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REVIEW

Use of engaging review application exercises to enhance understanding of critical concepts prior to summative examinations

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Abstract

Two distinct and engaging review application exercises were created in an immunology class for third-year pharmacy students that utilised the Team-Based Learning (TBL) instructional method. The goal was to enhance student understanding of critical concepts prior to summative examinations through the use of exercises that promoted creativity and teamwork. For the first application exercise, student teams created innovative and informative posters describing assigned subject matter using superheroes or other known caricatures. Student teams reviewed key concepts on posters created by fellow teams using a gallery walk format and graded the posters according to provided rubrics. For the second application exercise, teams created mnemonics, songs and haikus to highlight assigned material. These creations were displayed on a poster. The review application exercises were well received by students, with many students indicating that the review exercises greatly helped them utilise their creative talents to learn the material in a way that was fun and engaging.

Keywords: *TBL, Immunology, Review Exercise, Music, Haikus, Mnemonics, Posters*

Introduction

The goal of these educational team activities was to create engaging and interactive review exercises prior to summative examinations in an immunology class for third-year pharmacy students at California Northstate University College of Pharmacy (CNUCOP). Two distinct engaging and informative review application exercises were generated with the intent of providing creative and informative group activities to review material prior to summative examinations. This work describes the creation of an immunology cartoon poster (the 'cartoon-caricature' exercise), and an application exercise in which teams created songs, haikus or mnemonics (the 'song-haiku-mnemonic' exercise).

Initially, the application exercises used predominantly in the immunology course involved multiple-choice questions relating to either a clinical case or a description of an immunological disease or process, similar to how the course was conducted in previous years. The design of the two new review application exercises was partly based on the positive informal feedback received from students regarding a Jeopardy review game that incorporated team clickers and a team leaderboard (Cusick, 2016), as the review game was frequently mentioned positively in the course evaluations. An additional source of inspiration for designing these application exercises was from student-created posters in a pharmacology course that had used a 'Chemo-man' application exercise, in which teams of students created informative and entertaining drawings of a person, detailing both the sites of action, and the locations of side effects for selected medications. Students' enjoyment and learning effectiveness of the Chemo-man posters encouraged the use of similar exercises in the immunology course. As the idea for the cartoon-caricature poster was being developed, support for implementing such an exercise was received after consulting a focus group selected from the students in the immunology course. The informal supportive feedback received from students following implementing the cartoon-caricature exercise contributed to the creation of the informal and low-stakes song-haiku-mnemonic exercise, implemented prior to the summative final examination, as a way to provide a fun and stress-relieving exercise that could also serve to review topics relating to the final exam.

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These exercises were conducted in a class that utilised Team-Based Learning (TBL), a small group active learning pedagogy (Parmelee & Michaelsen, 2010; Parmelee *et al*., 2012) as the main instructional method. In recent years, many programmes and instructors have adopted TBL, which promotes team work and critical thinking through the use of application exercises, a cornerstone of the TBL teaching method (Whitley *et al*., 2015). TBL has been demonstrated to be an effective teaching pedagogy in pharmacy education (Ofstad & Brunner, 2013; Whitley *et al*., 2015) in addition to other healthcare professions (Burgess *et al*., 2017). The activities described in this report deviate from the traditionally defined TBL application exercises, which utilise the '4 S's' (Significant problem, Same problem, Specific choice, and Simultaneous report) (Parmelee & Michaelsen, 2010), additional examples that deviate from the traditional TBL format include a debate exercise used in an infectious disease class (Viswesh, Yang, & Gupta, 2018) and a team-review exam prior to a summative exam (Khansari & Coyne, 2018). As more programmes and instructors have adopted this pedagogy, the successful use of alternative application exercises in TBL is consistent with a growing trend of using multiple modalities of teaching to engage students of the twenty-first century. The incorporation of the arts and creative team exercises represent additional modalities that have been successfully implemented into scientific education (Crowther, 2012b; Gurnon *et al*., 2013; Pollack & Korol, 2013; Quillin & Thomas, 2015; Brown, 2015; Kim *et al*., 2019), and the cartoon-caricature and song-haiku-mnemonic exercises are two additional activities that encourage students to utilise their artistic talents and team-building skills to design creative works relevant to an approaching summative exam.

Methods

Description of review exercises

The application exercises described in this report were conducted in an immunology course at CNUCOP for third-year pharmacy students using TBL as the instructional method. The class met for two-hour sessions biweekly throughout a semester. The class utilised three high-stakes summative examinations; the final exam was cumulative. The class contained 103 and 117 students in successive years and there were typically six students on each team. For both exercises, student teams were assigned immunology topics relevant to an upcoming summative exam. The poster creations from these exercises remained displayed in the classroom for approximately a week, providing opportunities for student viewing as the summative exam approached. With as many as four or five posters describing a single subject, students were able to identify posters that were most helpful with their unique style of learning.

Figure 1: Rubrics and evaluation form for the cartoon-caricature exercise

Indicators	Sub-standard (0-5)	Developing (6-10)	Developed (11-15)	Proficient (16-20)	Grade
(Accuracy) How accurate is the information on the poster	Poster contains non-specific information with many inaccuracies	Poster demonstrates a minimal understanding with few inaccuracies	Poster demonstrates sufficient understanding with no inaccuracies	Accurate and in-depth poster displaying the essential aspects of ļeukocyte function	
(Completeness) How well the poster describes pertinent information relating to immunology regarding the disease 1-underlying pathology 2-prominent Th subsets and other leukocytes associated with disease 3-prominent cytokines associated with disease 4-most prominent therapeutics used to treat the disease	Poster does not convey pertinent information regarding the disease	Poster presents some pertinent information, yet other pertinent information regarding the disease is missing or unclear	Poster presents the majority of pertinent details regarding the disease	Poster thoroughly presents pertinent information regarding the disease	
(Presentation Style) How well organized the poster is	Not clear, difficult to follow, too crowded	Evidence of information organization	Information presented sufficiently clear and at a sufficient depth	Exceptional organization, easy to follow, pertinent info displayed, yet not too crowded	
(Teaching Tool) How well the poster can be used as a teaching tool to fellow pharmacy students regarding pertinent information of the disease	Poster is a sub-standard teaching tool due to inaccuracies, incompleteness, being too crowded, or difficult to follow	Poster is a minimally effective teaching tool	Poster is an adequate, though not exceptional, teaching tool	Poster is an exceptional teaching tool that will help students both grasp concepts and remember pertinent information	
(Uniqueness and appeal) How creative, original, engaging and visually appealing the poster is, in a way that helps the poster serve as an effective teaching tool	Not at all	Minimally	Sufficiently	Unique and exceptionally appealing in a way that will help the poster serve as an effective teaching tool	
Total Points					

Team Number of Poster : _____ **Disease portrayed in Poster:**_____

Theme of Poster: _____

General Comments_____

_____

_____

Positive Features of Poster:

1. _____
2. _____
3. _____
4. _____
5. _____

Constructive Criticisms of Poster:

1. _____
2. _____
3. _____
4. _____
5. _____

Figure 1: Rubrics and evaluation form for the cartoon-caricature exercise. The rubrics were used by both volunteer faculty and student teams to critique poster creations during the gallery walk. As indicated, the posters were graded based on their accuracy, completeness, presentation style, uniqueness and appeal, and how well the poster could serve as a teaching tool to fellow pharmacy students. Each of the five sections was worth 20 points, for a possible point total of 100 points. The rubrics were provided to the students during the initial brainstorming session to ensure adequate communication with regards to the expectations of the final poster. The evaluation forms provided evaluating teams and faculty the opportunity to provide anonymous feedback regarding the posters.

Application Exercise #1: The cartoon-caricature exercise

The cartoon-caricature exercise (please refer to Table I for an example) was conducted three times over two years, and covered subjects relating to lymphocytes, leukocytes of innate immunity, and diseases of the immune system. The methods described reflect subtle changes that were incorporated during the sequential refinement of the exercise.

The cartoon-caricature exercise accounted for a significant portion of the team grade and between 3-4% of an individual student's final grade. The information about the poster exercise was communicated to the students in advance through the syllabus. Teams were asked to draw an assigned type of leukocyte as an action hero, cartoon character or television caricature in a manner that incorporated information pertinent to an upcoming summative exam. Teams had the option to use images from magazines or the internet in creating their final poster in case a team did not collectively feel as confident in their drawing abilities. The exercise was conducted over two learning sessions. A gallery walk (Rodenbaugh, 2015) was conducted on the day the posters were due. In brief, student teams, in addition to faculty volunteers, reviewed, scored and provided feedback for the creations of fellow teams using provided rubrics and evaluation forms (Figure 1) during the gallery walk. Individual and team Readiness Assurance Tests (iRATs and tRATs respectively) (Parmelee *et al*., 2012) designed to cover newly assigned reading material were conducted normally on both sessions. The two sessions were not scheduled to be back-to-back, in order to prevent a backlog of new material that had not been covered and discussed through the use of application exercises.

First session: Brainstorming session

The cartoon-caricature exercise (Table I) assigned the subjects among the different groups and provided a list of essay questions that served as a guide regarding material to include on the poster. Answers to the essay questions and a rough draft of the poster, including the concept chosen by the team, were required to be displayed on a poster at the end of the first session. The requirement for the rough draft of the poster to be posted by the end of the initial session was designed to ensure that the entire team participated in the creative process. The rubrics used to grade the posters (Figure 1) were provided during the first brainstorming session, to ensure students were well-informed regarding the expectations for the final poster.

Table I: Description of cartoon-caricature poster assignment

The following is an OPEN book application exercise.

Draw your favorite innate immune cell as an action hero, cartoon, or TV caricature!! Each team is responsible for drawing a detailed colorful picture portraying an innate immune cell in a manner that is engaging and educational. For this assignment, each team will sketch one of the following four leukocytes we have thus far discussed in detail. The table below indicates which leukocyte each team is assigned.

Dendritic cell	Monocyte/ Macrophage	Neutrophil	Natural Killer cell
Teams 1, 5, 9, 13, 17	Teams 2, 6, 10, 14, 18	Teams 3, 7, 11, 15, 19	Teams 4, 8, 12, 16, 20

Items due at the end of today's class period for today's brainstorming exercise:

1. Brief descriptions of how the cell functions (fill in the boxes included on subsequent handouts).
2. Rough draft of poster is due to be posted on the wall by the end of the period. Indicate Team number on poster. *Focus primarily on topics we have already covered in class.*
3. Return all pens in the box provided by the end of the class period.

Final poster required to be displayed in designated area BEFORE class on day of gallery walk.

iRAT begins at 1:00 PM, so have poster mounted in designated area prior to 1:00 PM.

A gallery walk will be used in which student teams and volunteer faculty will judge the final posters based on the rubrics provided.

Final poster is worth 3 % of an individual's final grade in the course.

Use *primarily* your textbooks and handouts, as well as Access Pharmacy or other resources, to describe the following on the poster. Turn these descriptions in by the end of our initial brainstorming session:

1. The main function(s) of the cell
2. Indicate the prominent location(s) of the cell your team was assigned. How does the location of the cell change in response to activation by either the presence of antigen and/or inflammation?
3. Indicate the process by which the cell is activated, by other cells or by inflammation, including signaling events required to activate the cell.
4. Does the leukocyte the team was assigned activate other cells? What are the prominent cells that are influenced by the leukocyte the team was assigned? What effect does the cell have on inflammation?
5. What are the primary cytokines the cell responds to? What is/ are the source of these cytokines, and what is the effect of these cytokines on the leukocyte the team was assigned?
6. What are the primary cytokines released by the leukocyte team was assigned? What affect do these cytokines have?

Second session: Gallery walk of final posters
Each team was assigned ten minutes to both view and critique an individual poster as specified by the gallery walk schedule (Figure 2). The incorporation of a gallery walk schedule was introduced to prevent large crowds of student teams from congregating around individual posters as occurred during the initial implementation of this exercise. Student teams were required to critique less than one-third of the posters (Figure 2), as conducting a shorter gallery walk permitted time to conduct a small mini-application exercise, covering new subject material in the pre-assigned reading prior to the gallery walk. A representative from each team was assigned to present their poster midway through each ten-minute period, in case the visiting team had any questions regarding the poster. This modification was introduced in response to student feedback from the initial run of the exercise, as some student teams indicated that they occasionally required more explanation regarding the concept of a particular poster. Students were assigned numbers, and the student required to present the team poster alternated during the exercise as indicated by the gallery walk schedule (Figure 2). A form containing both the rubrics, and an opportunity to provide both positive feedback and constructive criticisms regarding the posters (Figure 1) was required to be turned in by each team at the conclusion of the gallery walk. Additionally, a review document was provided to faculty judges which highlighted relevant information that should be covered on the posters, to assist the ability of faculty judges to grade posters with regards to their accuracy and completeness.

Application Exercise #2: The song-haiku-mnemonic exercise

The exercise was conducted as one of two application exercises in a single class session. The exercise was a low-stakes component of the team grade and accounted for less than 0.25% of an individual student's final grade. Furthermore, the exercise was graded leniently provided students on a team were engaged during the activity.

Teams were encouraged to create songs, haikus, or helpful mnemonics that would ideally serve to help students prepare for the summative exam. Haikus are short forms of Japanese poetry, that in its most popular form, consist of three phases with five, seven and five syllables (Gustafson, 1979). Mnemonics are devices such as patterns of letters or ideas that can be used to assist organising information for recall (Bellezza, 1981). Subject material most relevant to an approaching summative exam was divided amongst the teams (Table II). Teams were permitted to change the lyrics of a popular song in order to create an 'original' song about immunology. Students were required to display their creations on a poster, yet no formal gallery walk was conducted for this low-stakes exercise. Extra credit was provided to teams that performed their song creation to the rest of the class. Teams were permitted to double one low-stakes team score (*i.e.* tRAT or graded application exercise), provided that all members of the team helped perform the song to the rest of the class.

Table II: Song-Haiku-Mnemonic exercise assignment

The following topics covered on block exam #2 are listed below.

Think of a rap song, a rhyme, haiku or a helpful mnemonic to help your team, and potentially your classmates, study for the exam. If haikus are chosen, make at least 4 of them to compensate for how short haikus are in nature.

Each team should strive to create an original work that can serve as a teaching tool to help study for new subjects covered for the final exam. An "original" work can be classified as finding a popular song/poem and changing the lyrics so that it is about a topic relating to immunology.

If, in addition to creating an original work, a team finds a rhyme or mnemonic on the internet to help prepare for an exam topic, that is acceptable to include also, **yet each team must create an original work designed to help students study for the final exam and post it on the wall by the end of the class period.**

IT IS IMPORTANT THAT ALL WORKS ARE APPROPRIATE AND "G" RATED.
Be considerate of those who have suffered or died from a particular disease.

Try to create works that would be helpful as a teaching tool, or would be beneficial to help fellow students remember complex material relevant to block exam #2.

Team#	Topic to create song, haikus or mnemonic
1, 10	**Autoimmune disorders**
2, 11	**Transplantation**
3, 12	**Mucosal immunity, Introduction to vaccines**
4, 13, 20	**Vaccines**
5, 14	**Congenital immune deficiencies**
6, 15, 19	**HIV and AIDS**
7, 16	**Cancer and the Immune system**
8, 17	**Chronic inflammation and cancer**
9, 18	**Antibodies: Therapies and Diagnostics**

Results

The cartoon-caricature and song-haiku-mnemonic exercises were well received as informally assessed by positive feedback received in the course evaluations. In response to the question "What did you like most about the course?", 24% (19/78) and 16% (11/69) of students from the 1st and 2nd year respectively either specifically mentioned the activities in this report, or highlighted activities that fostered creativity as one of the things they liked most about the course. The cartoon-caricature and song-haiku-mnemonic activities were the only application exercises used in the course that could be described as fostering student creativity, in which teams of students were asked to collectively assimilate creative

Figure 2: Gallery walk schedule for viewing final posters of the cartoon-caricature exercise

Team viewing poster listed below ↓	Poster to view 11:00-11:10 Team Member #1 go back to explain original poster after 5 min to visiting team	Poster to view 11:10-11:20 Team Member #2 go back to explain original poster after 5 min to visiting team	Poster to view 11:20-11:30 Team Member #3 go back to explain original poster after 5 min to visiting team	Poster to view 11:30-11:40 Team Member #4 go back to explain original poster after 5 min to visiting team	Poster to view 11:40-11:50 Team Member #5 go back to explain original poster after 5 min to visiting team	Poster to view 11:50 - Noon Team Member #6 go back to explain original poster after 5 min to visiting team
1 –Asthma	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7
2 – Rheumatoid arthritis	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8
3 – Crohn's disease	Team 4	Team 5	Team 6	Team 7	Team 8	Team 9
4 – Plaque psoriasis	Team 5	Team 6	Team 7	Team 8	Team 9	Team 10
5 – Multiple sclerosis	Team 6	Team 7	Team 8	Team 9	Team 10	Team 11
6 –Asthma	Team 7	Team 8	Team 9	Team 10	Team 11	Team 12
7 – Rheumatoid arthritis	Team 8	Team 9	Team 10	Team 11	Team 12	Team 13
8 – Crohn's disease	Team 9	Team 10	Team 11	Team 12	Team 13	Team 14
9 – Plaque psoriasis	Team 10	Team 11	Team 12	Team 13	Team 14	Team 15
10 – Multiple sclerosis	Team 11	Team 12	Team 13	Team 14	Team 15	Team 16
11 – Asthma	Team 12	Team 13	Team 14	Team 15	Team 6	Team 17
12 – Rheumatoid arthritis	Team 13	Team 14	Team 15	Team 16	Team 17	Team 18
13 – Crohn's disease	Team 14	Team 15	Team 16	Team 17	Team 18	Team 19
14 – Plaque psoriasis	Team 15	Team 16	Team 17	Team 18	Team 19	Team 20
15 – Multiple Sclerosis	Team 16	Team 17	Team 18	Team 19	Team 20	Team 1
16 – Asthma	Team 17	Team 18	Team 19	Team 20	Team 1	Team 2
17 – Rheumatoid arthritis	Team 18	Team 19	Team 20	Team 1	Team 2	Team 3
18 – Crohn's disease	Team 19	Team 20	Team 1	Team 2	Team 3	Team 4
19 – Plaque psoriasis	Team 20	Team 1	Team 2	Team 3	Team 4	Team 5
20 –Multiple Sclerosis	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6

Figure 2: Gallery walk schedule for viewing final posters of the cartoon-caricature exercise. Student teams listed in the far-left column would view and critique posters made by their peers using the rubrics according to the indicated schedule. Based on student feedback, one member from each team would go back to their team poster midway through each 10-minute viewing period to briefly answer any questions the visiting team has regarding the concept, vision or layout of the poster. For example, by 11:05, Team member #1 from Team 1 would have stopped viewing a poster describing rheumatoid arthritis created by Team 2 and would return to Team 1's poster about asthma to answer any questions, or provide any needed clarifications concerning the concept or layout of the poster.

works onto a poster. In contrast, most of the application exercises conducted in the course used multiple-choice questions relating to clinical cases or an immunological process, along with the occasional Jeopardy review game, and therefore positive feedback relating to activities promoting student creativity was inferred to be describing the cartoon-caricature and song-haiku-mnemonic activities. Examples of student responses to the question "What did you like most about the course?" were:

- "*The instructor added different activities that allowed creativity and other means of learning the material. The inclusion of creative activities helped prevent burnout when overall course loads became heavy"*
- *"Very engaging with students and gives opportunities to develop student creativity"*
- *"He is very creative in designing different methods for students to learn the concepts such as doing a cartoon poster, playing jeopardy, and writing rap songs"*
- *"The singing, posters, and creative extra study tools (e.g., raps, songs etc.) to help us memorise topics"*
- *"The poster drawing presentation, it allows students to use their creativity to incorporate materials learned from the class."*
- *"...provides assignments that encourages creativity in his students such as lyric composing and posters"*
- *"The lyric poster application was fun and he even gave us an example of one he did previously."*
- *"Made learning fun. Also, class was very entertaining when they sang"*

Two negative comments regarding the creative applications were received in the second year in response to the question "What could have been done to improve the course?". The negative comments were primarily directed towards the cartoon-caricature exercise:

- *"There were also too many creative applications. Posters were graded very hard."*
- *"Personally, I don't like posters because they don't help me learn the material"*

The majority of student creations were not congruent with publishing due to copyright concerns; examples of the student creations that did not have copyright protection concerns are provided for the cartoon-caricature exercise and the song-haiku-mnemonic exercise (Figure 3). Many teams effectively used a superhero-villain theme to describe the assigned subject material in the cartoon-caricature poster exercise. For example, with regards to describing cells that prevent microbial infections, components of the immune system were portrayed as heroes from popular culture, while microbial pathogens were portrayed as villains. Conversely, in posters describing asthma, rheumatoid

Figure 3: Examples of cartoon-caricature

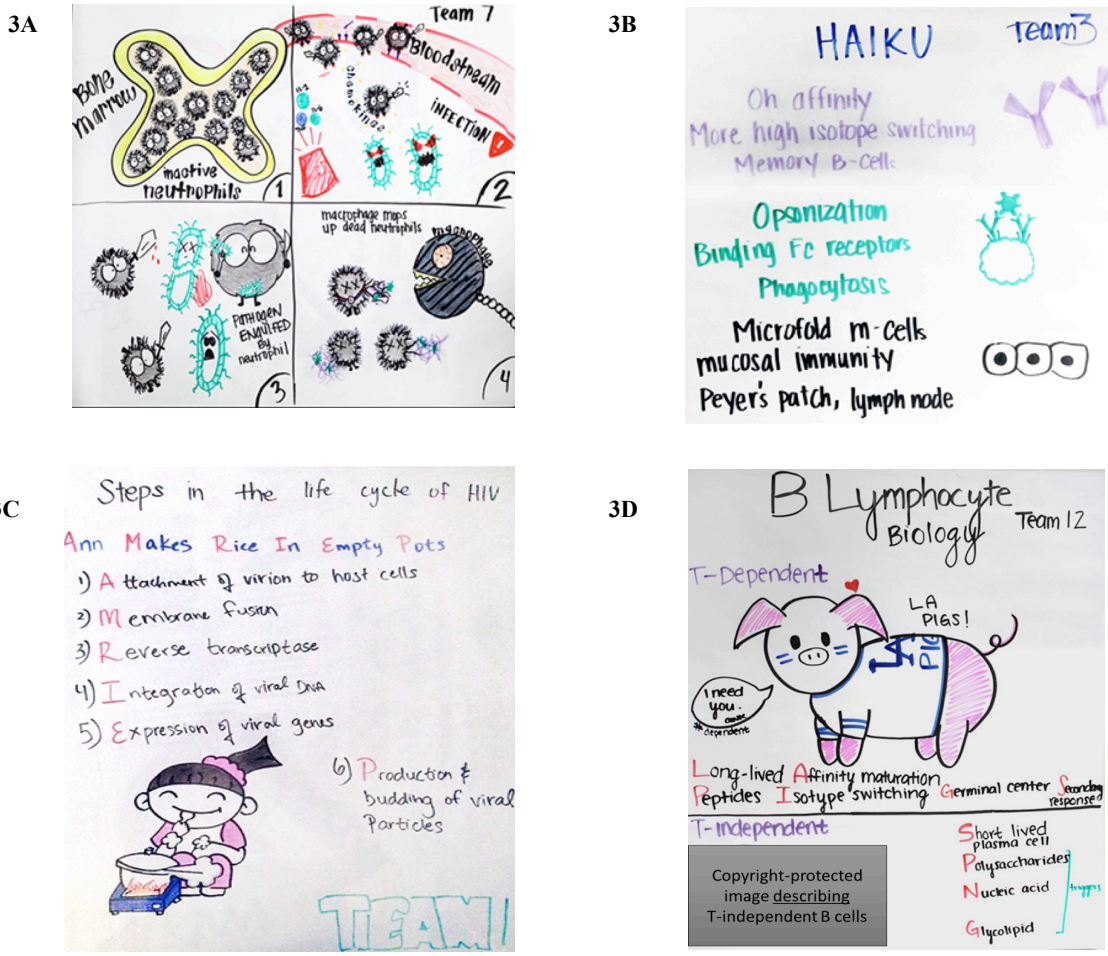

Figure 3: Examples of cartoon-caricature (3A), haikus (3B) and mnemonics (3C, 3D) created from the review exercises. Figure 3A: An example of a creation by a student team for the cartoon-caricature exercise that did not have copyright-protection concerns. The poster describes neutrophil extravasation promoted by inflammatory cytokines and chemokines, neutrophil phagocytosis of microbes, and the action of macrophages to remove dead neutrophils. Figure 3B: An example of haikus created by a student team for the song-haiku-mnemonic exercise describing humoral immunity. Figure 3C and 3D: Two examples of mnemonics created by student teams for the song-haiku-mnemonic exercise. A mnemonic describing the steps in the life cycle of the HIV virus is combined with an appealing drawing. The properties of T cell-dependent and T cell independent B cells are described in an additional mnemonic with appealing drawings. The drawing associated with the mnemonic to help remember properties of T cell independent B cells was of a popular cartoon, and had to be omitted due to copyright-protection concerns.

arthritis or other autoimmune diseases, the inflammatory components of the immune system were portrayed as villains, and therapeutic drugs used to treat the condition, or naturally occurring anti-inflammatory signalling molecules, were portrayed as heroes. For example, caricatures from the movie 'Minions' were used to explain rheumatoid arthritis in a colourful, engaging and informative poster entitled 'Despicable Knee', as opposed to the proper name of the movie 'Despicable Me'. Therapeutics and anti-inflammatory signalling molecules were depicted as the altruistic yellow minions, while the pro-inflammatory signalling molecules responsible for disease were depicted as the purple villainous minions. Lastly, the number of teams that earned extra credit by performing their song for the rest of the class improved from one (out of 19 teams) in the first year, to nine (out of 20) teams in the second year.

Discussion

This report describes the creation and implementation of two application exercises, a cartoon-caricature exercise and a song-haiku-mnemonic exercise, into an immunology course for third-year pharmacy students. The goal of these exercises was to foster learning and student creativity through the use of interactive and engaging educational activities. An Institutional review board (IRB)-approved protocol was not a part of this report, as this was not a scientific study. However, comments about the exercises in the course evaluations were overwhelmingly positive, with many students indicating that the review exercises greatly helped them learn the subject matter in a way that was engaging and entertaining. Both of the exercises described in this report utilised themes from popular culture, which have been used successfully in scientific education previously, as incorporating concepts from popular culture promotes

engagement and association skills in acquiring and applying scientific knowledge (Zehr, 2014; Lofgren, 2016). The potential benefits of incorporating music and the arts to teach scientific principles have been well documented (Crowther, 2012b; Kumagai, 2012; Gurnon *et al*., 2013; Brown, 2015). The exercises described in this report represent two additional strategies of incorporating creative activities into science education that promote active learning, student creativity and team building skills**.**

The incorporation of student-created drawings, songs and haikus as described in this manuscript is consistent with the concept of 'entertainment-education', which has its roots in early civilisations, as Aristotle promoted the use of dramatic plays to teach lessons about morality in ancient Greece (Piotrow, 1994). A strong link between the arts and the creative thinking of successful scientists (*e.g*., Nobel prize winners and National Academy of Science members) has been demonstrated, as world-renown scientists of distinction were shown to be more likely to have artistic interests than either other scientists without such honour, or the general public (Root-Bernstein, 2008). Leonardo da Vinci serves as a historical example of the potential benefits of integrating the study of science and the arts, while Dr. Donald Ingber, the founder of the Wyss Institute for Biologically Inspired Engineering at Harvard University, serves as a more recent example. Dr. Ingber attributed his interest in the tensegrity of cells, the mechanical forces that govern molecular and cellular behaviour, to his undergraduate years at Yale University, when his combined passions for cell biology, sculpturing and the arts contributed to his pursuit of a novel and fruitful line of research (Ingber, 1998).

Both sculpturing and creative drawing exercises have been utilised successfully to explain scientific topics (Gurnon *et al*., 2013; Quillin & Thomas, 2015), and the cartoon-caricature exercise serves as an additional method of incorporating student imagination, artistic ability, and teamwork to construct a poster that can be used as a teaching tool for fellow students. Although cartoon posters describing scientific phenomenon can be found using the internet (*e.g.*, runawaylabbook.com and Chemo-man images on med-source.blogspot and pinterest.com), literature searches did not reveal learning exercises that used student-created drawings of cartoon caricatures to explain scientific concepts. The cartoon-caricature exercise was cited favourably in both years, however, conducting the exercise twice in a semester was perceived as excessive by at least a couple of students, as the only negative comments regarding the exercise were received when the cartoon exercise was conducted twice in the same semester. The exercise was worth a significant portion of the final grade received by a student (3-4%) each time it was conducted. This may have also contributed to some negative feelings regarding the poster exercise when conducted twice in the same semester. In some cases, posters that were very artistic and visually appealing were not deemed to be either informative or effective as a teaching tool, as assessed by fellow student teams and volunteer faculty judges using the rubrics, and this led to some posters receiving a poorer than expected grade. The use of the hero-villain concept used by many teams in the cartoon-caricature exercise is applicable to many other areas of science relevant to pharmacy education. In the case of atherosclerosis for example, HDL molecules or therapeutics designed to prevent atherosclerosis could be drawn as heroes, and agents that promote atherosclerosis (*e.g.*, LDL, high-cholesterol diet, foamy macrophages in vessel wall *etc*.) could be portrayed as villains.

Mnemonics, music and haikus are additional forms of art that have been incorporated into scientific education (Crowther, 2012b; Cirigliano, 2013; Brown, 2015; Quillin & Thomas, 2015), and the song-haiku-mnemonic exercise incorporates all of these art forms into a low-stakes review exercise. Mnemonics can be extremely helpful for students pursuing terminal degrees in healthcare, as the amount of information required to be assembled can be daunting. Students in the health sciences often create and share mnemonics independent of specific instruction to assist the recall of information, and there are several online databases devoted to healthcare related mnemonics, such as medicalmnemonics.com. The benefit of music to scientific education has been reported previously (Crowther, 2012b; Cirigliano, 2013), as music is not only entertaining, it may also increase the ability to remember concepts (Schulkind, 2009). Although songs have traditionally been used to educate young children, increasingly, songs have been used to explain complex scientific processes in the higher educational setting. For example, the SingAboutScience.org database contains over 7,000 submitted songs, with over 750 songs dedicated to the student age range of 20-40 years old (as of October, 2018), and the database averaged between 50-100 unique visitors per day when tracked during one month of 2011 (Crowther, 2012a). Musical lyrics can also be constructed in a manner to form mnemonics, and musical mnemonics designed to aid in the study of health sciences have been perceived by students as being very helpful in preparation for summative exams, as assessed informally by comments left on informative YouTube videos (Cirigliano, 2013). Finally, haikus have been successfully used in the teaching of science in higher education previously (Pollack & Korol, 2013; Lewis, 2018). A benefit of asking students to use haikus to explain a scientific subject is that the concise nature of a haiku forces students to describe the essential nature of a complex subject or process in an extremely condensed poem.

The use of songs and music (Modell, DeMiero, & Rose, 2009; Crowther, 2012b), haikus (Anthony, 1998; Pollack & Korol, 2013; Lee, 2017; Lewis, 2018) and mnemonics (Cirigliano, 2013) to facilitate the understanding of scientific principles have been individually reported in the literature previously. However, the advantage of the song-haiku-mnemonic exercise (Table II) is that it permits teams of students an opportunity to discuss and choose the art form most congruent with their collective

artistic talents and interests to explain an assigned scientific topic. Several groups chose to either make haikus or mnemonics, which often included colourful drawings that served to allure fellow students to their poster creation (Figure 3). The song-haiku-mnemonic exercise was modified to require teams to compose four haikus, if haikus were the form of expression chosen by the team, to account for the concise nature of haikus. Many of the creations were alterations of popular songs, and the number of student teams that performed their song creation for a small amount of extra credit increased from one to nine in successive years. Permitting teams to play background music and dimming the classroom lights in the second year may have increased the willingness of student teams to perform for the rest of the class. Overall, student comments received in the course evaluations that mentioned the song-haiku-mnemonic exercise were extremely positive, and multiple positive comments regarding the song performances by student teams were also received, as they were generally perceived to be entertaining and an effective stress reliever prior to an upcoming summative exam.

The incorporation of scientific subjects into the creative drawing and concept design of the cartoon-caricature posters, in addition to the creative writing and composition of works for the song-haiku-mnemonic exercise, both align favourably with the highest levels of learning according to Bloom's taxonomy (Krathwohl, 2002). Additionally, the exercises also aligned with course and programme learning outcomes that integrated knowledge of the immune system with the mechanism of drugs, as drugs used to treat inflammatory diseases and asthma were a major focus of the cartoon-caricature poster, and were regularly featured in the song-haiku-mnemonic exercise. Furthermore, both exercises also mapped well with national (USA) Center for the Advancement of Pharmacy Education (CAPE) outcomes, particularly CAPE outcome 1.E, which specifically described the importance of a functioning knowledge of the immune system, how the immune system responds to injury and disease, and how the augmentation of the immune system can be used to prevent disease. Lastly, the incorporation of active learning strategies correlates well with teaching millennials, which collectively have a greater preference for team-oriented interactive learning when compared to previous generations (Roberts, Newman, & Schwartzstein, 2012).

The exercises did not require an extensive amount of materials, the song-haiku-mnemonic exercise and the initial rough draft of the cartoon-caricature exercise only required multi-coloured pens and inexpensive poster-sized sheets of white paper with adhesive, to facilitate posting the student-created products on the classroom walls. Since the final cartoon-caricature exercise was worth a more substantial percentage of the final grade, many student groups elected to use additional materials available in the university library, for example, multi-coloured paper, scissors, glue and tape *etc*. Students were encouraged to be considerate and clean up any refuse after using such items in the university library, yet otherwise these exercises did not place any additional burden on university resources or staff.

The exercises described in this report had several unplanned long-term benefits. First, as mentioned previously, the posters created were displayed on the classroom walls for at least a week prior to the summative examination. Secondly, the best cartoon-caricatures created from a previous year could be used during an informal gallery walk in subsequent years. For example, lymphocytes were the subject material covered the first time the cartoon-caricature exercise was conducted, and the lymphocyte posters were displayed for students in the subsequent year. An informal gallery walk was conducted, in which student teams viewed and collectively ranked the lymphocyte posters informally using sticky notes, thus enabling students to learn from the best posters created in previous years. Third, the posters created from the exercises served as an excellent tool to recruit applicants not familiar with TBL during the admissions process for the college. The display of posters in faculty offices during one-on-one interviews, in addition to the display of posters in conference rooms, helped visiting prospective students grasp the benefits of attending a school that used innovative and creative team application exercises within the context of a TBL curriculum. Finally, the posters created from these exercises were also featured by the institution to successfully highlight teaching innovation and student creativity during an accreditation site visit. A future line of research using the posters could be to assess whether some of the best student creations improved student performance on summative examinations, for example by dividing the class into two groups, and providing access to the posters during a viewing period to half of the class prior to a summative examination in an IRB-approved scientific study.

Conclusion

The two exercises described in this report received overwhelmingly positive feedback from students in course evaluations. Many comments specifically highlighted the enjoyment students received in learning the subject material in a way that fostered creativity and teamwork. The creation of innovative and effective teaching modalities that stimulate imagination and creativity provide students with educational experiences that foster personal skills, teamwork and higher levels of in-class Bloom's taxonomy learning. It should be emphasised that the application exercises described are amenable to topics other than immunology, and although TBL was the methodology used, this exercise is applicable to other styles of teaching, provided that students are broken up into teams.

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