GRAPHIC NOVELS IN BIOLOGY - A NOVEL ASSESSMENT IDEA

Galileo once said, "You cannot teach a man anything, you can only help him find it within himself." (Goodreads, 2020). I have often pondered upon how best I could use this advice. I have been an educator for 24 years and have loved every minute of it. During this time, I have seen students of all cadres come and go, but they all have one thing in common - their innate fear of written assessments. In general, students in high school tend to have a different perspective on education than their adult counterparts - they tend to procrastinate, are usually terrible at managing their time and are very creative at coming up with excuses for their poor performance on assessments, with few exceptions. On the other hand, there are always a handful of good students, who work very hard and manage to reflect their passion for learning in their articulation on assessments.

The words "written assessment" tend to convey ominous forebodings that encourage students to procrastinate studying for the test, creating a perfect formula for both student and teacher frustration. I have noticed that students who do well in class tend to enhance their own learning through techniques such as visual aids and hands-on techniques that they develop themselves. Trying out various methods on their own often encourages them to ask for clarification, which in the end helps them improve their understanding of the material. Encouraged by their success, I started thinking – if these methods worked well for these self-starter kids, would it not also help students with different learning abilities in the class? Could I create similar hands-on and visual techniques for the entire class, and most importantly, did I not owe it to myself and my students to at least try?

However, that was easier thought than done! One thing was in my favor - I have always been extremely fortunate in that I am able to create and modify my curriculum at my school. I have always favored student-centered teaching throughout my teaching career. Over the years, as I worked toward my National Board certification, and later, National Board renewal, I found myself consistently making small yet significant changes in my curriculum, slowly converting my class from a teacher centered to a student-centered classroom. The key was implementing many hands-on activities that required students to think about what they were doing and why.

When I joined the Illinois Math and Science Academy in 2005, I designed and taught the elective course Physiology and Disease. I started out with the traditional teacher-centered techniques but was curious to see what would happen if I converted my classroom to a completely student-centered one. Accordingly, I collected data from my Physiology and Disease course for 5 years (2006-2011) and noticed a significant increase in student submission ($P<0.0002$) and test performance ($P=0.0125$) when I converted all the inquiry-based labs in the course from partly student-centered to completely student-centered. There was also significant improvement ($P=0.012$) when students designed their own labs as compared to the teacher telling them what to do (Anjur, 2011). Since then, I have continued implementing innovative changes in my classes and created the Pathophysiology course in 2019, which integrates artificial intelligence and Arduino based learning into a curriculum heavily based on the study pathologies driven by changes in homeostasis. The student-centered model of teaching has been well documented (Weimer, 2002; Estes, 2004) and continues to remain the better option for student learning.

My objective has always been enabling students to take responsibility for their own learning. I constantly explore different options to help students achieve this objective. The most successful hands-on project that I implemented was having students create 3-D heart models to better study the cardiovascular system. Students were required to learn some degree of heart anatomy to begin this project, and the proposition of having this project replace the much-dreaded written assessment encouraged them to pursue the project with renewed vigor. Students were thrilled at the prospect of the demise of the ominous cardiovascular test and were enthusiastic to work on the heart model. I gave students 2-3 weeks outside of class to build their models, which they later presented to the class. Students followed up with a written reflection describing how they solved any problems that arose during construction of their heart models. They also connected blood circulation in their models to principles of biophysics, model design and the inner biochemistry of the heart. I have described this project in detail in a previous publication (Anjur, 2015).

Charging myself with professional development in the form of computer programming, I was able to build upon the initial heart model project and have students construct Arduino based heart rate monitors to measure their heart rates for the cardiovascular lab. Currently, I am working with my students on modeling the electrical system of the heart, using arduinos and electrical sensors for the intrinsic conduction system. This last project has posed quite a challenge because while the mechanical system of the heart is easier to model, the electrical system is much more complicated and requires correct placement of the electrical nodes to simulate depolarization and repolarization. These projects have given students a different perspective on the concepts that they need to learn. They also enjoy working on these projects and do not realize that they are studying basic concepts without being specifically asked to do so!

I was very encouraged by the receptiveness of students to my innovative assessments, but realized that there was more to do. The cardiovascular system had been relatively easy to model, but there had always been a general lack of enthusiasm when students were studying the nervous system, especially while listening to peer presentations of common nervous system diseases. Modeling neurons was easy enough but when it came to learning the differences between diseases that presented similar symptoms, such as the dementia in Huntington's, Alzheimer's and Parkinson's, students stubbornly refused to make any effort to do so. I tried bribing them with extra credit but it was not as successful as I had hoped. This was frustrating because it was necessary for them to assimilate the material to move on to the next unit.

It was then that I hit upon the idea of having them create graphic novels (comics) to replace the nervous system unit assessment. I have had success with innovative student assignments, and this would be fun to work on. How then to assign it? I decided to let students self-select into small groups of 3-4 and start research on their topics. Since my class is based on the principles of pathophysiology, and studying homeostasis in organ systems is the lifeline of the class, I decided to give them the task of deciding which two organ systems they would like to research.

Students were given two weeks for researching and drawing the comics. They were given full liberty to use their artistic talents to depict the causes, symptoms and treatment of two diseases of each of their chosen organ systems (total four diseases). Furthermore, they were required to make notation of the inputs and outputs for each system that overturned homeostasis leading to

specific pathologies. Students had mixed reactions to this announcement. They had heard of graphic novels, of course. However, whoever heard of graphic novels in Biology, what was the teacher thinking? I patiently listened to my students rant over my proposed assignment and then pulled out my trump card – I told them that this assignment was going to replace the neuromuscular system unit test. I would be okay with them drawing the graphic novels in place of the same. That did the trick! All ranting was forgotten and the ominous cloud of "written assessment" had once again been averted!

All of a sudden, students were motivated to brainstorm ideas. They moved into natural groups, discussing what organ systems they should choose, some students asked me to clarify their questions, others were involved in animated discussion. I gave students some class time to work together, especially since they were all engaging on their task so well, and walked around the tables where students were sitting in various groups, answering and asking questions. I do have to admit that this project engaged students best among all the projects that I have unleashed on my class!

Students worked on their graphic novels, finessing them and showing off their artistic skills until they were finally ready. I had the student groups present their graphic novels to each other in class and these presentations in turn generated many questions for discussion, something that I would have had difficulty doing naturally in class.

Students opted to do their projects in many different ways. Some students chose posters, others made a pop-up book, and still others chose to depict one disease per poster. Each group chose two organ systems to model their diseases on, and were given complete freedom to decide how to present their work. They were required to discuss integrations of their organ systems with others when they presented their work; it was not required to show this on their posters. Students were not required to choose the nervous system as one of their organ systems but most students ended up doing this anyway. This project replaced the nervous system written assessment.

Figure 1 (Abdul et al., 2019) and Figure 2 (Balto et al., 2019) are examples of student work. In Figure 1 (Abdul et al., 2019), students opted to depict all four of their chosen diseases – Diabetes Type I, rheumatoid arthritis, stroke and epilepsy on a single poster. They chose the endocrine system (Diabetes Type I and rheumatoid arthritis) and the nervous system (stroke and epilepsy) for their project. These students chose to create the superhero "Medicine Man" to counteract the effects of rheumatoid arthritis caused by the immune system turning berserk and injecting antibodies into their human victim. They covered the causes (auto immunity), symptoms (pain as depicted by their human victim sitting down and moaning) and treatment ("Medicine Man" giving immune suppressants and anti-inflammatories to the afflicted human) of the disease. The stars of their stroke story are Emma the neuron and Spencer the cholesterol molecule. Joe the immune cell and Samantha the islet cell, who is destroyed by Joe are used to explain Type I diabetes. Finally, a young boy is in an accident, following which he experiences a seizure when watching the bright lights of a TV show, which trigger his seizure. This was a perfect example of students working together to create a composite picture of diseases. I was proud of my students for working so hard and doing a great job. They showed creativity and initiative through their project, and learned the material much better than memorizing it.

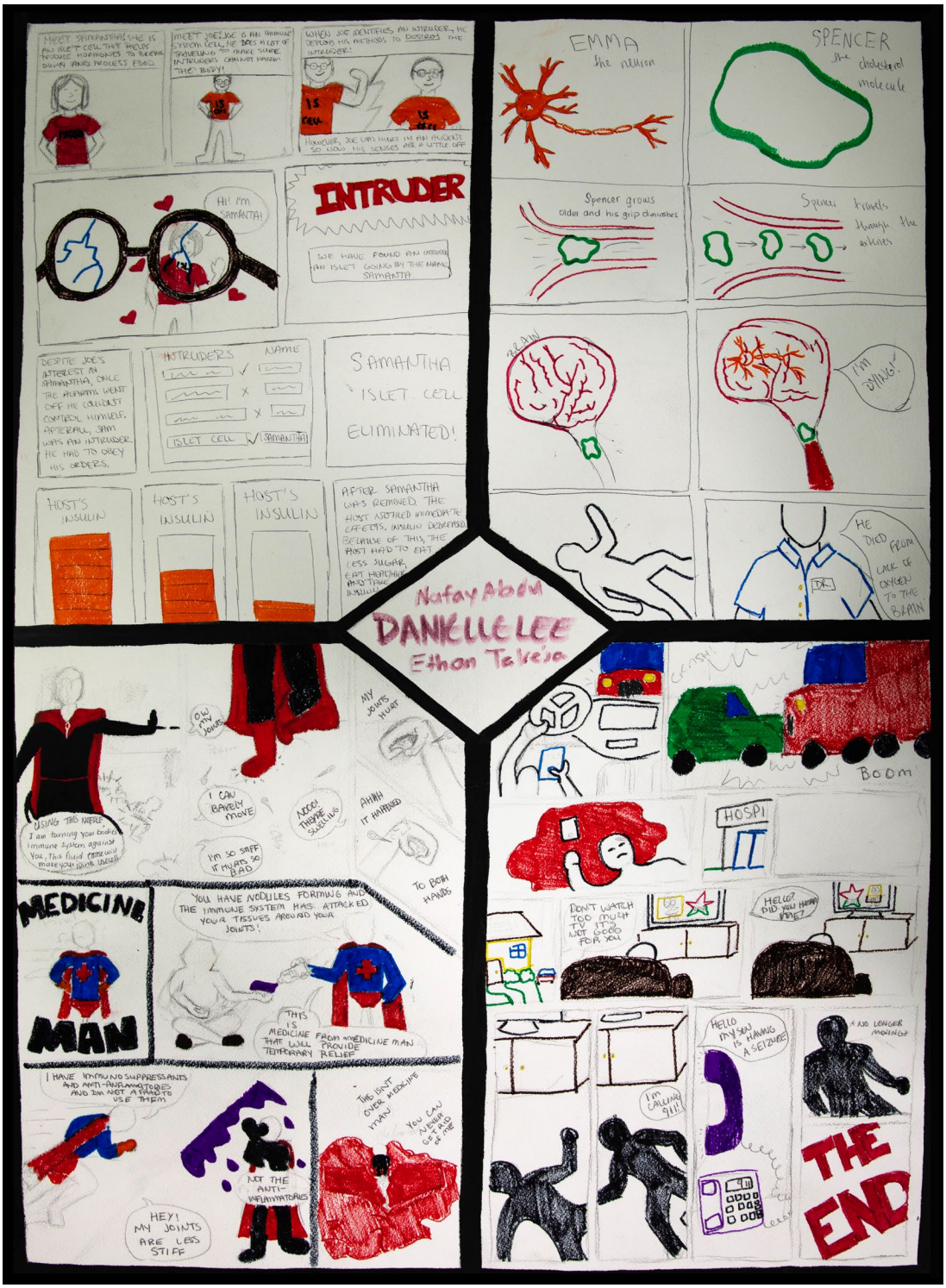

Figure 1: Student graphic novels depicting the pathophysiology of (clockwise) Diabetes Type I, Stroke, Rheumatoid Arthritis and Epilepsy.

Abdul, N.; Lee, D. and Talreja, E. (2019). "Diabetes Type I, Stroke, Arthritis and Epilepsy". *Human Diseases Graphic Novels*. 8.
https://digitalcommons.imsa.edu/hd_graphic_novels/8

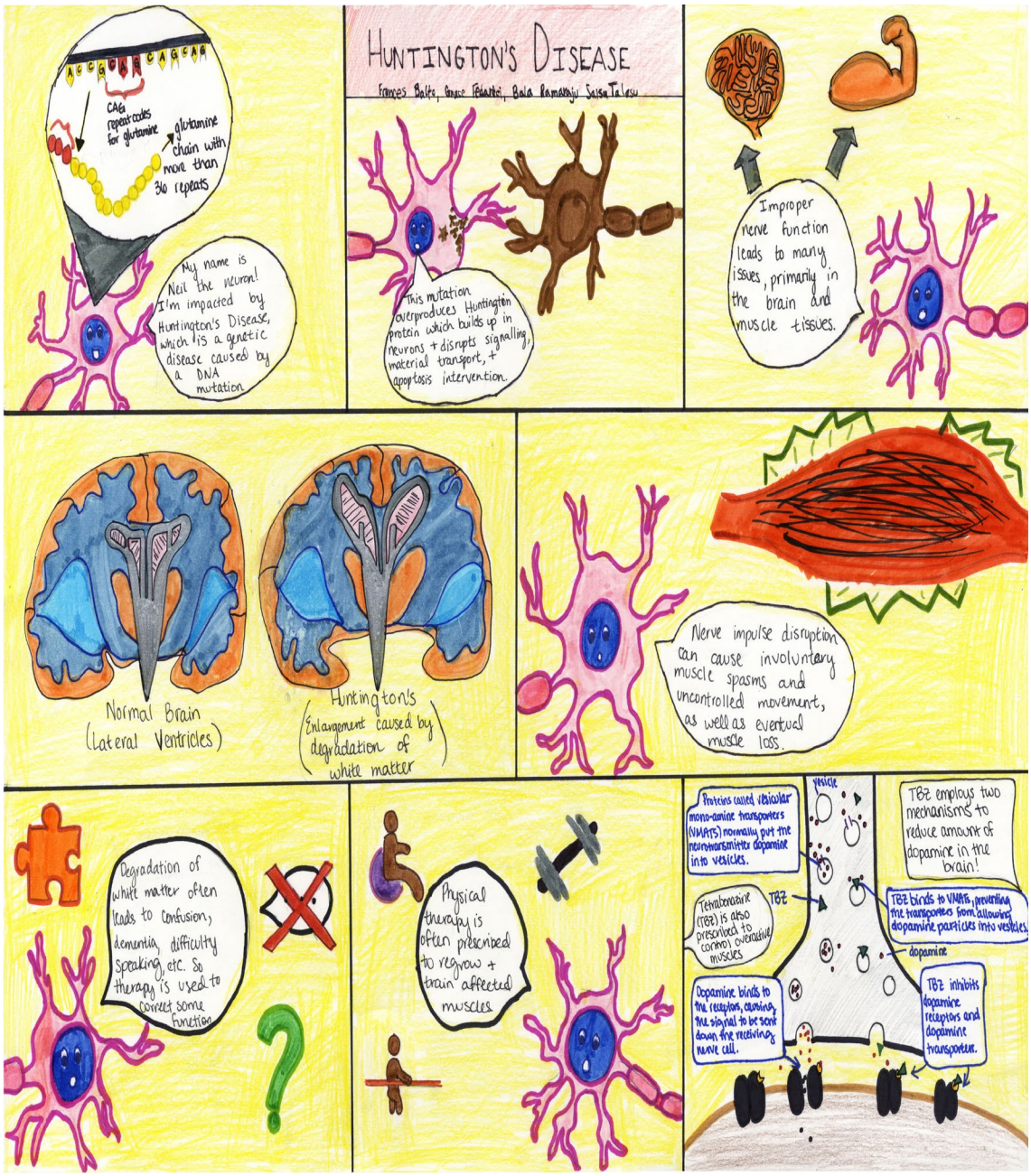

Figure 2: Student graphic novel depicting the pathophysiology of Huntington's Disease

Balto, F.; Federici, G.; Ramaraju, B.; and Talasu, S. 2019). "Huntington's disease" .*Human Diseases*

Figure 2 (Balto et al., 2019) is an example of how students used an entire poster to depict a single disease. They chose to highlight Huntington's disease, meticulously explaining the cause of Neil the neuron's problems (mutation), progressing on to symptoms (spasms, uncontrolled movements and muscle loss) and treatment (TBZ and Dopamine). These students went into great

detail with their diagramming but did not include superhero characters like the previous students. These students also made three other posters for their other three diseases.

Students presented their graphic novels to the class and engaged in discussion of the problems that they faced; how they went about completing their project and how they would do it better next time. They also pointed out the causes, symptoms and treatments for the diseases in their graphic novels, and engaged in discussion of how homeostasis was disrupted in these conditions. Particular emphasis was placed on the inputs from other organ systems and outputs to other organ systems. For example, in kidney failure, students discussed how the kidney was unable to process the inputs it received from the digestive system, and how the outputs to the urinary system were greatly reduced due to the inability of the kidney to make enough urine. This aspect of pathophysiology is very important because it gives students a clear idea of how the different organs systems are integrated and how pathologies result if these organ systems cannot work with each other.

Overall, the assessment was a great success, students who normally did not participate in class discussions were observed leading the project during class, and everyone seemed naturally interested in researching their chosen diseases and depicting them creatively. Student groups engaged in friendly competition with each other both in their creativity and drawings, and overall, the class atmosphere was one of intense learning. When surveyed later, students admitted that this project had been a very enjoyable experience and that they learned a lot from doing it.

Our school has a Technical Services Supervisor who is also in charge of our Digital Commons. I approached her and asked if she would be willing to digitize these student graphic novels from my class. She readily agreed and when the students had completed their project, they worked with her to upload their work on our school digital commons. This gave students a sense of responsibility and importance, especially since they are given credit for their digital work, which earns them a publication in high school.

This idea for an alternate exam was a great one, no doubt, but there remained the problem of how to grade this assignment. I thought about this for a long time, and decided to evaluate student graphic novels based on creativity, accuracy and connections to other organ systems.

It has been a year since I implemented this assessment into my curriculum. In retrospect, I feel that this assessment was a success because students realized that they had to take responsibility for their own learning, and therefore worked harder and faster than before. Working in groups of 3-4 also helped them discuss and finesse ideas and research.

Watching students grow as they worked through their projects has reinforced for me that students are willing to work, if presented with different ways of demonstrating their understanding. They do not always see eye to eye with the teacher but given a chance, will work hard to prove themselves. As I continue working on new and improved ways of devising meaningful assessments for my students, I get closer to understanding what Galileo meant when he said "You cannot teach a man anything, you can only help him find it within himself." (Goodreads, 2020) – indeed, in creating a diversity of ways in which students can express their understanding,

we educators can help them find their passion for learning, which helps them articulate better and ultimately eliminates both student and teacher frustration.

REFERENCES:

Abdul, N., Lee, D. and Talreja, E. (2019). "Diabetes Type I, Stroke, Arthritis and Epilepsy". *Human Graphic Novels*. 8.
https://digitalcommons.imsa.edu/hd_graphic_novels/8

American Association for the Advancement of Science (1993). *Benchmarks for Science Literacy: Project 2061.* Washington, DC: American Association for the Advancement of Science.

Anjur, S. (2015) Using Heart Models for Physiology Teaching and Learning. Spectrum (the Illinois Science Teachers Association Journal (Winter 2015 issue), 40(3): 33-37.

Anjur, S.S. (2011). Student-centered physiology in high schools. Advances in Physiology Education: 35(2):161-167. DOI: 10.1152/advan.00076.2010.

Balto, F., Federici, G., Ramaraju, B. and Talasu, S. (2019). "Huntington's disease" *Human Diseases Graphic Novels*. 28.
https://digitalcommons.imsa.edu/hd_graphic_novels/28

Brock, D. 2009. Working Model Hearts. The Science Teacher, 76 (9), 36-40.

Cardinal T.R**.** *Teaching Physiology to Biomedical Engineers Using Team-Based Learning and Inquiry Research* (online). http://works.bepress.com/tcardina/3 [28 March 2011].

Casotti G., Rieser-Danner L., Knabb M.T. (2008) Successful implementation of inquiry-based physiology laboratories in undergraduate major and nonmajor courses. *Adv Physiol Educ* 32: 286–296.

Catalano G.D., Catalano K.C. (1997) Transformation: from teacher-centered to student-centered engineering education. *Proceedings from the 27th Annual Frontiers in Education Conference* 1: 95–100.

DiPasquale D.M., Mason C.L., Kolkhorst F.W. (2003) Exercise in inquiry: critical thinking in an inquiry-based exercise physiology laboratory course. *J Coll Sci Teach* 32: 388–393.

Disciplinary Core Ideas. (2012). In A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington D.C.: National Academies Press.http:// www.nextgenscience.org/hsls1-molecules-organisms-structures-processes

Estes, C.A. (2004). Promoting student-centered learning in experiential education. Journal of Experiential Education, 27(2), 141–160.

FitzPatrick K.A, Campisi J**.** A (2009). Multiyear approach to student-driven investigations in exercise physiology. *Adv Physiol Educ* 33: 349–355.

Galileo Galilei Quotes (Author of Dialogue Concerning the Two Chief World Systems). (2020). Retrieved April 17, 2020, from https://www.goodreads.com/author/quotes/14190.Galileo_Galilei

Illinois Mathematics and Science Academy**.** *Profile* (online). https://www3.imsa.edu/about/profile [28 March 2011].

Illinois State Board of Education. *Illinois Learning Standards. Science* (online). http://www.isbe.state.il.us/ILS/science/standards.htm [28 March 2011].

Indian Prairie District 204 High Schools**.** *Course Catalog–Revised 6/9/2088* (online). http://www.ipsd.org/Uploads/DEC_High_08-11_COURSE_GUIDE. pdf [28 March 2011].

Krontiris-Litowitz J. (2009). Articulating scientific reasoning improves student learning in an undergraduate anatomy and physiology course. *CBE Life Sci Educ* 8: 309–315.

Lord T., Travis H., Magill B., King L. *Comparing Student-Centered and Teacher-Centered Instruction in College Biology Labs* (online). http://stemtec.org/pathways/Proceedings/Papers/Lord-p.doc [28 March 2011]

Luckie D.B., Maleszewski J.J., Loznak S.D., Krha M. (2004). Infusion of collaborative inquiry throughout a biology curriculum increases student learning: a four-year study of "Teams and Streams". *Adv Physiol Educ* 28:
199–209.

Madison Metropolitan School District. *Falk Elementary School* (online). http://www.madison.k12.wi.us/011.htm [28 March 2011].

NSTA Position Statement on Scientific Inquiry (2004). http://www.nsta.org/docs/PositionStatement_ScientificInquiry.pdf

The National Academies Press. *National Science Education Standards*. *Chapter 6: Science Content Standards.* http://www.nap.edu/openbook.php?record_id_4962&page_103 [28 March 2011].

National Science Foundation (1996). *Shaping the Future.* Washington, DC: National Science Foundation Directorate for Education and Human Resources, NSF 96-139.

Silverthorn, D.U. (2006) Teaching and Learning in the Interactive Classroom, Advances in Physiology Education, 30(4):135-140, DOI: 10.1152/advan.00087.2006

VassarStats: Website for Statistical Computation. *Homepage* (online). http://faculty.vassar.edu/lowry/VassarStats.html [28 March 2011].

Weimer, M. (2002). Learner-centered teaching: Five Key Changes to Practice. 2nd edition. San Francisco: Jossey-Bass. ISBN: 9781118119280

Biography:

Sowmya Anjur received her doctorate in Biochemistry and Molecular Biology from Iowa State University, Ames. She is currently is a Science Faculty member at the Illinois Mathematics and Science Academy, a residential school for students gifted in math and science. During her 23 years as an educator, she has developed her classes to be mostly student-centered with many hands-on activities to develop and nurture student creativity and enhance articulation. She incorporates high tech, challenging and inter-disciplinary projects such as the construction of heart models, Arduino heart rate and blood pressure monitors and other bioengineering topics into her Physiology classes.

Affiliation: Science Faculty, Illinois Math and Science Academy

Email address: sanjur@imsa.edu

Abstract

Students enrolled in my Pathophysiology elective class were given a novel assessment to replace the traditional written assessment for the nervous system unit. Students self-selected into small groups of 4or 5 and researched information on two diseases of each of any two organ systems they chose. They then brainstormed to create graphic novels of these human diseases, emphasizing deviations from homeostasis causing these pathologies. Students presented their graphic novels to the class, identifying connections between their diseases and the inputs and outputs from other organ systems. Students were allowed complete freedom as to the layout of their graphic novels, which were later digitized on our school digital commons.

Keywords

Graphic novels, alternate assessment, human diseases, hands-on, student engagement