Mitosis	The division of the nucleus of a cell
Mutation	A change in the gene sequence of DNA
Tumor	Abnormal growth of tissue within an organism
Spiculate	Irregularly shaped margins of a lung nodule.

Troubleshooting Tips

It is important to download the 3D slicer program software in advance to test and ensure the program installs and works properly. DICOM data from the Cancer Image Archive should also be loaded in advanced. DICOM data may be provided to students via an offline portable flash drive or a class website for troubleshooting purposes. Lung Cancer patient data used in this lab: (download entire DICOM Images package)

https://wiki.cancerimagingarchive.net/display/Public/LungCT-Diagnosis

Other Helpful Information

It is revealed at the end of the lesson that Laura McCracken passes away. It may be wise to preview 'Laura' segments of the lesson prior to including them in the lesson. Not all of Laura's video segments are specifically needed, it is advised that teachers use professional judgment with consideration of time limitations, and the emotional maturity of their students. Parental notification may help avoid potential conflicts. An example notification is provided below.

Dear parents,

Our upcoming lesson includes a non-fictional account of a one person's battle with lung cancer via a series of video and written blog posts. All material is publicly available and has been included in this lesson with the express permission of the individual's family. Students will be afforded time to share experiences in the classroom through written and verbal reflection.
If you feel this subject matter may be inappropriate for your child or may cause undue emotional distress because of personal or familial experiences, please contact me at your earliest convenience so that appropriate measures may be taken.

Thanks,

Attachments

- Day 1 PowerPoint
- Day 2 PowerPoint
- Day 3 PowerPoint
- Cancer@Home Notes (handout)
- 3D Slicer Install Tutorial (handout)
- Meet Laura Reflection Log (handout)
- 12 Patient Data Sheets (handout, 1 patient per student group)
- Patient DICOM Image files (https://wiki.cancerimagingarchive.net/display/Public/LungCT-Diagnosis)
- Lung Cancer Staging Reference Sheet (handout)
- 3D Slicer Tutorial PowerPoint
- Lung CT Survival Data (teacher, optional)
- Computer Vision Assignment Choice (handout)

References

1/6/08 – Part 1: Amazing Facts About Lung Cancer
https://www.youtube.com/watch?v=PWia320ztuM

1/6/08-Part 2: Not Getting Lung Cancer Diagnosed Early!
https://www.youtube.com/watch?v=mu8yCSEcwL8&t=23s

Adit Deshpande – Cs Undergrad At UCLA ('19)
https://adeshpande3.github.io

Bagci, U. (n.d.). CAP 5937 Lecture 8: Medical Image Segmentation: Region Based Algorithms. Retrieved July 7, 2018, from http://www.cs.ucf.edu/~bagci/teaching/mic16/lec8.pdf

Blog #2-What lead up to all of this
https://www.youtube.com/watch?v=mcY08LOlhNk&t=5s

Blog #3 – 2 weeks in the hospital, fun!
https://www.youtube.com/watch?v=DutPULUbS1U

Blog #4 What now? Treatment.. Staying at home...pink hair!
https://www.youtube.com/watch?v=tv8ltFth6m0

But What *is* a Neural Network? | Chapter 1, Deep Learning
https://www.youtube.com/watch?v=aircAruvnKk&t=317s

Cancer Facts & Figures 2018
https://www.cancer.org/research/cancer-facts-statistics/all-cancer-facts-figures/cancer-facts-figures-2018.html

Cancer Imaging Archive
Cancerimagingarchive.net

Cancer Patient, Mom Find Comfort in Adopted Puppy
https://www.petsmartcharities.org/adoption-stories/cancer-patient-mom-find-comfort-in-adopted-puppy

First Hello in 6 months!
https://www.youtube.com/watch?v=sSCrtB0KyAc&t=3s

Fox35 Covering Lung Cancer Ai Research At UCF
https://www.youtube.com/watch?v=Cryh1ydwnFM&sns=em

Future of Cancer Incidence in the United States: Burdens Upon an Aging, Changing Nation
Benjamin Smith-Grace Smith-Arti Hurria-Gabriel Hortobagyi-Thomas Buchholz - Journal of Clinical Oncology - 2009

Geoff Hinton: On Radiology
https://www.youtube.com/watch?v=2HMPRXstSvQ

How Computer Vision Is Finally Taking Off, After 50 Years
https://www.youtube.com/watch?v=eQLcDmfmGB0

Icnet For Real-time Semantic Segmentation on High-resolution Images
https://www.youtube.com/watch?v=qWl9idsCuLQ

Lungevity "breathe Deep Dfw" Lung Cancer Walk 2011
webwawa - https://www.youtube.com/watch?v=cJjaNYSRfkQ

Meet Geoffrey Hinton, U of T's Godfather of Deep Learning
https://www.youtube.com/watch?v=zPqFbkdcvWQ

MIDL 2018 Panel discussion about radiology and artificial intelligence
https://medium.com/@erik.ranschaert/midl-2018-panel-discussion-about-radiology-and-artificial-intelligence-2bec1d252adb

Negative chest X-rays in primary care patients with lung cancer.
Sally Stapley, Deborah Sharp, William Hamilton. British Journal of General Practice 2006

Reduced Lung-Cancer Mortality with Low-Dose Computed Tomographic Screening
New England Journal of Medicine – 2011

Research Mechanics: Putting the Brakes on Cancer
ResearchChannel - https://www.youtube.com/watch?v=2XvHVBhUqj4&t=3160s

Risk Stratification of Lung Nodules Using 3D CNN-Based Multi-task Learning
Sarfaraz Hussein-Kunlin Cao-Qi Song-Ulas Bagci - Lecture Notes in Computer Science Information Processing in Medical Imaging - 2017

Supervised and Unsupervised Tumor Characterization in the Deep Learning Era
Sarfaraz Hussein, Maria M. Chuquicusma, Pujan Kandel, Candice W. Bolan, Michael B. Wallace, Ulas Bagci
Submitted to IEEE Transactions on Medical Imaging 2018

Webwawa - Welcome!
http://www.webwawa.com/

YOLO: Real-Time Object Detection
http://pjreddie.com/yolo

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