How Choreostorming Informs Thinking In Molecular Genetics And Cancer Biology

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Abstract
The medium of interpretive dance to convey basic science is well regarded but not commonplace for college level instruction or scientific hypothesis development. The molecular biology of cancer involves multiple polymer languages that coordinate genome information flow from DNA, to RNA, to proteins. The author describes a college course entitled “Choreographing Genomics” that 1) uses a non-binary art and science approach to teach the molecular biology of cancer; 2) communicates cellular processes to cancer patients in order to empower them to understand the biology of what they are experiencing; and 3) assists cancer scientists in developing hypotheses through kinesthetic and visual enactment of cellular processes. Non-trained movers and scientific thinkers together participate in “choreostorming” which is a non-binary process where all participants work as science thinkers and artists to develop, and extend, thought experiments into the movement laboratory. Choreography thus becomes a vehicle for blending science and art.

Kinesthetic Thinking Adds Value to Teaching, Learning, and Communicating Biology

A historical dance idiom film on protein translation combines the Nobel Prize winning scientist Paul Berg introducing the protein translation with static drawing and contrasting his description with the movement happening that will follow. This work was directed by Robert Alan Weiss and created by the University of San Diego, Senses Bureau (https://library.ucsd.edu/dc/object/bb90484996) [1]. Scientific description is then layered on top of dancers and hippy generation movement captured through the filming of an event entitled “A Protein Primer”. This film uses dance as an approach to articulate scientific concepts. A more recent collaboration pairs professional dancers working with choreographer Carl Flink and scientist David Odde to assist in hypothesis development in a process they call bodystorming [2].

Herein, the author describes that dance as an approach to explore scientific concepts should not be a binary separation of scientists and dancers. The shift to a non-binary form allows a fluid combination in which each mover and artist is also a scientific thinker. This changes the nature of the work from a binary approach of scientists watching dancers to a fluid approach of movers being scientists and artists at the same time. This concept of the non-binary artist/scientist using movement to articulate and create more robust science and art understanding through dance, is being described in this article and is called “choreostorming”.

The Science magazine competition of “Dance Your PhD” organized by the correspondent John Bohannon encourages skilled scientists to express their work through interpretive dance [3]. Scientists use their bodies to conduct body experiments to test, and communicate, their hypotheses in ways that expand and extend their science [4]. John Bohannon collaborated with Carl Fink to explain how dance communicates more effectively than PowerPoint. He uses professional danc-

The use of language that metaphorically implies an understanding of spatial and kinesthetic process is used to articulate biological concepts, and is found in complex scientific writing. Science papers often make use of choreography as metaphor to demonstrate three-dimensional thinking. Some examples include:

2. Spatiotemporal choreography of chromosome and megaplasmids in the Sinorhizobium meliloti cell cycle [7].
3. Choreography of molecular movements during ribosome progression along mRNA [8].

Multimodal thinking that incorporates kinesthetic elements to influence biology hypotheses is not a common form of teaching or inquiry-based learning. In the Hunter College City University of New York course “Choreographing Genomics” we use the process of choreographing, and moving, as a method for teaching, and learning, genome information flow. DNA is at the heart of this so we start with DNA replication. The Hunter Biology Course list provides a description of BIOL 175-Choreographing Genomics [9].


Choreographing Genomics uses the lenses of science and Post-modern dance to introduce students to the central dogma of the biological polymers DNA, RNA and protein. The students learn the molecular biology of cancer and choreography from Professor Bargonetti. They read and learn about Post-modern dance and choreopoem through the writing of dance historian Sally Banes [10] and an essay discussing Ntozake Shange’s creation of choreopoem [11]. Science readings are assigned from the internet and from a James Watson textbook [12]. Visiting artists empower students to reidentify art and science as one combined process. The students must intertwine art and science from the first day of class. Assessment methods are based on formal exams, written and quantitative assignments, choreographic assignments, and an end of semester performance. The course was taught for the first time in 2015 with five cohorts completed by December 2020. Data from these cohorts show that science and non-science majors grasp the concepts. A total of 67 students have taken the course and all have earned a grade of B or better. One of the students went on to become a dance major, another a science major with a dance minor, and over one-third have become science majors. Many have asked for recommendation letters to go on to participate in summer science research programs, science graduate schools, and medical school. During “choreostorming”, participants must allow themselves a non-binary, mixed artist/scientist identity that explores the scholarly and artistic endeavor in a fluid format. A non-binary identity is a necessity for “choreostorming” scholarly work. “Choreostorming” uses the freedom (or in some cases the restrictions) of movement with untrained or train dancers who are provided with the scientific foundation to produce choreography that can test formulated molecular biology hypotheses. The finished products do not have to be equally focused on detailed science or perfect choreographic form. The non-binary model is used for the mover/dancer/choreographers to be artists and scientific thinkers. The PBS special American
Graduate Day in 2016 highlighted how this instruction and process became a part of the Hunter College curriculum and highlights this as a career spotlight:


When contemplating this method alongside the method of bodystorming, the method of “choreostorming” requires all persons to be non-binary scientist/artists and to work fluidly as scientist/artists to articulate the biology. Persons actively move as multiple polymers and signaling molecules in space while utilizing choreography and “choreopoem-spoken word” to clarify concepts. It is creative, while having the previous scientific information and paradigms as starting points. Static images, and ideas, are transported to dynamic processes that can change as scientific data is generated to influence hypotheses development. Undergraduate students at Hunter College taking the course Choreographing Genomics have modeled the DNA replication helicase “roaring across the nuclear plane” as well as many other molecular biology pathways. This “choreostorming” by undergraduate students is carried out weekly in the BlackBox theatre and students asked to be both scientists and artists.

Students access knowledge through multiple learning styles that occur through multiple intelligences, as proposed by Howard Gardner [14] and the four sensory modalities described by Neil D. Fleming [15]. Requiring students to use their bodies in space improves three-dimensional thinking skills and does not allow for student distraction by cell phones or computers. The students cross boundaries that make it clear if they do not understand concepts that are being taught because if they do not understand then they end up in an incorrect location. Dancers have often used choreography to cross boundaries but this is not the norm for scientists [16, 17, 18].

Studies focused on kinesthetic and visual processing use creative artistic movement to present data and research findings, and these demonstrate multiple learning benefits [19, 20]. The noted choreographer and dancer, Bill T. Jones, developed an artistic research method that he used to conduct an inquiry of how people living with serious illnesses (like HIV) cope and survive. This became part of his 1994 choreographic work “Still Here” [21]. Another notable dancer choreographer, Liz Lerman has collaborated with scientists to inform public access to science knowledge [22]. The Howard Hughes Medical Institute funded a multi-year collaborative project between artists and educators where Liz Lerman and her students and dancers worked with scientists to produce a professional multimedia piece entitled Ferocious Beauty: Genome, http://www.hhmi.org/news/dancing-science [23]. Through this collaboration Liz Lerman worked alongside biologists to develop a movement-based approach to teach biology [24]. The making of the piece brought these collaborators to the recognition that the tools used for dance making could be adapted to improve instruction. They developed a public website to explore the intersection of art and science and kinesthetic learning http://sciencechoreography.wesleyan.edu/ [25]. These tools are geared towards high school teaching but also lend helpful instructions for the complexities required for assisting college students.

There are only a few bodies of work that concentrate on using visual and kinesthetic approaches to increase understanding of three-dimensional abstract biological reasoning. Some of this research focuses on learning in health-related fields where execution of the job requires a kine-
thetic awareness. The studies show that student engagement and learning are improved by using multimodal teaching approaches that incorporate kinesthetic components [26]. Many of these fields (nursing, dentistry, surgery) may self-select for people who are strong visual and kinesthetic learners.

The work of Carl Flink and David Odde explores how science can be informed by dance and vice versa. The collaborative leaders in art and science have done this through The Moving Cell Project [27]. This pairs professional scientists who watch professional dancers carrying the movement and this is what is called bodystorming. For “choreostorming” we use the fluid form of Post-modern dance that identifies with the fact that all humans are dancers and allows all scientific thinkers to be dancers and choreographers. “Choreostorming” does not have persons taking part as scientist viewers or artist creators but rather all persons must be fluid to work between the boundaries of science and art. The development of the dance your PhD competition has worked to encourage high-level scientific thinkers to articulate their idea through movement but does not encourage the basic learning experience at all levels.

**Inviting Community Members to Collaborate with “Choreographing Genomics” Students Facilitates Communication**

Some common processes between sciences and the arts are noticing, wondering, exploring, visualizing, and communicating [28]. Communicating can take the form of explanation and dance performance can serve this purpose. In Liz Lerman’s *Hiking the Horizon* she contemplates the question: who gets to dance? “Dance is a birthright and as we know about birthrights, they are easily stolen”. It is a right for all in our community to dance. It is a right of all of our community to understand how genes influence cancer development. At Hunter College we have brought these rights together in collaborative dance spaces. In these collaborative spaces students and community members together, notice, wonder, explore, visualize, and communicate. It is the right of the students to understand that people “touched by cancer” are part of our community. Therefore “Choreographing Genomics” incorporates community members “touched by cancer” into workshops that utilize Post-modern dance accumulation methods (inspired by Trisha Brown [29]) to explore cancer. We also have student participants create final presentations that are shared as performance for, and with, the community. This process includes students and community members sharing choreopoems, watching dance, contributing personal stories, sharing touch and growing in understanding together.

A choreopoem I share articulates that humans originated from an “Eve” who lived in Africa [30] and that “Eve” passed on her mitochondrial DNA (as well as chromosomal genes), that when mutated, can promote cancer. The choreopoem, entitled “Fragments of African DNA” (written and performed by J. Bargonetti), sets the stage for communicating that cancer genes do not discriminate against any ethnicity. This choreopoem connects our community and can be viewed at:

https://www.dropbox.com/s/nc72qu2o64n5cig/EDITED%20CHOREOGRAPHY%202.mov?dl=0 [31].

It begins with the spoken word as follows:
Fragments of African DNA
Unite the human family
Twenty-three times two in you and me
Fragments of DNA we see
Unite the human family

Choreostorming adds Value to Hypothesis Development for Mutant p53 Working at Replication Forks

Liz Lerman has posed the question “What if scientists were choreographers?” [32]. To expand the teaching and learning experience we have blended scientists into choreographers and choreographers into scientists. We developed thought experiments with cancer specific studies and took them to a movement laboratory (see Figure 1).

Figure 1: Students from “Choreographing Genomics” and PhD students from the Bargonetti laboratory choreostorming. Different shirt colors indicate different mtp53-PARP-MCM biochemical activities and different biopolymers. The mtp53 fires two replication forks and shows a crowded double helix. Useful link for viewing students moving as models of DNA replication. https://www.youtube.com/watch?v=gHfLz1Xs7Iw [35]. (© Kurt Brungardt)

The Bargonetti Laboratory PhD students collaborating with Professor Bargonetti’s “Choreographing Genomic” students carried out this work. They collaborated fluidly all as scientists, and dancers, and choreographers to examine how bodies in space (acting as the molecular polymers) influence DNA replication in the presence of the tumor promoting molecule mutant p53 (mtp53). Figure 1 shows the students and Professor Bargonetti in the movement laboratory. In Figure 1 two converging replication fork are shown at the X formed by the rope in the middle of the picture. The two ropes represent the DNA that is being copied; the colored pieces of fabric hanging on the rope are newly synthesized DNA molecules, and the students all were designated bio-
chemical protein roles (for example as mtp53 or helicase or the DNA repair protein PARP). Different independent variables and proposed functions were assigned for each experiment and the dependent outcomes were evaluated. This helped the team to recognize the torsional stress and stochastic collisions that influenced dependent outcomes and suggested that if mtp53 caused more replication origins to fire the oncprotein would promote more genomic instability and therefore promote more aggressive cancers. The PhD students in the laboratory are now testing this hypothesis. The choreostorming method has helped us formulate higher-level hypotheses by coordinating the thought experiments with movement experiments. The dependent outcomes are now being tested in the laboratory. The image in Figure 1 shows mtp53 firing two replication forks rather than just one. Watching the people designated as the different polymers bang into each other, and counting the seconds for them to finish their tasks, demonstrated that if more replication origins were initiated by the mtp53 then greater turmoil ensued.

The Bargonetti laboratory studies the oncogenic mtp53 pathway. The normal functioning p53 protein works as the “guardian of the genome” and the oncogenic mtp53 is a highly stable protein that promotes cancer in a way that is not well understood [33]. The team recently discovered that mtp53 works as a complex on replicating DNA together with replication proteins MCM2-7 coordinated with the DNA repair protein PARP [34]. It is called the mutant p53-PARP-MCM axis. How these proteins function together is unknown. The “choreostorming” experiment described above helped to formulate a clearly articulated hypothesis that mtp53 causes more replication origins to fire and this requires more DNA repair proteins to assemble at the converging replication forks.

Dance can develop cancer molecular biology hypotheses to a level beyond the use of scientific vocabulary. The vocabulary of how proteins influence DNA and RNA signaling are drawn into the dynamic dance lexicon that requires participants to explore their range of motion, traveling in different directions to explore torsional strain that occurs inside the cell (see Figure 1). Choreography is a vehicle for learning about anything in greater detail because when we don’t understand we can try many different possibilities through movement. Thoughts must be translated in the group interaction for all to see and discover together during the dance communication. An initial picture in ones’ mind can be moved from a thought experiment that uses molecular biology language of proteins, DNA and RNA to a movement experiment by designing a choreography that begins to test a concept with bodies in space. When the human bodies collide, or are needed to help each other in specific ways to proceed from one step to another (like in a biochemical reaction) the group must communicate to articulate the various levels of understanding. These new realities can then be tested through state-of-the-art laboratory experiments that explore the molecular pathways. Communication and connection happen during “choreostorming” in a way that is similar to what happens at scientific meetings or dance performances but because “choreostorming” is not a binary art or science process there is no need for classification. This science as art accepts fluid identities. Choreographing, and performing, the molecular biology of cancer can assist in all components of knowing and communicating the different outcomes of the disease.

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