The Human Brain: Investigating the Structure, Function, and Diseases of the Human Brain using Additive Manufacturing

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<th>Grade level: 6-7</th>
<th>Time required: Two 60 minute sessions</th>
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<td>Keywords: engineering, additive manufacturing, brain, cerebrospinal fluid, anatomy, function</td>
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Summary
The two lessons outlined here will introduce students in grades 6 and 7 to the structure and function of the human brain and to the importance of advancing biomedical research of the human brain. Students will learn about the structure of the human brain and how the cerebrospinal fluid interacts with the brain, as well as how diseases of the cerebrospinal fluid affect the brain. Students will also learn how additive manufacturing plays a critical role in the advancement of biomedical research and how a three dimensional model of the brain can be developed from additive manufacturing for research purposes. Students will apply their new knowledge through creative activities that solidify the concepts of human brain anatomy and additive manufacturing.

Learning Objectives
After completing the lessons, students will be able to:
1. Identify the major structures of the human head, specifically the skull, the brain, and the cerebrospinal fluid.
2. Be able to identify the skull, brain, and cerebrospinal fluid from both textbook illustrations as well as actual MRI scans.
3. Describe hydrocephalus as a disease of the cerebrospinal fluid, including what the disease is and its side effects.
4. Understand and explain what additive manufacturing is and how it can be used for research applications.
5. The advantages of a three dimensional model as opposed to a two dimensional drawing.
6. Learn and apply creative problem solving skills to various situations.

Lesson Plan Details
These two lessons are divided by concept. Lesson 1 will address the brain anatomy and diseases of the cerebrospinal fluid. Lesson 2 will teach students about additive manufacturing and then take the concepts from Lesson 1 and show students how they can apply additive manufacturing to medical research. Both lessons consist of one to two interactive activities, lecture notes to be used in a short lecture session, and discussion prompts.
Lesson 1: Anatomy and diseases of the human brain, skull, and cerebrospinal fluid
*Note: Students should have a preliminary understanding of human head anatomy*

Opening Activity: Review of the human brain, skull, and cerebrospinal fluid anatomy

*Time: 15 minutes*


*Preparation required: None*

*Instructions: Divide the students into groups of 2 or 3. Provide each student with a sheet of paper, and each group with a set of colored pencils, a copy of both the textbook illustration and MRI scan of the human head (both the textbook illustration and MRI scan must show the skull, the brain, and the cerebrospinal fluid, including the cerebrospinal fluid inside the third ventricle). Once the materials are distributed, ask the students to review the textbook illustration and identify the skull, the brain, the cerebrospinal fluid, and the cerebrospinal fluid inside the third ventricle of the brain. Once they have reviewed the textbook illustration, they should identify the same structures on the MRI image. Finally, the instructor will take away the handout with the textbook and MRI illustrations, and ask the students to draw the human skull, brain, and cerebrospinal fluid from memory. Once all students have completed their drawings, regroup the students and discuss the activity using the prompts below or your own. Be sure to emphasize difference between the textbook illustration and actual MRI image, and introduce the importance of three dimensional modeling by emphasizing the details that can be lost using a two dimensional drawing as opposed to a three dimensional model.*

*Discussion prompts:*

- Did your group have any problems completing the drawing? How did you overcome these problems? Did your group have to leave out any details when completing the drawing?
- How does the textbook illustration compare to the MRI image of an actual head? How does your drawing compare to the textbook and MRI images?
- How would a three dimensional model be better than a two dimensional image? What could a researcher do with a three dimensional model that could not be accomplished with a two dimensional image?

*Lecture: Introduction to the function and diseases of cerebrospinal fluid*

*Time: 20 minutes*

Depending on the preliminary classes they have taken, students may or may not understand the function of cerebrospinal fluid. The instructor should ask the students what they think the function of cerebrospinal fluid is in the brain and make a list of all answers on the board. Once all answers are given, focus on the two main functions of support and protection against impact. Make sure that the students understand how the cerebrospinal fluid supports the brain from crushing under its own weight and from crushing the nerves in the spinal column as these concepts will be investigated in the final activity for this lesson.
The second concept for this lecture is to introduce one specific disease of the cerebrospinal fluid – hydrocephalus. Detail that hydrocephalus is an abnormal buildup of cerebrospinal fluid in the third ventricle. Use the analogy of “water on the brain” to help student understanding of what hydrocephalus is. Ask students what they think that the buildup of cerebrospinal fluid will do to the brain and how it will affect the brain. Ensure that they know how much the pressure on the brain will increase and the serious side effects of that pressure increase.

Closing Activity: Investigating the two main functions of the cerebrospinal fluid

_Time:_ 25 minutes

_Materials:_ 1 clear plastic cup per group filled with water (the cups must be large enough for the students to be able to insert their hand), 1 small weight that can be submerged fully in water, 1 plastic straw per group

_Preparation required:_ Fill the cups with water of no water is available in the classroom

_Instructions:_ Divide the students into groups of 2 or 3 and have them fill their cups with water if they are not already filled. Remind them that the cerebrospinal fluid is 97% water.

The first function of cerebrospinal fluid that will be investigated is support of the brain by weight reduction. Remind the students of this function and that the cerebrospinal fluid, being mostly water, reduces the weight of the brain. First, have them hold the weight in their hand and feel how heavy it is. Then, instruct the students to place the weight in the water and then hold the weight underwater to feel how much lighter it is. Make sure they understand that this same phenomenon of buoyancy supports the weight of the brain.

The second function of the cerebrospinal fluid that will be investigated is protection of the brain from impact. Have the students empty their cups and place the straw inside. Instruct them to shake the cup and notice how much the straw moves around inside the cup. Then, have them refill the cup with water and insert the straw again. Instruct them to shake the cup again (being careful not to spill the water) and take notice of how much the straw moves inside the cup with the water present. Make sure the students understand how much the water decreases the movement of the straw and that they understand that the same concept protects the brain during impact.

_Closing discussion prompts:_

1. Did you feel the weight become lighter when it was supported by the water? How does this happen with the brain and cerebrospinal fluid?
2. Did you see the straw move less when it was in water? How does this happen with the brain and cerebrospinal fluid?
3. What disease of the cerebrospinal fluid did we learn about today? How does this disease harm the brain?
4. How is a three dimensional model better than a two dimensional model? How can a three dimensional model help scientists research diagnosis and treatment of hydrocephalus?

Close the lesson by telling the students that now that they know the importance of a three dimensional model, they will learn how three dimensional models can be made during the next lesson.
Lesson 2: Introduction to additive manufacturing and brain modeling

Opening Activity: Building a model using additive manufacturing
Time: 30 minutes
Materials: Thick cardboard or foam core, scissors, glue
Preparation required: None*
Instructions: The students will build a model using a simple version of the additive manufacturing process. Instruct the students to choose a simple shape (a cube, pyramid, sphere, etc.) that they would like to build using a process similar to additive manufacturing. Instruct them to cut out the shapes that they need to build their model, and let them know that they will be stacking the layers they cut to build their model. Once all the shapes are cut, instruct them to stack the layers of cardboard or foam core together and glue each layer to the next to build their model. Once the students are done, discuss the activity using the following prompts or your own. Emphasize that additive manufacturing models can be detailed, accurate, and three dimensional.

Discussion prompts:
1. Did you encounter any difficulty creating your model? How did you overcome the difficulties?
2. How is your three dimensional model different from a two dimensional drawing? How does this relate to a model of the human brain?
3. Is your model accurate and detailed? Why or why not? How much more accurate do you think a computer model would be?

*L If the students have trouble visualizing the shapes they will need, it may be beneficial to have an example prepared beforehand

Lecture: Introduction to additive manufacturing
Time: 15 minutes

Let the students know that the process they just used to create their models is very similar to the process of additive manufacturing! Define additive manufacturing on the board very concisely (example: “Additive manufacturing is the process of creating a three dimensional model from a computer model by fusing layers of material together). Discuss the various machines, materials, and methods of fusing the materials together that are utilized in additive manufacturing (Resource: www.rpc.msoe.edu). Discuss how additive manufacturing can be used to create models of parts of the human body and how and why these models will help advance research.

Closing Activity and Discussion: Relating Lesson 1 and Lesson 2
Time: 15 minutes
Materials: Paper, pencils
Preparation required: None
Instructions: Divide the class into groups of 2 or 3. Instruct them to come up with a list of additive manufacturing materials that could be used to build one part of the brain model. For example, come up with one machine OR material that could be used to build a three dimensional model of the human skull. The teacher should circulate throughout the room to assist the students as this may be challenging since the students have likely never encountered additive
manufacturing materials or machines. Complete the teaching module by discussing student ideas and emphasize how valuable additive manufacturing is in creating accurate three dimensional models for medical and biomedical research.

**Closing discussion prompts:**

1. What machine and materials ideas do you have? Why did you choose a specific machine/material?
2. How does additive manufacturing build three dimensional models? How does the layering process allow accurate model creation?
3. How can additive manufacturing be used to create a model of the human head (as discussed in Lesson 1)? How will such a model be useful in researching diagnosis and treatment of hydrocephalus?