Using dramatizations to teach cell signaling enhances learning and improves students’ confidence in the concept

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Abstract

Certain physiology concepts can be difficult for students to understand, and new strategies need to be implemented to teach these concepts. Cell signaling is a core concept in physiology and is presented to undergraduate students starting with their first-year Principles of Biology course. Flipped teaching (FT) combined with dramatizations were used to teach steroid hormone and protein hormone cell signaling in an Animal Physiology course. Student knowledge level improved, as demonstrated by posttest scores compared to pretest scores. Their confidence level in the material improved after the dramatization activities were completed. In conclusion, the combination of FT with dramatizations enhances student learning and confidence level.

active learning; cell signaling; dramatizations; flipped teaching; student confidence

INTRODUCTION

For many years, active learning has been used in the undergraduate classroom, and its use has been demonstrated to increase student performance, engagement, and understanding of the concepts taught (1–5). It has been shown that actual learning versus the feeling of learning in response to being actively engaged in the classroom was inconsistent (6). Some faculty are hesitant to adopt active learning strategies for two main reasons: these instructors may lack both the knowledge to implement active learning and the time to design the innovative curricula that fit the learning objectives of the course (7). Yet using active learning in classes is highly beneficial to students, since it provides the opportunity to be engaged and their learning experience is improved (1, 8, 9).

Flipped teaching (FT), no longer a new concept, is designed to assign lecture materials utilizing media, such as videos, along with assigned readings, which allows students to stop and relisten or reread content at their own pace. During the face-to-face class time, students are encouraged to ask questions on any difficult topics they encountered (10). FT has been demonstrated to improve student performance, increase student engagement, improve preparation and motivation, help students appreciate and respect student diversity, and increase positive interactions with instructors compared with lecture-based traditional classes (11–16). A key aspect of FT is engaging students in a student-centered classroom rich in collaboration and peer teaching through self-paced learning, instant feedback for formative assessments, and differentiated instruction to promote knowledge retention (12, 17). In this pilot project, FT combined with active learning in the form of dramatizations was implemented to teach cell signaling in a small undergraduate Animal Physiology class. In this context, dramatization is defined as a recounting of events in the cell signaling pathways.

Cell signaling is one of the core concepts of physiology because of its application in other biosciences such as pharmacology and pathophysiology (18, 19). Therefore, it is important for students to understand the concept thoroughly. The cell signaling topic is usually taught in a traditional lecture style utilizing a detailed figure from a textbook that includes colored shapes, acronyms (ATP, GTP), Greek letters (α, β, γ), and arrows. This type of figure is commonly found in textbooks, but for students each component is difficult to remember, yet alone understand (20). Even though this important concept is repeated at many levels (years 1–4), students often have difficulty understanding (21). One reason for this difficulty is that students often equate memorization with learning, but instructors know that memorization does not always lead to understanding (22, 23). When instructors teach students to rely solely on their memory, these students are often confused, disengaged, and unable to solve problems (21, 22). To facilitate learning and increase student understanding of a topic such as cell signaling, dramatizations were added to the Animal Physiology lecture section of the course.

Dramatizations have been shown to effectively engage students in learning the cardiac cycle, action potentials, and other science concepts (24, 25). This type of student-centered activity makes learning fun, focuses the students’ attention on the subject, and increases their understanding of physiology (1, 24). The goal of this study was to combine FT with
dramatizations to measure enhancement of student learning of the cell signaling concept.

**METHODS**

The present study was conducted with junior- and senior-level science undergraduates who had all completed the Principles of Biology II course, where they were first presented with the concept of cell signaling. Depending on their curricular path, students were presented with the cell signaling concept again in Anatomy and Physiology, Cell Biology, Endocrinology, Pharmacology, and Animal Physiology. This small class ($n = 8$ students) is the typical class size for upper-level courses at the university where this study was conducted, which typically ranges from 8 to 12 students. The small class, however, was ideal for using FT combined with dramatizations. For this study, the FT approach was used for the first time, where students were assigned readings from the textbook and videos on cell signaling pathways to review before the class meeting. At the beginning of the class session, the students took a 10-question multiple-choice quiz that measured their knowledge and level of confidence with the material. Each student was then assigned a role to play in the first dramatization activity. This intervention has been successfully used in previous courses, but this was the first one at the University of New Hampshire. Institutional Review Board (IRB, no. 8005) approval of the study protocol was obtained, and students gave consent to have their photographs used.

Steroid hormone signaling was the first dramatization introduced, and the assigned student roles were steroid hormone, steroid hormone receptor, transcription factors, DNA, and mRNA. Each student wore a placard with the name of their role written on it (Fig. 1). Because of the small class size, two parallel rows of classroom desk chairs served as the plasma membrane and the nuclear membrane. The first time the dramatization was performed, the instructor guided the students through their roles while narrating the events taking place in the cell signaling pathway. More specifically, the steroid hormone moved through the plasma membrane, bound to an intracellular receptor, and then diffused through the nuclear membrane. The steroid hormone-receptor pair of students bound to a transcription factor, and, next, all bound to the DNA to turn on transcription. To simplify transcription, the student wearing the mRNA stepped forward to illustrate that transcription had taken place. Once the first trial of the dramatization was completed, the students repeated the activity, narrating their roles. Immediately after this activity, the class reflected on their learning and several students asked pertinent questions about the concept. After their questions were answered, the students switched roles and the dramatization was repeated. This sequence of events was used for each of the activities.

The next concept the students dramatized was protein hormone signaling. In the first trial of this activity, three students were given different colored placards that were each labeled “hormone receptor.” These students stood in a line, and the class was told that the hormone receptors are embedded within the plasma membrane. The rest of the students were given paper circles of different colors and identified as protein hormones or agonists (Fig. 2). The instructor reminded the students about the different types of receptors on the plasma membrane and how the receptors were cell type specific. In addition, the students were informed that the protein hormone binds specifically to its own receptor so that the signal will be received by the cell. The students who were designated as protein hormones then moved toward the plasma membrane and were instructed to bind with their specific receptor. There was only one instance where the hormone (blue)bound to its specific (blue) receptor, which emphasized that once hormones are released into the blood they can go anywhere in the body, yet the hormone will only have an effect on a cell that has its specific receptor bound to the plasma membrane.

Once the students were familiar with the receptor location and its specificity for the protein hormones, the cell signaling concept was expanded further. The students were assigned the following roles: protein hormone, protein hormone receptor, G protein, adenylate cyclase, ATP, protein kinase A, and an intracellular protein (Fig. 1). The instructor guided the students through the activity, which dramatized the activation process. The placards that the students wore with the name of their role were double-sided, and when the step of the pathway was activated the students flipped the placard over to indicate one of the following states: G protein activated, adenylate cyclase activated, cAMP, protein kinase A activated, and intracellular protein phosphorylated. The instructor emphasized that the intracellular protein could be many different molecules depending on the cell type.

A posttest with the same questions as the pretest was given after the activities were completed. The questions and answers on the posttest were reviewed and graded in both the pretest and the posttest incorrect answers were marked, but only the posttest was graded, and the student scores were applied to the overall course grade. The Student’s two-tailed paired $t$ test was used to analyze the frequency of correct answers between the pre- and posttest data.

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**Figure 1.** Supplies for steroid hormone signaling dramatization (left) and for protein hormone signaling dramatization (right).
STUDENT SURVEY RESULTS AND FEEDBACK

The students’ confidence levels increased after they performed the activities (Fig. 3), and their scores on the posttest (9 ± 0.93) significantly improved (P = 0.0002) compared with the pretest (4.5 ± 2.14; Fig. 4). When asked on the posttest if performing the dramatizations helped improve their understanding of the concepts, all students (100%) answered “yes.” Students then provided details as to how the different aspects of the activities enhanced their learning (Table 1).

DISCUSSION

For instructors reluctant to implement FT and active learning in their classrooms, this study serves as an example of taking one complex topic and redesigning the method of instruction for that particular topic. When new modalities of teaching are introduced, the entire course does not need to be redesigned; only the most difficult concepts can be chosen for redesign. The focus of this intervention using dramatizations was on cell signaling, and this topic was chosen because students have difficulty comprehending and often not enough class time is devoted to ensuring their understanding of the concept, yet it is a core concept in physiology that is beneficial for the students to understand since it plays such an important role in understanding cell-cell communication and physiology overall (18, 19).

Most textbooks introduce the concept of cell signaling by discussing protein hormone signaling first and steroid hormone signaling second. In this class, the order was reversed, as the steroid signaling pathway is seen by students as more direct because the hormone can move through the membrane, thereby eliminating all the cellular machinery in the membrane (receptor, G protein, adenylate cyclase, etc.) and therefore requiring them to learn fewer steps. One interesting observation was that the students asked a lot of questions during the dramatizations compared with traditional lecture format and were given immediate feedback by the instructor. Students need a nurturing classroom environment with instructor encouragement to ask questions, and as they progress through their undergraduate degree this need increases (26–28). An example of this theory became apparent in this study when a high-performing second semester senior asked a basic question that displayed her misconception of the topic. This should not have been surprising, as students often do well in their courses by memorizing the material without fully understanding it (22). Although it was expected that she knew and understood the concept, her question provided an opportunity to resolve the misconception, which benefited the entire class. Because this student was recognized as a leader in the class, other students were emboldened to follow suit and they then asked additional questions. Misconceptions are common, often prevalent with some topics, and students can hold on to them for long periods of time (8, 29–31). Although it was a disappointment that for 4 yr this student believed this misconception to be true, it highlights the need for students to reach out to their instructors for clarification when they have trouble understanding these complex topics. Students will benefit from the clarification and be able to successfully build on more complex concepts as they progress through their undergraduate careers.

Figure 2. Students performing agonist-receptor binding dramatization.

Figure 3. Student confidence level in the material was selected by the students, using a Likert scale with 5 choices (not confident to extremely confident) before (pretest) and after (posttest) the dramatization activities. This question was ungraded and not part of students’ scores.
When students do not ask questions, instructors assume the concept is understood and they move on to cover additional content, since there is always more content to impart (6, 13). Having taught the concept of cell signaling for >20 yr, this was the first time that students asked a lot of questions in class, which allowed the instructor not only to answer the questions but also to clarify specific details of the process. This classroom experience echoed Harold Modell’s words, “His job was to help the learner to learn” (31, 32). By providing students with a new way to learn complex material and guiding them through the activities, we are helping learners to learn. As instructors, we should never assume that because students do not verbalize their confusion it means they fully understand.

Dramatizations can help students learn science by making some difficult concepts more visual, increasing student interest in the subject and their motivation to learn (25). By making the activity fun, instructors demonstrate their passion for the content, students become active participants in their learning, students are more relaxed and willing to ask questions, and their confidence in the material increases. More time was spent on the cell signaling concept than in other courses, this was the first time that students asked a lot of questions, and their confidence in the material increases. Without the FT approach to move lecture out of the classroom, an activity such as dramatization would not have been possible. These dramatizations will be used in several different classes in the future to teach cell signaling.

A limitation of this study was that the student surveys were multiple choice, and similarly formatted questions were not used on unit exams. Thus, there needs to be a new assessment created to measure long-term retrieval of information. Any time a new teaching method is implemented, a new style of assessment should be given (5). A different style of assessment to measure students’ long-term retrieval of information will be developed and implemented in future course offerings. The dramatizations were effective in engaging students, increasing their confidence in the material and ability to learn the content. Without the FT approach to move lecture out of the classroom, an activity such as dramatization would not have been possible. These dramatizations will be used in several different classes in the future to teach cell signaling.

Although this class was very small (n = 8 students), this approach can work in large lecture classes with some modification. One possibility is to break students into groups of 15–20 and run several dramatizations. Another approach would be to include these dramatizations in the laboratory sections, recitations, or lectorials. Working with more students allows for additional roles to assign such as the plasma membrane, nuclear membrane, additional enzymes, and intracellular proteins. For students to gain the maximum benefit of the

**Table 1. Students’ explanations of how the dramatizations during class helped them understand the concepts**

| Explanation                                                                 | Frequency |
|-----------------------------------------------------------------------------|-----------|
| I believe visualizing and acting the process out allowed us to learn the topic in multiple ways as well as engaging the students. | 3         |
| The dramatizations helped because talking through the cell signaling processes helped me understand/remember the concepts better than just watching the modules and taking notes. I can visualize it and describe it more effectively. | 4         |
| The dramatizations were extremely helpful. During the dramatizations, you have to pay attention and participate which helps retain the information. | 2         |
| Viewing the different mechanisms and how each product is affected gave a clear understanding of the process. | 1         |
| I now understand what hormones are doing. | 1         |

**Figure 4.** Performance by the students on the 10-question pretest and posttest. The score or number of correct answers is shown. The correct answer frequencies between the pre- and posttests were compared with Student’s t-test; P = 0.0002, n = 8 students.
activities, the students who initially performed a more passive role (plasma or nuclear membrane) should move to a more active role (e.g., enzymes, receptors) when the activity is repeated, and levels of complexity can be added for higher-level classes or more sophisticated concepts. For the protein hormone dramatization, the different subunits of the protein kinase A could be used (regulatory and catalytic), and the nucleus, DNA, and subsequent cellular machinery could be added. For the steroid hormone dramatization in the nucleus, several different genes could be represented by students on the DNA or more enzymes could be added or different cellular effects (short and long term) incorporated. For a pharmacology class, drugs that act as agonists and antagonists could be included to demonstrate their role in therapies.

In conclusion, the dramatization activities combined with FT were an effective way to teach undergraduates cell signaling. This type of activity could be modified to present other types of science content in all levels of science instruction. With some additional planning, these activities could be performed during remote delivery as well.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

P.A.H. conceived and designed research; P.A.H. performed experiments; P.A.H. and C.G. analyzed data; P.A.H. and C.G. interpreted results of experiments; P.A.H. and C.G. prepared figures; P.A.H. and C.G. drafted manuscript; P.A.H. and C.G. edited and revised manuscript; P.A.H. and C.G. approved final version of manuscript.

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