Teaching Membrane Transport Concepts Using Flipped Teaching & Dramatizations

ABSTRACT

Cell membrane transport is an important topic discussed in the biology classroom from the middle school to the graduate level. Membrane transport is complex, and students are often confused between different types of transport mechanisms. Dramatization is an active-learning strategy to engage students in learning. The flipped teaching method is designed to introduce lecture content prior to class meeting, thus creating time during class to adapt active-learning strategies such as dramatization. In this work, students were given a pretest prior to the dramatization activity. As each type of membrane transport was discussed, which included simple diffusion, osmosis, facilitated diffusion, and active transport, students were assigned specific roles to demonstrate the movement. The dramatization activity triggered many questions related to the topic, and these questions were addressed immediately. A posttest was conducted at the end of the dramatization activity. Our results demonstrated increases in the students’ understanding, engagement, and confidence level. The combination of flipped teaching and dramatization thus serves as a student-centered active-learning strategy for teaching difficult biological concepts.

Key Words: flipped teaching; dramatizations; membrane transport; active learning.

Introduction

Membrane transport is an important topic that is taught in science courses from middle school through professional school curricula (Seear et al., 1995; Goodman & Percy, 2005; Liang, 2009; Rundgren et al., 2010, Next Generation Science Standards, MS-LS1 From Molecules to Organisms: Structures and Processes). For some students, confusion can linger when differentiating between the types of passive and active membrane transport. Often students do not understand the diagrams that are presented in class, and new ways to teach students these concepts need to be developed (Kottmeyer et al., 2020). It is essential that students learn these fundamental concepts, for their own understanding and to be able to apply this knowledge to new discoveries and clinical cases (Goodman & Percy, 2005).

Dramatization is a type of active learning that engages in the subject matter and improves students’ learning experience (Carvalho & West, 2011). Flipped teaching (FT) is a student-centered method in which the lecture content is introduced before class to make time for engaging activities during class (Delozier & Rhodes, 2017; Gopalan et al., 2020). The goal of this project was to use FT and dramatizations to reintroduce the different types of membrane transport, clarify misconceptions, and increase student confidence in the material.

Methods

A total of nine undergraduate students (six females and three males) were enrolled in both lecture and laboratory sessions of Animal Physiology; each session met once a week for three hours. The students, seven seniors and two sophomores, had all previously taken Principles of Biology I and Principles of Biology II; five were BA biological sciences majors, four were BS biotechnology majors, and one BA student was a double major in BS neuropsychology.

An explanation of flipped teaching was provided to the students the week prior to the FT session. Using the FT design, students were introduced to the topic by assigning PowerPoint slides and several videos and animations on the different types of membrane transport – simple diffusion, facilitated diffusion, osmosis, and active transport – to complete before the lecture session. The videos and animations ranged in length from 1:08 minutes to 13:13 minutes and were accessed on YouTube (Table 1).

Prior to the class meeting, students were informed that they would be performing dramatizations and that their participation in these activities would enhance their learning. These dramatizations were successfully performed the previous semester (fall 2019) in two different courses (BMS 702 Endocrinology and BSCI 735 Cell Biology), yet there was no IRB approval to collect data.

At the beginning of the in-class portion of the FT session, students were given a multiple-choice pretest on content and rated their confidence level in the subject. Each student was given a role to play and was guided through the activity with the instructor.
Students were assigned to view the videos and animations before the flipped class meeting on membrane transport.

| Membrane Transport Topic          | Video/Animation Title          | URL                               | Time (minutes) |
|----------------------------------|--------------------------------|----------------------------------|----------------|
| Osmosis                          | Osmosis [HD animation]         | https://tinyurl.com/yaq2rm3m      | 1:43           |
| Diffusion and Osmosis            | Diffusion and Osmosis          | https://tinyurl.com/gql5en4       | 13:13          |
| Diffusion                        | Diffusion [HD animation]       | https://tinyurl.com/yxzj55xw      | 1:29           |
| Osmosis and Tonicity             | 1-Minute Lab: Osmosis & Tonicity | https://tinyurl.com/ybx9kahd     | 1:08           |
| Active Transport                 | Active Transport               | https://tinyurl.com/joxvkj4       | 3:49           |

narrating. After performing the activity once, the students repeated the activity while narrating their own actions and then switched roles with another student and repeated the activity. Throughout the activity, students asked questions about the concept they were demonstrating, during which the dramatization was paused and class discussion ensued. This method was followed for each type of membrane transport. At the end of the session, students were given a 10-question multiple-choice posttest to assess their knowledge plus 13 Likert-scale questions (1 = strongly disagree, 2 = disagree, 3 = don’t know/neutral, 4 = agree, 5 = strongly agree) where they rated their confidence level in the subject and to determine whether FT helped them learn. A two-tailed Student’s t-test was used to analyze the data. University of New Hampshire Internal Review Board (IRB no. 8005) approved this study and the use of photographs and designated it as Exempt. Examples of the membrane transport pretests and posttests are provided in Supplemental Material Appendix S1, available with the online version of this article.

**Simple Diffusion of Solute**

The classroom chairs were arranged in a single row and identified as the plasma membrane. The extracellular space was defined as the area toward the back of the room, and the intracellular space was the front of the room. All students were given a green paper circle representing solute molecules. Most of the class stayed in the extracellular space while a few students moved inside the cell. Students were asked: “What is a gradient? What is the driving force for solute to move across a membrane? In which direction will you move and why?” Students then diffused across the plasma membrane from the extracellular space into the cell. It was then emphasized that solute molecules did not stop moving, and the term net movement was defined as when a large number of solute moves in one direction. The students then switched roles and repeated the dramatization. This format was used for the rest of the simple diffusion and osmosis activities.

**Simple Diffusion of Oxygen & Carbon Dioxide**

Half of the class were given blue circles (= oxygen) and half were given yellow circles (= carbon dioxide). An additional row of chairs was added parallel to the plasma membrane row. One row of chairs was defined as the capillary membrane (facing the front of the room) and the other was the alveolar membrane (facing the back of the room; Figure 1A). The instructor described the two gradients of oxygen and carbon dioxide. It was stated that it was simple diffusion of gases that allowed carbon dioxide to exit the capillary and enter the alveoli, while at the same time oxygen was diffusing from the alveoli into the capillary. The process of diffusion of gases was dramatized in a stepwise fashion. The students carrying blue circles (oxygen) diffused across the alveolar membrane toward the capillary membrane (Figure 1B). The students carrying yellow circles (carbon dioxide) diffused across the capillary membrane toward the alveolar membrane (Figure 1C). Then both sets of students were told to diffuse, and each moved down the respective concentration gradient (Figure 1D).

**Osmosis**

For this activity, all students were given blue circles that were defined as water molecules. The intracellular concentration of solute was defined as high. All students stood in the extracellular space and then diffused into the cell. It was emphasized that water is moving down its gradient into the cell.

**Facilitated Diffusion of Glucose**

In this activity, three students were selected to be glucose transporters and they stood in between the single row of chairs embedded in the plasma membrane. The remaining students, given yellow circles and designated as glucose molecules, stood in the extracellular space. The glucose molecule could move through the plasma membrane only if it interacted directly with the student serving as the glucose transporter. The students acting as the glucose molecules

**Figure 1.** (A) The row of chairs in front of oxygen molecules (blue circles) is the alveolar membrane. Carbon dioxide molecules (yellow circles) are behind the row of chairs designated as the capillary membrane. (B) Oxygen molecules (blue circles) diffuse down oxygen’s concentration gradient across the alveolar membrane toward the capillary membrane. (C) Carbon dioxide molecules (yellow circles) diffuse down that gas’s concentration gradient across the capillary membrane toward the alveolar membrane. (D) Diffusion of both molecules occurring at the same time.
individually bound with a glucose transporter before being escorted by the glucose transporter across the plasma membrane.

**Active Transport**

One student was designated as the Na\(^+\)–K\(^+\) pump and stood embedded in the plasma membrane (red placards; Figure 2). He was given two clusters of rope: one had two strands, designated as K\(^+\) binding sites; the other had three strands, designated as Na\(^+\) binding sites. Students were given either a yellow circle designated as Na\(^+\) or a pink circle designated as K\(^+\). The student playing the role of ATP was given a white placard labeled ATP. When directed, the students, acting as K\(^+\) bound to the K\(^+\) binding sites, moved into the cell and the students acting as Na\(^+\) bound to the Na\(^+\) binding sites moved into the extracellular space. It was emphasized that there needed to be specific binding of both types of ions by the pump and that two K\(^+\) moving into the cell and three Na\(^+\) moving out of the cell, and that these ions were moving against their gradients. The class defined the three requirements for active transport via the Na\(^+\)–K\(^+\) pump as follows: pump, two ion gradients, and ATP hydrolysis. The activity was repeated with the addition of the student acting as ATP, who became bound to the Na\(^+\)–K\(^+\) pump and then flipped her ATP placard to read "ATP hydrolyzed." Students then switched roles and repeated the activity.

○ **Results**

Overall student performance on the multiple-choice questions on the posttests were significantly improved in comparison to the pretests (\(P = 0.0463\), SEM = 0.8226; Figure 3). After performing the dramatizations, the students became more confident in the material (Figure 4) and all students felt that the dramatizations increased their understanding of the concepts (Table 2). The Likert-scale questions demonstrated that students reported they were more engaged in the class activities (strongly agree, \(n = 4\) students; agree, \(n = 4\); disagree, \(n = 1\)), that the classroom environment/atmosphere helped them learn the course content (strongly agree, \(n = 4\) students; agree, \(n = 4\); disagree, \(n = 2\) students).

!! Figure 2. Students dramatize active transport with Na\(^+\)–K\(^+\) pump. The student in the middle is the Na\(^+\)–K\(^+\) pump, red placards are plasma membrane, the white placard is ATP, yellow circles are Na\(^+\) ions, and pink circles are K\(^+\) ions. The pieces of rope are K\(^+\) binding sites on the left side of the pump and Na\(^+\) binding sites on the right side of the molecule.!!

- **Discussion**

Our results demonstrate that students’ understanding of membrane transport were improved after participation in the dramatization activities. Using group activities effectively engages students in their own learning and generates robust discussion of the concepts (Carvalho, 2011). The classroom environment/atmosphere helped them learn the material, and their attitude toward FT was favorable. While the pretests and posttests were given during the same class period as their dramatizations, the results demonstrated engagement and learning. The next step is to design exam questions that would test their long-term retrieval of the concept.

**Limitations**

Our college’s upper-level courses range in size from eight to 20 students. For larger class sizes, additional roles can be assigned and, as a final activity, several dramatizations of different types of transport can be performed at the same time, moving varied ions/substrates across a single plasma membrane. The next time this activity...
is performed, some of the class time will be allotted for a group discussion of the posttest questions and answers to reinforce the material.

○ Conclusions

Overall, the dramatizations were a success and the students enjoyed the experience. By designating roles and having the students get up and move, they were engaged in learning the concepts. Designing these activities to teach some basic concepts was fun for the instructor and provided a hands-on, student-centered activity that enhanced student learning. This method of teaching will continue to be used in future course offerings.

Table 2. Student explanations of how the in-class activities helped them learn the material.

- “Seeing the visualization helped as well as Dr. Halpin asking us to recall the info. I also liked how the setting was low pressure so just throwing out guesses was welcome.”
- “Physically moving around helped me remember short term but I’d like to have more labels for the membranes (alveolus vs. capillary etc.).”
- “Seeing how everything worked and participating in demonstrating it made what was happening clearer.”
- “Helped to see and understand the process better.”
- “Actually performing the actions imprinted the meaning of each word and process into my head. Performing the same actions multiple times was helpful.”
- “The activity helped me visualize the different transport system and actively learn the material better. Since the answers were not simply given to me.”
- “Being able to interact and actually act out the process was much more efficient than learning from a textbook. Additionally it incorporated subjects from past classes I am already supposed to know.”
- “Participating in the activities allowed a better understanding of the processes.”
- “Kinesthetic learning does tend to help me as well as collaboration. Not just watching videos/papers.”

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