EFFECTIVENESS AND STUDENT PERCEPTIONS OF AN ACTIVE LEARNING ACTIVITY USING A HEADLINE NEWS STORY TO ENHANCE IN-CLASS LEARNING OF CELL CYCLE REGULATION

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Abstract
An active learning activity was used to engage students and enhance in-class learning of cell cycle regulation in a PharmD level integrated biological sciences course. The aim of the present study was to determine the effectiveness and perception of the in-class activity. After completion of a lecture on the topic of cell cycle regulation, students completed a 10-question multiple-choice quiz before and after engaging in the activity. The activity involved reading of a headline news article published by ScienceDaily.com entitled “One Gene Lost Equals One limb Regained.” The name of the gene was deleted from the article and, thus, the end goal of the activity was to determine the gene of interest by the description in the story. The activity included compiling a list of all potential gene candidates before sufficient information was given to identify the gene of interest (p21). A survey was completed to determine student perceptions of the activity. Quiz scores improved by an average of 20% after the activity (40.1 ± 1.95 vs. 59.9 ± 2.14, P = 0.0001, n = 96). Students enjoyed the activity, found the news article interesting, and believed that the activity improved their understanding of cell cycle regulation. The majority of students agreed that the in-class activity piqued their interest for learning the subject matter and also agreed that if they understand a concept during class, they are more likely to want to study that concept outside of class. In conclusion, the activity improved in-class understanding and enhanced interest in cell cycle regulation.

Keywords: active learning; cell cycle; cell proliferation; education; teaching

Introduction
Incorporation of active learning activities in conjunction with more traditional approaches to teaching in the classroom, such as the classic lecture, have proven to be more effective for student learning and retention compared with lecture alone (3, 8–10, 14, 19). Moreover, students prefer a mixture of various teaching methods compared with one method alone, which is typically the lecture format (6, 16, 20). Active learning methods promote higher-order objectives on Bloom’s taxonomy, such as analysis, synthesis, and evaluation (1, 15). Most educators are likely aware of the learning advantages that active learning teaching methods confer but have difficulty incorporating this style of teaching into the classroom (15, 21). Reasons include lack of necessary class time, insufficient time to develop materials, and a high comfort level with traditional lectures (15). Tied to insufficient time to develop materials may be lack of creativity in designing and implementing specific activities specialized for a particular subject matter. It was found that biology educators were much more successful in changing their approach to teaching and incorporating active learning when they were provided with curricular units that included-instructional commentary that guided the implementation of structured activities (22). Cell cycle regulation can be difficult subject matter for students to learn and to apply to the “real world.” Therefore, it is often challenging to instill appreciation for learning the subject matter by students, especially those who are more clinically oriented. Incorporating active learning methods would likely improve student learning and application of cell cycle regulation, as proven for various other subjects. However, very little has been
published in the peer-reviewed literature regarding active learning methods and activities specifically designed for learning cell cycle regulation (7, 10). Thus, the purpose of the present study was to describe an active learning activity applied directly to cell cycle control and to determine its effectiveness and student perceptions on in-class learning and subject matter interest.

Methods

Experimental design.

Participants were first-year students enrolled in a 4-yr doctoral degree pharmacy program. After completion of a lecture on the topic of cell cycle regulation, 96 students completed a 10-question multiple-choice quiz before and after engaging in an active learning activity. The lecture spanned two 50-min class periods on consecutive days, which was a component of a five-unit integrated biological sciences course required in the first semester of the pharmacy program (5). The third class period consisted of the prequiz, the active learning activity, and the postquiz. A follow-up perception survey was emailed to students via Survey Monkey and completed outside of class. All procedures were approved by the institutional research review board.

Description of the active learning activity.

The activity involved reading of a headline news article published by Science Daily entitled “One Gene Lost _ One Limb Regained” (www.sciencedaily.com/releases/2010/03/100315161913.htm; see APPENDIX A). The name of the gene (p21) was deleted from the article and, thus, the end goal of the activity was to determine the gene of interest by the description in the story. The activity included compiling a list of all potential gene candidates before sufficient information was given to identify the gene of interest. More specifically, the news article was read to the halfway point, and students were then given 20 min to review through their lecture notes and compile a list of genes that if knocked out could potentially lead to enhanced cell proliferation. Some of the cell cycle proteins and regulators that were discussed in lecture included all cyclin-cyclin-dependent kinase (CDK) complexes, retinoblastoma tumor suppressor protein, transcription factor E2F, Myc, MAPK pathway signaling proteins, p27, ataxia-telangiectasia mutated protein kinase, ataxia-telangiectasia mutated and Rad3-related protein kinase, Mdm2, p53, p21, anaphase promoting complex, CDK-activating kinase, Wee1 (Cdk-inhibitory kinase), Cdc25, Cdc20, securin, and separase. The purpose of compiling the list of potential candidates was to direct students to critically evaluate the function of each protein and to determine its overall effect on the cell cycle. This exercise was also implemented to prepare students with the knowledge necessary to understand the upcoming lectures on the molecular mechanisms of cancer regarding loss-of-function and gain-of-function gene mutations. Once students completed their lists, the function of each potential candidate was discussed as a class to determine its general effect on cell proliferation. Individual students were randomly called upon, not by volunteer, to share one potential gene candidate that they had on their list. Before the activity, students were told that there would be random selection to enhance the number of students engaged in the activity. After completion of the class discussion, the second half of the news article was read, this included details about the specific function of p21 in the DNA damage checkpoint. With the added details, students were able to identify the gene of interest as p21. Knowledge of the p53/p21DNA damage checkpoint was required to identify the gene of interest. Quizzes. The pre- and postquiz consisted of the same 10 multiple choice questions regarding the specific function of various cell cycle regulators (see APPENDIX B). Students answered the questions...
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using a scantron. Although the active learning activity involved small-group effort, the quizzes were individual effort. Answers to quiz questions were not given in class but posted later online for access once the perception survey was completed. The quiz scores did not contribute to the course grade, nor was participation in the study a required part of the course. 

Perception survey. A perception survey was e-mailed to all students enrolled in the course via Survey Monkey and completed outside of class (see Supplemental Table S1 in the Supplemental Material). The survey consisted mostly of rating-type questions with a Likert scale regarding their perception of the effectiveness of the activity on their in-class learning and the value of the activity on stimulating interest for the subject matter. The survey also included two open-ended questions for students to write comments. Since the survey was original, it was pretested on a small group of students (n = 10) who completed the course and the same active learning activity the previous year to assure that the questions were being interpreted correctly.

Statistical analysis.
A Student's t-test for paired data was performed to compare mean differences in pre- and postquiz scores. Data are presented as means ± SE. A Cronbach _-statistic was calculated to determine the internal consistency of the Likert scale questions using the R (version 3.2.1) psy package.

Results

The effects of the active learning activity on in-class learning were assessed via completion of a pre- and postquiz. Quiz scores improved by an average of 20% after the activity (40.1 ± 1.95% vs. 59.9 ± 2.14%, n = 96,  P < 0.0001; see Fig. 1). Although no students scored 100% on the prequiz, five students did on the postquiz. Change in scores from the pre- to postquiz ranged between -20 and 90 points (each question was worth 10 points). Ten students performed worse on the postquiz compared with the prequiz. Eleven students exhibited no change in scores. The remaining 75 students (78%) improved their scores on the postquiz. The majority of the students (90-93%) who participated in the in-class activity answered the perception survey questions (see Supplemental Table S1). The Cronbach _- for the Likert scale questions was calculated to be 0.79. The majority of students (79.3%) believed that the activity enhanced their understanding of cell cycle regulation. The percentage of students who improved their quiz scores corresponded closely with the percentage of those who believed the exercise enhanced their understanding (78% vs. 79%, respectively); 16.1% of the respondents felt neutral that the activity enhanced their understanding of the subject matter. Only one or two students expressed that they did not enjoy participating in the activity or did not find the content of the news article interesting, respectively. The majority of the students (77%) felt that the in-class activity piqued their interest in learning the subject matter, whereas 18.4% were neutral. Only 4.5% disagreed. Most students (93.2%) felt that including both the lecture and in-class activity was the best approach for optimizing learning of cell cycle regulation; 3.4% felt that the in-class activity would be sufficient (no lecture). Finally, 76.7% of students felt that they were more likely to want to study a concept outside of class if they understood the concept during class; 12.4% felt neutral, and 9% disagreed. A qualitative analysis was used to determine if there were emergent themes to the responses of the open-ended questions in the perception survey (see Figs. 2 and 3). The first open-ended question was “Why do you think that the in-class activity did not improve your quiz grade?” Respondents (n = 17) revealed that the primary reason for a lack of improvement was due to not being fully engaged in the activity (Fig. 2 and Supplemental Table S1). The second most common reason was that some sort of modification to the activity may be required for improvement in learning, such as increased time.
to complete the activity or to be able to read the article instead of listening to it being read. The second open-ended question was “Do you have other comments about the in-class activity.” Twenty-four students responded to the question, with 14 students commenting that the activity was enjoyable and/or helpful (without offering any suggestions for improvement). Seven students gave suggestions for improvement, which included more time to complete the activity and to receive a printed copy of the article beforehand, as also mentioned previously. Additional suggestions were to review the answers to the quiz questions in class and to review the mechanism of every gene candidate (see Fig. 3 and Supplemental Table S1).

Discussion

Cell cycle regulation is a difficult concept for students to master and can be considered a dry topic for some, especially for clinically oriented students. Thus, an active learning activity was incorporated to enhance in-class learning and interest in the subject matter. Ninety-six first-year professional pharmacy students enrolled in an integrated biological sciences course participated in the study (5). After completion of lecture on the topic of cell cycle regulation, students took a prequiz to gauge their baseline understanding followed by a postquiz after completion of the activity. The mean improvement in scores suggests that the activity enhanced the in-class learning of the material compared with the lecture alone. As previously noted some students did not improve or even performed worse on the postquiz. Several possible explanations exist. First, students worked on the activity in small groups; thus, some in the group may have done the work for the others. Second, some students may have not been engaged in the activity due to other distractions.

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The students participating in the study are professional degree students who all have the same rigorous course and exam schedules throughout the semester. Several students stated in the comments section of the perception survey (see Supplemental Table S1) that they did not believe that they improved on the postquiz because they were not engaged during the class activity since they were studying and/or distracted by a looming quiz in the class immediately afterward and also a midterm exam in another course the following morning. This is a common challenge that faculty members continuously face, especially in professional degree programs with high course loads and rigorous exam schedules. Incorporating active learning activities in the classroom improves engagement (12, 13, 17) but does not guarantee 100% engagement.
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by all students. It is possible to use additional methods to improve student engagement even further, such as strict classroom monitoring while students engage in the activity or tying a formal assessment to the active learning exercise. Third, some students commented that the activity would have been more effective on in-class learning if they would have studied the material after completion of the lecture and, therefore, had a better grasp of cell cycle regulation before partaking in the activity. With a better overall conceptual understanding, one can learn new information more efficiently because they can relate the new information with what they already know and place the information in an already existing “framework” (2, 4, 18, 23). Fourth, several students commented that slight modifications to the activity would have enhanced their learning. Some of the modifications suggested were to increase the amount of time spent on the activity and to provide a format of the article that would allow them to read it for themselves, instead of being read aloud. Although more time spent on the activity may have improved outcomes, the time allotted for the activity was limited by the length of the class period. Despite students desire to personally read the article, it likely would not improve learning outcomes. The article did not contain content necessary for learning the desired course material. The learning took place during the process of answering the following question: “Of the cell cycle regulators that we discussed in class, which ones could potentially lead to stimulation of the cell cycle if its gene was knocked out?” (24). The article was not required to go through the exercise of answering this question. The purpose of the article was to put a real-world perspective on the usefulness and application of the material. Figure 2 shows the number of respondents for each of these possible explanations for lack of improvement. It is worth noting that even among those who felt that they did not improve on the postquiz, it was stated that they found the activity helpful in knowing how to approach studying the material in preparation for the related course exam. It is possible that implementation of the in-class activity as an individual effort and/or delaying its incorporation at a later time point, to allow students the opportunity to review the subject matter after lecture completion to gain a more baseline understanding of cell cycle, may enhance the effectiveness of the activity on in-class learning. However, collaborative learning has shown to instill a deeper understanding of physiology, promote classroom discussion, and improve student scores (11).
The questions on the pre- and postquiz were relatively difficult due to the detailed nature of the answer choices. Thus, it was not surprising that the absolute scores on the pre- and postquiz were low, averaging near 40% and 60%, respectively. Detailed difficult questions were used for three reasons. First, the questions were representative of what to expect on the related course exam. Second, difficult questions were used to avoid a potential ceiling effect, which could limit the range of improvement between the pre- and postquiz. Finally, detailed answer choices were used to reduce the chance of the student from "memorizing" each question with its corresponding answer choices on the prequiz as they engaged in the activity, thus reducing the chance that the improvement in quiz scores was due to familiarity with the questions. In addition to improving in-class learning, the activity piqued the students' interest in learning the subject matter. With the belief that the activity enhanced their understanding and piqued their interest in learning cell cycle regulation, it is plausible that engaging in the activity increased their motivation to study the material outside of class; the majority of students agreed on the perception survey that if they understood a concept during class they are more likely to want to study that concept outside of class. Thus, the active learning exercise may have impacted in-class and outside-of-class learning of cell cycle regulation. However, the amount of studying and learning that took place outside of class was not assessed in this study.

There are some limitations to the study. First, it cannot be ruled out that the improvement in the quiz scores was not simply due to the extra time spent reading over the lecture notes rather than the active learning activity itself. Second, it also cannot be dismissed that having repeated questions in the pre- and postquiz did not contribute to the improvement in scores, despite the fact that the answers to the quiz questions were not given after the prequiz nor were students told that they would be taking a postquiz. A separate "control" group given time spent reading lecture notes during class, instead of engaging in the active learning activity, would be required to make both delineations. However, to incorporate an appropriate control group, the study would have had to been implemented outside of the normal class periods since the course does not consist of multiple "sections" of students. Other arrangements, such as splitting the class in half and separating them in different classrooms during class time, introduces additional limitations.
external variables that could affect in-class learning. Despite these limitations, it is believed that this study adds value to the existing literature. The study introduces an active learning exercise that can easily be implemented into the classroom, increases student interest in the topic of cell cycle regulation, and is a means to apply the subject matter to the real world, which is sometimes difficult to do with basic science topics involving detailed cellular signaling/regulation. In summary, the active learning activity improved in-class learning of cell cycle regulation. Furthermore, student perceptions were overwhelmingly positive, revealing that the activity was enjoyable, the content of the news article was interesting, and that it piqued desire to learn the subject matter. This activity may be an option for those who wish to incorporate an active learning exercise in their teaching of cell cycle regulation. In addition, the concept of this active learning activity could be applied to other topics using an alternative news article.

Appendix A: News Article Used For the Active Learning Activity
The original copy can be retrieved at http://www.sciencedaily.com/releases/2010/03/100315161913.htm.

Appendix B: Prequiz And Postquiz
1. Which is a function of retinoblastoma protein?
   A. To bind to and inhibit the action of E2F
   B. To bind to and stimulate the function of E2F
   C. To bind to and inhibit the function of G1 CDK
   D. To bind to and stimulate the function of G1 CDK
   E. None of the above
2. What is the function of Wee1?
   A. To phosphorylate and inhibit M CDK
   B. To phosphorylate and stimulate M CDK
   C. To dephosphorylate M CDK
   D. To phosphorylate cdc25
   E. None of the above
3. The function of mouse double minute 2 homolog (MDM2) leads to:
   A. The degradation of ataxia-telangiectasia mutated (ATM) protein kinase
   B. The degradation of p21
   C. The degradation of p53
   D. The degradation of G1/S cyclins
   E. None of the above
4. What is the function of p21?
   A. To stimulate the transcription of p53
   B. To inhibit the activity of p53
   C. To stimulate the transcription of p27
   D. To inhibit cdc25
   E. None of the above
5. What is the function of cdc25?
   A. To phosphorylate and inhibit M CDK
   B. To phosphorylate and stimulate M CDK
   C. To dephosphorylate M CDK
   D. To bind to and stimulate the function of G1 CDK
   E. None of the above

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D. To phosphorylate the anaphase-promoting complex (APC)
E. None of the above

6. Which is a function of p53?
A. To bind to and inhibit G1/S CDK
B. To bind to and inhibit M CDK
C. To stimulate the transcription of cyclins
D. To stimulate the transcription of G1/S CDK
E. None of the above

7. Which is a function of ATM?
A. To phosphorylate and stabilize p21
B. To phosphorylate and stabilize p27
C. To phosphorylate and stabilize p53
D. To ubiquinate p53, leading to its degradation
E. None of the above

8. What is the function of CDK-activating kinase (CAK)?
A. To phosphorylate and inhibit M CDK
B. To phosphorylate and stimulate M CDK
C. To dephosphorylate M CDK
D. To phosphorylate cdc20
E. None of the above

9. Which is a function of APC?
A. To phosphorylate cdc25, leading to its activation
B. To ubiquinate securin, leading to its degradation
C. To ubiquinate cdc20, leading to its degradation
D. To directly cleave cohesins
E. None of the above

10. What is the function of securin?
A. To phosphorylate and stabilize p53
B. To bind to and inhibit Wee1
C. To bind to and inhibit APC
D. To bind to and inhibit separase
E. None of the above

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