INQUIRY & INVESTIGATION

Demonstrating the Role of Osmosis in Diabetes Using Growing Spheres

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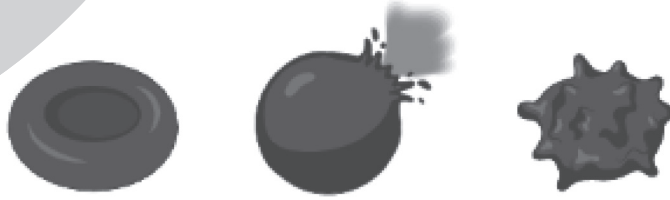

Abstract

"Hands-on inquiry" has become a buzzword in science education but does not have an exact definition for most practitioners. This leads to many different ideas of what inquiry should look like in the classroom, and researchers have discovered that just doing hands-on activities does not lead to deeper understanding. This is why it is important to incorporate the scientific practices of the Next Generation Science Standards *into activities in the classroom, particularly designing an investigation and analyzing data. A new twist on a classic high school biology lab demonstrates how students can design and analyze their scientific investigation to draw conclusions and apply their new understanding to the human body. This activity also demonstrates how teachers can incorporate instructional material into an inquiry activity, since time constraints are a particular concern in the high school classroom.*

Key Words: *red blood cells; osmosis; homeostasis; model-based inquiry; diabetes; blood glucose; NGSS; high school.*

○ Introduction

The high school science classroom is currently undergoing a major transformation in how students learn and interact with scientific concepts. The *Next Generation Science Standards* ask teachers to move away from just focusing on scientific facts and information and to embrace a three-dimensional approach to teaching that incorporates the disciplinary core concepts, scientific and engineering practices, and crosscutting concepts (NGSS Lead States, 2013). These new standards help teachers have a better understanding of what good inquiry-based learning looks like in the classroom. Each learning activity a teacher incorporates into the classroom should focus on this three-dimensional learning to be most effective.

It is important to remember that just because an activity is "hands-on" does not necessarily mean it will result in the most amount of learning for our students. When Holmes and Wieman (2018) investigated the role of lab instruction in supporting content covered in undergraduate introductory physics courses, they found that concepts covered in lecture that were then reinforced by a lab activity did not show any statistically significant gain in understanding when compared to content covered just in lecture. This result seems to go against what science education literature has highlighted – that inquiry-based learning is a more effective teaching strategy. However, Holmes and Wieman (2018) also found that students gained more understanding when given some options concerning lab activities – particularly, being able to design portions or all of a lab, determine how to collect and analyze data, and learn and adapt from failure while doing a lab. Similarly, Khaparde (2019) found that students gained more understanding when provided "experimental problems" to solve instead of prescriptive labs to complete. Problems to solve engage students better than steps to finish, the students are more engaged in the science, and the activity better replicates the true process that scientists use to understand the natural world.

These results highlight the significance of scientific and engineering practices, especially designing and carrying out a scientific investigation. When students have some control over designing their own lab procedure, they are more engaged in the learning activity and are likely to learn more from the experience (Holmes & Wieman, 2018). Teachers may be concerned about the amount of time required for such lab activities, but traditional lecture material can be incorporated into the activity instead of being delivered separately. It is also important to note that constraints and some guidance need to be provided to students when they design their own lab procedure in order to know what the goal of the activity is and a pathway to achieve that goal.

○ Osmosis Inquiry

A common way to introduce students to the concept of osmosis is to use dialysis tubing and solutions with varying concentrations of salt or glucose. Then have the students determine changes in weight when soaked in these solutions, possibly with some loose connection to the human body. The traditional dialysis tubing lab is often difficult

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for students to set up, which makes it hard to have students design their own investigation plan, and the results can vary widely among groups, making it hard to have a good class discussion about what is happening. Also, the lab is rarely tied to a real-world phenomenon, so it is difficult for students to apply their understanding of the topics covered in the lab. However, this traditional lab can easily be adapted to have students design their own investigation, producing deeper understanding, and changed to use growing spheres instead of dialysis tubing to get quicker, more accurate results. This activity also ties what is happening to the growing spheres in the lab to what happens to the cells in our body when blood sugar levels are not managed, giving this lab more real-world applications for students than the traditional dialysis tubing lab. The activity described below serves as an example of how to implement inquiry in the classroom while introducing instructional material so that time is not a constraint in the inquiry classroom (Table 1).

○ Teacher's Preparation

The setup for this investigation is easy and straightforward for teachers. Growing spheres (Orbeez) from either Amazon or Educational Innovations need to be purchased in the small to medium size. These growing spheres need to be rehydrated for 24 hours in tap water. You do not need many growing spheres, so be careful how many are added to a 1000 mL beaker for rehydrating – because if too many are used, they will spill out of the container. Make sure the growing spheres are completely rehydrated before use (if they are not, it will affect the results students get).

Three solutions must be made to represent hyperglycemia, hypoglycemia, and normal blood glucose levels. The amount of solution needed depends on how many students will be completing the investigation, but I usually allow my students to use 50–100 mL of each solution. Students should be given this parameter when designing

Table 1. Alignment of diabetes and growing sphere activity to *Next Generation Science Standards* (NGSS) dimensions (NGSS Lead States, 2013).

NGSS Dimension	Name & Standard Code	Activity Component
Science and Engineering Practices	Planning and Carrying Out Investigations Analyzing and Interpreting Data Constructing Explanations and Designing Solutions Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information	Students design an investigation plan to determine how a growing sphere will change when placed in solutions with varying tonicity. Students collect data and use a graph to analyze the data. Using the analyzed data collected from the lab, students construct a scientific explanation that answers the investigation question. Student groups share their findings with their classmates and determine the best explanation of how the tonicity of solution affected the growing sphere.
Disciplinary Core Idea	LS1.A: Structure and Function Systems of specialized cells within organisms help them perform the essential functions of life. (HS-LS1-1) Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-2) Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-3)	Student groups conduct a scientific investigation into how cells respond to changes in blood sugar levels using growing spheres (cells) and solutions with different tonicities. Students apply their understanding of how cells respond to changes in blood sugar to how the body is affected by unmanaged diabetes.
Crosscutting Concepts	Stability and Change Cause and Effect	Students explain how and why the cells (growing spheres) were affected by different solutions.

their investigation but should not be told exactly how much to use. For the solution representing hyperglycemia, a large amount of salt or glucose should be added to tap water and then dyed green with food coloring. For the solution representing hypoglycemia, distilled water (using distilled water is the easiest way in the classroom to represent a solution with a low solute concentration similar to hypoglycemia) should be used and dyed red with food coloring. For the solution representing normal blood glucose levels, tap water should be used since it was also used to rehydrate the growing spheres and dyed yellow with food coloring. The only other supplies that the students will need are weigh boats, a scale, and small beakers.

○ Designing the Investigation

When students are designing a scientific investigation for the first time, they need to have structure and constraints to work with. A quick discussion about what makes a good investigation plan is useful if students are not familiar with designing their own experiments; students should understand that their plan needs to be reproducible, produce quality data, and be written out in numbered steps in a logical order. For this investigation, the students are given the question "How does glucose level in the blood affect cells?" Students should also predict what they think will happen to cells in a high-glucose solution, low-glucose solution, and normal level of glucose solution. Before writing the investigation plan, students need to identify the independent, dependent, and controlled variables to create a high-quality experiment.

At this point, students can work in pairs or small collaborative groups to design an experiment. As a teacher, try not to steer the designing too much and allow students to set up their experiment as they see fit. Students may design an experiment that does not produce good-quality data or does not quite answer the investigation question, and if time allows, these students should redesign their investigation based on what they learned from their mistakes. Some students may need a little guidance on getting started, so I like to remind the students of the investigation question and have them think about how they can use the materials to answer the question. Students should also be prompted to include in their investigation plan how they will collect, organize, and analyze their data. A couple of things to point out to students while they are designing their experiment is that the growing spheres can sometimes fall apart after soaking, so they need to write precautions into their investigation plan about how to avoid losing pieces of the growing spheres, and that growing spheres should only be soaked for about 25–30 minutes. Having students design their experiment really forces them to think deeply about the purpose and results of the investigation. For an example activity handout, see Handout 1 in the Supplemental Material (available with the online version of this article).

○ Incorporating Instructional Material

Having students design their own investigations and engage in inquiry-based learning typically takes more time than traditional lecture-based instruction. This extra required time can often deter teachers away from using inquiry-based methods in their teaching (Fitzgerald et al., 2019), but there are ways to incorporate the instructional material into the activities to avoid issues of time constraints. With most lab investigations, there are periods of downtime while students wait to collect data. This presents a perfect time to introduce instructional material to the students.

In the example activity, students work with their group members to research information about osmosis and blood glucose levels in the body while the growing spheres are soaking in different solutions. The instructional material should be directly connected to the lab investigation, and students should have to apply this information to analyze and explain their data. In the activity, students have to apply how osmosis works in the body to explain how the growing spheres (representing cells in the body) changed size while in the different solutions. The students also take this information a step further by explaining how the change in cell size relates to issues in the body that diabetics commonly experience (see Handout 1).

○ Presenting & Discussing Results

In order to reach a class consensus and make all students' thinking visible, results should be shared publicly with the class. In my classroom, this is typically done using larger whiteboards for students to briefly describe or diagram their investigation plan, graph data, and write out a scientific explanation. There are many different ways to format how students share their whiteboards with the class, but the best way I have found for my classroom is to have a gallery walk. At least one group member stays with the whiteboard to present information on the board while the other group members walk around to other groups' boards to hear presentations, write down information about the other groups' investigations, and ask any questions they have. If this is the students' first time doing a gallery walk, it may be beneficial to explain the process, discuss what information would be helpful for them to write down, and brainstorm with them good questions to ask. It also may be helpful to discuss how presenters should answer questions, noting the insufficiency of responses like "I don't know" or "That's just what we got."

I have a discussion monitoring sheet (Supplemental Material: Handout 2) that includes a checklist of items the students should have on their board, a notes area for me to take notes on each of the boards, and discussion questions to make sure all students have a thorough understanding of the concept being investigated. While the students are engaging in the gallery walk, I also walk around and fill out my discussion monitoring sheet.

When the students have completed the gallery walk we have a class discussion. Your role as a teacher during class discussion is to provide guidance but not lead the discussion. You may need to start off the discussion with one of the questions on your monitoring sheet or you can open the floor to student questions. The students should be the leaders of the discussion and asking questions, but the teacher at times may need to steer the discussion toward the main takeaway points to ensure that the concept being covered is understood. Comparison of investigation plan setups, graphical results, and scientific explanations (especially reasoning) are all good areas to focus on during the discussion. Application questions can be completed as check-in during the discussion to determine student understanding.

Table 2. Activity Implementation.

Activity Component (Handout 1)	Implementation
Introduction	Students read this before starting the activity to engage in the focal phenomenon/concept.
Part I	Students complete online demos and read background information.
Part II	Students work in small groups to complete the Prediction and Investigation Plan
Part III	While students are waiting to complete the remaining sections of Part II, they complete the readings in Part III.
Part II	After waiting 25–30 minutes (and completing Part III), students return to Part II and complete the Data Collection, Data Analysis, and Scientific Explanation sections.
Present and Defend	Once Part II is complete, the small groups work to create a presentation on their Investigation Plan, Data Analysis, and Scientific Explanation. These presentations are shared with the class using a gallery walk. The students then discuss the class findings, based on what they learned during the gallery walk.
Application Questions	When the class discussion is complete, the students complete the activity Application Questions.

○ Conclusion

This activity provides a new twist on a classic high school biology lab by engaging students in scientific practices and has the students apply the knowledge from the activity to a real-world situation. Giving students the opportunity to design their own scientific investigation will create variation in results, which leads to great discussion topics and also helps students better understand the concepts being covered. This activity is an example of how teachers can integrate instructional material into inquiry to avoid time concerns and how to make the concepts being covered apply to the students' everyday lives. The workflow for implementing this activity is shown in Table 2.

○ Suggested Online Resources

- http://mw.concord.org/nextgen/#interactives/biology/diffusion-bio/diffusion-bio-semipermeable-membrane
- http://mw.concord.org/nextgen/#interactives/biology/diffusion-bio/diffusion-bio-drop
- https://www.khanacademy.org/science/biology/membranes-and-transport/passive-transport/a/diffusion-and-passive-transport
- https://www.khanacademy.org/science/biology/membranes-and-transport/active-transport/a/active-transport
- http://kidshealth.org/kid/diabetes_basics/living-diabetes/high_blood_sugar.html#cat20833
- http://kidshealth.org/kid/diabetes_basics/living-diabetes/low_blood_sugar.html#cat20833
- https://www.khanacademy.org/science/biology/membranes-and-transport/diffusion-and-osmosis/a/osmosis

○ Online Supplemental Material

- Handout 1: Example Lab Activity Student Handout (Activity 3.3)
- Handout 2: Present and Defend Discussion Monitoring Sheet

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References

Fitzgerald, M., Danaia, L. & McKinnon, D.H. (2019). Barriers inhibiting inquiry-based science teaching and potential solutions: perceptions of positively inclined early adopters. *Research in Science Education*, *49*, 543–566.

Holmes, N.G. & Wieman, C.E. (2018). Introductory physics labs: we can do better. *Physics Today*, *71*(1), 38–45.

Khaparde, R. (2019). Experimental problem solving: a plausible approach for conventional laboratory courses. In *Journal of Physics: Conference Series*, *1286*.

NGSS Lead States (2013). *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press.

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