

Using Formative Assessment to Understand  
Human Systems, Support, and Movement

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### Abstract

This paper examines how formative assessments can be used to diagnose students' strengths and weaknesses at the beginning of a unit of study, monitor their progress, and help teachers determine their effectiveness (Popham, 2011). It is discussed in the context of exploring human body systems, specifically the skeletal and muscular systems, with seventh grade students. The overarching learning goal for this chapter of study was for students to understand that body systems work together to perform specific functions. Formative assessment tasks are described and rationalized, and student work and learning are analyzed. My teaching methods are also reflected upon. This paper describes how best practices in science teaching were used, based on information from leading organizations and authors in science education, most prominently, the National Research Council (NRC) (2005, 2012), Popham (2011), and Furtak (2009).

*Key words:* formative assessment, human body systems, overarching learning goal,

National Research Council, Popham, Furtak

## Using Formative Assessment to Understand Human Systems, Support, and Movement

The seventh grade science chapter that explores human systems, support, and movement focuses on the complexity of the human body, some of its systems, and how they work together to carry out specific functions. According to the Teacher's Edition of *Human Biology* (Trefil, Calvo, & Cutler, 2005), students may struggle with this topic based on the following common misconceptions: (1) Humans may only use one or a few organ systems for each activity they do (when, in fact, almost all human body systems are at work constantly); (2) bones are not living tissues because of their solid, rock-like appearance (when, in fact, they contain cells, blood vessels, and marrow); and (3) muscles push on bones (when, in fact, muscles don't move bones directly—they contract, pulling on tendons, which attach muscles to bones, and the bones move.) Keeping the above in mind while teaching, these misconceptions were addressed directly during the lessons (Dial, Riddley, Williams, Sampson, 2008, p. 57).

### **Targeted Learning Goals**

An overarching learning goal is the overall concept students should learn, usually based on a content standard. This goal is achieved by students accomplishing supporting learning goals along the way that are formatively assessed (Furtak, 2009, pp. 16-7). The overarching learning goal for this chapter is that students will know that the human body is made up of organ, or body, systems that work together to perform necessary functions. Supporting learning goals to be formatively assessed are that (1) the human body is complex and is made up of many parts and systems (see Tasks #1 and #2 in the following section); (2) the skeletal

system provides support and protection (see Task #3 in the following section); and (3) the muscular system makes movement possible (see Task #4 in the following section).

### **Formative Assessment Tasks**

Students completed four tasks to be formatively assessed throughout this chapter of study. The first served as a pre-assessment in order to discover what prior knowledge students already had, or to diagnose their strengths and weaknesses (Popham, 2011). The purpose of the second and third tasks was to monitor students' progress and accomplish the supporting learning goals of the chapter (Popham, 2011). In order to continue monitoring progress as well as to determine my effectiveness in teaching the concept of body systems working together, students completed Task #4 so that they could apply the supporting learning goals to the overarching learning goal (Popham, 2011).

#### **Task #1: Pre-assessment**

Students wrote a response in their notebooks to the following warm-up prompt as an introduction to the chapter: "List as many human body systems as you can think of." After a discussion and creation of a class list of all the organ systems, students worked in small groups and drew a person doing an everyday activity (eating lunch, running, sleeping, etc.) Next to the drawing, they wrote any organ systems they thought were involved in that task. The activity concluded with another whole class discussion to determine that most, if not all, of the organ systems are involved in all daily activities.

#### **Task #2: Monitoring progress**

In order to review concepts taught earlier in the year so that they could be applied to this chapter of study, students drew either a linear or bull's eye concept map (Furtak, 2009, pp.

22, 73) to show the relationship among cells, tissues, organs, organ systems, and organisms. They also had to include a definition, example, or drawing for each level (See Appendix A).

### **Task #3: Monitoring progress**

In order to prepare for this lesson, students completed a study guide the previous night that paralleled the skeletal system section in the textbook. In class, students answered the following warm-up question in their notebooks: “What was the most surprising thing you learned about the skeletal system?” After a small group and then whole class discussion, students moved on to Task #3, which was a two-part task. First, after looking at a diagram in the textbook of the inside of a bone, small groups discussed the function of the parts inside the bone (spongy bone, cells, blood vessels, and marrow) in order to confirm that bones are living parts of the body. Second, we looked at bones from a real skeleton and held a class discussion on the function of different bones based on their structures (i.e., femur for support and skull for protection). Next, after a brief vocabulary lesson on the words “axial” and “appendicular”, students colored those two main sections of the skeleton and then labeled the major bones, using the textbook as a guide.

### **Task #4: Monitoring progress and determining teacher effectiveness**

The goal of Task #4 was to help students connect how muscles and bones work together to produce movement, and subsequently relate to the overarching learning goal of understanding that organ systems work together to perform specific functions. Students had to first understand what connects bones and what connects muscles to bones. They answered the following warm-up question in their notebooks: “What is the difference between ligaments and tendons?” After determining that ligaments connect bones to bones and tendons connect

muscles to bones, I took a class survey in order to address the common misconception that muscles push on bones. I asked students to raise their hands if they thought muscles push on bones to move them. Then I asked them to raise their hands if they thought muscles pull on tendons, which pull on bones to make them move.

Next, students participated in a kinesthetic activity with me. We moved the various joints in our bodies and categorized them as angular (“hinge”), rotational (“ball and socket”), or gliding. We then did some bicep curls and tricep bends. We placed our fingers on each of those muscles in order to feel them contracting, allowing the tendons to pull on the bones to make them move. Afterward, everyone made a model of an arm with tongue depressors and rubber bands. (See Appendix A, Figure 15). The rubber band “muscles” had to be pulled to contract, causing the “tendons” to pull on the “bones” (which counters the misconception that muscles push on bones directly to make them move). They also labeled the parts of the arm model. Lastly, students wrote an answer to the following prompt: “Explain how the skeletal and muscular systems work together to produce movement.”

### **Formative Assessment Tasks Rationale**

#### **Task #1:**

The response to the prompt about listing body systems demonstrated students’ prior knowledge they had about how the human body is made up of complex systems that work together to perform functions. After class discussions and group drawings, I expected students to change their ideas about how many organ systems there are and how they work together. I expected that they would add organ systems to their drawings that they initially hadn’t thought about.

**Task #2**

The concept map demonstrated students' understanding of the hierarchy of the structure of an organism and the relationships between each level. Students could have had the idea that the various levels function separately; the concept map (and the details they added to each section) visually aided them in seeing the connections between each level. This task also allowed students to bring to mind the concepts learned earlier in the year, beginning with the function of the parts of cells and building from there. The seventh grade biology units apply the National Research Council's (2012) cross-cutting concept of "Structure and Function" throughout the year, so that students can continue to build upon their prior knowledge (pp. 96-8, 144).

**Task #3**

Students may have had the idea that bones are not living tissues, or they might not have realized that bones have different functions based on their structures. I expected that the textbook diagram and actual bones from the skeleton model would change those ideas. The class discussion on the skeletal system gave me an idea of whether or not students applied the concepts of the relationship of structure and function and that bones are made of living tissues. By discussing bones as living tissues, students had to recall the knowledge learned earlier in the chapter about the relationship of the levels of an organism's structure (cells and tissues inside bones, bones as organs, and the skeletal system as an organ system). Their drawings showed if they have a basic understanding of the structure of the human skeleton and the locations of the major bones.

**Task #4**

Students may have had the idea that bone and muscle movements are not connected; this lesson and model creation established that they are. The arm model showed me students' understanding of the relationship between the two systems and the relationship between the basic structure of the arm (made up of muscles, bones, ligaments, and tendons) and its function of movement. Their responses to the prompt about the relationship between the skeletal and muscular systems demonstrated their achievement of the overarching learning goal, which is to understand that organ systems work together to perform specific functions.

**Analysis of Student Work and Learning****Task #1**

I expected students to recall a few of the “more obvious” organ systems as they wrote their answers to the prompt. I also expected that some students might get some of the organs confused with organ systems. Students met my expectations for the pre-assessment. Their answers to the warm-up prompt in their notebooks showed that 18 out of 26 students listed systems such as nervous, muscular, skeletal, digestive, cardiovascular, and respiratory. Five students wrote some of those as well as cells, brain, lung, kidney, and stomach. Three students wrote nothing, but it is unclear as to whether they were wasting time or they did not know any possible answers. Based on these results, we created a class list in order to include as many systems as possible. Students also referred to their books to add additional items to our list. We also reviewed the levels of organization in an organism so as to differentiate between organs and organ systems.

As groups made their drawings of a human performing a daily activity, I expected that the discussion within each group would lead students to bounce ideas off of each other so that they would discuss how particular body systems were involved in the activities they chose. I also thought that students might not have thought about some of the “less obvious” body systems at work, which addressed one of my expected misconceptions. Most of the group drawings met my expectations as well. Six out of eight groups included at least five body systems in their drawings, which demonstrated their understanding that body systems have to work together. Two groups only labeled two or three systems because they spent too much time drawing and ran out of time to label. (See Appendix A, Figures 1-8.) (Also see Appendix B for a list of all assessment results.)

Many groups did not initially think about the immune system always at work to protect the body from illness. They also hesitated on including the digestive system until we looked up on the Mayo Clinic website that it takes an average of six to eight hours to digest food through the stomach and small intestine, and it takes an average 40 hours for food to pass completely through the system (Picco, 2012). Students then determined that it was appropriate to add the digestive system label to their drawings. These are two examples of “less obvious” systems that, once discussed as a group, students went back and added to their drawings. The goal of the discussion after students completed their drawings was to help them understand that most, if not all, of the body systems are constantly working together in order for human bodies to function properly.

**Task #2**

The goal of this assessment was to help students recall what they learned earlier in the year and apply it to the current chapter of study. I expected that most students would be able to draw and label the levels of organization of an organism and give a definition or write or draw an example. Unfortunately, this task did not go as planned. I was not actually teaching science that day, but my colleague and I agreed that students would perform this assessment anyway, since it was a concept with which students were already familiar. However, my colleague had a substitute teacher in her class that day, and she had forgotten to include that task in the sub plans.

In order to get a very basic idea of my students' knowledge on the topic, the next day I asked four of the seventh graders in my homeroom to complete the task. Two of the students mastered this assessment, as they drew all the levels of organization and included an example for each. The other two students also included all of the levels, but left out one or two examples. (See Appendix A, Figures 9-12.) Based on our class discussions during Task #1, I believe that most of the students would have performed similarly to the other four. I also determined that leaving out one or two examples would not hinder students' understanding of the new concepts as we moved on in the chapter.

**Task #3**

The purpose of the warm-up question "What was the most surprising thing you learned about the skeletal system?" was to address the misconception that bones are merely hard objects and are not living. Indeed, students met my expectations here. Twenty-one out of 25 students answered that they were surprised that bones were living tissues or that they had

other living materials in them (such as blood, marrow, or spongy bone). Four students wrote nothing for their responses.

With their small groups, students then looked at a diagram of the inside of a bone and discussed the functions of the various parts. Having a visual aid to discuss reinforced the concept of bones as living materials. Students also looked at bones from a skeleton, and several of them pointed out the spongy bone clearly visible in each vertebra. This showed me that these students were applying what they had just learned to what they were observing.

Students also had to agree with their groups on the function of the bones at their tables, based on the structures of the bones. I expected that students would be able to determine the function (either support, protection, movement, or a combination) because all of them had seen models or drawings of skeletons before, so they were familiar with what many of the bones looked like. They did meet my expectations, as all groups answered correctly.

Lastly, students had to color the axial and appendicular skeletons different colors and label the major bones. (See Appendix A, Figures 13 and 14.) I thought students would understand the words axial and appendicular better if we also did a brief vocabulary lesson. Since they are familiar with determining the meanings of word roots in my English class and relating them to other words they know, we discussed how the axial skeleton is like the Earth's axis. It runs down the middle, and everything stems from there. The axial skeleton includes the head and the core of the body. After determining that appendicular comes from the same root as "append", which means "to attach", much like an appendix in a book attaches to the end of it, students explained to me how the appendicular skeleton is made up of parts that attach to the axial skeleton. With this new knowledge, I expected that students would easily be able to

differentiate between the two sections of the skeleton. They met my expectations, as all students colored the skeleton correctly. All students also labeled the major bones correctly, using their textbooks as guides. My goal for them was not to memorize the bones, but just to be familiar with them for future discussions and lessons. Since students demonstrated a good general knowledge of the skeletal system and the functions of various bones, I determined that they were ready for the next step, which was to learn about the muscular system and make a connection between it and the skeletal system.

#### **Task #4**

Just as students had done for the skeletal system, they completed the study guide the previous night that paralleled the muscular system in the textbook. There were two goals for this lesson. The first was to correct the misconception that muscles push on bones to move them. The second was to have students complete a final formative assessment that related this lesson to the overarching learning goal.

I knew time would be the biggest constraint for this lesson. I also thought it was important to discuss joints, ligaments, and tendons before making the arm model, so that students could put the model into context. Students went beyond my expectations in terms of addressing the misconception mentioned above. When I took the class survey, all students raised their hand when I asked, “Who thinks muscles pull on tendons, which then pull on bones to make them move?” This showed me that everyone completed their reading and study guide the previous night.

Time did, in fact, run out before everyone could finish their arm models. However, they wrote their assessment question down in order to complete it for homework. My colleague

had students finish their arm models the next day. Most students' assessment answers met my expectations. Fourteen out of 23 answered correctly by mentioning that muscles contract and pull on tendons, which pull on the bones to create movement. Six students had partially correct answers. Two of these students mentioned that muscles pull on tendons, but wrote nothing else. Two students had the concept correct, but wrote "ligaments" instead of "tendons". One student stated that muscles pull on bones, but did not mention tendons. Instead, he used "joints" to describe the function of tendons. The last student mentioned the correct parts but reversed the concept. He stated, "[The muscular and skeletal systems] work together like a pulley system. The tendants are the cords that help pull your muscles and bones. The skelletal system is support for the muscles."

The last three students did not answer the question correctly. One student wrote, "Muscles are attached to bones. Muscles cross one or more joints between their attachments." Another stated, "Muscles and skeletons have a special job. Skeletons help you with posture and along with muscles, to create movement. Muscles give you strength." This student wrote about the functions of the systems individually, but did not make the connection between the two. The last student wrote, "The muscles push the things around the bones to make them move." This was the most disappointing answer since this student is very bright, and she used very vague terms and explained the concept using the misconception that we spent time in class correcting.

For all of the other tasks, I provided verbal feedback during our discussions. This time, I have provided written feedback on students' assessments. Since I will not have any more opportunities to follow up with these lessons, I plan on showing my colleague the results of the

assessments and suggest that she have students demonstrate on their arm models the correct concept and then have students struggling with this concept revise their assessment answers.

### **Reflection on Teaching**

Based on the warm-up responses used to gauge student misconceptions, I determined that I needed to address the ones the teacher's guide had mentioned. Addressing these proved to be a launching point for the lessons. Then, using the results of each of the first three assessment tasks, I determined that I could move on to the next supporting learning goal, as students had a good general understanding of each concept. The first assessment showed me that students understood that multiple body systems were at work at all times in order for humans to function.

The second assessment, though it had far fewer students to assess, still showed that students understood the levels of organization. They had applied the knowledge they had learned up to that point in the year to understand that life starts at the most basic unit, the cell, and builds from there.

The third assessment, in addition to the discussions about bones as living materials and the function of the various bones, provided me with enough feedback to know that students were ready to take the next step in this chapter, that is, understanding how muscles and bones work together, which would help them achieve the overarching learning goal.

The written assessment from the fourth task provided me with the most feedback since it related to the overarching learning goal. The results showed me that some students need to review the concept of how the muscular and skeletal systems work together to produce

movement, whether it be through a demonstration on the arm model, revising their statements, or both.

If I were to teach these lessons again, particularly the fourth one, once students were finished with their arm models, I would ask them to push on the “muscles” to see if they could get the desired movement of the “bones”. Obviously, the bones wouldn’t move. This would reinforce the concept that muscles don’t push on bones, rather, they pull on the tendons to move the bones. Yin, Tomita, & Shavelson (2008) state that it is important to provide counter-evidence to misconceptions, and demonstrations are effective ways to do this (pp. 35-9). Perhaps this extra visual demonstration would have helped more students fully understand the concept in order to answer the assessment question correctly.

### **Conclusion**

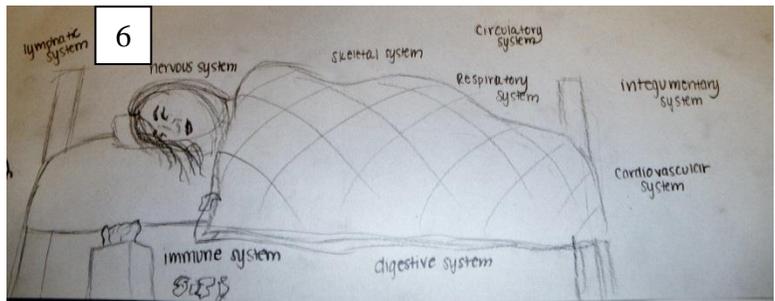
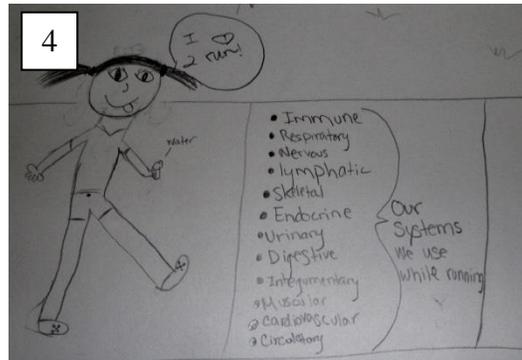
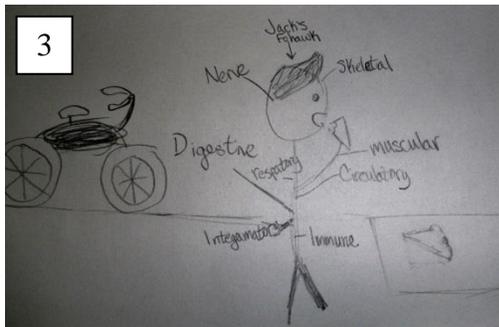
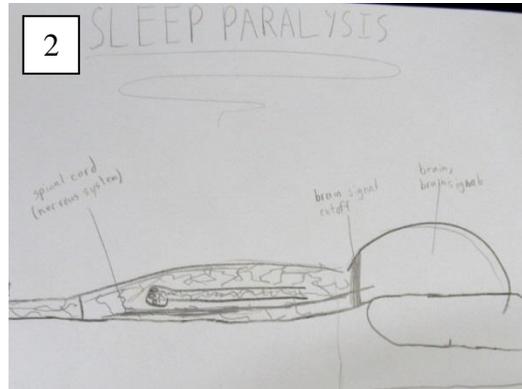
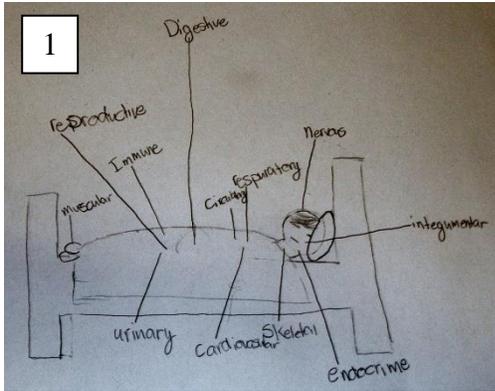
One of my roles as a teacher is to help students bridge the gap between their prior knowledge and new concepts in order to achieve conceptual understanding (NRC, 2005). One way to do this is to formatively assess students along the way. It is imperative to understand where students’ knowledge begins when starting a new unit of study so that teachers can be better prepared in their planning and for combatting misconceptions. It is also equally important to continually monitor students’ progress. Teachers must use this knowledge to determine whether to move on or reteach a concept. In doing so, teachers can help students achieve overarching learning goals and learn broad concepts that can be applied to many concepts further along in their education.

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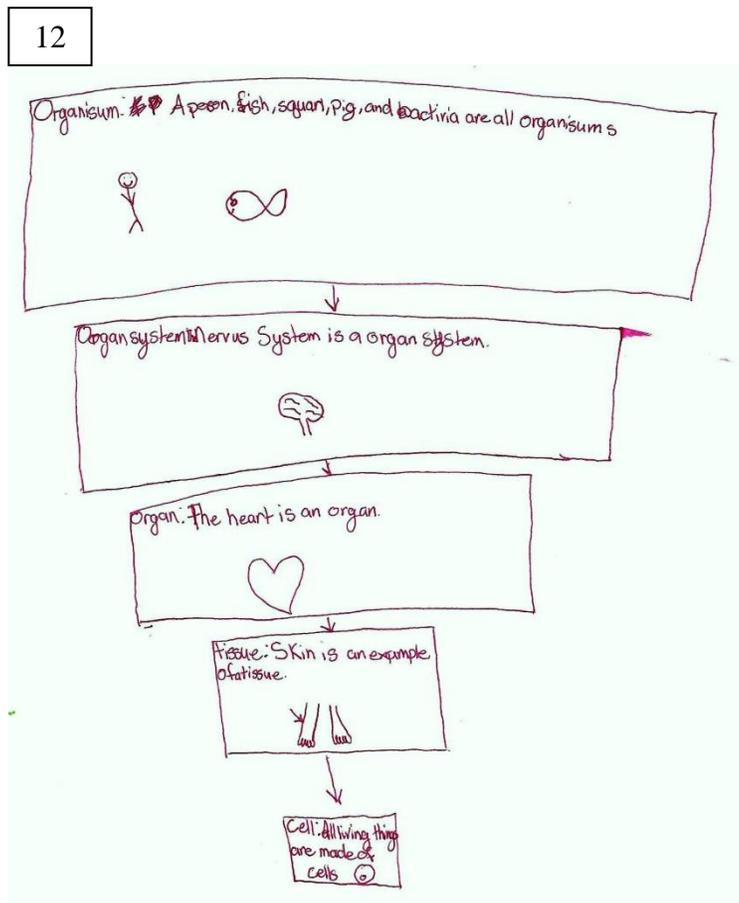
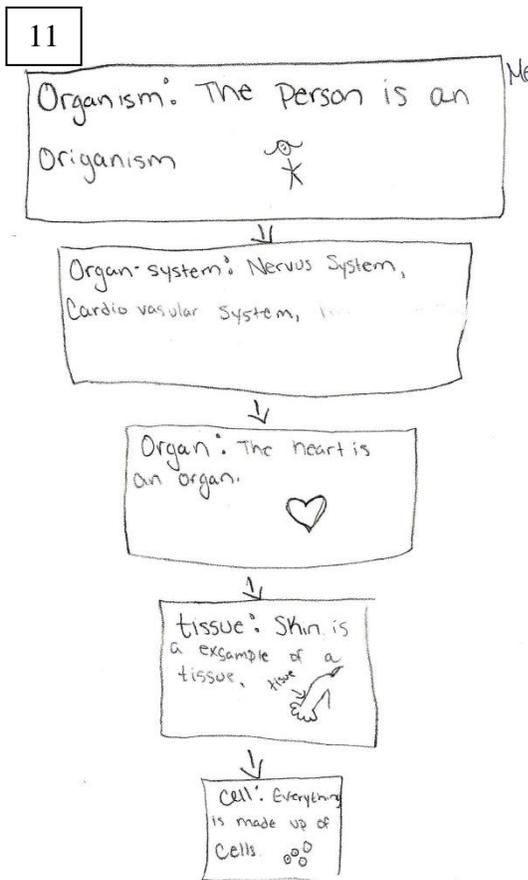
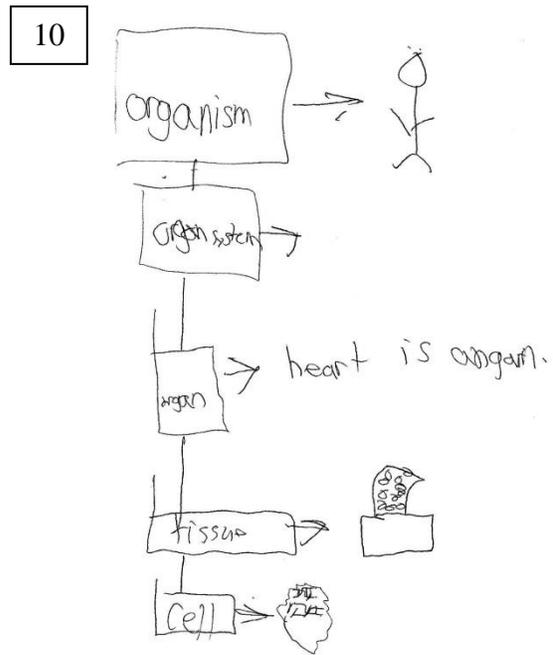
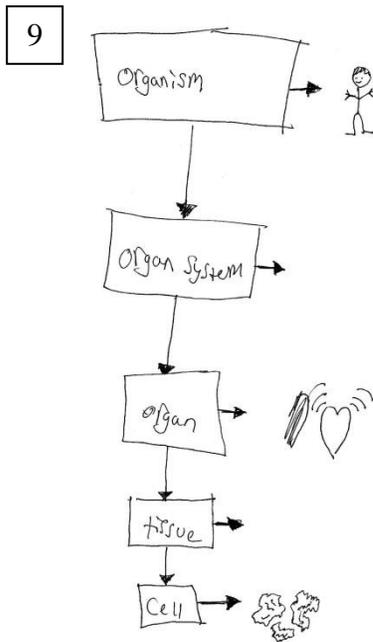
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Appendix A

Figures 1-8: Group drawings of body systems working during a daily activity (Task #1)



Figures 9-12: Student concept maps of the levels of organization in an organism (Task #2)



Figures 13-14: Skelton diagrams showing the axial and appendicular skeletons and the major bones (Task #3)

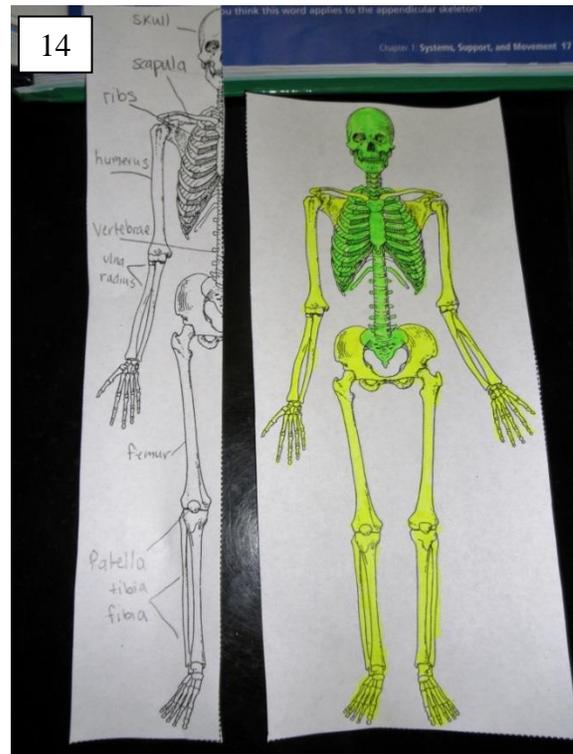
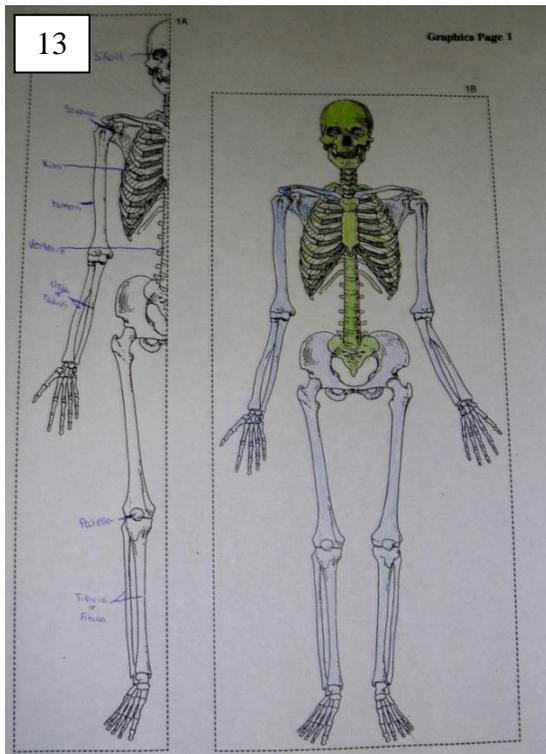
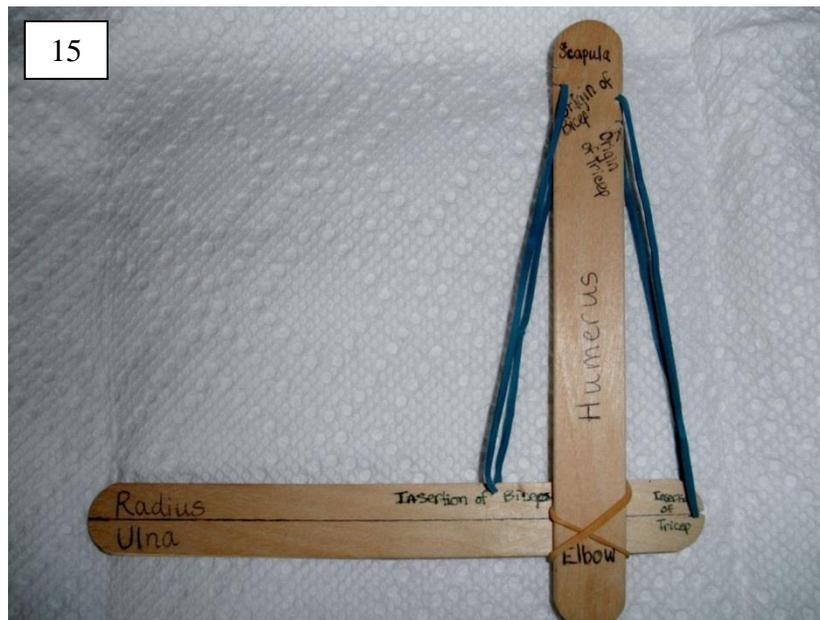


Figure 15: Arm model (Task #4)



Tongue depressors represent bones; blue rubber bands represent muscles; notches where rubber bands are inserted represent tendons; beige rubber bands represent ligaments.

## Appendix B

Scores for student assessment tasks:

3=mastery    2=partial understanding    1=little or no understanding

Task #1: Must label at least 5 body systems working together (out of 37 students\*)

3= 30 students

2= 7 students (Figures 2 and 8)

1= 0 students

Task #2: Must label the levels of organization correctly and give a definition, example, or drawing for each (out of 4 students\*)

3= 2 students

2= 2 students (Correct hierarchy, but left off an example for 1 or 2 levels; see Figures 9 and 10)

1= 0 students

Task #3: Must color axial and appendicular skeletons correctly and label the major bones correctly (out of 26 students\*)

3= 26 students

2= 0 students

1= 0 students

Task #4 (Part 1): Must assemble all parts of model and label the parts of the arm correctly (out of 37 students\*)

3= 28 students

2= 0 students

1= 0 students

Task #4 (Part 2): Must write that muscles contract or pull on tendons, which then pull on bones to produce movement (out of 23 students\*)

3= 14 students

2= 6 students

1= 3 students

\*Lessons were taught on different days, so some students were absent and were not able to turn in their results before the due date for this project. Many students were absent on the last day when I collected their notebooks, and a few failed to turn in their work (see discrepancy in numbers for Tasks #3 and #4, Part 2).