Science Choreography (SC) –
Dance and Science in Education, Research, and Performance

Past, Present, and Future of Science-Dance Interactions

by

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I have a dream ... for education, research, and performances that know no boundaries... for socially just, accessible, and stimulating environments that help the generations discover their leadership potential and passion to make a difference in their communities...

Let Science Choreography pave this path!

–Elena Georgieva,
in memory of Prof. Laurel Appel. Wesleyan U.
Abstract:

The main goal of my study is to understand how dance and science intentionally interact and inform each other in the fields of education, research, and performance to become, through embodiment (the kind of connection between mind and body), what I broadly name science choreography (SC). To understand how SC affects contemporary creators and their communities, I conducted a review field and interviews with several science researchers, science and dance educators, and artists; I led a movement exploration of SC with college students; and I taught a SC class with local home-schooled students. The data indicate SC’s existence from centuries ago and enormous influence on the dance and science disciplines.

The results revealed that participation in SC activities leads to a significant educational social impact. Here I suggest that with its accessibility and impact, SC parallels John Dewey’s very successful model for community service learning. If the importance of SC as a powerful interdisciplinary tool is recognized and implemented in fields such as science communication and learning, SC could have an immense effect on academia, research, and the arts. Further research to support this hypothesis should address the limitations of this study including: the number of interviewees, the amount of relevant historical, pedagogical, psychological, and scientific literature reviewed, and the lack of quantitative measurements in my movement explorations and teaching studies.
I. Introduction, thesis statement, and research questions

1.1 Science Choreography – background, definition, and questions

Just as global tendencies of free communication have and will continue to remove boundaries between people around the world, so will divisions between scientific and arts disciplines continue to meld. The more we learn about life, the more interconnections appear and thus necessitate that we reach out to other disciplines to help our understanding and progress in certain areas. Sciences, education, and arts are all fields that constantly go beyond their own limits in the search of new methods to describe the complex phenomena that challenge the understanding about the environment. These fields have also been closely interrelated in the history, when each discovery has had a great impact on our thinking about the world and the way we behave in it. But well beyond this macro-cosmos of interrelated ideas, as mediated by our philosophical understanding of the world, now we have reached an era where literal interpolations of one area come into play into another, influencing directly and irreversibly the development of either.

Such direct interdisciplinary connection can be seen in the emergent field of *science choreography* (SC) (which I will further define) – an interaction of science and dance that has broad implications in the realms of education, research, and performance. However logical this interaction seems to me now, the reason why I undertook the study of SC as a place where science and dance interact and shape our understanding of the world, was because in a modern society like mine these fields, science and dance, have been dichotomized to an exclusive extent. To demonstrate how I subvert this exclusive notion, I show the benefits of such interdisciplinary interactions as supported by my theoretical and practical research.
In this thesis, I first define what science choreography is, based on the manifestations and examples I have found in literature and art work. Second, I address SC’s purpose in terms of where and how it could be used and also what value this not easily definable mix has based on data I have collected. And third, by underlining the significance of this field as it develops, I pinpoint some of the directions that could be taken in this process in my discussion.

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The term *science choreography* (SC) has emerged from a collaboration in 2004 between Wesleyan University's Molecular Biology and Biochemistry Department and the Liz Lerman Dance Company, which was promoted by Pam Tatge – the director of the Wesleyan’s Center for the Arts (CFA). The idea of merging dance and science on Wesleyan grounds then helped support the development of a dance piece called the “Ferocious Beauty Genome” (2006) performed by Liz Lerman’s Dance Exchange for the first time on the stage of the CFA Theater. Around that time Prof. Michael Weir was the first to come up with the name SC for this embodied way of bridging science and dance. As the collaboration developed over time, the term SC expanded naturally to include the outreach and workshop activities used to popularize the program through engagement with the local community and student body.

With this in mind, I am borrowing the term SC to refer to any general dance-science intentionally inspired collaboration initiative or performance. The multifaceted nature of this broad and exhilarating field I aim to define in this and the following chapters. this is totally fine. While the term SC has emerged only in the last years, interdisciplinary projects of such kind have a long history. For example, in the court of the Medici, Galileo performed dances about his discoveries on planet motions to affirm his work [1]. In the modern technological
era of video-recording capabilities, one of the earliest manifestations of this dance-science mix was the “ribosome dance.” This huge site-specific dance performance showing the process of protein translation in cells, was developed in 1971 by Paul Berg, a professor in Molecular Sciences at Stanford, and his students [2]. There is hardly a student or a professor in biology that has failed to remember seeing that dance. Most of the scientists I know vividly recall the first time they were introduced to this dance, and all note the huge impressions it had on them. I still think of the perplexed face I had when I saw it my freshman year in my intro biologyclass, and the scale of that project still evokes a fascination inside of me every time I look at it.

But what makes a dance representation of this scientific process so memorable and powerful? What exactly is the impact it has had on the science and dance communities? What is the value of this project, and why are we being interested in the interface of dance and science more than ever before? And last but not least, what are the manifestations of this mix nowadays and how will it develop in the future? While I cannot address these questions conclusively in the limits of my work, I will use them to frame my research.

In my research I will aim to answer these questions by touching upon several topics in the introduction: first, I talk about the concept of embodiment as a logical descriptor of SC. Second, I mention what social issues in our modern developing world play a catalyzing role for the development of SC and with this I discuss some questions related to my study. Third, I briefly list some the various dance science combinations that exist already while separating them into several categories before I go into more detail about them in the second chapter. Last, I discuss the physical approaches I take to study what SC is and where it can be applied.
1.2. Embodiment

Having defined the term SC and the questions about it that frame my study, I would now like to describe the way in which science choreography unites science and dance. Although science and dance can be very similar in the way they approach their material (which I later discuss), in SC, science and dance combine to form something else that goes beyond what either discipline does individually. What makes SC stand as an independent interdisciplinary field is the unique connection between the scientific and dance thoughts on a physical level.

The term used to describe this process is embodiment. In this context, embodiment refers to the physical conceptualization of a concept or idea. The term itself is used in many other contexts and has expansive meaning in dance and philosophy. Therefore, in order to understand the full meaning of an embodied SC experience, I briefly look at some other sources that describe what embodiment means.

According to a general dictionary definition, embodiment refers to the act of embodying or being embodied\(^1\). The latter can be further described by a body-mind perception as a whole, as opposed to the physical body only\(^2\), or just the mind. In a physical theatre training, the word reflects a process “that seeks to unite the imaginary separation of body and mind.”\(^3\) According to a general dictionary definition\(^4\), embodiment can be “a representation of an abstract idea in concrete terms” or “the act of attributing human characteristics to abstract ideas.” To sum up, by definition embodiment is a tool that implies a body-mind connection which relates abstract ideas with more concrete physical terms. In

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dance terms I would think of it as the act of putting a concept into motion, which automatically brings mind and body into one.

If we try to extrapolate that idea by bringing together dance and science, as in bringing physicality and conceptualization together, it turns out that **embodiment is the means through which these two areas connect to become what I define as SC.** But what is not science choreography then?

Earlier I mentioned I am borrowing the term SC to refer to any general dance-science inspired collaboration initiative or performance. Obviously, however, if embodiment is not an intermediary between science and dance, as my definition evokes, that would not be SC; someone simply using technical innovations such as lighting on a dance stage is doing no more SC than a scientist saying that molecules dance. However, if the dancer is actually researching on how science of lighting can contribute to their artistic expression (just like Loie Fuller which I discuss later), or a scientist is putting this molecular dance through their bodies (just like Galileo with his discoveries) then this becomes science choreography.

**2. Directionality and Destination – Descriptors of Science Choreography**

With the SC definition in mind, I would like to talk about the ways in which one can go about SC. To do that, I first must introduce two descriptors – *directionality* and *destination*, because I later use these to differentiate between the SC manifestations when I address them in the introduction and the literature review.

The first term, *directionality*, refers to the starting point – scientific or dance concept and the problem which it tries to address, which means every time we have an inquiry, it is the tool we approach it with that defines our direction. Definition of directionality is important because if two concepts such as science and dance are connected, we could
theoretically start from either one to access the other, and then go back and forth as we
further delve into the process. For example, we could put a scientific idea through our body,
in other words model it and use our body as a literal representation, or we could refer an
abstract dance movement pattern to a specific scientific process. Either way these are
versions of SC, and yet, understanding their essence would be hard without the context of
their goal or application.

Therefore we need the second descriptor of SC, *destination*, to refer to the field of
application, in other words where, or for what, the final SC “product” can be used. There are
three broad destination fields on which I am concentrating: science and dance *education*,
science and dance *research*, and *performance work*. While by definition these would
mostly remain separate categories, often they are observed in a merged form because of the
interplay between them. I cannot imagine, for example, science teaching not being related to
scientific discoveries, or a dance piece being created without a movement exploration
beforehand. For these reasons, I will use the term *destination* to only aid my subsequent
categorization of existing work, yet without presuming any stringent limits between the fields
based on my terminology.
3. Application fields of SC:

To justify the choice of those three destination fields and why I think it is important to research more about how dance and science can affect them, I first outline some area-specific characteristics, problems, and necessities. Second, I suggest why SC could be a useful tool to apply in those areas based on my knowledge/background. Third, I am going to address the things I am interested to know more about and that I would later use to support SC use. Then I discuss how I go about addressing my inquiry based on where the limits of my expertise fall.

3.1. Dance in Science Education, Research, and Performance

3.1.1 Dance in Science Education

I start with the science education field, and first, I would like to address why there is a great need for introduction of interdisciplinary ideas/approaches in it. Because of the amount of science discoveries every day, it is equally hard for scientists and non-scientists to catch up. The common media pours tons of information on us daily, the market offers more and more gadgets, our jobs and lifestyle require more that we understand how to function in a globalizing world. Exactly here we might run onto the issue how to access all of this new information, a question which is especially relevant in education.

While the complexity and the breadth of topics in science curriculum relevant to our lives is increasing, the number of hours to cover these topics is not [3]; thus, even though the amount of things to be memorized increases, the time for educators to transmit the most important point curriculum elements remains the same. What makes it even harder for educators and students, is the fact that science deals with a lot of abstract concepts and involves a lot of jargon memorization, which might limit students ability to relate to concepts
in an explorative and creative way [4]. This is why a major educational issue remains the question how a great amount of information can be successfully transmitted in an accessible way. Moreover, how this information can be retained in the long-term from students, so that they can apply it to real-life problems that go beyond fulfilling state requirements and solving standardized tests, is of great interest for the economy and the job market.

For these reasons, in my study I would like to see what role SC could play in this ongoing educational research process. Pedagogical observations and literature often state that movement games and small rituals, such as clapping in the classroom in response to a rhythm given by the teacher, can be a very effective way to keep student's attention alert and to increase their participation through physical engagement [5]. In addition, use of various pedagogical methods beside frontal lecturing could also increase students' interest in a subject and the motivation to learn [5]. Therefore, from an educational perspective it would be very interesting to understand how the use of SC as tool to assist the teaching process can be beneficial for learning. Also knowing in what situations it can be applied effectively, for what type of students, and for what subject areas it would be most beneficial would be very useful too.

While these issues remain a hot topic for future psychological and pedagogical studies, I do not have the expertise to conduct such research. Therefore, in my research I am interested to know qualitatively why SC is such a valuable tool for the classroom. For this reason, I interviewed a set of science professors that have been involved with science-dance projects at Wesleyan University, and I discuss these endeavors more in chapters two and three. Although I know about several high- and middle-school local teachers who implement

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Footnote:

Frontal Lecturing is a pedagogical term that refers to a class set-up in which the professor lectures the students by literally staying in front of them (hence frontal). This style of teaching, as defined, excludes any interactive activities between students and refers to passive acquirement of information.
SC as a result of Wesleyan outreach programs, I concentrate on Wesleyan professors because the work SC at Wesleyan University has been very prominent and indirectly informs me about these outreach activities. These findings I then compare to some current literature findings suggesting the positive impact of dance involvement in (science) learning and education. Thus, I hope to contribute to the acclamation of the SC field as a science pedagogical practice by briefly codifying our current knowledge for it and thus laying a base for future reference.

3.1.2 Dance in Science Research

Now I would like to address the role of SC for science research. Similarly to science education, having another method for approaching a question in a nonconventional way through dance, could in fact stimulate innovative thinking. For example, one of the most useful and powerful ways movement can be used in science research is through embodied modeling [4]. And having a good model in science is a big deal, probably more than we ever think about because modeling of any scientific system is so ubiquitous that we might take it for granted. Because the answers for questions we have are not obvious, we need approximations to get as close as possible to the right answer. Often research starts with a model proposal that gets tested through various experiments, and at the end it finishes with a model again, based on the interpretations of the data acquired and the insights that they give us. Indeed, theory, i.e. modeling, goes along with empirical research hand in hand, and a great amount of theoretical work precedes and follows any data work. Therefore having the value of a good model that can be tested remains unquestionable in the scientific fields.

A good scientific model is one that can be used to codify and appease sometimes controversial data, and at the same time give us an idea how a system would behave in the
future, i.e. has a predictive value[6]. As such, a good model would explain the experimental observations and would further the current understanding of the system when used predictively even when it has limitations, so long as we can be aware of them and how they affect the behavior of the model[6]. However, sometimes the assumptions and the model components are not as well definable as we wish they would be[4], or when they are, it is done through reduction - the variables are taken apart and studied individually thus going away from the big picture. In either case, the properties of a system cannot be unequivocally understood and another way to look at a problem (why not SC?) seems to be needed.

This is why in my research I would like to study how and in what context dance can become a powerful research tool for any scientist or person asking a specific science question. I am interested to know how else and with what advantage (if any), beside merely representing a scientific concept, embodiment can give us an opportunity to look on concepts from another angle. For this I interview scientists such as David Odde, who uses movement in science studies, in order to see how research could be approached through SC. I also look at how scientists using dance to perform, or teach (like in the case of the “Dance your PhD” contest or in a classroom setting respectively) view this SC potential, more details about which I will provide in chapters two and three. In addition, I would be interested to explore a research process physically hoping to get a taste for how SC can help us unravel ideas we would not reach otherwise. While I am not in the position to conduct actual science research considering my time-constraints, I would still like to comment on the feasibility of SC application to research and the insights it could bring.


### 3.1.3 Dance in Science Performances: science communication

Having talked about how dance can be used in science research, I will now look at how SC can be used in scientist-created presentations. While the latter case might involve embodiment representation of a science model, the difference between the use of dance as a research tool and as a science presentation is the context in which they are viewed in, as well as their final goal (destination). A modeling representation becomes performance once it is defined or recorded as something that is meant to be performed/shown to a broader audience. My definition is largely based on the fact that such SC work could be both informative and artistic because it is science based yet uses artistic tools to transmit its message. In the bottom line, I refer to modes of science as methods of modeling and communication, and refer to dance as such an untraditional method.

A couple of examples that fit the above stated description are the ribosome dance of Paul Berg from the seventies, as well as the pieces of “Dance your PhD” program which are much more recent. Because in both cases scientists use dance to present a scientific work, I am going to try to understand how they (with presumably little dance experience) go about creating such works and what their goals are. Because of the competitive character of the program, I will try to understand what criteria are used to evaluate a science-dance as good. Next, I will try to learn how (if) their SC work has affected their research and life. I am interested to know, again through descriptive research, what effect sharing a SC experience with other people might have, in other words what the social implications of such works are in the community they live in. For that purpose, I interview the creator of the program as well as the winners in the four categories (physics, chemistry, biology, and psychology) from the past 2010 and 2011. Although my research is qualitative and size-limited, which will be later taken into account in my analysis, understanding the patterns from the interview
responses provides information to SC’s success among the participant and it provides clues for future research.

With this in mind, I compare works of scientists to the works with which I became familiar through science-artists collaborations such as those of the choreographers Liz Lerman, Susan Marshall, and others (chapter 5). Thus, I also hope to understand what the differences are between scientists and dance choreographers who produce SC work while concentrating on the intellectual contributions and communicative values of the works more so than their performance qualities. The latter comes from the fact that I am looking at how dance applies in the fields of science research and choreography with the purpose to study, illustrate, and communicate concepts in an unconventional way rather than to make art. With this, I hope, again, to lay out a base for future reference and research as to how SC could influence the fields of science presentation and research.

3.1.4. Movement exploration

In addition to interviews and observational data, I used movement exploration of SC as a method to inform my study. To understand SC’s use and applicability to education, research, and performance, with my dancers I have reproduced some existing movement material and tried to critically assess its value. With my dancers, I also aimed to contribute to SC’s development by creating own science models and research systems based on personal or group impressions of scientific concepts. Thus I used the process to gain an insight into some of the challenges that come along when SC work is done and applied. This knowledge I aimed to later apply in the outreach program with local middle-/high- school students. To place my movement exploration in the context of my greater study, I compare my impressions with the challenges professors, artists, and students face while dealing with SC.
More information about my movement exploration process can be found in chapter three and four (Methods and Results).

3.2. Science in Dance Education, Research, and Performance

Until now I have talked about the research I undertake to study the use of dance through embodiment for science education, research, and performance, but now I address the other direction in these three destination fields: how science, through embodiment, can inform dance education, research, and performance. Similar to the examination of the first direction, I use the scheme from before – I look at some general background and issues, pointing out the need for interdisciplinary approach in the destination fields, then I introduce some questions that have to be addressed. While these remain mainly outside the focus of my research, I try to illustrate the importance of studying how science influences the dance field by mentioning some of the work that has been done in this direction in chapter two.

I have been looking for a type of specific scientific influence on the dance field that rather than a broad socio-economical aspect of it. I would be specifically interested to know how science broadens movement explorations, choreographic perspectives, as well as ways to teach and learn dance. Historically, there have been numerous examples showing that scientific discoveries and the way they influence our understanding of the body, life, and place in the world have greatly affected the way art – and dance specifically – is created and taught.

One example comes from the work of a dance scholar dealing with issues in body alignment and how we perceive it. In her article, “Body Alignment: from a Mechanical Model to a Somatic Learning One,” Glenna Batson talks about the change in mindset of body perception once the evolution of non-linear science theories such as quantum- and systems
theory have come up in the first half of the 20th century to fill in the gaps of what classical physics could not explain. She describes that the body rather than a “mechanical structure that obeys physical laws” becomes a “psychophysical unity whose meaning emerges from living experience that is non-linear and unpredictable.” She further proceeds to compare a somatic model versus the Cartesian mechanical model and mentions how they influenced the way dance teaching and learning was approached, [7].

I am more interested in knowing how science and SC can be applied in dance education. Science is everywhere and more influential than ever: for example nowadays in theater we have lights, technological props, music systems, video and projection equipment whose complexity extends far beyond what was available a hundred or even forty years ago. Such advancements have inevitably changed the way dance performance and history is approached today since we can now create any visual effect, and we can record dance and preserve its visual history alongside its written one with our powerful modern tools. Yet, a dancer might use the science creations to serve their artistic goals without necessarily knowing how they function, just like a scientist without necessarily knowing much about dance would use movement embodiment to model a scientific concept. While a detailed knowledge might not be absolutely necessary, a basic understanding of science and how it can influence dance is crucial in dance education6.

3.2.1 Science in Dance Education

Somewhat similarly to the role of dance in science pedagogy, science has found its place in dance education, especially if we consider the past century and how the use of technology and our scientific understanding of the body has revolutionized dance education.

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6 Science as in related to technology of performance, to the body, and to its historical influence.
Nowadays, for example, it is hard to imagine a college dance program without at least a semester on lighting, music, and other technical aspects used in dance making. Nor is it thinkable to have a dance teaching program without an anatomy class covering the most important aspects of body motion. It goes without saying that a lot of medical discoveries related to physical injuries have changed the way dance technique is taught.

These somewhat distant modes of scientific influence on dance education have also found more concrete terms in modern dance technique education such as that of Margaret H’Doubler (see Literature review for more detail on her teaching). While science has been partially included in some form in dance education curricula for the past fifty years, SC has not been included. SC, in the form it exists today –direct collaborations with scientists in dance classes – has become a conscious choice in dance education only recently. Although the beginning of SC’s inclusion in dance curriculum is a matter of future research, based on my interview data I speculate that it occurred in the past 15 years.

Although my work does not explore SC in dance education, the biggest questions that remain to be addressed in this relation are when it first occurred, and in what form, and how the inclusion of SC in dance education developed. Also, how is it beneficial for learning and creativity? Or, looking into the future, where in dance education (history, choreography, technique, etc.) would SC have the most influence considering its embodying principles? Although I have been able to partially reflect on these questions through my interview data and second semester movement exploration, a teaching practicum, these questions remain largely unanswered.

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7 I interviewed a couple of Wesleyan University professors in dance, Rachel Boggia and Katja Kolcio. See Appendix for data.
3.2.2. Science in Dance Research and Making

The next topic I am interested in exploring as part of my broader goal to define SC, is how the sciences manifest in dance research and making nowadays. This is yet another way in which science can influence the dance field, although it is difficult to distinguish between a direct and non-direct science influence. With direct I refer to a conscious choice for interdisciplinary exploration, while non-direct refers simply to an intersection of dance and science in the dance research process.

This section includes science inspired dance choreography created by dance choreographers or performance artists (as opposing to the “Dance your PhD” pieces created by scientists). I would like to know how choreographers and dancers use their science knowledge to ask questions and address issues using dance. While I do not concentrate on this topic beyond presenting a review of who has done research in this way so far, I analyze the movement research I conducted as a source of information.

3.2.3 Science in Dance Performance

The next question in my SC exploration relates to how dance choreographers use science concepts not only as part of their research process, but also as part of their performance repertoire\(^8\). Similar to the questions I ask contest participants, I would like to know what advantages dancers find in doing interdisciplinary work and how this helps them develop personally and professionally. To study this, I look at some performances and collaborative work (mostly described in chapter 2), and I try to understand (though only based on this limited observations), how (if) collaboration with scientists influences the artists.

\(^8\) Here it is important to specify that SC work would be considered one that intentionally deals with/uses science concepts in favor of art making, and not one that incorporates scientific discoveries without conceptualization (theoretically any dancer uses scientific discoveries every time they turn on the lights in the dance studio or play music!).
and their communities. While trying to answer those questions is outside of the scope for this thesis, I reference some of the video work and recorded interviews with choreographers and performers I have found in chapter 2.

Future research should address and analyze such works based on the goals the artists set themselves and the way their goals evolved as they progressed through their SC exploration. In a similar fashion, by looking at my own work, I would like to compare how I, a scientist and a dancer, go about creating pieces and what role SC has in it.

4. Summary and Preview

First, science choreography (SC) is a combination of dance and science through embodiment – a term describing the connection between mind and body. Second, SC has a specific starting point-direction (dance or science) and destination field (science or dance education, research, and performance). Third, fusion of dance and science into SC could have great potentialities for the development of the destination field, but many unanswered questions remain.

In the subsequent chapters I study what the value of SC is and how SC is created and applied, especially in the fields of science education and performance, through field review (chapter 2), interviewing, and performance analysis as described in my methodology and results (chapters 3 and 4). I will compare the findings to my personal movement exploration, teaching, and choreography (chapter 4). With this work and the limitations I encounter I hope to better understand what SC is, and what its place among academia, research, and arts is. Thus, by summarizing a good amount of the work that has been done in this field and pointing out the issues/research questions that need to be addressed in the future (chapter 5), I hope to lay the grounds of this emerging field.
II. Review of SC in the fields of education, research, and performance

In this chapter I generally review work that deals with the fusion of dance and science and SC. Based on the classifications I defined - directionality and destination I group the works into several categories. These are, broadly speaking, two major categories: in the first falls work done by scientists and teachers in science modeling, science research, and science education; in the second falls explorative and performance work done by dancers with the aim to do embodied SC research, teaching, or addressing the community. With that I will pinpoint the works I will later concentrate on.

1.1. Dance in Science Education

First, I talk about how dance (as art and movement technique) can be defined in education. Dance and movement can be categorized as part of “Staging Techniques”\(^9\) and “Teaching-Learning”\(^10\) tools to be utilized in the classroom [5]. The teaching-learning techniques, such as stage work, art work, and learning movement games, have their history in the past centuries and millennia of human civilization, when they have been developed and reshaped based on the social context. The staging techniques which, beside dance, can also be language, numbers, music, or actions, are seen as good methodological tools to engage the students and to promote their independent learning [5]. But how does this relate to SC?

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\(^9\) Inszenierungstechniken (de.): these refer to small verbal and non-verbal, mimic, gesticular and body-language, image and music techniques/practices that are used and interpreted both by the students and educators in the process of the work.

\(^10\) Lehr-Lernformen (de.): these, lit. translated “teach-learn forms,” refer to historically developed codified forms for appropriation of reality. They have a specific beginning and defined roles, an arc of suspense, and a clear ending. Examples are Impromptu play, sculpture, pantomime, text-theater, socio-, and biblio- drama, cabaret, revue; painting, collage, music composition/performance.
SC can be referred to as specific movement tools in science education. Meyer mentions\(^\text{11}\) in his book “What is good Teaching” a couple of examples such as the “Clap if you can hear me” game used as an attention catcher, or the “walk and talk”\(^\text{12}\) tool used to promote discussion among students. Interestingly enough, similar methods have been developed for the use particularly in the science classroom by the choreographers Liz Lerman and Elizabeth Johnson in collaboration with science professors from Wesleyan University [8]. As such, science choreography (SC) finds its way into education with a set of teaching suggestions and lesson planning tips\(^\text{13}\). For example, there is a set of modules concentrated on genetics (Genes and Mendel and Ethics & Genetic Testing), or the DNA Helix, with a bunch that are still to come: “The Cell Cycle: Mitosis, Meiosis and Cell Signaling,” “Evolution and Global Warming,” and “Biological Complexity.” The Wesleyan linked website also provides a set of questions to guide the planning of a new classroom session, a number of useful video downloads created from Liz Lerman’s Dance Exchange, as well as a page full of reviews and comments from professors, local teachers, and students [9].

Liz Lerman has initiated collaborative work with several science departments at Wesleyan University (Molecular Biology and Biochemistry, Biology, Neuroscience, Environmental Studies). Professors from these departments already incorporate some of the tools in their teaching. For example, Prof. Laura Grabel makes a “Menstrual Cycle Dance” as part of her “Biology of Women” course using the “Equivalents” tool. Prof. Amy McQueen and Manju Hingorani have developed and used a “Protein Folding” unit as part of their

\(^{11}\) Hilbert Meyer is a prominent German educator whose books form the base for any student in Education. Some of his basis works include “Unterrichtsmethoden (I & II)” - Teaching Methodology for theory and practice. Because I studied pedagogy in Germany, I refer in several places to Meyer’s ideas when I discuss educational aspects of SC throughout this thesis.

\(^{12}\) The term “Walk and Talk” I borrow from Liz Lerman’s Toolbox (Tools: One to Ten) – a set of movement techniques she has developed to access various research questions and to create choreographic movement. It turns out, however, that a similar tool was developed independently in European teaching.

\(^{13}\) [http://sciencechoreography.wesleyan.edu/for-educators/](http://sciencechoreography.wesleyan.edu/for-educators/)
Molecular Biology class. These are just a couple of the examples on which I elaborate in chapter 4 (Results).

The collaboration between artists and scientists at Wesleyan has led to the co-teaching of a course about tropical ecology and neotropical environments in South America by Barry Chernoff, Director of the Environmental Studies Program and Professor of Biology, and Cassie Meador and Matt Mahaney of the Liz Lerman Dance Exchange. Prof. Chernoff further collaborates with the performance artist Anne Carlson to bring about a heightened awareness of the environmental issues [10]. Another interdisciplinary course is ‘Dance Biology’ done by Prof. Manju Hingorani and Katja Kolcio [11]. The documentary “Connections within a Fragile World” by Paul Horton, a Middletown based photographer and film maker is yet another source that describes what happens when science students, researching in Guyana, combine their research with dance and movement exercises to more fully understand the topics and to express the research in new ways [10].

On a local level, the work of Prof. Weir inspired by his collaboration with Liz Lerman has contributed to an outreach with science teachers among local schools. Richard McCarthy, a science teacher in the Frank Ward Strong Middle School has become a crucial part of the program; as a teacher aiming to reach every student in his classroom, he has realized the power of bringing dance into science education to engage even students that do not conform to the traditional science teaching techniques.

Another example where the use of dance and movement games for teaching science has been utilized is in a science outreach project with Kids Corner as part of the “Science Pedagogy for Elementary Students” course in Wesleyan. My colleagues and I found it

14 http://www.youtube.com/watch?v=vZ6OTjMe1W8  
15 http://sciencechoreography.wesleyan.edu/classroom-reflections/
especially difficult to have children aged K-5\textsuperscript{16} sit and concentrate on science experiments during our after school visits. Hoping to increase their excitement for science, we decided to incorporate and use movement games more often in the lesson plans to help the students’ engagement through embodiment of science concepts and active participation in the various activities.

Taking a look outside of Wesleyan, a course entitled “Movement and the Molecular” was taught in Wake Forest University (NC, USA) in the spring of 2012. The class, which was taught by Associate Professor of Chemistry Rebecca Alexander and Assistant Professor of Dance Christina Soriano bridged chemistry and dance concepts. Not surprisingly, the inspiration for this course came from the 1971 video on protein translation from Stanford University [12]. Interestingly, Liz Lerman has also held a workshop with this course and has presented her experimental SC work on the “The Matter of Origins,” at the university [13]. Soriano had also led in 2010 a class entitled “Dance and Parkinson’s” as part of a broader project to see whether certain forms of dancing can help restore some of the physical losses caused by Parkinson’s [14].

At Ohio State University an earlier paradigm of SC comes from as early as 2003 with the work of Prof. Fisher who was teaching biology to non-science majors. In response to students’ different learning styles, she commissioned Rachel Boggia, a dance professor to make a dance piece about DNA transcription. Boggia worked also on superconductors in collaboration with Prof. Nandini, a physicist from Ohio State. This collaboration resulted in a piece on electron behavior which was performed at the Columbus major science museum [15].

\textsuperscript{16} K = Kindergarten, 5 = 5\textsuperscript{th} grade. The whole course of study in the U.S. is usually labeled as K-12.
Considering the currently increasing popularity of SC among educators, this list of examples is probably omitting many others that use dance to teach science despite my desire to be comprehensive\textsuperscript{17}. While I will be looking at some of the above-mentioned examples to try to understand how beneficial introduction of dance into science education is for the student development, a much more comprehensive study is necessary to evaluate the popularity and feasibility of such interdisciplinary work in the long-term. Among the factors that need to be considered in such study is the appeal of SC fusion into the educational system, the constraints and limitations that prevent most educators to do so, and the necessary steps that need to be taken to catalyze this process.

1.2. Dance in Science Research

Considering that SC has emerged as science research tool only recently, not as much as has been done in this respect, which is why I do not concentrate on it in my research. Although I hope to find more examples in the future, here I mention these I have learned about already, yet without trying to be comprehensive.

Through my preliminary research, I have come across the work of David Odde, a professor at the University of Minnesota. “To get a more intuitive handle on his own research, Odde is using human dancers to model and explore how the cell’s skeleton of microtubules spontaneously assembles and falls apart. He is finding that using dance allows him to compare mechanisms faster than he can simulate them on the computer” says John Bohannon about Odde’s work [16].

Recently (December 2012), Odde and his collaborator Carl Flink (a dance professor) published a paper in “Trends in Cell Biology” describing their work on the use of dance and

\textsuperscript{17} I hope that other educators contact me and share their work with me in the future. (A more detailed list of other examples is exposed in the Appendix.)
science to produce bodystorming. The paper abstract reads “To develop our intuitive understanding of cellular and molecular processes, we are exploring the concept of ‘bodystorming’, where human ‘movers’ act as molecules that diffuse, undergo reactions, and generate/absorb forces” [17]. In addition, Emily Tubman, a PhD candidate working with Odde, is using dancers to simulate mitosis to test different hypotheses on how a cellular protein responsible for this process may function spatially [18].

Glenna Batson talks about the exchange between dance and neuroscience in an online publication on the SEAD organization website [19]. She mentions several examples of interdisciplinary research work such as “William Forsythe (Ballett Frankfurt), Wayne McGregor | Random Dance UK, and Shirley McKechnie and Catherine Stevens, University of Melbourne. Each has generated projects close to home, with research extending several centers for cognitive neuroscience in the US (David Kirsh, University of San Diego and Scott Grafton, University of California at Santa Cruz)”. Batson also critically comments on the success of these collaborations:

These projects have been examples of multi-directional research and creative practice, engaging a wide range of information technology and digital media, with nascent, but significant outcomes. Despite initial momentum, the field remains fragmented. Creative clusters have not advanced theories or methods to evolve a focused discourse. While major funding sources have fertilized the ground beyond the pilot level in Europe, US funding sources have little grasp of the importance of this topic. Although dance affords extensive opportunities for empirical investigation, projects face obstacles, such as constraints on time, access, training, and limitations within technologies and digital media, as well as an underdeveloped strategic vision, commitment, and cohesion across disciplines, both within and outside of the academy [19].

Although I am not including that in my discussion, it would be interesting to compare how the potential and difficulties of SC collaborations in science research compares to those of SC in science education.

[18] SEAD Network for Sciences, Engineering, Arts and Design.
At Wesleyan, an attempt to incorporate dance as a research method was made in the class of “Social Ecology.” Together with his students, in the spring of 2010, Prof. Fred Cohan attempted to create a movement model to study the spread of lime disease ticks [20]. At Princeton, another endeavor inspired by the beauty and complexity of animals in motion such as bird flocks and fish schools was the work done by Naomi Leonard and Susan Marshall [21]. They created a class uniting science and dance in the study of ‘Flock Logic’[19], which culminated in two cross-disciplinary, cross-species performances [22].

1.3. Dance in Science Created Performance

This leads me to the next part of SC application – performance making. Technically speaking, all created and exhibited dance modeling done as part of class or research work listed in the previous two categories could be considered performance. Whether that is a legitimate definition and how the creators look on it is a question of further research.

The first and oldest example of SC used to communicate science is that of Galileo. He not only demonstrated his science works through formal dance events and performances, but he also convinced the Medici court audiences of their validity [1]. With the shift of science-validation process in the modern era, the context of SC to communicate science now takes a much more informal role. Science is often communicated at the so-called “science slams” such as the one organized by the Technical University of Dresden, Germany [23], or in Vienna, Austria [24].

Together with these works, “Dance your PhD” contest fully qualifies in this category of science performance, as well as the protein synthesis dance by Paul Berg from Stanford [2]. However few these examples are, in fact, in the online era of communication the “Dance

[19] http://www.youtube.com/watch?v=3n7atKkg2Cg

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your PhD” program has had an incomparable and constantly growing worldwide success [16]. In my research I will pay especially close attention to some of these works: how they were created and evaluated, and what socio-science consequences they bring to the participators. I will try to understand how SC is beneficial to its participants and their surrounding community.

The onset of “Dance your PhD” program several years ago has definitely provoked more people to think about dance in research, and generally has been welcomed by the scientific communities (based on my interview data). How exactly (if) different scientists use dance in their research after participating in the contest remains unclear. Although it remains outside of the focus of my thesis, I addressed this question during the interviews with the contestants (see Appendix data for more information).

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To summarize, until now I have looked at examples where dance has been applied to science education, research, and performance. The review shows that the idea of dance utilization to communicate science (i.e. performance) is several centuries old (Galileo), and yet well-forgotten only to have been rediscovered in the 1970s (Berg). Several decades later, the use of dance as a tool in science education and research reemerges as a new trend that, with its rapidly increasing popularity, is yet to be developed. Because of its potential as an educational and communicational tool, SC in education and in performance will receive special attention in my subsequent chapters. More specifically, I describe data from interviews with Wesleyan science professors and “Dance your PhD” contestants.
2. Science in dance education, research, and performance

2.1. Science in Dance Education

Because I am not going to look at how science influences dance education beyond this chapter, I concentrate on a couple of instances from Wesleyan University and on one crucial historical figure - Margaret H’Doubler. This renowned dance professor and excellent scholar is now considered the mother of American dance education for her contributions to the field. Her relation to science and dance is in that she used her science, physical education, and philosophical background to lay out the first methodology of dance teaching[25]. Her work clearly falls in my initial description of SC and for this reason it is just as significant to the definition of SC’s place in the broader dance education context.

H’Doubler’s scientifically inspired work shows one way for science interaction with dance in the field of education – that of application of the scientific methodology to the founding of an art discipline. In his book, “A history of dance in American higher education,” Tom Hagood talks about H’Doubler’s way of connecting science and dance:

The essence of her inspiration was that studies in dance must be grounded in knowledge of the moving body itself. This revelation led her toward an approach to dance that she could associate with substance and it led her toward a science of dance. Attention to scientific underpinnings of dance must have made perfect sense to H’Doubler. She was educated in the biological sciences and in the philosophies of progressive education. H’Doubler came to dance with experience teaching in physical education where rules, strategies, and measurements dominate the disciplines approach toward instruction,[25].

Hagood further adds about the scientific approach:
H’Doubler approached instruction in dance procedurally; beginning classwork with the introduction of a motor activity for rhythmic, kinesthetic, and scientific exploration (14). (…) After movement activities had been experienced they were analyzed kinesiologically and rhythmically. Attention to analysis brought the experience into conscious awareness and promoted intellectual understanding[25].

More specifically, Hagood refers to H’Doubler’s analysis of the connection between emotion and movement framed in the idea of the kinesthetic sense: “the subjective-sensory feedback received from proprio-receptors (nerve endings), located in the inner ear” and how it “informs the mover of joint position and pressure, the body’s relation to the horizontal, and its velocity (17).” Along with the idea for intellectual understanding which informs and enables the dance art, H’Doubler highly promoted originality in her students as opposed to imitative education that “fails to give students a way to express their own reactions, [25].”

Another aspect of scientific thought was how H’Doubler organized the study of dance as an academic discipline: “dance should involve a variety of conceptual approaches, and the different aspects of dance should be learned in their specific context.[…] Dance, as a field of study, included course work in the science of movements (kinesiology), practice in developing fundamental movement skills (technique), understanding historical perspectives (dance history), manipulating movement creatively (composition), understanding the relation of movement to rhythm (rhythmic analysis), how to teach the body to move (teaching methods), and developing an understanding of classic and contemporary thinking on the moving body (dance philosophy),[25].”

Interestingly enough, I have applied a similar philosophy to the creation of my own movement explorations. I owe this to my own college dance training which is framed after H’Doubler’s theories. 

[25]
Here, I cannot miss to draw the inescapable parallel between dance and science education. Science, as a field of study, includes course work on basic science concepts, practice in basic laboratory techniques, understanding historical perspectives (science history and discoveries that lead to the current status quo), manipulation of scientific questions and experimental design, understanding the relation of experimental results to questions asked (data analysis), science teaching methods, and science philosophy at to how it relates to our life.

Further, I later show with my interview data that science and dance as disciplines are much more connected than originally thought. The power of SC, it turns out, lies in the emotive, intellectual, and creative aspects of its implementation, which is exactly what H’Doubler promoted in her dance theory. In this way contemporary dance education, which has been present long before modern SC initiated (first half of the 20\textsuperscript{th} century vs. the turn of the 21\textsuperscript{st} century), has subconsciously informed the implementation of SC in science education. While I discuss this intricate dynamics between science, dance, and SC, in chapter 5, here I would like to mention a couple of other examples of how scientific knowledge is applied to dance education.

The first example comes from Wesleyan University’s dance department, and more specifically a course entitled “Repertory and Performance”. A couple of different dance professors that have taught it, like Rachel Boggia and Nicole Stanton, have collaborated with the science professor Michael Singer. In these courses they used ecological concepts as a ground for movement research and choreography. Boggia said that in the class process rather than representing a science concept and using dance as a learning tool “they used performance to understand where each individual stood between science explanation and
their relationship to nature; what are the different ways to interact with nature—through science, literature, documentaries, and physical experience”[15].

The second example draws from physics studies applied to the understanding of dance motion. More specifically, Amy Howton talks about how teaching of physics principles to dance students might help them improve their control, jumps, and turns [26]. Stacie Strong, moreover, explains in her article entitled “The Physics of footwork” how understanding certain science principles can help quick advancement in tap dance[27].

2.2. Science in Dance Research

Despite the fact that this science approach to dance is not taught in any dance institution, choreographers’ fascination with science often helps them find their own way to connect the two fields. On a practice exploratory level, Shannon Castle, a dancer in Garth Fagan Company shares that “dance is like science.” She describes the process of working your way through a movement sequence as a set of small discoveries after several trials and errors: “You try one thing, and then over and over again until you find the right way,” she says. Talking about a deeper research level, however, I have to mention choreographers such as Jennifer Monson, Liz Lerman, Carl Flink, and Wayne McGregor, and how they used science to inform their dance research and making.

To begin with, I will look at the collaboration of Wayne McGregor[28], a British choreographer for the Royal Ballet, with various scientists on topics ranging from heart biology to cognitive psychology and robotics [29]. In his cognition project he collaborated with the arts researcher Scott deLahunta and with scientists “studying the relationship between movement and the brain/ mind (1)” with the aim to engage in “an initial exchange of
ideas on connections between choreography and cognition that would be scientifically and artistically interesting.” The second phase of this project, as a follow-up of the first, was intended to “provide a platform for some of the scientists to observe, intervene and formulate questions arising from their individual research interests in the context of the creative choreographic process.” Phase Two was thus scheduled to take place in the rehearsal studio during the artistic research for a new choreography “as opposed to phase one which took place in offices.“ The two core research questions\(^{21}\) (first, related to artistic research, and second, related to scientific research) were “what might be discovered by opening up the choreographic process to alternative modes of looking, analysis and questioning through the eyes of the invited scientists?” and “How can useful scientific research information be obtained in the context of a choreographic process and what are some of the issues for research design, experimental control and data collection? [28]”

In his heart project he collaborated with heart consultant at the Royal Brompton hospital with the aim to expand his understanding of the body processes and choreographic diapason. He gained a lot of new information, among which what his own heart looks like and what medical tests are used. With this research he shares the thought of challenging himself about choices related to extracting sets of information related to how he perceives time, body, and space, and how he feels about this process. The collaboration has made him think differently, which is a challenge he has chosen. He realized the things that interested him most were related to philosophical concepts – how the heart communicates something and how it’s related to emotion. He further shares that this work was a place the unexpected was allowed to have a life, and that wouldn’t happen without having an interaction with those

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\(^{21}\) See Appendix for more details.
individuals. With this information he proceeded to create a piece “Amu,” about which I will talk in the following section (science in dance making) [30].

Carl Flink, a dance professor at the University of Minnesota and the principal choreographer of Black Label Movement has collaborated with David Odde, a science professor studying cellular motion via computer modeling for a couple of years now. The work of David and Carl has essentially started because of their interest to study how organization could come out of chaos [31]. Further, their creative “bodystorming” processes have brought a lot of questions (here specifically in focus for the choreographer) such as “how do we take a graphic image and make it clear by putting it through motion?” and “what is the technique of having contact/bodily impact based on the science ideas explored?” This highly fruitful teaming up has led to the creation of a piece called “Hit” [32].

Liz Lerman, just like McGregor, has collaborated with scientists across the country (e.g., Wesleyan University, James Madison University, and University of Michigan) to expand her visions on genetics. In her exploration she looked at scientific and social aspects of heredity: among related topics are problems associated with genetic diseases and ethical decisions related to gene manipulations. Questions that guided her inquiry are “How is science beautiful? What is beauty to you?” On this note, for example, came the topic of genetic mutation and where its beauty and importance lie. With this in mind, Liz Lerman, in tandem with Elizabeth Johnson (and the rest of the “Dance Exchange”) has also actively tried to reach to the community as part of her research. She tried to understand how people perceive information and what the role of beauty [of dance] can play in this process [33].

On another occasion, Liz Lerman looked at the origins of the universe and the physical laws driving it in collaboration with scientists from the University of Maryland and
Harvard. As part of her research she also visited CERN to better understand how atomic collisions lead to formation of new particles. With this she went onto asking more general philosophical questions related to origins and how our life begins [9].

Another choreographer (and artistic director) actively involved in across-the-dance-border collaborations is Jennifer Monson. She created a dance research organization called iLAND (Interdisciplinary Laboratory for Art, Nature and Dance) with “a fundamental commitment to environmental sustainability as it relates to art and the urban context.” In her work for the organization she aims to cultivate cross-disciplinary research among artists, environmentalists, scientists, urban designers aspiring to “investigate the power of dance in collaboration with other fields to illuminate our kinetic understanding of the world,” [34].

An earlier project originating in 2000 called BIRD BRAIN was a “multi-year navigational dance project that investigates migratory patterns and habits of birds and other animals, as well as their biophysical and metaphorical relationships to humans as fellow travelers in the world.” This mega project, which involved several yearly projects on different bird species, utilized four inter-related basic organizational components – “free site specific outdoor performances; navigational dance workshops for students and the general public; panel discussions on issues of migration, navigation and conservation; and a web site linking the worlds of science/conservation and dance/art.” The project involved collaboration with Bell Museum of Natural History, the College of Natural Resources in the University of Minnesota, and local schools as part of its solid educational component\textsuperscript{22} [35].

\textsuperscript{22} Goals of the Educational Resource Guide:
\begin{itemize}
  \item to lead students to connect their own navigational skills to those of animals
  \item to use movement, dance, writing, and art as tools to teach students about bird navigation and physiology
  \item to help students become aware of their environment and to become educated stewards of the environment through both scientific and artistic exercises
  \item to use the interconnectedness of migratory bird habitats as a metaphor for how our own communities are linked
\end{itemize}
While my brief review shares a part of the whole story how science can be applied to dance research and who has done it, this is a good base for discussion where and how collaborative projects of this kind occur. It seems a lot of them are affiliated with a university/research institution and feature multi-dimensional components such as community outreach, and education. Sometimes it is choreographer driven process (W. McGregor or Liz Lerman), and sometimes it is the other way around (Carl Flink), but in either way there seems to be a willingness for crossing of interdisciplinary boundaries and desire to learn from those experiences from both sides. Because of that, the participating parties seem to recognize a mutual benefit of the work together.

2.3. Science in Dance Performance

The dance research work I have talked about in the previous section has been mostly associated with dance performances that came as a result of these collaborations. For example, the research work of the choreographers Wayne McGregor, Carl Flink, and Liz Lerman has brought to the creation of pieces such as “Amu” and “AtaXia” (W.M.); “Hit” (C.F.); and, “The ferocious Beauty Genome” and “The Matter of Origins,” (L.L.).

Another work that incorporates science, in a more literal sense, was done by Chunky Move, an Australian dance company, which presented their work "Connected" at Wesleyan during Dance Masters 2012. The piece is directed and choreographed by Gideon Obarzanek and features a kinetic sculpture by California-based artist Reuben Margolin. This unique sculpture, which follows the motions of the dancers attached to it, works on principles related mathematical translational methods. The artist’s collaboration with Obarzanek led to the innovative utilization of his mathematically based creation directly in the dance piece [36].
Other examples from the dance history where technological discoveries have contributed greatly to artistic creations are the works of Loie Fuller (1862 – 1928). A pioneer in modern dance, she was well known for her stunning light effects and use of props (dresses): “Fuller held many patents related to stage lighting including chemical compounds for creating color gel and the use of chemical salts for luminescent lighting and garments (stage costumes US Patent 518347).” With her work she gained respect not only among French artists, but also scientists including Jules Chéret, Henri de Toulouse-Lautrec, François-Raoul Larche, Henri-Pierre Roché, Auguste Rodin, Franz von Stuck, Maurice Denis, Thomas Theodor Heine, Koloman Moser, Stéphane Mallarmé, and the Nobel Laureate Marie Curie [37].

Many other choreographers, although more conceptually than literally, have used science concepts to develop their pieces. Here I cannot fail to mention Merce Cunningham who built up his dances based on random events (similar to the Moving cell collaborative). Another very famous company is Pilobolus, which connected their understanding of nature to their dance making in pieces such as: Symbiosis – the birth of a relationship between two creatures sinuously and sensuously intertwined, a darwinnian investigation and a love story; Shizen – coupling as a biomorphic reflection on the world; Megawatt- “a full-throttle, full-company piece, it blends startling energy with an ironic take on the excess and high-voltage state of the world in which we live”; Day-two- enacting the second day of the creation of the world, from its earliest forms of life to the moment at which creatures of the earth take flight into the air; Aquatica- a breathtaking meditation set in the oceanic underworld, a fairy tale using images of exotic marine life to probe the depths of the human psyche; and BUgonia- a biomorphic fantasy of a day in the life of an imaginary and whimsical creature that is part plant and part animal [38].
In relation to environmental issues, a lot of performance work has emerged across the world to bring awareness for various issues ranging from global warming to pollution and species loss. At Wesleyan University, as part of the Feet to the Fire project featuring several interdisciplinary science-art (dance) collaborations, several works from dance professors have been created. Hari Krishnan performed in 2010 “Liquid Shakti” – the river goddess. The dance, which is a deep extraction of his own personal relationship with the environment and India embrace movement and image effects of aggressive industrialization [10].

Nicole Stanton, in collaboration with Gina Ulysse, an associate professor of anything ropology performed “Threshold Sites: Skin to Skin”, which “looks at the ways in which choreographic processes can explore and address the social and cultural issues that contribute to lack of ecological awareness” [10]. Another piece collaboratively developed by Stanton and Ulysse also with Michael Singer, assistant professor of biology, and Andrea Olsen, chair of the dance program at Middlebury College, entitled “Threshold Sites: Body and Earth” was performed by Wesleyan students. Another massive project involving the whole first-class student body in Wesleyan has been “the common moment.” This project, in collaboration with Liz Lerman’s Dance Exchange, has led to the development of a common dances concentrating on energy (2008) and water (2009) usage [10].

On individual level, the choreographer Jill Sigman has created several site-specific works aiming to bring awareness about recycling and the excessive amount of garbage produced daily “by questioning our personal relationship to the things we throw away.” “Our Lady of Detritus” (2009) was a highly-interactive, portable performance installation that traveled to parks and outdoor spaces in multiple NYC boroughs. A scientific innovation to make this work possible was a green-energy powered speaker system [39].
Joyce Morgenroth talks about how three different choreographers use physics in their works in her article entitled “Physics in Performance”. She describes how Elizabeth Streb “focused on forces and modeled her process on that of science,” how Karole Armitage and Amanda Miller “have metaphorically translated concepts of physics in making choreographic choices,” and how Merce Cunningham “has shifted long-accepted conceptual and compositional paradigms,” [40].

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In this chapter I have traced a number of examples where science and dance meet in the fields on education, research, and performance. SC, as a field where different disciplines meet, seems to have been present for almost about a century (although it was not defined as SC at the time). Starting with H’Doubler’s groundbreaking work in dance education, through the works of companies such as Cunningham and Pilobolus, to modern collaborations at Wesleyan University and many academic centers across the country, SC has found its place in various forms. Numerous choreographers have incorporated science principles in their works and collaborated with scientists in their research processes.

It turns out SC is just a new term to describe a process that is more ancient than one would suspect. Considering the amount of interdisciplinary inspired work, it seems SC work was more “the norm” in the past century than the science and dance connection is considered today. Looking at this review, it is surprising to me how collaborations across disciplines of such sort are considered today more unusual than not. Future research should probably address where the conservatism in this view originates from.
III. Methodology

So far I have described a lot of instances of what SC could be and what manifestations of it have come up in education, research, and performance. In order to understand what SC’s value is and why it is successful, I here share the questions I address divided based on the type of research area I study. The specific questions and answers for the interviews are part of the Appendix.

1.1. Dance in Science Education

The issues I address are connected to: the motivation behind using of the SC approach, the difficulty of implementing SC in a curriculum or in research, the benefits from doing so, and the perspectives educators see in SC as a tool in the classroom or the laboratory. In addition, I review some data of student responses to SC in education, and I conduct my own interviews and surveys. I discuss my data in relevance to literature in the pedagogy, psychology, or dance fields.

1.2. Dance in Science Research

This section is not of major concentration in my work and not present in my analysis, although I have some information from a short interview with Professor David Odde (University of Minnesota) I conducted over the summer of 2012. In order to understand how he and his collaborator Carl Flink conducted their research process, I asked him about his choices in the making of human models, his research questions and goals and how they evolved over time, how he interpreted his observations, and what difficulties he encountered in working with people vs. bench research (see appendix for first interview). The questions that I hope to address in the future relate to the limitations of their models and how they are planning to address them. In addition, I would be interested to know how their innovative
research approach affects their personal lives: e.g. how they look on research and dance now vs. in the past, and what future they see in their work.

1.3. Dance in Science Performance

In this section I concentrate on the winning works from the online contest “Dance your PhD” for the years of 2010 and 2011 for which I have gathered information through interviews and internet posts. First, I try to understand how the winning PhD students became involved in a SC project like this and what kept them engaged in the process. Next, I asked them about their choices for choreography, music, and setting, and how they balanced their lab commitment with their artistic endeavor. Similar to the questions I ask scientists who use SC in educational setting, I asked the contestants to comment on the prospects for their work and that of other “Dance your PhD participants,” on their personal stance about such interdisciplinary work, and on how they perceive SC’s future. With this information I have been able to understand how SC is created and how it is valuable to the contest participants in relation to their social and professional life. I have compared this information to the interview data from professors in chapter 5.

2.1. Science in Dance Education

Although I am not going to look at that part of SC beyond the past chapter, for future research it would be interesting to address the question of how successful bringing science in the classroom is, and whether and how more involvement of sciences in dance education could be achieved. I have attached in the appendix an interview with the dance professor Rachel Boggia who talks about experiences with SC.
2.2&3. Science in Dance Research and Performance

In order to understand how SC works as a tool in arts making, future research should try to compare how different choreographers such as Liz Lerman, Carr Flink, and Wayne McGregor approach their research processes and creation of choreography: where from they started their research process and how they got involved with SC; what they were aiming to do with their dances; and how their goals evolved over time. Also, how do the choreographers view their SC work in the dance world and what value they find in it.

More specifically, questions should address: how they engage emotionally and artistically in their research and choreographic processes; how they use embodiment to approach science choreography; and how they envision or express what their understanding and feelings about the world around is; how they satisfy their curiosity and how they go about meeting challenges such as understanding science.

3. 1. Movement exploration 1st semester

In my movement exploration of how science can inform and contribute to dance teaching, research and making and vice versa, I have introduced my dancers to some of the SC resources I have found and to several choreographic tools that allowed them to understand the process of SC making better. I then asked them to apply scientific concepts of their interest (or mine) to dance making. With this I tried to observe how they approach this process. Further, I tried to assess their growth as learners, movers, and performers. I framed my research process based on their written and spoken responses throughout the semester movement exploration.
With the SC research we did with my dancers, we created a small workshop-presentation that introduced the audience to our work, and required their active participation in the process. Using some of the Liz Lerman’s dance tools [41], we tried to engage the audience in discussion about their perceptions and expectations for the presentation. I then introduced the audience to my research, i.e. what SC is and how we could go about it. I touched upon the sense of directionality and destination of SC by introducing how dance can be applied to understanding molecular motion, and how science can be used to create dance. The four things we concentrated on during the presentation were: learning about a molecular system; exploring of a cellular protein system; observing of how science concepts can lead to dance choreography; and using science concepts put into motion from the audience members to inspire an improvisational dance (see Appendix for the program of the event).

With that workshop I tried to understand what effect experiencing SC might have on the viewers. By distributing a small survey at the end I evaluated the success of SC as a research tool and of my SC work in particular. The success of the different activities was measured by the audience’s responsiveness– their excitement, cooperation, and output. The results’ relevance and accuracy for future work is discussed in chapter 5. At a later stage (several days to months after), I hoped to be able to reevaluate, again qualitatively through written observations, the impact of our SC exploration on my dancers by asking about the way in which they approach science learning and dance making. With this I hoped to gain insight on: first, what any short-term as well as long-term consequences SC has on the dancers and how successful my approach to SC with them was. However, I do not discuss these observations as part of my thesis, for I use my reflections simply inform myself about the limitations in my SC approach and what issues I need to address in the future.
3.2. Movement exploration 2\textsuperscript{nd} semester

The second goal for my movement exploration work was to use what I had learned about SC and lead a class in a local school. Aiming to apply SC in a social context, I have taught explored SC with home-schooled students based on my choice of the movement methods/SC objectives. In parallel, despite unforeseen circumstances, I have been monitoring the students’ progress and how they address challenges. I have tried to assess their level of enthusiasm and commitment to advancing in their school work. Even though I was not in the capacity to make any long-term observations of their school behavior, I tried to conduct a qualitative evaluation based on their responses and comments from their parents. In this way I have obtained a more realistic picture of some advantages and difficulties in SC implementation in education. This information I compare to the data from the interviews I conducted with professors and scientist that have implemented SC.
IV. Results and Analysis

1. Dance in Science Education – (Molecular) Biology Professors share their experiences from the classroom

The goal of my study in this section is to try to understand how beneficial for a student’s development introduction of dance into the science classroom is. Among the factors that I have considered are the motivation behind using of the SC approach, the difficulty of implementing SC in a curriculum, the benefits from doing so, and the perspectives educators see in SC as a tool in the classroom. Here I have laid out the results from the interviews with several professors from Wesleyan University.

1.1. Interviewing Process

I contacted several professors (mostly from Wesleyan University) via e-mail to arrange a meeting and ask them a set of prepared questions that they had mostly (with some exceptions) seen before that. The interviews were conducted at the end of October and the beginning of November 2012. The fully transcribed interviews are attached at the appendix; I was taking notes during the conversation. The following table summarizes the information about the interviewees, their position, and the science courses they have taught in which they included dance exercises or movement components.
Table 1. List of interviewed professors and their areas of teaching. They are all from Wesleyan University, Middletown, CT, USA.

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Dance Back – grounded yes/no</th>
<th>Courses Taught</th>
<th>Science topic explored through which exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Robert Lane</td>
<td>Associate Professor of Molecular Biology and Biochemistry</td>
<td>no</td>
<td>Gen Ed^{23}: &quot;Copernicus, Darwin, and The Human Genome Project&quot;</td>
<td>1&amp;2. networks, chaos-order Triangulation or versions of it (explored multiple times)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Genetics &amp; Genomics</td>
<td>“signal versus noise” significance (statistics)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Introductory Biology</td>
<td>protein folding</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(With Liz Lerman Dance Exchange)</td>
<td>(explored once)</td>
</tr>
<tr>
<td>2. Laura Grabel</td>
<td>Professor of Biology, and Lauren B. Dachs Professor of Science and Society</td>
<td>Yes, since the age of 5, modern dance</td>
<td>Gen Ed: Reproduction in the 21st Century</td>
<td>Menstrual Cycle, genetic testing and ethics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gen Ed: Biology of Women</td>
<td>ask a question – ethics &amp; summary; embodying disease state and how it can be cured with stem cells, leading to a stem cell dance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stem Cells from basic biology to clinical application (With Liz Lerman Dance Exchange)</td>
<td></td>
</tr>
<tr>
<td>3. Frederick Cohan</td>
<td>Professor of Biology</td>
<td>No</td>
<td>Introductory Biology</td>
<td>Origin of species</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gen Ed: Global change and infectious Disease (With Liz Lerman Dance Exchange)</td>
<td>ecology of Lyme disease</td>
</tr>
<tr>
<td>4. Michael Weir [4]</td>
<td>Professor of Molecular Biology and Biochemistry, Professor of Biology, Co-</td>
<td>No</td>
<td>Introductory Biology</td>
<td>Protein synthesis</td>
</tr>
<tr>
<td></td>
<td>Director for Informatics and Modeling Certificate Program</td>
<td></td>
<td>Bioinformatics</td>
<td>module on genetic networks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gen Ed: Genomics, Modern Genetics, Bioinformatics, and the Human Genome Project (With Liz Lerman Dance Exchange)</td>
<td>module on Mendel</td>
</tr>
</tbody>
</table>

^{23} Gen Ed stands for General Education Course. Wesleyan students are highly encouraged to take three courses (credits) from each of three Gen Ed divisions: Arts & Humanities, Social Science, and Natural Science and Mathematics. Generally Gen Ed science classes are more appropriate for non-science majors in terms of their level.
### 5. Michael Singer

**Associate Professor of Biology**

No

<table>
<thead>
<tr>
<th>Dance Repertory and Performance: Spring 2009 with Prof. Nicole Stanton, Spring 2010 with Prof. Rachel Boggia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecology of Eating: Reporting from the Fields of Science and Art Fall 2010 (with Cassy Meador).</td>
</tr>
<tr>
<td>Science Choreography teaching module: Spring 2011-present (with Elizabeth Johnson).</td>
</tr>
</tbody>
</table>

| Threshold sites: Body to Earth” integrating scientific and artistic perspectives |
| “HEDGE: Within/Without Nature” integrating scientific and artistic perspectives. |
| Collaborative teaching module on nature observation. |
| Natural Selection. |

### 6. Amy McQueen

**Assistant Professor in Molecular Biology and Biochemistry**

Yes, modern dance since the age of 5.

<table>
<thead>
<tr>
<th>Molecular Biology$^{25}$ (2010-2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(With Elizabeth Johnson)</td>
</tr>
<tr>
<td>Science in dance making with Dianne Eno – Fusion Danceworks 2011</td>
</tr>
</tbody>
</table>

| Protein Folding – class embodiment activity + video watching on Huntington’s |
| Mitosis vs. meiosis – gestural |
| Spindle checkpoint |
| Environmental Dance |

### 7. Katja Kolcio

**Associate Professor of Dance and Environmental Studies**

<table>
<thead>
<tr>
<th>Molecular Biology (2010-2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen Ed: Body Languages: Choreographing Biology (with Prof. Manju Hingorani - Associate Professor of Molecular Biology and Biochemistry and visiting Liz Lerman Dance Exchange)</td>
</tr>
</tbody>
</table>

| Protein Folding |
| hydrophobicity, mutations, mitosis |

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$^{24}$ He does not use dance tools to teach his own courses, but he has collaborated with artists in interdisciplinary dance projects and courses.

$^{25}$ Amy McQueen co-taught Molecular Biology with Prof. Hingorani, (which is why I do not repeat the same dance-science topics for the latter.)
1.2 Data Description: professors from Wesleyan University talk about how they incorporate dance into their science classes

1.2.1 Involvement, engagement, and difficulties

a. First encounters with SC

In this section I aim to point out how and why the professors I interviewed decided to either use dance in their classes or to collaborate with dance professors in the classes.

Because all of the professors are from Wesleyan, their first encounters with dance in relation to science were through Liz Lerman and her company around the creation of the “Ferocious Beauty Genome” performance in 2006. The collaboration between this choreographer and scientists was promoted by the Wesleyan Center for the Arts and was thus a catalyst for the birth of various class modules and workshops for college students for the following years. The collaboration was funded by the National Endowment for the Arts and followed a general campus-wide initiative to bring arts and sciences together to promote awareness of global phenomena \[42\] (see introduction).

The scientists started using dance tools in their classes for various reasons which fall in three categories: to access different kind of learners in their classes, to teach complex science phenomena, and to provide a space for students to reflect more deeply through dance. While dance was not necessarily the tool they would normally choose to work with because it was unfamiliar to them, they saw potential to access these three points. Yet I do not want the reader to assume that the categories are exclusive, i.e., I have aimed to show the diversity of reasons why professors use dance in a science classroom.

Amy McQueen, for example, who loves telling stories in the classroom, reasoned that using dance/movement in the classroom to embody concepts could help her to get the story
across more easily, especially considering that she works with a varied student population with different kind of learning styles (visual, movement, etc.) [43]. Frederick Cohan started using dance because he found it to be a good metaphoric tool. Because some science concepts can be very abstract or technical and thus hard to comprehend, he believes it is important to use analogies and metaphors to transmit these concepts, [20]. On this line of thought falls also Laura Grabel’s idea for use of gestural dance to explain complex biological processes in her classroom. During her meetings with Liz Lerman, she was asked what concepts she found most difficult to teach, especially to non-science major students, and with this she decided to use SC [44].

While using dance tools to get complex scientific ideas across and to reach students with different learning styles is a valid way for science-dance interaction in the classroom, yet another way emphasizes the ability of unconventional learning methods such as embodiment to give access to students to reflect in different territories and to address issues from new perspectives. Robert Lane, for example, sees embodiment not only as a way to grasp an idea beyond what images and text can offer, but also as a tool for science interpretation. A believer of the lasting outcomes of context-dependent learning, i.e., problem solving instead of memorization, he considers dance the kind of context through which science concepts could be digested and remembered [45]. Michael Weir’s understanding of embodiment agrees with that idea and further stresses the role of dance to stimulate science thinking. He looks at dance as a catalyst for experiences that challenge assumptions in our understanding of scientific processes [4].
b. **Educational tool (module)**

creation and implementation process in the classroom

Although it worked faster for some than for others, the process of creating and implementing a SC module in the science classroom has required careful planning and selection of topics for all of the interviewed educators - like Laura Grabel says, “it’s easy to think it’s easy, it’s difficult to come up with a module that works” [44]. According to her, one needs to put in a lot of preparation time (at least initially) and consider the numerous factors (which I will discuss along this section) that play a role in the classroom such as the size of the class, the choice of music, and the choice of the topics involved and how they provoke the students’ thinking. Along with that, one has to consider the classroom space and what kind of movement it allows for, the energy in the room, and the complexity of the concept explored [20]. Amy McQueen says that not every concept works for the purpose of SC because “some are too simple, some too complicated,” [43]. Cohan thinks that “the metaphor (dance – science) has to be simple, but the science idea should be complex enough and out of the ordinary thinking of the students to be worth using it,” [20]. Similarly to Cohan, McQueen also agrees that coming up with the two basic concepts the students need to take home with them is one of the hardest things to do, but once this is in place, lesson planning becomes much easier [43].

Some of the professors who have used SC for a longer period of time also admit that their ideas have evolved tremendously [4, 45]. Sometimes that involved careful observations during module implementations and reiteration of the class exercise based on additional reading and reflections [45]. Sometimes it involved experimentation in the classroom and “a

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26 I will use the word *module* to describe a specific educational SC tool related to a science topic in a classroom. Module is in this case interchangeable with “class topic.”
certain amount of bravery” considering the opportunities for failure [44]. The change for failure, they all admit, is making them feel uncomfortable to a certain extent. However, all professors agree that figuring out why the failures happened and how it could work has been just as informative [4, 20, 43-46].

One of the most important factors in lesson planning remains the environment of the classroom [46] and more specifically the energy that the class leaders being with them. All of the professors have collaborated directly with Liz Lerman and/or Elizabeth Johnson27 in designing the modules and admit how important collaboration with a movement expert is. Elizabeth Johnson in particular, who has been very often the movement leader in all of these instances, has been considered “the right person” to be able to bring energy and enthusiasm, to engage professors and students equally, and to drive the module creation and implementation, [4, 20, 43-46].

c. Difficulties and points for consideration in SC implementation

So far I have identified several major difficulties the professors faced in SC class preparation such as choosing the right concepts, putting the necessary amount of hours to prepare the module (often with the help of a professional dancer), and finding the courage to implement an interdisciplinary approach to learning that might not work. Here I comment on the difficulties they encountered in the classroom related to student’s desire for collaboration, miscalculated class size, and mistakes in concept planning.

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27 Liz Lerman Dance Company Member, see “Literature Review” for more information.
For example, McQueen shared that one year when they created a module on checkpoint signaling in cell division, the class did not go that well because they were unclear about the concepts they were trying to convey. For this reason, the whole workshop turned “fuzzy” and probably confused and demotivated students rather than inspiring them. She observed that having an anchored conceptual frame and idea where one could “play” with it facilitates the teaching process [43]. Singer also agrees that one needs to be very clear about the content [46]. Weir adds that the clarity of the concept often depends on the amount of jargon used, especially when one works with non-science majors. He finds it important to stick to the main concepts and not on memorization of details that might detract from the students’ experience with SC [4].

On another note, even the most carefully planned concepts might not work sometimes because there could be a disparity between a professor’s imagination and what happens in practice [45] [20], which nonetheless should not be a concern, but an opportunity to appreciate the value of the process happening during that time [20, 45]. Lane, for example, says that although sometimes the exercise he dreams of does not work, during the discussion the students get so involved how to improve it that at the end “the exercise is still successful from a pedagogical standpoint.” Because engaging in active problem solving makes the students think deeply about the concept, he still reaches his class goals. An example he gave relating to that was when he worked on protein folding, which did not really work for logistical reasons related to the type of amino acids and their degrees of freedom and flexibility in space. However, they spent at least as much time on improving it, and this problem solving exercise was not just about the dance, but about the forces the dance was intended to teach them, which was, after all, “as useful as any class time“[45].

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28 As earlier specified, the works were almost always collaborative. She worked with Manju Hingorani and Elizabeth Johnson.
Cohan, unlike Lane, has a slightly different experience with his “Global Change and Infectious Disease” course, in which he wanted to do an embodied SC simulation of the ecology of Lyme disease. He planned to collect some data from this model which basically tried to answer the question how and why a forest full of predominant species such as mice vs. a forest full of various species would have different Lyme disease infection patterns. However, when three times as many students showed up than planned, and numerous students were unable to remain rigorous in following exactly the rules in their model representation, he quickly realized that the data were not going to be consistent enough according to scientific standards. Despite his failure to conduct disease research using students modeling a concept, Cohan found the value in this experience in enacting physically and visually an idea like disease infectivity. He thus found SC a suitable tangible metaphor able to transmit an idea to the students [20].

While the professors I interviewed clearly find SC useful for science learning and reflection, this is not necessarily that evident for students. All of the professors admit that there might be some students who feel uncomfortable dancing or moving in class [4, 20, 43-46]. It happens very rarely according to most of them, but Weir notes that computer science students are more prone than life science students to a higher level of discomfort based on the courses he teaches [4]. For such reasons of discomfort, some professors have received bad feedback for SC [45, 47], and even offensive remarks such as “Why do we need to dance?, That was obvious anyways,” “Are you kidding me?” or “This is stupid” [20].

Kolcio, too found challenge with students’ biases about what science or dance are supposed to be and how to be taught. According to Kolcio, a one-time workshop or module is very different from teaching a whole class combining dance and science, as one needs to put not only countless hours in preparation, but also has more hours to experience direct student
feedback. They (Kolcio and Hingorani) had to face a lot of comments on the inappropriateness of the classroom setting for a science class (a dance studio vs. a classroom). Based on class observations, the students also felt they did not have a rigorous enough training either in science or dance choreography. This was very surprising to her and her colleague, who thought that the students made unusually deep reflections and extremely creative high-quality work for their level of science or dance training. She also shared that the length of the class felt too short for the students to both absorb and digest what they had learned from the class and thus meet their learning expectations, which is why she thinks the student evaluations were “not so great” at the end of the semester29 [48].

Luckily, the majority found SC activities to be fun [20, 46] and the ones who felt uncomfortable initially might change completely their opinion after participating [47]. Singer further comments on the “immediacy of the science content” through the science and dance interaction, which he finds extremely enjoyable and successful among students [46].

However, Singer notes that despite the excitement from the students, a failed communication with the collaborating dancer could detract from his SC experience. When communication worked well, he found discussions to be much more fruitful both for him and for the class. When the communication was not that clear and open, he had a difficult time understanding how his collaborative efforts and scientific input influenced the way the dance making in the class was happening. Despite those challenges, he was careful not to confuse miscommunication with a certain artist as a failure of SC collaborations in general [46].

29 In Wesleyan University at the end of each class students are asked to fill evaluations about their professors, which mainly cover a couple of questions about the course content, and a couple about the teaching quality.
d. Recommendations for other educators planning to use SC in their classes

Advice from my interviewees revolves around points such as class organization and working with people. “Don’t think you can be casual!” says Grabel to other educators who plan to use SC in their classes. She thinks it is very important to make a conscious choice as to why one uses SC in his/her classes and how it contributes the students’ learning. She advises educators to get feedback from other people and to really reflect on their SC work [44]. Singer adds that collaborating with dancers is a very stimulating experience (given good communication). Again, he encourages educators to give themselves time to understand the people they work with [46]. Likewise, Kolcio agrees on the necessity for a good relationship between collaborators, especially considering the emotional and time investment in a project of this kind [48].

In that respect, it is important to consider how time-consuming that could be, not only for making the module, but also for finding the right space, encouraging students to come, and organizing smooth transitions between activities [4, 20, 48]. Simultaneously, having too many students or too complex topics might be an issue [20]. Kolcio further stresses the importance of clear expectations both for the content and the requirements of the students. Along with that, allowing enough time for movement explorations in and out of class she finds is just as important [48].

Weir suggests that creation of a framework, such as a PowerPoint presentation for example, could be very helpful in catalyzing the class work. A PowerPoint also allows for inclusion of video material, music, or referral to websites such as the Wesleyan science
choreography website. However, activities such as “Ask a question”\textsuperscript{30} discourage use of PowerPoint. Whatever the choice for the activity, he thinks it is important to start small, especially if that is the first time one encounters SC. He encourages educators to adjust the SC tools they want to use to their own teaching style rather than do something they are completely unfamiliar with. He further warns against use of prompts that might lead to disruption of the class flow and order [4].

Lane warns that the most important thing for one to recognize is that he/she might be losing control over the classroom. This might be a terrifying thought because one might lose the ability to even moderate like he/she would do during a discussion. To relieve the stress from failure, he encourages them to prepare well in advance: he for example simulates some of the activities he wants to implement in computer programs to see whether they will work. He also notes that it is relatively easy to notice when an embodiment exercise does not work, more so than in a lecture format. However, rather than taking that as a point for discouragement, this should be considered an opportunity for the teacher to address the issue and find value in the activity even when the students do not perceive that value [45].

McQueen suggests that for such problematic cases, it is important that one has a range of SC tools in backup, a variety of exercises or ways to reiterate the same exercise in order not to “get stuck” with something that does not work, especially if one is a novice. Changing activities and providing multiple places for engagement (movement, video, music), she says, creates a pace that makes a big difference at the end. Staying on one point, which to a professor might seem too simple, might be actually helpful for the students’ understanding when different SC activities revolve around one or two clear ideas. She further adds that

\textsuperscript{30}“Ask a question” is a tool adapted from Liz Lerman’s dance Exchange to encourage students to discuss questions in pairs, and thus contribute to a fruitful class discussion, \url{http://sciencechoreography.wesleyan.edu/toolbox/ask-a-question/}
even if there is something that does not work for five minutes, at the end it will not influence the overall success of the class. Risks are worth trying, for some might work, and when they fail, one should be able to move on, take notes, and later reflect why an activity was unsuccessful.

Yet, the success of SC among students might really depend on interaction with them [46]. For example, a charismatic figure like that of Elizabeth Johnson definitely helps to “sell” the SC. Being able to “break the ice,” lead an inspiring warm-up, or bring a lot of enthusiasm about science and dance is an important quality of a good lesson [20, 46].

1.2.2. Effect of SC participation on students and professors

a. SC works: professors share their observations on student behavior and evaluations comments

“Students took the menstrual dance into Pi café and were performing it there,” says Grabel when she talks about the first event that made her realize how successful SC incorporation in the classroom could be [44]. She leads the creation of a gestural dance describing the complex hormone cascade happening during the menstrual cycle, by assigning a movement to a single event in the cycle. She then combines the moves and makes a little dance out of that performed on a music background of student choice [49]. Because I had an

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31 A kinesthetic mnemonic—the Menstrual Cycle Dance is incorporated into a non-majors class on reproduction. Learning a cascade of events that characterize a biological process can be difficult to teach, and challenging to learn. Students have a tough time relating and remembering the complex interplay of changing hormone levels, follicle maturation, and changes to the uterine endometrial lining that occur during the human menstrual cycle. We have modified Equivalents tool from the Dance Exchange, in which a shape or movement is associated with a word in a sentence or phrase, to provide a useful kinesthetic mnemonic for recalling the sequence of events. The instructor makes a sequential list of the events and the class then assigns a shape or gesture to each. For example, both hands rising overhead indicates an increase in FSH and LH, and two hands joined together, then parting and moving away from each other represents growth of the oocyte and the follicle. Using small gestural movements allows the students to perform the dance standing in place at their seats in a large classroom. Musical accompaniment can be added once the dance is learned, 47. Michael Weir, L.G., Laurel F. Appel, Elizabeth Johnson, Richard McCarthy, Liz Lerman, Science Choreography: an Innovative Movement-Based Approach to Biology Teaching, unpublished.
opportunity to observe her class once, while in the class and also outside, I heard a lot of positive comments from students regarding the menstrual dance [49]. Grabel shared also her observation from her Stem Cell class where has used a partner exercise is discussion of ethics: she noticed that students liked talking to each other, and surprisingly, they got to hear comments of peers they would otherwise never hear a word from [44].

The class discussions following a SC exercise bespeak the immediate success of SC, says Lane [45]. There are always students who respond with “wow” and share verbally their excitement about the “Eureka” moments they have. McQueen, moreover, comments on the surprising level of comfort with SC that certain students share to have experienced despite their and her apprehensions [43]. Regarding the level of engagement SC provokes in some students, McQueen also gives an example about a dance the students voluntarily made to critique a paper they had to read for class. The students found a flaw with one of the experiments on sperm competition dynamics. To demonstrate the flawed conclusion, they created and filmed a dance based on improvisation which clearly showed that the numbers reported in the paper were not significant [43].

I was wondering if students include comments about SC in their course evaluations at the end of each semester. It turns out this is not the case, at least for the majority, which the various professors explain with the minute time of the course spent on SC. Therefore another source of feedback for the success of SC in the classroom has come from surveys individual professors distributed after modules and also workshops [4, 44]. During our interview Weir shared his delight that around 90% of the students were very enthusiastic about SC and they actually learned something, with an intuitive understanding that would not have occurred under other circumstances. He also commented on his perception of class participation for the years in which he used SC versus when he did not, like this one because of space limitations.
He finds the students from his previous years were much more engaged with the material in comparison to his current students [4].

The results of such surveys now culminate in a paper prepared for publication in 2012 in a Science Education Journal with the following authors: Weir, Grabel, and Appel, who are Wesleyan professors, McCarthy, who is a local middle-school science teacher, and Elizabeth Johnson and Liz Lerman from the Liz Lerman Dance Exchange. The paper, which is entitled “Science Choreography: an Innovative Movement-Based Approach to Biology Teaching,” covers topics such as: how the collaboration between scientists and dancers started, why they use SC in teaching, what kind of tools they employ and for which topics, and what surveys of students from courses and summer workshops revealed.

The surveys were quantified based on how many students agreed or strongly agreed with a certain statement in percentages (see tables below).

<table>
<thead>
<tr>
<th>Question: Science choreography experience</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>No opinion</th>
<th>Agree</th>
<th>Strongly disagree</th>
<th>% in top 2 categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contributed to the course</td>
<td>3</td>
<td>13</td>
<td>9</td>
<td>59</td>
<td>17</td>
<td>75</td>
</tr>
<tr>
<td>Helped your understanding of course material</td>
<td>2</td>
<td>23</td>
<td>9</td>
<td>51</td>
<td>16</td>
<td>66</td>
</tr>
<tr>
<td>Include in future course offerings</td>
<td>2</td>
<td>12</td>
<td>15</td>
<td>55</td>
<td>17</td>
<td>71</td>
</tr>
</tbody>
</table>

Table 2. Undergraduate student response to Science Choreography in 2 large non-majors courses. n=101 students. [47].

32 Table 2 summarizes data obtained from students in two large courses for non-science majors, Reproduction in the 21st Century, and the Biology of Women. In each class, the students generated a “Menstrual Cycle” dance to help learn the complex interplay of changing hormone levels and responses within the brain, pituitary, ovary, and uterus 47.Ibid..
<table>
<thead>
<tr>
<th>Question: Science choreography experience</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>No opinion</th>
<th>Agree</th>
<th>Strongly agree</th>
<th>% in top 2 categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can contribute to science learning</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td>Help remember a biological process</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>14</td>
<td>100</td>
</tr>
<tr>
<td>Deepen understanding through doing/dancing</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>12</td>
<td>94</td>
</tr>
<tr>
<td>Artistic impact contributes to interest in class</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>94</td>
</tr>
<tr>
<td>From the beginning, comfortable participating</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>38</td>
</tr>
<tr>
<td>By the end, comfortable participating</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>13</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3. Workshop participants responses, July 2012. 10 teachers and 6 undergraduates, for a combined n=16. [47].

In summary, the surveys provided plenty of observations:

(…)Three quarters of the students agree or strongly agree that the experience contributed to the course, and two thirds assert that it helped their understanding of the material. Those who responded positively described the experience as fun and enjoyable, while the minority who responded negatively indicated a level of discomfort or embarrassment. Interestingly, a number of students commented on their personal learning styles, for example claiming to be a “kinesthetic learner”, and therefore able to greatly benefit from this alternative approach, while those who had a
negative experience suggested they learn better “just from memorization” of text. Not infrequently, students participating in science choreography give feedback indicating that they are thinking about their thinking and learning – a consequence of science choreography that is likely to improve learning.

Similar surveys were also distributed during our summer workshops, which included middle and high school teachers and administrators, as well as interested undergraduates (Table 3). All chose to be there, so not surprisingly these responses were overwhelmingly positive, with 100% of the participants agreeing or strongly agreeing that Science Choreography can contribute to science learning and help students remember biological processes, and 94% agreeing or strongly agreeing the approach can deepen understanding. Almost one third of the participants admitted to being uncomfortable at the start of the workshop, but all agreed or strongly agreed they were comfortable participating by the end. This response is a strong reminder that using a movement-based approach requires a gradual break-in period for some in order for them to be comfortable enough to join in wholeheartedly, [47].

In the paper several individual responses were also included:

“...it really helped me and a lot of others in my class[,] I really liked it and I believe that others did too! It made me see the world in a different way, well genes and heredity anyway.” - Middle school student

“It was fun and helped us remember the sequence of events.” - College Student

“When you learn something from a textbook you’re not going to remember it as well as when you get up and do it, so this way of learning is more permanent.” - High school student

In summary, I have shown several examples of how SC incorporation and embodied learning in the classroom has been perceived as beneficial to students’ learning. Data supporting this statement ranges from spoken comments, through personal observations, to surveys. Later, in the chapter 5 I will comment further on how and why SC is working, again based on the interviews, the above discussed paper, and my personal observations.

b. Effect of participation in SC on science professors

It seems (based on interviewee’s comments) that SC participation has a limited influence on the professors’ lives. More specifically, this influence often remains in the
professional realm [20, 45, 46]. Whether because they met new people, or because they experienced the excitement and inspiration of students in the classroom, all of the professors admit that SC has had a positive influence on them.

Singer shared that participation in SC (in a dance class context) gave him personal satisfaction from trying out different pedagogical approaches and it gave him some helpful perspective on his own teaching in relation to other people’s teaching [46]. For example, he realized how important providing active learning activities is in his science classes. Although he started with a sceptical mindset as to how one could learn ecology from a dance class, he was also very impressed by how the students combined their minds and bodies and how deep emotional connections they were making. He found out that the stronger the emotional connection students make with the material, the better the learning outcomes are. Singer further adds that other kind of activities, such as field trips and field laboratories, can provoke equally intense emotional responses that movement provides. This, he shares, has been an enlightening pedagogical moment catalyzed by his SC interaction. For these reasons, he has tried to further develop places for such emotional connections in his classes, and at the same time, he does not want to sacrifice, in the place of SC, things (e.g. holding the class outside) he is already doing well. Because it is so time-consuming to develop a SC tool in the classroom, he thinks that professionally his time is more worth than the money he would get for doing so (Singer, 2012).

From another perspective, SC has brought about not only professional, but personal fulfillment to professors like Grabel and McQueen [43, 44]. The latter shared that her generally “shy and awkward” attitude in a way stopped her from imposing something unconventional such as dance on the students in a science class, which is why she was so pleasantly surprised when the SC work was received so well. She further commented on a
summer experience with the choreographer Dianne Eno as part of Fusion Danceworks initiative raising environmental awareness. Working closely with the choreographer, she realized how similar the processes of dance making and “lab running” are. She says that both dancers and scientists are trying to find some kind of truth and go through a similar process of asking questions, designing experiments, observing, incorporating feedback, and redoing experiments until they finally get to the moment when something, out of many unsuccessful trials, works. For these reasons, she finds very fulfilling that what she does in the lab is as a creative and an artistic endeavor as what all artists are doing, and she is happy that these two parts of her life, dance and science, have come together in this way [43].

Kolcio, too, has been surprised by how her relationship with science has evolved through dance. As a dance professor, she feels now much more connected to the science in a way “that broadens her world significantly.” For example, during her collaboration with Barry Chernoff from the Environmental Science department, she ended up working on the relationships of the body to a larger ecosystem, a concept she had never thought of. She realized she might have wasted too much energy at a younger age to combat against scientism, which is now something she highly appreciates especially because she realizes how closely scientists and dancers think and how interdisciplinary work helps her remove the blinders her single discipline imposes. Professionally, she says, with SC she has much more visibility and gets a lot more attention. She has met many interesting people outside of her field of interest (dance). She also has been invited to give talks on science-dance teaching at various conferences and at universities [48].

Grabel, moreover, shared that her ability to communicate science in a different way has improved. This she found to be particularly beneficial when she talks to friends and family, because she now is able to explain things through embodiment. In contrast to her
personal satisfaction with the topic, she also has been receiving skeptical comments from colleagues who consider SC as silly and frivolous. Although perceived as a negative response to her work, she is glad to be able to support her beliefs that SC works by showing data like these included in her upcoming publication. She thus finds a sense of credibility that other scientists may pay more attention to especially when she points out the fact that there are many different student learning styles that need to be addressed [44].

1.2.3. Educational prospects, personal stances, and future directions of SC

a. What is good education/teaching and what role does SC play into that?

Grabel defines a good education as one that aims to reach all students independently of their learning style. This is why she initially started to use dance tools – to help the students who learn in a different way [44]. Justification for her reasoning can be found in her co-authored article on SC [47]:

Since Howard Gardner published the groundbreaking Theory of Multiple Intelligences in his book “Frames of Mind” (Gardner, 1983), educators in diverse fields have been examining how to address the multiple learning styles of their students. Gardner’s Theory of Multiple Intelligences posits that there are seven relatively independent forms of information processing: 1) Logical-mathematical, 2) Spatial, 3) Linguistic, 4) Bodily-Kinesthetic, 5) Musical, 6) Interpersonal, and 7) Intrapersonal. Individuals differ from one another in the specific profile of intelligences that they exhibit, but intelligences are not static, and can be developed. In addition to Gardner’s Theory of Multiple Intelligences, contemporary classrooms are influenced by Neil Fleming’s VARK (Visual Auditory, Reading, Kinesthetic) guide to learning styles (Fleming, 2012), and Felder and Silverman’s “Dimensions of Learning Style”, (Felder and Silverman, 1988).

Grabel has seen the positive effect of embodied learning on non-science major students, who, although they might not be too interested in learning science, may easily relate to dance and thus to the class material. Because she has seen SC apply also to more sophisticated models involved in science major classes, she now uses SC as a way extend the classroom
experience by offering a venue for reflection on complex ethical issues that go beyond regular science-class material [44].

Grabel’s thinking is apparently not far from the reasoning of the other professors, who see SC as a valid tool able to not only engage the students, but also to give them access to unknown scientific territories. Cohan says that good education deals with “trying to put complicated ideas within the reach of students who have not thought about such ideas.” While he thinks there must be a “gazillion ways to do it,” he likes to think of dance as a metaphor [20]. Weir says, relating to equality in the classroom, that “good teaching encourages everyone in the room to develop deep thinking in a subject.” Using a range of approaches, parallelism, and interdisciplinary thinking that SC offers can lead to deep, powerful thinking. He further explains that because the cutting edge science thinking is non-traditional, SC being a very non-standard approach to science, it can be very helpful: ”the novelty of SC encourages one to think outside of the box,” he says [4].

In the same way, Lane sees SC as a good teaching tool because it can inspire students’ desire to learn more, to experience new ways at looking at the world, and to encounter stimulating new ideas, i.e. recognize the complexity of the unknown. A textbook, he elaborates, “is a useful place full of ‘knowns’ but not terribly inspirational,” which is why it remains an educator’s job to guide the students to the exciting moments of discovering the ‘unknown’. SC, he thinks, facilitates this process by giving accessibility to the puzzle through movement, and thus a very different approach to understanding complexity [45]. Singer, moreover, adds that “in a place like Wesleyan the professors do not need to worry about how smart the students are (because they are), but how engaged; the challenge is getting through to students with different learning styles.” This is where he finds dance and other movement
techniques useful – they make students active vs. passive learners, which changes the kind of conclusions they would draw from an embodied experience vs. not [46].

Singer further adds that because his goal in teaching is to reach diverse students with different learning styles (i.e. kinesthetic vs. visual), he aims to come up with various methods that are likely to appeal to his audience. Telling a good story, he says, is one common method to engage nearly everyone because human brains are wired for it. If he is not in a position to tell a good story, he employs other methods such as lab activities, field trips, thought exercises or games, showing art, or giving different assignments, thus hoping to grab every student’s attention at least some of the time [46].

McQueen’s reasoning very closely follows this logic: capturing a student’s capacities through different methods, e.g. audio, video, or dance tools, she finds very important. Method diversity, she says, “does not harm those who do not need it, but helps those having a harder time with the textbook only.” She still recalls a teacher who rarely used a textbook, but used unconventional methods of teaching. Dance in a science classroom can, in this simplest way, help to get students out their box. She also agrees that a good teacher should be able to engage his/her listeners by telling a good story. The success in good stories also comes from high enthusiasm: she adored the teachers who were so clearly thrilled by science and connected to it on an intimate level [43].

Kolcio adds that interdisciplinary work is one way to connect any education to a greater context. Similar to Lane’s idea about context-dependent learning, she believes that good teaching is not one that “puts blinders on students,” but one that is relevant in a larger context. Science (as in SC), she sees as one way to connect dance to the rest of the world, but there are more ways. What she stresses is that whatever the choice for education across
disciplines, it should be connected to the body, because “our body and emotions are always there” [48].

In summary, according to my interview data from several Wesleyan University professors, a good education is one that: reaches equally the diverse students with various learning styles in the classroom by providing a range of educational methods; that leads to bodily and emotional connections; that provides clear concepts presented in an enthusiastic and engaging manner; and that is relevant to a greater context beyond the specific study. SC is thus, although not the only one, a valuable tool through which all of these prerequisites can be achieved.

b. Value and future of SC in science education:

The biggest importance educators find in SC is that it is another, alternative method of teaching that is able to especially target kinesthetic learners and science-phobic students [44]. There are multiple reasons why SC is so valuable: for example, SC is a method that breaks up the staleness of the class period [43, 44] and that cheaply provides a place for students to experiment and experience hands-on learning [43]. Just like any art that has the potential to engage the body in a totally different way (vs. the typical sitting and listening), SC is a tool of embodiment that could be the laboratory of investigation in a science class, says McQueen. She thinks that if education is really in the mindset of learning through more practical experience, SC definitely has a place as a very accessible classroom tool [43]. Considering the cuts in funding in all parts of education including sciences33, Weir points out

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33 The collaboration between scientists from Wesleyan University and Liz Lerman’s Dance Exchange has been until 2012 funded by a Howard Hughes grant and also from the national endowment for the arts (NEA). The grant
that SC development does not require funding, although it does require a lot of work in the form of collaborations with choreographers or dancers and the development of class modules [4].

Along with being a practical science tool, SC is a method that, through modeling, allows true understanding of scientific phenomena [45]. Lane thinks that the true value of SC is in the ability to model emergent properties\(^\text{34}\), which, per se, goes beyond memorization based on movement analogies to science concepts. To support his point, he discussed a triangulation\(^\text{35}\) exercise he does every year in his classes in order to enact a single rule of chaos vs. order valid for various areas of science. Whether for DNA bonding, protein running through gel electrophoresis, or cellular signal transduction, one needs to know basic concepts of hydrogen bonding, hydrophobicity, and spatial constraints. The local rules behind these basic concepts determine the global rules, and based on how constraining they are, they either create chaos, order, or equilibrium. Therefore, triangulation is a very powerful yet easy to represent SC choreography tool, which is otherwise scientifically described by complex mathematical equations that can hardly reach the students’ intuitive understanding of the topic the way SC does [45].

True understanding of a process might also mean a true change in one’s thinking, especially if that is related to a concept that is commonly misconceived of, such as natural selection. Cohan says that the majority of students have some idea of how natural selection

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\(^{34}\) Emergent properties are those that exist only when a sum of parts with different individual properties come together. For example, assembly of all of the parts of a car, each of which has its own limited specific function, gives the emergent property of a car to transport people and loads in space, which none of the individual parts can do.

\(^{35}\) In a simple triangulation exercise people move freely into a space, trying to stay equidistant to two other people. The result is often that the participants come to a halt after a certain amount of time because there is a way to be spread in the space according to this rule without having to move. Sometimes the halt is dynamic, i.e. participants keep moving in a certain trajectory in aim to stay equidistant.
works, but often this idea is erroneous or incomplete [20]. To reverse the wrong thinking pattern, a professor cannot just assume that feeding in the right answer would change the students’ preexisting beliefs. Instead, an alternative method capable of provoking new strong concept associations in a student’s brain is necessary. Cohan thinks that SC, with its emotive force, is thus the suitable kind of method. He reasons that a strong experiential response to a new concept could coexist with an older belief and then the latter can be displaced by a conscious choice. Although not much at all is known about such neurological processes, Cohan considers SC experience valuable from an educational point of view, because education has to challenge and help rebuild one’s understanding of ideas. Unfortunately from his classes he has not had enough experience with SC to be able to build a strong survey- or observation-based support for this claim [20].

Because it is difficult to measure SC’s success on a general scale, it is unclear if and which parts of SC will emerge as a conventional educational practice [46]. Whether it will become a standard to teach meiosis through movement, he does not know [46], but is likely that SC efforts will remain individual and scattered rather than mainstream in the future [44]. There is, however, increased interest in interdisciplinary work of this kind from institutions such as NSF36 and NEA, funding from which now supports more collaborations between scientists and dancers [44]. Yet, what remains most valuable for SC is the fact that “it is out there” as a pedagogical option and it will certainly find a place among educators, even if only on a small scale [44, 46].

Furthermore, SC opens a valuable potential space for dancers and choreographers to bring their skills to any educational or professional setting [15, 46]. Singer has observed that when students interact on a physical level, they are much more cohesive. Dancers, he says,

36 NSF – National Science Foundation; NEA - national endowment for the arts; (USA)
could bring their ability to guide group dynamics through emotional connections and team building, a thing left generally unattended in a science class. Because students love to feel like they are part of a group and they can bond to other people, he thinks a dance leader in the classroom is an effective way to facilitate team-building. However, he thinks there are other ways to build camaraderie in the class [46].

c. Would you keep using SC in your classes? Why or why not?

The presence of valued dancers who bring their organizational skills and energy in the classroom seems a key element in the continuation of SC practices. Several professors admit that they would love to keep engaging in SC for its apparent contribution to the class learning, but would either not have the energy to do so, would think it is more “real” when an actual dancer comes [43], would not have the skills to run a workshop on their own [20, 46], or simply would stick to what works really well already [20, 45, 46].

Cohan says that he would rather use metaphors (e.g. baseball) in his classes just because dance metaphors are not his forte. However, he would be happy to work in his science classes with dancers like Elizabeth Johnson from the Dance Exchange or like Katja Kolcio from the Wesleyan Dance Department [20]. Singer, too, would be willing to collaborate with dance professors like Kolcio, but is also reluctant to substitute SC for existing parts of his curriculum, as he already uses a range of well-tested tools in his classes [46].

Other professors, on the other hand, would not stop implementing SC (even without a dancer) because it clearly involves the students in active learning. Weir notes that even the act of turning and talking to a neighbor is a powerful concept related to movement that keeps
students very engaged. In contrast, a lack of SC notably disfavors active class dynamics [4]. Lane adds that he would keep using something like the triangulation exercises as long as he likes to teach, because it is fun both for the students and for him [45]. McQueen also agrees that SC makes the design of a class much more interesting, especially for classes she has taught for several years. She is willing to explore other SC tools, and similarly to Lane, as long she sees a concept that could come across better with SC, she would use it [43]. Correspondingly, Grabel would use SC as long as she has to teach, for it is a nice change of pace that wakes the students up and allows their input rather than hers [44].

Kolcio would also keep teaching SC as long as her schedule allows. Despite her strong desire to be involved, the restraining way in which Wesleyan’s curricula are scheduled and the funding professors get do not allow for interdisciplinary work of such kind in the long term (a class vs. a workshop). She said that the only thing that permitted her to be part of the “Body Languages: Choreographing Biology” class with Hingorani was external funding allowing for a substitute professor for the other dance classes she generally teaches. She also believes that despite the great interests from students, time and curricula constraints are also limiting students from participation in such interdisciplinary projects [48].

1.3 Summary

In this section I have talked about how several science college professors at Wesleyan incorporate SC in their classes. I have traced their reasons to start implementing SC, their process in SC module construction and difficulties they faced, their opinions about the success of SC among students, and their personal life, as well as how SC fits a definition of good education, what is SC’s value, and what role it will play in the future of education.
While they started incorporating SC in their teaching for different reasons, through their experiences they have discovered SC’s value to reach students with different learning styles (whether science or non-science majors). SC can help students learn and access complex scientific ideas; it can promote student’s deep thinking abilities and ability to translate embodied experience to understand and recreate models with emergent properties; it can provide students with physical practical experience (laboratory) where they can learn actively and subvert erroneous assumptions; it can help break the class staleness for both students and professors by providing diversity in class flow and teaching methodology. Although not the only one, SC is a powerful tool that can provide what these professors define as a good education, because SC can provide a platform for equality to students disadvantaged in normal learning conditions; it can give an opportunity to the students to emotionally connect to their science subjects through physical activity and thus build long-lasting deep connections; and, it can engage the students and help them find a relevance of their studies to a broader context.

For these reasons, all the interviewees would like to keep using SC in their classroom or getting involved in SC collaborations. However, they also admit there are many prerequisites for a successful SC implementation such as: thoughtful class preparation providing meaningful intriguing concepts and various handy tools, good communication with collaborators and timely class design, clear expectations and guidelines for the students, enthusiasm and ability to guide group dynamics, as well as problem-solving skills and ability to analyze classroom behaviors in order to maximize class learning outcomes.

If these guidelines are followed, SC has the power to attract even the most restricted students, to motivate the students to engage creatively in their own learning outside of the classroom, to experience meaningful “Eureka” moments, and make peer connections. SC can
also contribute to the professors’ own understanding of the value of SC among their students, it can change the way in which they view science and dance relatedness by opening their horizons, it can promote their ability to engage their immediate friends or family with science on a more accessible level, and most of all, it can give them professional and personal satisfaction and broaden their social circle.

In the future, SC has the potential to make bigger impacts on academia for both students and professors, as well as for professional dancers whose skills can be adeptly used in SC settings. Yet, because of the current educational structures in US universities like Wesleyan, which promote interdisciplinary learning but have limited opportunities to implement it in the college curricula, SC might not become mainstream in the near future. SC, nonetheless, remains a relatively cheap and accessible method that could be a great addition to any class environment regardless of subject level.

2. Dance in Science Performance - “Dance your PhD” creator and winners talk about their experiences

The goal in my study of the “Dance your PhD” contest is to understand why and how scientists use dance to perform their science. I want to know if there is any magic formula for making a winning dance and what impact participation in the contests has on their science and social lives. Although my information is by no means complete and representative of the whole participating PhD student population in this contest, I aim to demonstrate several aspects of their personal engagement and participation: the way they became involved, choreographed, and felt about the process, and the impact they perceive on their life and the life of the rest of the community.
2.1. Interviewing Process with John Bohannon [50]

I contacted John Bohannon via e-mail and arranged a personal meeting in Boston on the 17th of March 2012. We met in an informal setting and went over the set of questions I had prepared for his role in the “Dance your PhD contest” and his TED-Talk participation in 2012. From him I acquired the contacts of the contest winners, after which we discussed my strategy for interviewing them. In my descriptions I rely on the transcribed answers I gathered at the moment of the conversation. This information can be found in the appendix.

2.2. Data Description

2.2.1 Contest history, organization, and judgment process [50]

The contest idea originated in a talk between John Bohannon and some his colleagues in 2007 during a big science party. Going off the question “How can you encourage scientist to dance?” they figured that it would be fun to have PhD students dance about their work. John mentioned during our interview that since a PhD is so rigorous, turning it into something comical that also takes the jargon of science communication away seemed a wonderful idea. With his theater background, he saw the potential for spectacle in mixing dance and science. Having little dance background but a creative mind and a desire to engage his fellow scientists, he then organized the first round with just twelve participants. Exhilarated by the success of the first trial, he kept it and it is still happening in a more developed format.

The contest now happens once per year with a deadline in October until when the participants need to submit a video of their PhD work in a dance form on a free website with their comments about it. The contest was initially evaluated only by the judges, but as it grew bigger (from 12 the first year to 55 in 2011), the winners of the previous years were asked to
do the so-called pre-selection. The judges include several scientists from renowned universities such as Harvard, Boston, Cornell, and others, as well as members of the Pilobolus Dance company (see website for specific names)[51]. They meet soon after the closing deadline and look through all of the nominated dances and grade them based on three categories: science, art, and the combination of the two. For each category the participants can receive from 0 to 10 points based on, first, the veracity of their science work and how clearly communicated it was, second, how creative and well-done the dance piece is, i.e. what is its artistic value, and third, how well the science is connected with the dance to become something unique with value of its own.

At the end, based on their total points, a winner for each science category is selected, and one of them becomes the winner of the contest. After the announcement of the winners, they are invited to go (for free) to a TEDxBrussels37 where they meet with John Bohannon personally. The contest winner receives a monetary price as well.

2.2.2 John Bohannon’s Comments about the participants [50]

On the question what kind of a scientist would engage in contest like his, John said that these are people who all have “exhibitionism” as something in common, by which he meant that they like the attention and are not afraid to be on stage. Beside that commonality, he did not see other similarities among the participants’ dance background, sense of humor, and the way they made the dances. Based on the winners I interviewed, I got a similar impression, for they really had different approaches to their participation in the contest. However, I also found similarities, about which I will talk in the next section.

37 “In the spirit of ideas worth spreading, TEDx is a program of local, self-organized events that bring people together to share a TED-like experience. At a TEDx event, TEDTalks video and live speakers combine to spark deep discussion and connection in a small group. These local, self-organized events are branded TEDx, where x=individually organized TED event. The TED Conference provides general guidance for the TEDx program, but individual TEDx events are self-organized” from http://www.tedxbrussels.eu/2012/about.php
But before I move to that, I would like to discuss John Bohannon’s thinking about the differences between scientists and dancers choreographing and why the first might be received negatively in the arts world. The main point he made was that while professional dancers (choreographers) express a more provocative sense of humor that aligns with the abstractness and prestige of their works, scientists are “goofy, child-like, and naïve” and explore their sense of humor on a more obvious level that is also suggested by the literal meaning of their dances (again, the dances have to clearly represent a science research). That is why he thinks dancers are more critical to such works and scientists seem to find them as a fun activity to do. He also conjectured that dancers might feel more defensive about their territories because the attention dancing scientists get is not proportional to the amount of work versus attention dancers receive. He further mentioned that dancers might feel like somebody is “entering their territory without permission” and necessary training, but as I later found out and John confirmed, scientists do not pretend to be professional dancers.

It is interesting to note the quality of the work of some of the scientists considering their mostly informal engagement with dance. John Bohannon pointed out that while the scientists’ work mostly remains a “do-it-over-the-weekend” activity with much less technical performance expertise, it is no less intellectually sophisticated work than that of professional choreographers. He argues that the scientists exhibit a high level of interpretation, involve themselves in complex of idea translation (i.e. science idea to motion), and have the difficult task to focus on the important points of their research just like professional dancers do. With that in mind I went on to ask him about his performance in the TED talk show with Black Label Movement company just about a year ago.

38 My impression is that both scientists and dancers might have some prejudice against each other, and they might be badly looked upon as amateurs among the professional fields. This is why I addressed this question in my interview with John Bohannon.
2.2.3 John Bohannon’s TED-talk performance [52]

I will first start with a short description of what topics are covered in the show. The talk, entitled “Modest Proposal” starts with a description of a superfluid, a very complex physical phenomenon explaining how light can be used to cool matter down instead of heat it up. He then says that “The experiment is not the end of the story, you still have to transmit that knowledge to other people,” and “if you are trying to give someone else the bigger picture, the essence, the fewer words you use, the better.” He then talks about how dance, surprisingly, can make science more understandable, referring to the “Dance your PhD” contest. He further touches upon how some scientists like David Odde use dancers to model their research, to make “efficient brainstorming” and explanation. He then goes on to compare how bad powerpoint presentations are a serious threat to the global economy, and how cutting the endowment for the arts to save the US from the national debt would be not only inefficient, but it will create a lot of unemployment. He then provocatively suggests his “modest proposal” that to solve the unemployment problem, we could put the artists back to work to use them instead of a powerpoint. His proposal stirs up the issue of scarce funding for the arts which, hopefully, will be solved one day and then we can sit down and enjoy “the motion of the human form” instead of planning provoking proposals. Throughout the talk the dancers from Black Label Movement John Bohannon collaborates with are dancing around him, often embodying the concepts he is talking about or making shapes he uses as props (e.g. an armchair), always closely following and exemplifying his wording.

Bohannon’s point is twofold: dance can help communicate and study scientific processes, but dance can also be appreciated for its intrinsic artistic value. In this way John Bohannon makes a poignant social remark about the cuts in funding for the arts. He engages in this way in a different kind of SC – one telling a story related to a social issue, i.e. dance.
embodiment can go beyond the goal to represent science. Understanding the content of the talk is just as important as understanding how John Bohannon, as a scientist explaining complex phenomena through dance in a socially engaged way, developed this work and why. Following the model of questions I developed for the interviewees from the contest\(^{39}\), I discovered that his involvement in SC of this form was for him a satisfying life-changing experience [50].

As for his creative process in the preparation for the TED talk, John Bohannon started by writing a detailed script, which he brought into the dance studio and examined with the dancers and the choreographer to see where dance could “fit” into his talk. He then reworked it several times and added the music at the end. One of the most interesting things he shared is that it was not translating ideas from text to human movement and making spectacle out of it that was the hardest to achieve. Instead making a flawless performance with very well-memorized lines and perfect coordination between him and the dancers was [50].

When I asked where John Bohannon sees the value of combining science and dance and also the future of SC, he said that his work contributes to bridge areas that are otherwise separated. He thinks there are many hidden dancers (artists) among the scientists, and he is therefore happy to provide an excuse for them to engage in something they are inherently curious about. Regarding his own participation in such interdisciplinary projects, he gladly admits it is a hobby that breaks the monotony of being a journalist, and he plans to continue his involvement with it [50].

\(^{39}\) The questions were related to SC involvement, creative process, issues, positive sides, and personal value.
2.3. Interview process with the winners of the “Dance your PhD” contest

The interviews were done at the end of September and the beginning of October 2012. I contacted the eight winners of the “Dance your PhD” contests for the 2011 and 2010 (four winners each year in each category – chemistry, biology, physics, and social science) via e-mail to arrange a meeting; six responded (table below), one by sending his written answers [53]. With the rest I then communicated via telephone or skype and I transcribed their answers at the moment of the interview. They were all given the questions in advance and at the beginning of the conversations I briefly mentioned what I am going to ask them about. We then talked about the ten specific questions I had prepared, and finished with a short description of my work and the way in which I am using the information I gather from the winners. For the purpose of staying brief, I will mostly list examples of the different aspects of the graduate students’ choreography approaches and their thoughts about the “Dance your PhD” project. I will summarize the information from the interview process, but the whole comprehensive data can be found in the appendix.

Table 2. The interviewed winners of the "Dance your PhD contest" from 2010 and 2011.

<table>
<thead>
<tr>
<th>Name</th>
<th>Category Winner, Year, University</th>
<th>Dance Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maureen McKeague</td>
<td>Chemistry, 2010 Carleton University in Ottawa, Canada</td>
<td>Selection of a DNA aptamer for homocysteine using systematic evolution of ligands by exponential enrichment</td>
</tr>
<tr>
<td>Cedric Tan</td>
<td>Biology, 2011 Oxford University, England</td>
<td>Smell mediated response to relatedness of potential mates</td>
</tr>
<tr>
<td>Joel Miller</td>
<td>Physics, 2011 University of Western Australia</td>
<td>Microstructure-Property relationships in Ti2448 components produced by Selective Laser Melting: A Love Story</td>
</tr>
<tr>
<td>Anne Goldberg</td>
<td>Social Science, 2010</td>
<td>Social Sciences: The negotiation of contributions to public wikis</td>
</tr>
</tbody>
</table>
| Steven Lade | Physics, 2010  
The Australian National University | Physics: Directed transport without net bias in physics and biology |
|------------|--------------------------------------------|------------------------------------------------------------------|
| FoSheng Hsu | Chemistry 2011  
Cornell University, USA | The Holy Grail to X-ray crystal structure of human protein phosphatase |

2.4. “Dance your PhD” contest participants comment on their science performances

2.4.1. Involvement, engagement, and difficulties

How the participants became involved in the “Dance your PhD” contest seems unique for each of them. The major ways were through friends, social networks (e.g. Facebook), the university, or colleagues. Whether they took it initially as a fun activity to do [54], an opportunity to communicate their science [54, 55], to dance [53, 56], or to do a fun activity with friends [57] or colleagues [58], they all devoted their attention to it and took the commitment seriously. It appears that the context of their work and the social support is what kept them engaged throughout. Even without any/ with little dance background, virtually all accepted this as chance to participate in such interdisciplinary work as a positively challenging activity.

Some of the difficulties they encountered were related to the organization of the creative process [56, 57] including the work with other people and presenting their ideas in movement. For many it putting everything together, music, dance, science, and video, was very thought-provoking and often a somewhat a disheartening process [56, 57] especially when they felt pressed by the deadline of the competition [57], [58] or felt misunderstood by other scientists [54, 56]. How does one find the skills/self-confidence in themselves to lead the process of science-dance making, to find and coordinate a team, to make choices about
choreography and set-up, or to make non-scientists/non-dancers express something they might have little or no idea of, are some of the basic questions that came up for all of the participants in one form or another. Other difficulties relate to how one deals with unpredicted events or things outside of their control such as a broken car [57], work with younger students [54], or missing dancers [56].

2.4.2. Choreographic process

Now that I have looked at how they became involved in the process, I wanted to know how exactly they created their dance pieces by analyzing categories such as time, choreographic order, setting, and feedback. In my interviews I got a whole range of answers, which would be later very useful information to compare with how dance choreographers create pieces.

On the question how much time it took them to accomplish the work and submit it, I heard more often than not that it was a one time or short-time commitment [53, 55-57], but for those more involved it was a whole process that took overall several weeks to complete [54, 58]. In the latter cases the length of the projects resulted because it was more spaced out between mealtimes and occasional [54] or more regular [58] meetings, eventually being not that big of a commitment. As for the number of people participating, there were ranges from one [53] to more than ten [54] people involved, which sometimes was a choice [53, 54, 56], and sometimes a coincidence [55, 57, 58].

Next, I looked at how assembly of the dance pieces was made in order to address my goal to understand if and how scientist choreographers are different from dancer choreographers. I gathered very interesting answers from which I noticed two major trends
related to the order in which music, concepts, and choreography came together. The first type goes from music to choice of space and dance moves to science concepts, or from music and science concepts to dance moves that correspond to the music and concepts. Choosing the music did not necessarily mean making dance moves on the prompts the music offered, because sometimes it was just an idea they started with. Sometimes this order was not as clear cut and the contestants might have choreographed the dances differently in a different context. Lade, for example, knew he had a day-long workshop in which he could only do the choreography, so he made sure to select the music beforehand, although his work originated from his science research.

The second type of choreography starts with the underlying concepts first, followed by choice of dance movements and setting, and concludes with the superimposition of music on the finished product. The start of the creative process involves figuring out the story line, thinking of the concepts that needed to be represented, or coming up with the underlying message. The middle of the creative process requires specific choices of dance moves or creation of an improvisational frame according to which the choreography was created and filmed. The music then came last, often added during the editing process, which surprisingly worked out just as if the dances were made with it switch ref.

In both cases, whether the PhD students started with a conceptual framework or chose the music first, they all relied heavily on feedback and suggestions from other people (with the exception of Hsu who worked alone). Because the making of the dances was, with

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40 I chose these categories in order to have a comparison frame for the discussion later, and also because these are generally three basic performance elements. These elements were also the ones that the interviewees commented on.
41 Explain….
limited exception, not a one way process, it is understandable that the choreographers all experienced not only some difficulties but also multiple enlightening moments regarding how to come up with movement ideas, how to represent their concepts, or how to put the dance components together. Friends[56-58], colleagues[54], [58], family[57], or formal “science and dance” instructors[55] all had their place in the process, which leads to my next point, the impact this dance creation process had on the participants involved.

2.4.3. “Dance your PhD” effects on the participants and collaborators

In order to understand how SC affects the people engaged with it, I looked at the influence the contest participation had on the scientists’ careers and the people they worked with. The PhD students shared that their participation has had a quite impressive effect on their lives in various ways; for the most part it was associated with positive feelings, but there had been also negative consequences they had to deal with. As for the lab work, sometimes their participation made no difference to them, but sometimes it drastically changed the way they do research.

Starting with the neutral effects, it seemed that participation in the contest was considered an extra-curricular activity rather than an actual inclusion of dance into the science. The participants saw their work as representative, i.e., a way to express their work in movement, which is more accessible to the people around them. Because they did not involve their research into the process, making a dance about the research itself did not significantly change the way they did science, with one exception.

Goldberg admitted that participation in the contest turned out to be a catalyst for her to pursue dance in a more serious fashion. She is now not only much more involved with
dance teaching and performance, especially improvisation, but she also uses dance as a tool to approach her work and research. She is now doing postdoctoral studies that relates social network studies with art and has a job as facilitator. She is even pleasantly surprised that her performance related work is both extremely rewarding and better paid than her science work [56].

Although other participants’ lives have not changed as drastically as Anne’s has, they mostly reported very positive experiences. The most noted was the fact that their relationships with the people they worked with towards the contest have improved immensely. Cedric mentioned that because the work is so physical (dance), the boundaries between people melt much more easily [58]. Whether between colleagues in the laboratory, or between PhD and undergraduate students [54], [58], whether between friends or family [57].4ref, the bonds people made were of great significance to them. Further, the fact that they won the competition improved also their status as experts [53, 55, 57, 58], i.e. they were taken much more seriously when talking about combining dance and science. Winning apparently contributed to disseminating their work, and they received a lot of attention for their work from other scientists, educators, or family and friends [53-58].

Miller was contacted by University of Virginia for permission to use his video in an English Department program illustrating interdisciplinary work. He, being from Australia, also used the opportunity to do an exchange with labs in Europe around his visit to Brussels for the TED talk, which is the highlight of winning the contest. In this way his participation indirectly contributed also to his research worked. He further mentioned that the recognition of the award at his institution was a major shift in the university’s thinking considering the initial reluctance and even resistance towards that kind of unusual interdisciplinary work [57]!
On a more personal level, the participants seemed to have regained much more confidence in their SC abilities [56, 58]. It also helped them be more efficient with their work in the lab, because they were looking forward to their extracurricular dance activities [54, 58]. Here I cannot fail to mention the personal satisfaction of understanding one’s own work in broader terms and being able to transmit it to a general audience which was mentioned by each participant.

Unfortunately, their personal gratification was sometimes opposed by negative feedback from their working environments. While participation in the contest drew the attention of the department she was working in, McKeague’s lab also became known by some for its dances and not its science rigor [54]. Not until he won the contest was Cedric viewed as childlike and unserious, which also affected his shy attitude [58]. Goldberg met a lot of skepticism and was considered the crazy one in her department; she further felt very isolated in her interdisciplinary work, which she is still struggling to overcome even now when she is actively involved in dance as part of her research work [56]. Despite these problems, the winners were not discouraged to keep getting involved with similar kinds of interdisciplinary work.

2.4.4. Prospects, personal stance, future plans

In order to understand the long term effect of SC on the participants, I asked them how they have been involved in SC since their winning. My data revealed that all of the winners in the “Dance your PhD” contest have continued to participate in SC in one form or another. Initially, they were all asked to become part of the judgment collective, by previewing the (presently huge list of applicant) dances in the subsequent contests. In this
way they make the judgment process more efficient, because the rest of the judges, professors and professional dancers have a smaller applicant pool to review.

Coming back to the winners’ involvements, many participate in other forms of science communication and outreach: Lade, who is very involved with science communication in general, performed his dance during an event in Dresden, Germany, which called for untraditional science communication [55]. Miller is now in the chief position of the Perth chapter of the TED Talk and is now much more engaged with communicating concepts in a unique way [57]. Anne is collaborating with choreographers from Berlin and London for her interdisciplinary work; with her computer expertise she wants to promote the “Dance your PhD” website to make it more interactive and accessible for the general audience, including more specified science or dance oriented search options [56]. McKeague had been even more engaged with the school-students outreach programs, and is currently hoping to excite her new lab members for this kind of interdisciplinary work [54, 58]. Cedric is now in the process of making of more professional video and choreography work and has found a lot of interest and supporters around him [58].

But why do all of them keep getting involved and why do all of them highly recommend anyone’s participation in the contest or related work? The simple answer is “because it is rewarding,” and that means it is a great opportunity to view their work from a different perspective, to get the big picture of their research, to be engaged in something so interesting that makes the science routine all of sudden an exciting place for creativity, communication, and interaction. Many of them also recognize the educational value of their work and its ability to connect dance making with science or science making with dance. For these reasons, they collectively encourage anyone to participate in such venues and talk only positively about their overall participation.
They also did not forget to leave some notes and warnings for the contest and for future participants. First, because of the nature of the contest, to promote fun creative work that stimulates scientists to communicate their science through new media and create unique work [50], new participants should not get involved just to win the contest, but their motivation should be to have fun and to contribute to the process [56]. Although there are only four winners (one per category), both the creator and the winners from past years agree that there is a plethora of amazing work out there and people should be encouraged to participate. On this note, as participant counts have been rising over the last years [50] and it is never clear how many are going to enter the contest until the last week before the deadline when most applications get in, there might be a need for a country-specific pre-selection [57]. As this might require much more work for those directly involved in the organization of the contest, it might be necessary for staff to be hired, who will also sustain the contest website. However, the prospects for expansion seem gloomy as of now because this project needs funding to be sustained, and beside the sponsorship for the winners to visit the TED talk and their monetary award, currently John Bohannon is dealing alone with everything on voluntary basis.

2.5 Summary

In this section I have studied one example of how dance interacts with science performance. I have looked at the interview responses of the creator and six winners of the “Dance your PhD” contest and how they became involved with the project, what kept them engaged and the difficulties they faced; how they developed their choreography; what effect their participation had on their professional and social lives and those of the people around them (participants and not); and, what prospects they see for the project, how they plan to
engage in the future, and what the value of such dance and science collaboration is. In these descriptions several similarities and differences appeared.

The differences between the scientists were quite visible as to how they became engaged in the process and how they choreographed: everyone had different motives and ideas, ranging from a fun extracurricular activity with colleagues, friends, or family to active pursue of new ways for science communication. The choreography making followed two models, the first starting from music and layering of the conceptual information and movement with it, or the other way around, from concept to music applied at the end as in the second model.

The similarities among the participants lay mostly in the way they perceived their involvement in the contest and its impact on their social lives. For some there was little to no effect, for some there has been a drastic change, affecting the way they do research, engage with the arts, or become involved with science communication. For most it has had a moderate effect. Despite the difficulties they might have experienced in the creative process or afterwards, the participants associated the contest with positive emotions and highly recommended it for the benefits it has brought to them. It has allowed them to bridge dance and science in a unique way, to challenge their understanding of their work by viewing it from a different angle, to get the big picture of their research, and to be engaged in something so interesting that makes the science routine all of a sudden an exciting place for social interaction where creativity, learning, and science communication meet.
3. Personal Exploration

The goal of my personal exploration was twofold: on the one hand I wanted to experience SC creation and implementation and understand what the difficulties in this process are; on the other hand, by studying how successful my exploration was, I wanted to evaluate what information about my research this process could bring me.

3.1. First semester:

I used the first semester (8 weeks) of my movement exploration as a way to answer two basic questions in order to help me frame my study of SC: first, what is SC and in how many ways can we experience it, and second, how can we make a performance that presents best what SC is? The basic steps in the process involved: finding of dancers and practice time, execution of weekly practices, and creation of a final event.

I worked with several Wesleyan students with whom I had had the chance to participate in either science or dance classes or events. I chose the people to work with based on their background either in each of these disciplines (or both), as well as teaching experience. It was important to me to have a very diverse group to work with, and gladly that was the case: the people had dance background in break, modern, belly, Indian, theater, African, or Latin-American dancing, and science background in molecular biology, biophysics, physics, neuroscience, or basic exposure only. We practiced twice a week, for about 4h in total.

3.1.1. Exploration

The practices evolved around movement explorations of SC, video observations, discussions, and choreography. These elements were part of every weekly exploration. Initially we started the semester with familiarizing ourselves with the different ways in which
dance and science can interact (direction and destination). We then set up goals for what each of us wanted to achieve, and decided on what kind of concepts to work with in order to represent SC. Specifically, we explored nearly all of the exercises from the Liz Lerman created Dance Exchange toolbox\(^\text{42}\) and science concepts relevant to molecular motion (single molecules, water motion, biomolecular assembly, molecular motors).

For example, we used the “Walk and Talk\(^\text{43}\)”\(^\text{[41]}\) to ask questions such as “What is SC?” and “What is fascinating about dance and/or science?” (week 1). Or, we used “Build-a-phrase\(^\text{44}\)”\(^\text{[41]}\) with a science video prompt, and then choreographed the pieces together; we also modeled a cellular process (kinesin walking on assembling microtubules) and explored its limitations with change of conditions (week 2). By the end of the semester we explored basic principles of improvisation, choreography, partner work, as well as concept representation, research through movement, and learning through movement. We used this material to create a final performance, which later evolved into a workshop with active audience participation. The second format, workshop vs. proscenium performance, allowed for much more interaction with the audience and their involvement. This is why I chose to use it for SC specifically, because it seemed to be a much better way – through experience vs. through observation – to convey to the audience what SC is.

The final performance included four parts related to the science and dance combination in the fields of education, research, and performance. First, we started with a warm-up “Walk and Talk” activity to tune the audience into thinking about SC and sharing their experiences with strangers. Second, the audience learned about how molecules move in

\(^{42}\) [Link](http://danceexchange.org/toolbox/home.html)

\(^{43}\) “Walk and Talk” is an exercise with alternating ‘random walk’ sections with music accompaniment and ‘question and answer’ sections executed in pairs.

\(^{44}\) “Build-a-phrase” is an exercise whose goal is to create a dance phrase from a set of concepts each of which is associated with a particular move with a specific beginning, middle, and end.
space (or in a box) and each person embodied a molecule to demonstrate that process. Third, after demonstration and with the help of my dance cast, the audience embodied the molecular system we had explored during practices, and followed with discussion on how the two models studied worked. Last, the dancers created an improvisational dance based on four science-related movements that came from the audience (“Equivalents” [41]). The workshop occurred in two nights – pre-premiere and premiere. At the end of both nights I distributed a survey from which I gathered 63 total responses (Table 3).

3.1.2. Survey Description

Through my semester exploration I was able to experience how SC is created, which I then implemented during a final workshop. Because I wanted to see how effective SC is in general, I relied on the data (in the context of my work) from the surveys I distributed after each performance. In order to understand what was strongest about my SC presentation and which aspects of SC stuck with my audience, I asked what their favorite part was (question 1). Because SC is known to provoke a strong emotional response, I wanted to know if and what excited my audience and what surprised them, i.e. what unexpected things happened to them (questions 2 and 3). Although I was publicizing my performance as interactive, I did not specify more than that, which is why I tried to understand the audience perception of SC (optional question 4). Through the responses I wanted to evaluate in what way SC works, i.e. what effect it has on people, and which parts of SC leave that mark. The questions and the results are summarized in the table below. The answers are categorized for easier analysis later.
Table 3. The table summarizes the results from the survey distributed at the end of the presentations on my SC work as part of my movement exploration for the first semester (April 2012). 63 answers were collected, see appendix for raw and transcribed data. The categories on the left describe how the answers were grouped.

<table>
<thead>
<tr>
<th>Questions / Category</th>
<th>Favorite part?</th>
<th>What excited you?</th>
<th>Something unexpected?</th>
<th>Other comments?</th>
</tr>
</thead>
</table>
| 1. Social Aspect/ interact-ions | -Walk and talk – getting to know other people  
-supporting friends / seeing them dance  
-Interactions with others (strangers), physical and communicational  
-Team work during modeling | -“molecular interactions became anything ropomorphic and colored by human emotions which made them more memorable”  
-Talking to strangers  
-Group engagement despite the unexpected situation, attracting the audience that would trust;  
-large audience participation  
-Working together with the rest of the audience | - Amount of interaction  
-Interaction with different people  
-Collisions with “molecules”/people  
-Care from the dance leaders about experience  
-Meeting and dancing with new people  
-Unexpected level of interactivity and fun |                                                                                           |
| 2. Active participation | -being part of the show instead of watching;  
-Resourcing the dance making | -Involvement  
-The opportunity to dance my feelings about science | -Didn’t think they’d be comfortable, but are very glad they just went for it  
-Embodying a molecule  
-felt in tune with music and wanted to dance  
-Lack of self-consciousness  
-Performing and getting energized |                                                                                           |
| 3. Creativity/ Dance | -making up science moves  
-dance creation from scientific concepts  
-choreography | -Creating | - Dance move related to science  
-The dancers incorporating quickly movements from the audience into a dance |                                                                                           |
| 4. Movement/ Enjoyment Aesthetics/ Modeling | -enjoyed modeling/movement because of intimate connection to the concepts | -The dancers (break dancing, embodying the energy and it was exciting to watch)  
-Moving in such a big | - A single entity (molecule) vs. a process  
-Embodying (becoming) a science | - Fun connecting dance and science |
<table>
<thead>
<tr>
<th>5. Chance/Novelty/Unexpected things</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Enjoyed movement because of how it looked in the space</td>
</tr>
<tr>
<td>- Dynamics of motion</td>
</tr>
<tr>
<td>- Observing interaction and motion</td>
</tr>
<tr>
<td>- Enjoyment but lack of science understanding</td>
</tr>
<tr>
<td>- Begin to see the beauty in the processes we take for granted</td>
</tr>
<tr>
<td>- Unique and original experience</td>
</tr>
<tr>
<td>- Experiencing something that would not happen outside of Wesleyan</td>
</tr>
<tr>
<td>- The Unexpected in the presentation</td>
</tr>
<tr>
<td>- That Wesleyan supports such kind of activities</td>
</tr>
<tr>
<td>- Interesting way to learn about science in general</td>
</tr>
<tr>
<td>- No unexpected moments (several responses)</td>
</tr>
<tr>
<td>- Innovative experience</td>
</tr>
<tr>
<td>- Made people smile</td>
</tr>
<tr>
<td>- Interesting and refreshing</td>
</tr>
<tr>
<td>- Unclear what the improvisation at the end represented scientifically</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. Learning/Reflection/Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Moving helped understand the concepts observed afterwards;</td>
</tr>
<tr>
<td>- Seeing the same concept of microtubule formation from different angles helped solidify the concept a lot</td>
</tr>
<tr>
<td>- Learning about the body through the body</td>
</tr>
<tr>
<td>- Understood certain molecular interactions much better</td>
</tr>
<tr>
<td>- Started thinking more about the dynamics of the cell</td>
</tr>
<tr>
<td>- Learning science in a fun way</td>
</tr>
<tr>
<td>- Thinking about straight molecular trajectories</td>
</tr>
<tr>
<td>- Learning something new/science</td>
</tr>
<tr>
<td>- Learned new way of thinking about science</td>
</tr>
<tr>
<td>- Unexpectedly educational performance</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. Organization/Choreography/Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Clearly articulated activities - made science meaningful;</td>
</tr>
<tr>
<td>- Content</td>
</tr>
<tr>
<td>- How well the structure model related to the video</td>
</tr>
<tr>
<td>- The success of the event considering the lack of background for the audience</td>
</tr>
<tr>
<td>- Science interpretation of the and cargo movement across microtubules</td>
</tr>
<tr>
<td>- Being cut off by the music in the middle of a sentence</td>
</tr>
<tr>
<td>- Well organized; “care in planning is important; choice of microtubule + motor = excellent; motion of molecule - good choice for SC</td>
</tr>
<tr>
<td>- Desire for helpful SC links in the program</td>
</tr>
</tbody>
</table>
### 8. Atmosphere / Setting / Performance elements

- Lighting – change of colors
- Use of the space
- Music – uplifting, important choice in SC
- Video

- the lights, how they changed
- music

- Great lighting
- Great Music

### 9. Potential/ Application/ Value of SC

- Seeing potential in SC, although it was considered “silly”
- Seeing an unsuspected connection between dance and science

- For choreography, inspiration for movement
- TED talk – replacing presentation with dance
- Great middle school biology class program to get kids engaged; “I hope it serves as intro of science in primary education”
- “loved it. Should be used to teach kinesthetic learners scientific concepts”
- For development in many directions
- For psychology project (research potential)
3.1.3. Survey Analysis

The anonymous survey covered just four questions in order to make their collection easier. Because I aimed to get a first idea about what kind of thoughts SC is provoking among my audience, I was not interested in collecting data about the participants (e.g., age, occupation, science, or dance background). Because I want to concentrate on how unknown audiences perceive SC, here I also exclude any information I gathered from my dancers throughout the semester exploration.

The analysis of the data revealed that, surprisingly, every one of the participants had a favorite part. There were no negative comments for the first question (What is your favorite part?) and people identified a whole range of things to be their favorite (column 1). I identified basically eight categories in which the responses from this answer fell; they were related to: the social aspect of the performance and the interactions with audience members and dancers (1), the active audience participation in the making of the presentation (2), the creative process in which they engaged and which they observed in the improvisational dance at the end performed by my dancers (3), the joy of moving in space and modeling science concepts, processes, or objects (4), the learning about what SC can be (5), and new science concepts (6), the organization of the event (7), and the atmosphere in the room (8). The ninth category, potential of SC for application and development (9), came out from the other three questions. The category with the biggest number of fans was the creative improvisational dance one (3), followed by the social interactive aspect (1), the active participation (3), and the atmosphere of the room and choices about the setting (8).

I believe future research in the SC field should address what kind of audiences it deals with in order to be able to understand better the dynamics of the responses and what they depend on. Study of homogeneous vs. non-homogeneous groups might thus bring different results than mine.
The fact that the audience members commented on all of the performance elements speaks about, first, the success of the event, and second, about the audience diversity, and how different elements (visual, audial, kinesthetic, etc.) appeal to different people. This reminds me of the notion of diverse methods in a classroom, which Professor Amy McQueen talked about in her interview. She thinks that tool diversity is crucial for the success of SC in a class in order to reach the various kinds of learners in the classroom [43]. Because I had several different SC activities (“Walk and Talk,” molecule embodiment, structure modeling, discussion about the models’ success, dance move creation based on science concepts, and dance improvisation), as well as different setting elements (video, music, lights, presentation) this could explain the success of the SC workshop.

It seemed that the very things that excited people (question 2) were also present in the “favorite thing” category list, although no person wrote the same answer for any of the questions. A concept that particularly excited the audience was the unique nature of the SC experience and how it occurred in an institution like Wesleyan. The unexpectedness of the activities and the success of the audience participation in the presentation surprised people. It also provoked people to think about applying SC to different audiences (e.g. children) and contexts (e.g. classroom).

Analogously to the answers to ‘favorite part’ and ‘exciting moment,’ similar insights came out as ‘unexpected’ to the audience members (question 3). However, there was a difference in the category distribution. For example, creativity (category 3) was less defined as ‘exciting,’ and more as ‘favorite’ and ‘unexpected.’ Active participation (category 2), was also more heavily regarded as ‘unexpected,’ and furthermore, people commented on how their initially low level of participation comfort changed throughout the performance. This is very similar to the findings of Weir et. al., who reported clear differences between the initial
and final levels of comfort (increasing) with SC among students [47]. I will discuss this correlation in detail in the following chapter 5 (Discussion).

Coming back to the analysis of the survey response categories and how they explain the success of my workshop, I noticed that movement in the space (category 4) was always associated with enjoyment. Whether the audience members were moving/embodifying science/interacting or observing other people move/dance/interact, they were thrilled by the motion. Motion allowed some of the people to connect intimately to the science concepts, to see the beauty of science processes, to view science from its artistic side, or have fun connecting science and dance. Moving also helped many audience members to understand and learn the science concepts from the workshop, although not everyone. One audience member stated she/he did not understand the science that well, although she enjoyed the workshop. I guess that even with careful planning and clear explanations and examples, there still might be students/people that do not grasp the content of a class. Probably one should not forget that students who miss basic science concepts might need more than SC (SC is, after all, an additional educational tool – ref. Results).

Yet, for the rest of the 63 people who came, SC seemed to make a lot of sense, and many expressed that they learned a lot of new things, including new ways to think about science and scientific concepts, and to learn about the body through the body (category 6). Interestingly, learning during the workshop was perceived by many as ‘unexpected’ or ‘favorite’, but there was only one answer rating it as ‘exciting’. I owe this result to the type of venue because generally people would not expect to actively learn things when they go to a performance (as it was advertised as interactive performance); they probably would expect to observe and perceive passively. In addition, several people noted the unique nature of such an
interdisciplinary event and shared their excitement about this happening in a place like Wesleyan (category 5).

Here I would like to insert a comment about another surprising remark from one of the audience members, who seemed to be unclear about what the improvisation at the end represented scientifically. My original goal was to create not an improvisation that actually represented something, but the improvisation itself was demonstrating the act of creating science inspired choreography, hence a form of SC\textsuperscript{46}. I was surprised by this comment for two reasons. First, having assumed everyone connects with SC, I had dismissed the opportunity that there was somebody who was confused. And second, because one confused person in a classroom often means many more than that, I was surprised that only two people in total expressed their difficulty in understanding the material. Considering that I was not aiming to teach the audience all of the things we did, but I aimed to show them what one could do with SC, my goal was still rewarded in the survey responses.

Several people saw an application potential of SC to education, choreography, and research (category 9). While I was hoping to get across the idea of what SC is, I was surprised to receive feedback full of exciting suggestions regarding its application in the three fields I studied (education, research, and performance). Several people found SC as a great way to engage younger (elementary school) audiences or kinesthetic learners. Targeting a different kind of learner was also what the professors I interviewed mentioned (see Results). Somebody connected SC to making presentations like those in TED talks. I cannot know if they had seen John Bohannon’s “Modest Proposal,” but if they have not, it is fascinating they made that connection. Yet another person saw SC as a potential tool for psychology research.

\textsuperscript{46} Science and dance interaction can create art, not just representational dances of scientific processes. Science can be inspirational, a source for choreography, and not the focus of the dance itself. This is seen in the work of many performing artists – Wayne McGregor, Liz Lerman, etc.
Here I agree that SC could be used to study how people learn, for example, and how that connects to emotional responses caused by music, visual elements, or movement. Maybe for future reference I should address ‘the potential of SC’ as a separate question in order to get more ideas beyond what I have discovered or suggested already.

From the ‘category 9’ comments I received, what struck me most was one stating that SC does not seem silly to that person anymore. Being able to change somebody’s preconceived notion of what is “silly” is really significant in my opinion. Although I can only reflect on the reasons about the potential this person saw in SC, I am very excited that my event helped “make some converts.” Probably the reasons for this effect do not lie far from the reasons why people feel more comfortable with SC over time (discussed in following chapter). I also think that the organization of the event contributed highly to that. Many people included positive comments on the content choice and the success of the event despite the audience’s lack of exposure to SC.

In conclusion, I have examined the success of my presentation/workshop on SC after my first semester of movement exploration. By analyzing the audience’s responses from a survey I distributed, I was able to understand what about SC works. I learned what their favorite parts of my SC workshop were, what excited them most, and what they found as unexpected (Table). There were various elements that grabbed the audience’s attention, which in all three cases related to nine categories: the space atmosphere and the event organization, the level of active participation and movement, the learning and creativity components, the social context, and the potential of SC for further application.

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47 This is one of the primary goals of my teaching assistant. Fukuoka, Y., “Science and Dance” Class Discussions, E. Georgieva, Editor 2012: unpublished for the second semester of my movement exploration, which is teaching a ‘science and dance’ class.
I further compared the survey observations with the interview observations from professors and winners from the “Dance your PhD” contest. Interestingly, the observations for the valuable elements of SC from the interviewed professors and the contest winners match many of the elements the audience from my workshop pointed out as “favorite,” “exciting,” and “unexpected.” How these elements explain why the level of participant comfort rose in comparison to the beginning, I discuss in chapter 5.

I am pleasantly surprised by how many important SC elements I managed to capture from the survey in a way that matches and expands the data from the interviews. Working with primary data such as the immediate audience responses, which are full of emotional phrases, exclamation marks, smiles, and exciting phrasing, has been thus quite rewarding because it provides me with evidence for the value of SC as a method of physical exploration, and also as a method of inquiry. The use of SC for conducting research is yet another exciting application of this interdisciplinary field. However, at this point I do not plan to include my observations from interviews with researchers like David Odde, who uses SC as a way to address questions in a science research setting (ref. Introduction)48.

3. 2. Teaching exploration 2nd semester (Fall 2012)

The goal for my second semester movement exploration was to implement what I had learned about SC from the first semester and lead an SC-based class with local students. In this way I aimed to build on my understanding of how SC works and what makes it valuable in an educational and service-learning context. In this section I describe what and how I taught, what difficulties and successes I had, and how my observations relate to observations

48 I have included my raw interview transcription in the Appendix, but due to time limitations, I am not able to address these results. They, however, should become part of my future studies on SC.
from the interview data. My notes are based on class observations, written work from the students such as class tasks and quizzes, and comments from the teaching assistant [59].

The course was planned to occur regularly once a week for 10 weeks\(^{49}\) and was attended by home-schooled students\(^{50}\) from the state of Connecticut, whom I found and contacted through some of their Wesleyan University collaborators. I chose to work with these students because in this way I could have a target group of middle to high-school age students with various backgrounds and necessities. I was hoping to address the needs of individual students, e.g., the difficulties they might have had with science classes, or the things they wanted to learn.

My initial goal was to create a performance based on the content of the class (although this was not feasible due to unforeseen circumstances) and generally I imagined the class evolving around choreography study, as well as around scientific concepts that would be helpful to the students based on their school level. This is why my first task was to determine what material to cover, which I did with the help of the students during the first class. I asked the students three basic questions to understand their motivation to participate in such an interdisciplinary class. These questions covered best and worst things about science and dance (separately), their motivation to go to class, and what they hoped to get out of it. The answers that amazed me most indicated three main things: dance might be harmful to the body, the students want to meet new people, and they want to understand how dance and science could connect and be applied to other concepts.

\(^{49}\) The actual course continued for fewer weeks due to unforeseen circumstances.  
\(^{50}\) Home-schooling is a type of student-driven education. The students do not attend any particular school, but prepare themselves individually and in order to graduate, they receive a high-school diploma after covering certain standardized tests.
For these reasons I designed a class entitled “The body: the place where science and dance meet.” With this I hoped to address healthy dance practice and how that relates to skeletal alignment and physiology, which led me to consider basic physics principles (gravity, forces, impact) that guide how we interact with the environment around us. I then decided to focus on the internal bodily environment (water, salt, nutrients) and the immune system. These science concepts I connected to specific choreography topics I wanted the students to master such as how to work with time (rhythm), space (levels, personal vs. external, physical vs. mental), energy levels, improvisation, partner work, release techniques, and choreography. Also, because the social aspect of the class seemed very important to the students, I included plenty of partner and group activities. For detailed descriptions of the class lessons you can refer to the appendix.

The class design basically allowed me to jump back and forth between science and dance concepts in a way that made the study a unique SC approach that does not fit any of the categories I used in order to define how dance and science interact (i.e. through directionality and destination). Because the goal was to learn not just about dance or science, but about both in the way they related to the body, I focused on what one can do with the body based on the knowledge of both disciplines. This centralized way of teaching (vs. collaborating with another teacher which was the original plan and which has been the practice with other SC endeavors) really empowered me to keep the class under control from the very beginning (by applying the movement rules I discussed in the previous section), with clear expectations and course plan.

While keeping the class organization for myself made planning easier, it somewhat limited my ability to approach the curriculum from different angles with a co-teacher. However, with my teaching experience in both science and dance during my undergraduate
career, as well as a varied science and dance background, I did not find it too difficult to design the classes. The most difficult part was deciding on what exactly I wanted to teach, but once I had a clear goal, coming up with warm-up, exercises, and homework tasks was relatively easy. I also made sure to have a range of things happening (exercises, discussion, video, creative parts) and a good pace to keep people engaged. This I found extremely helpful because I observed how quickly the students would lose attention if we stayed on a task for too long. (Considering that a person’s attention span ranges from 30 seconds to 5 minutes [5], I was not surprised that even in a dance class where they need to be bodily aware for most of the time, the students had a hard time concentrating on any single task for longer than 5 min.)

Interestingly enough, concepts such as good organization and clear class design, a varied choice of class activities, and class flow, have appeared also from the interviews with Wesleyan professors (ref. Results). I also found it hard to choose the concepts I wanted the students to take away with them from our SC experiences. Planning, too, required a good amount of time, especially coming up with a time-frame that was realistic considering the one-hour class time. I also quickly realized that I need to have back-up exercises and ideas in case of unforeseen circumstances such as dysfunctional technical equipment. These observations, however, do not seem to specifically apply to SC; rather, they seem to be valid about any general class design. In this way SC seemed to work as a catalyst helping me to identify general teaching issues.

Here I would like to describe briefly SC specific issues in class design by giving as an example how I approached the physics unit. First, I had to match the science concepts to movements through which they could be experienced, e.g., a hand falling freely or in a controlled fashion to talk about gravity, weight, and resisting forces. Second, I carefully considered how the science principles can inform the way we move through space, e.g., pain
upon falling can be reduced if the fall takes a longer time. And third, I used the combination of principles and motions to create a dance phrase that united everything we had discussed in class. Because I wanted to evaluate the students’ performance on this material, I administered a take-home quiz and I kept observations of their progress.

I experienced a problem with the observation due to a constant flow of students in and out of the class throughout the semester. Although some students were present from the beginning until the end, several more were present for only a certain period of time, which limited my opportunity to follow their progress. Although my original goal was to try to understand if and how the work in our class influenced the students’ performance in science classes in school, this was not possible considering the organization of the class. First, they did not have regular school teachers I could address to ask how they did, and second, even if I asked their parents, we did not meet often enough in order for the SC experience to have a significant influence on their schooling. Because of unpredicted circumstances, we had to cancel several classes which pushed back the curriculum and shortened it by four classes. This deprived the students from the opportunity to develop their own choreography by the end of the semester and perform it. My further comments are limited because of the timing of the course in respect to my thesis submission (the course finished after I submitted the work).

Considering these issues, I guess one of the biggest difficulties in organization of this class was to have students commit to it. I never perceived the students as non-enthusiastic about the class (SC), but I clearly understood their limitations to come to class for factors outside of their control. This reminds me of Kolcio’s comment on how there are many students (or professors) interested in SC, but due to other constraints they cannot engage in such interdisciplinary work [48]. This is why I believe that if one teaches a SC class, it has to be really centralized and supported by a bigger institution. Finding dancers for the whole first
semester of my movement exploration, for example, was aided due to a credit reward system at Wesleyan university. This was not the case during the 2nd semester exploration, which made the hourly meetings in the weeks when we met highly insufficient for the same kind of in-depth work, especially considering the less than a semester class span than in the first case.

Despite my inability to get a good qualitative observation from my SC teaching exploration, my concluding remark is that SC has a lot of potential to transmit complex material to students. I cannot judge whether the students I worked with were very enthusiastic and open-minded in principle or because of my enthusiasm and open-mind for the class, but I could definitely see their engagement with the material in a way that I did not expect. No matter what tasks and concepts I introduced to them, they attentively followed my directions and were neither science-, nor dance-phobic.

Bridging the two fields seemed to make a lot of sense, particularly when we covered the physics unit. Because we used the body to experience and derive physics principles, I was delighted to see how they conceptually acquired half a semester worth of physics from a regular college class in just two sessions of SC. In addition, I observed the students made very deep connections between science and dance, and in a way, prematurely predicted how they could use their SC knowledge. For these reasons I will keep teaching SC and try to design classes in settings which allow me long-term work with the students.

51 The dancers received a partial credit for their participation that counted towards their transcript and graduation requirements.
V. Discussion

1. Revisiting my initial goals

Because interdisciplinary work is increasing in importance globally, my goals in this study were to understand how science and dance interact in the fields of education, research, and performance and what the value of this process is. To begin with, based on a review of science-dance connections that occur in the three aforementioned fields, I have defined what SC is (chapters 1 and 2). Next, I wanted to know how SC is made and implemented in the realm of science education and performance (communication) and what difficulties and successes this process has. I explored this both through interviews with science professors and PhD students, and through my movement explorations (chapters 3 and 4). Last, in this chapter I aim to analyze my discoveries and explain how they can be framed through a general model in the context of service learning and democratic values as formulated by John Dewey [60]. I thus underline the significance of SC and point to future directions in the study of SC that need to be addressed.

2. What is SC? A connection between science and dance that educates and enables social transformation.

I started this work by defining SC as any intentional interaction between dance and science in the fields of education, research, and performance. Based on my research and data of what people considered SC, my definition of SC has evolved to include the concept of the discovery of the dance-science connection in itself and how this combination leads to a unique form that goes beyond any of the starting disciplines. Therefore I propose that SC is a form of social transformation because it challenges the existing definitions of what dance and
science are and how they are practiced. Here I list examples from my research that confirm this proposition.

The concept of the discovery of the dance-science connection appears as a common motif on multiple levels in this work. By this I mean the moment of discovery about the unique way in which science and dance combine. Whether in representational, conceptual, or applied form (elaborated below), the connection is unexpected, exhilarating, and groundbreaking for the people who come across it.

The emotional response for this connection is especially evident from the survey data I collected after my first semester movement exploration and also from the second semester observations. In the first case, multiple people commented on the uncommonness of science and dance interaction, which was both socially and contextually perceived. On the one hand, breaking the notion that science or dance can be studied or done in a certain way was a prominent discovery of several audience members. On the other hand, the institutional support for such interdisciplinary work was also surprising to them. As for the second semester, on the question “Why are you here?” most of my students replied they wanted to learn how dance and science connect.

The connection between science and dance has been a paradigm in science teaching and communication that stood out from many professors’ and contestants’ remarks. For the winners of the “Dance your PhD” contest, bridging science and dance was also a unique experience that allowed them to embrace their science work on a different level and communicate it to a new audience – the general spectator. John Bohannon, the founder of the contest, is proud of the contest’s ability to urge scientists to do something they would not

52 I refer to my interview data with Wesleyan professors and “Dance your PhD” contest participants.
otherwise do – to engage artistically and emotionally their audiences using their science expertise and creativity to connect various disciplines. Several of the winners shared how attitudes towards their SC and science work changed in a more positive direction after they won the contest. A greater understanding of the value of SC, together with the popularity of the contest, has thus been a catalyst for social change at a university level.

The power of science and dance connection to communicate science more easily has been acknowledged by multiple professors like Laura Grabel and Michael Weir. Especially when the interviewed professors compared SC to other preferred teaching methods, the use of SC as a metaphor – a way to embody processes that are otherwise too complex to be envisioned on paper – was a logical and an unusual realization.

Furthermore, professors like Amy McQueen and Katja Kolcio experienced the similarity between the creative processes in science and dance, i.e. running a lab or designing experiments is very similar to leading a dance company and designing movement explorations (ref. Results). Having experienced both worlds – science and dance research, and having seen that the only difference between them is not the process, but the matter the disciplines deal with, I strongly agree with this statement. The way I approach these seemingly different disciplines helps me connect them logically, and thus helps me to understand the idea of translating knowledge and models across disciplines. This is exactly what the PhD scientists seem to have done in their dances.

My results showed that the “Dance your PhD” scientists do not differ from dancers in relation to their creative processes. I attempted to compare the approaches to several basic elements of choreography making between the two groups, only to discover that there was hardly any difference. Beside the generally shorter time it took most of the scientists to put
their dances together, the choices they made in relation to music, choreography, and conceptualization were just as complex as those of other dance-based choreographers I had the opportunity to study, including myself. The dances did incorporate multiple interesting choices regarding the visual representation, they were clear and could convey the science concepts, and they were distinctively combining props with movement and science concepts. This “magical combination” is exactly what won them the top places in the contest. John Bohannon’s clarification of what a good dance in this contest would be considered also supported this claim (see Results).

While making the comparison between dancers and scientists is outside of the scope of this thesis, understanding the similarities (or differences) between scientist and dancer-driven choreography and research might be useful information for people from different disciplines (like art and sciences) who want to collaborate in the future. Here I want to refer back to the comments Kolcio and McQueen mentioned in their interviews, more specifically their amazement how similar the processes of art and science inquiry are, and how this realization helped their collaborations with scientists and dancers respectively (see Results). Therefore my recommendation to future SC-ers is not to look at how the people they work with are different, but how they are similar and how this informs their collaboration.

While the connection between dance and science seems logical based on the examples above, this is not necessarily the case for many other people. The fact that the dance and science connection has been and is still seen as unusual, suggests that these disciplines are indeed highly separated. Professors like Amy McQueen, for example, who has connected dance and science for years, have always remained surprised at how strongly people make distinctions between the disciplines. She explained in her interview how during a performance with Liz Lerman where she took part as a leader in an audience discussion, she
found it astounding that her conversation partners identified themselves based on “how much “science” or “dance” they were” [43].

McQueen’s point leads me to the body-mind separation idea I introduced earlier in my thesis when referring to the influence on scientific thought on the discipline division. The application of Cartesian coordinates, mechanical views on the body, and Descartes’s “I think therefore I exist” have had powerful influence on the way we view the body as separated from the mind, hence dance separate from science. Yet, because the mind resides in the body, an important future direction in the research on SC would be to point out how modern-day philosophies and cultural views about the world and the body fit, or favor, this kind of natural body-mind/dance-science connection. This could help us also understand why a certain sense of discomfort appears among SC participants and how it can be dealt with.

It is interesting to note that science philosophy and approach to studying a discipline has indeed influenced modern dance education to such an extent through Margaret H’Doubler. Surprisingly, a major scholar like her has made a direct translation of science ideas and methodology to develop an experience- and context oriented dance teaching vs. the very image- and rule-based one at that time. This innovation was not easy to implement, but once dancers and educators around the country realized the value of H’Doubler’s approach, her teaching has made a major shift in multiple dance programs around the U.S.

Looking at the opposite direction, as in dance (SC) in science education nowadays, I see a clear parallel to H’Doubler’s introduction of science methodology into dance. The introduction of an innovative approach like SC in science education can provide for the highly appreciated experimental and context-based learning, which in practice, is currently not available to all students. SC can thus be the tool for the sciences that science was for
dance at H’Doubler’s time. Although not easy to implement largely, SC can educate students in values of social transformation by allowing them to adopt an open-minded and creative thinking. Thus, SC will contribute to a significant change in education and economy if embraced on an institutional level.

3. How does SC work? Overcoming difficulties in social service

While connecting dance and science seems to be one promising way to educate students in values of social transformation, it does not mean it is easy to do so. SC might be cheap because by using the body as the experimental tool, it does not require something as expensive as laboratory equipment. However, it does require meaningful collaborations, substantial preparation, careful planning, and time for multiple revisions. For these reasons, SC is also difficult to implement on larger (number of students) or longer (time) scales, because the way in which the current educational or research systems are set does not support projects of such magnitude. Whether university curricula are too packed or laboratory life is too intense to allow for “extra” interdisciplinary work, the conclusion is that many people fail to engage in SC regardless of their preference to do so. All of these issues are also related to funding, which is mostly available to bigger institutions (like grants from NSF, NEA) rather than to individuals, especially in the current economic condition. This basically “leaves the ball in the hands” of institutions like universities or wealthier magazines like “Science” to decide the long-term fate of SC. This process seems to be similar to the role of universities in the transformation of American dance education from the past century. H’Doubler’s ideas

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53 While I promote SC’s potential to make a major shift in science education, I do not want the reader to think that SC is the only tool that can do this.
might have been very progressive, but they have only made a difference on national level because the big dance educational institutions embraced her teaching methodology.

While waiting for other universities across the U.S. (e.g., beside Wesleyan, Wake Forest, or University of Minnesota) and around the world to incorporate SC in their priority lists, I have to acknowledge multiple people who engage in SC on a much smaller scale. These commitments are often on voluntary basis, related to social service, or based on raising awareness causes. This is true regardless whether I refer to the multiple collaborations between professors from dance and science departments, scientists with dancers, professors with local teachers, or my own movement explorations. Despite the constraints that all of these people have faced in the context of their socio-economic systems, the fact that their love and interest for SC has been flourishing rather than dying out in the past ten to twenty years, points to the power of the internal satisfaction engaging in SC provides them.

4. How is SC implemented so successfully? What is its value? A method for reflective inquiry, democratic community, and learning through embodied experience.

Both science professors and PhD students shared how the non-traditional approach of SC to their work has brought about rewarding moments when they experienced the success of SC among their audiences. It has also contributed to the diversification of their professional life and therefore their interest to engage in non-traditional methods for science communication. And last but not least, both professors and contestants reported predominantly positive emotions regarding their SC experience (despite the difficulties they have had), they are all still involved in SC in one way or another, and they highly recommend SC to other people.
Some of the differences between the impact of SC on professors and contestants lie in the way they applied SC. Clearly, in the case of the “Dance your PhD” contest which was an extra-professional activity for the researchers, for some SC made a significant difference to their social life and how they communicate science to the people outside of their work circle. On the other hand, SC influenced the professors mostly in their professional sphere, which is where they were also applying SC – to teach science to students. There were, of course, exceptions where in the first case the contest influenced the research of a couple contestants (Goldberg and Miler, see Results), and in the second where it influenced the personal life of a couple of professors (McQueen and Grabel).

Although some might argue that these SC participants have been predisposed to think of SC positively, I do not consider this possible because my data points to the fact that SC is not met with high enthusiasm throughout, but SC can “make converts.” There are several findings that support this notion. First, the study of Weir et.al showed that only about one third of the students participating in SC actually felt comfortable from the beginning, but then 94% did by the end. Second, some “Dance your PhD” scientists needed their colleagues’ or friends’ encouragements to start the contest, but really enjoyed the process by the end. And third, the comments from my movement exploration survey stated how pleasantly surprised people were by the level of comfort they found with SC.

So why do students (people) feel more comfortable with SC at the end of their participation than at the beginning in classroom and workshop settings? Why does SC cease to be “silly” and what makes it seriously engaging among observers or participants? This observation can be explained by several factors and how they contribute to fair treatment of any SC participant. These factors relate to the presenters or leaders: having clear guidelines and participant expectations, beginning energetically and creating a welcoming atmosphere,
exhibiting enthusiasm and encouragement employing a variety of activities and media, including active group participation. Hereafter, by discussing the factors that could have influenced the success of my first semester presentation, I make a parallel to the success of science classes taught by Wesleyan professors, and of the dances from the “Dance your PhD” contest.

First, setting a tone and clear rules, spoken or unspoken, at the beginning of any untraditional work involving SC is based on my observations one of the most useful habits for any science choreographer. For my workshop and class I borrowed from Elizabeth Johnson three basic rules. These include: 1 – “You are highly encouraged to participate throughout, but you are the owner of your own body and you decide what to do with it and whether to participate”; 2 – “If you choose not to participate, you have to observe and reflect on why you made that choice”; and 3 – “If you don’t feel comfortable to be in contact with other people, it is ok to define your comfort zone.” These rules helped establish the audience’s active engagement and responsible participation throughout the activities.

Another related factor that might have influenced the level of participation for the audience is the very beginning of my workshop, which started with the “Walk and Talk” exercise. As the audience started moving in the space with the dancers, one of the unspoken rules in the presentation was that passive reception should be discouraged. Likewise, I have noticed that Elizabeth Johnson’s workshops often started with a full-body shake exercise just “to get the blood going” and to set the tone of “we’ll be moving today.”

Second, the encouragement for active participation seems to be also just as important for setting the tone of any SC activity. Along with stating the rules, I had observed multiple times that Elizabeth Johnson brings a vibe of energy in the space along with the words “There
is nothing right or wrong, this is a place for exploration,” Because these words seemed to encourage people try out new things, my dancers and I kept a positive and encouraging attitude throughout the workshop.

Third, along with the clear guidelines and an energetic encouraging start, I have found that a well-articulated outline of the goal of the workshop helps to give people some expectation to hold onto, which gives a meaningful framework to otherwise unusual exercises. Specifically for my presentation, I made clear that the goal is to understand what some of the potentialities of SC are by sampling different activities. I utilized this approach because I am used to framing my science talks in a similar way, and because this is a pedagogical “trick” I noticed while reading Meyers’ book “What is good education?”[5]. My approach in framing the workshop seems to be one of the recommendations Weir had for other educators (see chapter 4 - Results).

In summation, a warm-up and an introduction, which might have different purposes in different contexts, are the activities that set the rules, expectations, and tone for a SC class or a workshop. For these reasons, they are a very important SC component that engages the participating audience from the very beginning. What keeps the audience engaged throughout is the variety of exercises that follow – a professors’ recommendation. During my workshop, for example, the dancers helped me keep the pace and the flow by introducing the concepts one after another, while I was keeping track of the transitions. Thus, the variety of exercises and constant flow between them must have allowed different audience members to grab onto the most interesting aspects of SC without lingering for too long on anything in particular.
Similarly, this flow effect was observed for the range of setting elements (e.g., space, music, lights, etc.) that the audience members could experience during the workshop. Multiple people rated performance elements such as music and lights as their ‘favorite’ or ‘exciting’ or ‘great’. Maybe the dimensions of the physical space and how they evoke emotional response from an audience are also one important factor for the comfort of the SC participants. Although the importance of the set up was only briefly discussed from the professors and the contestants, I argue that the environment allows for specific SC qualities to stand out. For example, the environment of the dance studio in which I held my workshop promoted a certain sense of equality among the participants, because they had to share the dance space with the rest of the audience throughout the time. In fact, because sitting might have made some participants stand out when not participating, they might have been by default involved.

And last, relating to this notion of “standing out,” the level of comfort with SC among the participants during mine, and other workshops, might have risen because the activities have involved group dynamics that do not single out individuals. I have observed that often it is usually the teacher or the leaders that get the attention on themselves and the participants are noticed only to be praised for their collective creativity and engagement. Being and creating SC together, i.e. the importance of the social aspect, came out of many of the comments from the survey after my workshop. This social aspect was perceived as very exhilarating, surprising, and stimulating for the participants. The social aspect of creating and/or sharing SC has been just as important for the “Dance your PhD” contestants as well.

54 In preparation for the workshop I paid special attention to design the activities in a way that would not draw the attention to any single individual, yet would leave plenty of space for individual actions in the context of the group. This was also true for my dancers, who received some attention for the sections they led, but only one at times throughout the workshop, so they did not have the pressure of drawing constant attention.
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With this section I have analyzed several aspects that influence the SC’s practical implementation through the comfort level of the different participants. As qualitative, my research points out several environment- and leader-dependent factors that, if analyzed further, might give insights into why SC can be so successful in an educational, performative, or more general setting. These factors relate to group participation, enthusiasm and encouragement from the presenters (workshop leaders), energetic beginning, variety of activities and media utilized, as well as clear guidelines and participation expectations.

Although not in the context of SC, there is plenty of psychological literature on group dynamics or on the role of teacher’s enthusiasm for student motivation, as well as pedagogical literature on how class organization and choice of content, class flow, and stimulating social environment contribute to higher quality of learning and participation among students. This information leads me to suggest that there might be many similarities between the pedagogical rules in leading SC workshops and any teaching. For the future implementation of SC, this means that SC could be much more accessible for educators than originally thought. Moreover, the factors required for a successful SC event could serve as a model list for anyone willing to incorporate non-traditional learning methods in a classroom.

Beside this value for educators, with my data I have suggested how valuable SC is for learning in general – SC promotes deep thinking and creativity, making of emotional connections with the material, finding relevance to self and a bigger context, and experiencing memorable hands-on activities. SC is thus appropriate not only for non-science-major students or science-phobic audiences, but also for higher level science works which include very complex ideas (ref. Results).
Further, SC can be applied to a variety of science subjects from ecology and evolution, to biochemistry, and ethics, social sciences, as well as non-science subjects. This is obviously supported by the diversity of workshops, dances, classes, and performances I have mentioned in this thesis. The age of the students or participants also does not matter based on my survey and observational data: whether college, high-school, middle-school students, or adults, they are equally surprised and affected by their embodied experiences. SC’s effective application mostly depends on the teacher preparation and ability to lead an embodied experience\(^{55}\) in a clear, structured, enthusiastic way.

SC seems to have received predominantly positive feedback in short-time workshops like those at Wesleyan, or in dance making context of “Dance your PhD.” However, biases and discomforts with SC have come up in longer term projects such as “Body Languages: Choreographing Biology”. Like Kolcio said in her interview, meeting and challenging the expectations of students of how science or dance education should be done might be especially difficult in long-term SC projects. Therefore answering the bigger question, why people (students) embrace SC more whole-heartedly later rather than earlier, should be reviewed for short-term vs. long-term SC projects, the context in which they were made, and how it matters. Educational level, the kind of academic subject taught, the number of leaders (educators), the class grading, the expectations for students, cultural assumptions, and gender differences are just a set of the topics that future research on SC needs to address so we can understand whether and how these factors increase the influence the long- and short-term success of SC.

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\(^{55}\) An embodied experience in SC refers to an activity that intentionally and explicitly connects scientific concepts with movement.
Before ending this sub-section, I would like to comment on the relatedness of my research activities. It is interesting to note that I made the presentation (in May) before I interviewed the contestants and the professors (in October) and before I knew what their recommendations were going to be. Regarding this, I am glad that my intuitive movement exploration and survey data was able to extract not only a good amount of the information that came from the professors, but also gave me more material to reflect on why SC works for different people, which I will discuss below. In this way, the detailed interview study gives me the confidence that my presentation observations and received feedback are valid contributions to unraveling the complexity of SC’s successful implementation and value.

SC’s value is principally based on three concepts: first, SC can bring together two fields like dance and science and promote accessibility and inquiry to both in a unique manner that the fields cannot do separately; SC has the potential to make a strong influence on various people’s professional or personal spheres of life independent of where they encounter SC; and altogether, SC’s greatest potential lies in the fact that it can simultaneously affect and transform multiple fields of social life, i.e. education, performance, and research, through embodied emotional experiences and can thus highly contribute to education in critical citizenship.

5. **Relevance to Dewey’s educational model for service learning in democratic values**

The idea of SC’s potential to promote education in critical citizenship is especially clear when I trace how my results defining what SC is and how it is successful and valuable find their place in a service-learning model originally constructed by John Dewey. Dewey’s contribution to service-learning was framed by John Saltmarsh in a five-step model
underlining several democratic community values [60]. The model includes five points related to (1) linking education and experience, (2) democratic community, (3) social service, (4) reflective inquiry, and (5) education for social transformation (Figure below). As such, the model expresses the most important components, according to Dewey, of a good educational system with values imbued in democratic learning. The reason why I put SC in the center of these five interconnected ideas is because SC is and/or can do each of these things.

First, I argue that SC is capable of linking education and experience. This is easily supported by the professors’ interview comments and my own movement explorations. SC, by definition, is a science-dance interaction through embodiment, and embodiment implies
bodily experience in itself. When introduced as a tool in education, SC is the means allowing students to make sense of, learn, and explore concepts directly through kinesthetic experiences. Further, the involvement of body and mind reveals SC’s value to model emergent properties which none of the fields, dance or science, can do separately. This idea of SC as an experiential education was also present in the surveys from the first movement exploration, and I used embodied experience as a way to teach science in my class during my second movement exploration.

Second, my results show that advanced modeling allows the students to engage in deep thinking and hence reflective inquiry based on the strong emotional connections they make, not only to convoluted science concepts, but also to emergent properties and global concepts. Because of its potential to be a research tool, SC has thus allowed me to reflectively approach through my movement explorations what SC actually is and how it works.

Third, SC can provide the grounds for a democratic community. Because lack of method diversification disadvantages students who have different learning styles, bringing of SC to the classroom allows equal learning opportunities to these students. Through an encouraging environment, clear setting, and place for exploration, SC can offer multiple levels engage its participants through emotion, observation, creativity, and reflection.

Fourth, SC is inherently a form of education for social transformation, for it bridges disciplines like science and dance that are otherwise seemingly separated. This has come across throughout my data – interviews, observations, and explorations. SC contributes to breaking assumptions about what science or dance (education, research, or performance) can be, and stimulates new ways of thinking across disciplines. SC allows us to see the connections in creative process between the different disciplines and translate ideas between
them. And last, SC can give us a direct way to approach global issues related to our environment. By helping us to understand them and our place in these contexts, SC can empower us to make informed internally motivated choices.

And fifth, SC has been and is a form of social service. Whether through the service work from the Liz Lerman Dance Company, through the outreach by Wesleyan professors or scientists from the “Dance your PhD” contest, or through my course with local students, SC has found multiple venues to impact the communities in which it exists. Because of the untraditional approach of SC to issues and concepts, SC both originates from and disseminates to the community through a lot of art- and voluntary- work.

To sum up, fitting SC in Dewey’s model allows me to frame SC’s place in the fields of education, research, and performance, and therefore in our society. Through this analysis I aim to affirm SC’s potential to make a difference in a world that embraces values for critical citizenship. This somewhat philosophical approach to SC is thus the synthesis of my qualitative work for this thesis and provides a base for reference and future studies in SC.

6. Future directions and unanswered questions

Now that I have done the major review of SC and studied how dance influences science education and performance through interviews with professors and PhD scientists as well as through movement explorations, I would like to list the questions that I leave for future research.

First, by concentrating on dance in science education and performance, I have briefly touched on the section about how dance, and SC, can be applied to science research. Understanding this process would be of great importance for researchers across the world.
Considering the growing weight of interdisciplinary research in general, addressing the limitations and potentialities of SC as such a multidisciplinary approach is very important.

Second, for the same reasons mentioned above, I have omitted to talk about the dance side of the SC interaction. Interviewing dance professors, choreographers, and researchers would be a crucial step in understanding the other side of the coin, i.e. how science impacts the dance field and how interdisciplinary work like SC is perceived in the dance world.

Coming back to what I have done already, it would be important that my study is expanded on also in the science world. Additional interviews with science professors and educators outside of Wesleyan University who engage with SC in their classrooms would probably add a lot of intriguing information about SC’s potential on university and school level. Also, my study about the contributions of SC to students’ development from the educators’ side only misses a whole set of primary student data required to understand why and how SC is successful in an educational setting.

In a similar fashion, the lack of data about other scientists from the “Dance your PhD” contest leaves my conclusions from the six I interviewed only as a basic frame. It would be helpful to understanding how the non-winners perceive their SC engagement and how that affects their social (or professional) life and if that differs from the winners’ perceptions. Also, I have not analyzed or studied in detail any of the dances and how they have been approached. The PhD contestants alone have opened a whole new, or better to say, a well-forgotten, page in dance-making that is by no means irrelevant to the choreographic and historical aspects of dance studies. In this respect, it would be interesting to trace how the contest develops in the future and on what factors that process depends.
As for my movement explorations, and more specifically the first one – movement research and a workshop-presentation – I would be very interested to discuss and compare my approach to SC with other dancers like those from the Liz Lerman Dance Exchange, or scientists like David Odde, for example, who have a lot more experience in exploring and creating SC. Informing my own practices through their work would help me identify the conceptual biases I have inadvertently introduced into my embodied work and analysis in this thesis.

In my second movement exploration – the class I taught with home-schooled students, I only sampled how useful and successful the SC approach is for the students. A future step would be to allow myself much longer time to lead such a class and be able to trace the progress of the students from the beginning until the end. Further, I would like to know how exactly SC’s implementation promotes an emotive force and kinesthetic potential and how these two work, psychologically speaking, towards effective learning.
VI. Conclusion and personal stance

This work, being the first of a kind to study and examine as a whole the interaction between dance and science in the fields of education, research, and performance, opens space for further research to address the numerous questions that I have not been able to provide answers for. My study has been just the beginning of understanding what science choreography, SC, is, which is why I have aimed to be as comprehensive as possible. While some quantitative data would have been extremely supportive of my research, the re-definition and growth of SC as a novel field, while I am writing, has left me with the important task, and limitation, to make sense out of everything that has been done so far. My original goal was to create a thesis that serves as a guide for me and other SC enthusiasts. However, I quickly realized the importance of my research as a way to codify and put into perspective the field of SC. With my research I have not only managed to address the questions such as what SC is, how it works, and why it is successful, but I have also managed to show how this unique connection between the originally separated fields of dance and science is valuable for all of the SC participants and society in general.

During my study, I was surprised to discover how unbelievably connected science and dance have been in the past century and much much earlier (e.g., Galileo, ref. Introduction), and how this union has thrived on multiple levels in the performance arts and sciences especially for the past twenty years. What has left me even more perplexed was that despite these science-dance connections I have identified, science and dance have been and are still considered separate disciplines with more occasional, rather than deliberate, contact between them. Surprisingly enough, there has been renewed interest for the art-science interdisciplinary contact, which is present especially in academia, but and also in research and performance.
More and more science educators realize the education value of experiential and embodied practices for learning and creativity, and try, through SC, to address the labor market hunger for scientifically engaged deep thinkers [61]. Especially with the global crisis, there is the so-called U.S. renaissance in the STEM (Science, Technology, Engineering, and Math) which is counted on to rejuvenate the economy [61]. Along that line of thought, STEM has evolved to STEAM to include the Arts, because of their apparent value to promote “attention, cognition, working memory, and reading fluency,” [61]. Dance’s ability to develop the brain specifically, was laid out in a report by the Dana Arts and Cognition Consortium in 2008. The report suggests that early exposure to dance (through consistent training) might enhance the link between learning by doing and observing [62]. Further, the arts can “contribute amazingly well to learning because they regularly combine the three major tools that the mind uses to acquire, store, and communicate knowledge: motor skills, perceptual representation, and language [61].

Considering these contributions of the arts to the sciences, also supported by my data on SC’s potential in education, I have not been surprised to find a lot of positive comments posted under John Bohannon’s “Modest Proposal” performance on the TEDx website [52]. Many educators, for example, were inspired to share the potential they see in the bridging of arts and science in the school curriculum. One says:

“Re-Creating” a marriage between Art and Science could help academia better communicate and transmit knowledge to its viewers. As a high school dance educator, I firmly believe this experimental teaching method would engage our youth, and attend to the different learning style of our students, providing evidence of the Arts’ impact on education. This collaborative approach to education can render clarity and depth of content to the learner, and provide a more enriched learning experience for the students.”

Another goes:

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[56] Dr. Jerome Kagan, an Emeritus professor at Harvard University and listed in one review as the 22nd most eminent psychologist of the 20th century [58].
“This is a perfect example of why Dance should be incorporated in everyday learning for young students. It ignites the brain and the body to want to explore education through movement. (…) Some of us are audio learners and others are visual learners, using dance vs. PowerPoint gives the students an opportunity to engage in their type of learning, for me I am a visual learner and the movement clearly explains the experiment in a way I could understand.”

Others comment on dance’s powerful way to communicate ideas,

“John Bohannon’s radical idea (to “use dance to explain all of our complex problems”) highlights the great need for the arts as a means to connect people to one another, to their environment, and to the issues surrounding them. (…) Dance speaks powerful messages, but we need to cultivate a broader audience base to ensure that those messages are heard.”

or, on the powerful symbiotic relationship between science and art:

“We need the metaphor and humanity of the arts to work symbiotically with the theory and discovery of science. Without science, the arts lose their context, necessity and import. And without the arts, science loses its passion, heart and impact.”

Studying the content of these comments and analyzing how they relate to other discoveries in my thesis is a project worth attention of its own. However, I want to point out how Bohannon’s talk has inspired multiple comments (260 for the first year since it was published) that touched on several crucial aspects of SC and how SC relates to the world. These include: the appropriate nature of Bohannon’s proposal, the role of dance in arts education, the connection between science and dance, the necessity for innovation in presentations, as well as many others. The quotes have especially stimulated my desire to frame SC’s value in a bigger picture and provide plenty of “food for thought” for the reader.

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My concluding remark is that SC, as a field intentionally connecting science and
dance through embodiment, has a lot of unrealized potential to change not only its destination
application fields – education, research, and performance – but also communal thinking and
values for future societal development. As such, I hope that SC’s presence and my work will
not remain unnoticed, and that much more scholarly research and implementation will follow
my efforts to define SC in a broader context. With this, I wish my readers productive science
choreography encounters that build on and redefine my pioneering research.
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VIII. Appendix

1. Dance in Science Education – interviews with Wesleyan professors

   1.1. Cohan, Fred

1. What is your dance background? Have you experienced this often perceived dichotomy between science and dance?
No dance background;

2. When was the first time when connecting dance and science just made sense for you?
When a number of his colleagues engaged in the Liz Lerman program; in his mind it made a lot of sense; because when he learns something technical or abstracts – he sees it something abstract he knows about (baseball…) ; understanding through their own metaphors; maybe dance will help people learn things;

3. How do you use dance in your science teaching? Did your work this out from someone else, did you create the idea on your own, did you practice, or did you experiment with your class?
The most successful – twice now; into biology class – have a lesson on the origin of species using dance; in talking to Elsie Johnson, limit it to 30 people; he gave extra points for people to come; outside of class, extra credit;
He had just read about Fredrick the Falconer – interesting ideas about the origin of species; idea that can’t there be connection between; you can’t put the head of sparrow on a eagle; different parts of species were not interchangeable; boundaries on interbreeding when two populations are starting to diverge;
5 or 6 groups- come up with a series of dance moves – how a species moved from a place to its food to; 4 motions; then pairs of groups – how well the hybrids do – two steps from each gr; other species – impeding motions; get students thinking more metaphorically about difficulties in how maladaptive it is to mix adaptations of different species; some said now they really get it…; two species had to avoid interbreeding;
Anonymous evaluations – positive
Developed – with Elisabeth; took them long;
Before – “Global change and infectious Disease” – he wanted to do a simulation of lime disease of ecology; why a forest full of deer mice – vs. more species; set up the model; diff. properties of the infectiousness;
Run a model – have the people be a model; 2 mistakes – 142 students – too many; since they were trying to collect data, it was very important that students were rigorous how to follow the rules; and the data was not so good; then he realized that it is something visual and physical to enact an idea, collecting data, bad idea, it might be easier to do on the computer; have smaller group – focus;

4. Why did you decide to use this in your teaching? How long did it take you to develop this and implement it?
Joke” the “ – the end result was so simple – and they had gone through a lot of things - to arrive at the goal “ what happens when groups with different adaptations come together” -
Liz, Elizabeth, and he met in Usdan – had an hour to talk about their project; most of the progress – telephone; over weeks – couple of hours of telephone and follow up e-mail; and then met before class; a lot of time – over period of 4 weeks; not something quick;

5. What keeps you engaged in the process? Would you keep using this and why/why not?
The metaphors are important in understanding abstract ideas in science; then having read the evaluations – 90% were really enthusiastic and they learned something, a good intuitive understanding they wouldn’t get other ways; as long as Elisabeth can keep coming;
In collaboration with Katja – had her students interested in Biology– assist;
6. What difficulties have you had? Successes? How do you know what worked out, from students’ comments or your own perceptions or anything else?
They don’t get the extra points unless answer the survey
The 10% - “why do you need the dance” “that was obvious anyways” “are you kidding me”; some minority think it’s stupid; and maybe 95 had fun;
Elisabeth – warm-up – music; by the time you got through her warm-up you are part of the crowd to explore – self-conscious; for the shy students;

7. What are the things one should beware of when using it? Helpful suggestions for other educators…?
Size of class, space; the metaphor has to be simple; the idea should be complex enough and out of the ordinary thinking of the students to be worth to use it;
It takes a long time;
Cannot do it without the right energy of the class, the right person – engaging, warm-up – Elisabeth;
8. What is good teaching in your definition? How does (if) dance incorporation fall into this category?
Deals with trying to put complicated ideas within the reach of students who haven’t though about it; there must be gazillion ways to do it; he likes metaphors; Steven Jaygould – he loved baseball and he put it into his published biology work;
9. How has it influenced your academic, social, personal life? Has it had any undesirable or positive consequences?
Don’t know; dance work – limited academically – this one exercise; positive;
10. What is the future of SC in your opinion? Why is it beneficial to incorporate it into academia? What is its value?
Teaching abstract concepts; one thing that is limiting for dance – for him it makes more sense to use other metaphors; in writing it’s hard to use; he doesn’t know about it; it would be a limited audience; writing about dance would unlikely more clear something; but doing – it would be much more clear;
He couldn’t use it; the movement is its value – for his capabilities;
11. Have you thought of using SC in your research, and if yes, why would be feasible/impossible to use?
It doesn’t seem easier to use people to simulate a data; it’s easier to do it mathematically; understanding concepts from movement – physical metaphors;
1.2. Grabel, Laura

1. When was the first time when connecting dance and science just made sense for you?
Liz and Elizabeth (2005) were here and planning how you were going to take these concepts into the classroom. Liz – what is difficult to teach in the class – the menstrual cycle – complicated cascade – her idea to do a gestural dance; did it then – really fun, really engaged and surveys to support their learning, particularly about those; who have ; an aha moment; have been using since

2. What is your dance background? Have you experienced this often perceived dichotomy between science and dance?
Started dancing when 5; mostly modern; in NY; the new dance group – young choreographers- kept dancing straight through, danced in college, some choreography, in grad school – apprentice in a company in San Diego and san Francisco; always took classes; always a separate thing, never related it; back in the 70s – exceptions – the ribosome dance;
Honestly – much more interdisciplinary things now, people are much more open now to that;
Not like hiding my dance self , but if she tried to link them, she’d loose science credibility, and the dance world would be unwilling to accept it, science-phobic dancers;

3. What is good teaching in your definition? How does (if) dance incorporation fall into this category?
Seeing the value of body learning – started with non-major students; with those not interested in learning science or having hard time; many were relating easily to dance; initial justification – to help the students to learn in a different way ; good education tries to teach everybody even if they are different learners; since then, it can be used in sophisticated model building in advanced classes; thinking about ethical issues across science, also in more complex ways, help students go beyond, participate in model building can extend the classroom experience (workshops) ;

4. How do you use dance in your science teaching? Did your work this out from someone else, did you create the idea on your own, did you practice, or did you experiment with your class?
“it’s easy to think it’s easy” – it’s difficult to come up with a module that works; spent a lot of time how you are going to do this cycle; any time involving this in the class has involved a lot prep ; “just embody disaster” ; how do you get them thinking, size class, how music? Many factors - ; took ; genetic testing modules – expected 40, got 140 students; also willing to experiment and fail – taking that paradigm, figure out why, and how it’s going to work; certain amount of bravery; the rewards are worth it;

5. Why did you decide to use this in your teaching? How long did it take you to develop this and implement it? She uses it in every course; at least twice , or 3-4 times – depending on the class and initial response ; it takes less time now, but at first – 3-4 hours for 20 min module; once done it, about 1.5-2h; a lot of colleagues are doing this – Lane, Singer, Weir, Manju, Amy…

6. What difficulties have you had? Successes? How do you know what worked out, from students’ comments or your own perceptions or anything else?
One of the things- early on that told – students took the dance into a café and were performing it there; they were using it in a real way; students would ask more; ethics – ask a questions; the students liked to talk to each other- not in an arbitrary way, got to hear the point of someone else they don’t hear; tries to use tools for material she wouldn’t ordinarily use it for;
Survey for the last 2-3 years; also in a summer workshop; and sometimes when doing outreach;
Generally not a lot of comments in the students evaluations because they were not many modules; mostly positive comments; that’s why they went to the surveys; why not comment – not main focus; sometimes students share their comments personally – always students – who don’t enjoy – always ”turn discomfort into inquiry”; rarely – occasions – people who choose to sit out; these were not ready; in the survey – these are the people embarrassed moving; In the workshops – at beg – end – discomfort disappears; unknown, bodies, shyness; have to be aware of that; don’t make everyone do it, if they don’t want it; don’t be judgmental;
7. What keeps you engaged in the process? Would you keep using this and why/why not?
As long as she has to teach – it makes it more enjoyable – it is a change of pace, wakes people up, allows info to come from them rather than from her ( ask a questions, walk and talk); she doesn’t see stopping SC;
8. How has it influenced your academic, social, personal life? Has it had any undesirable or positive consequences?
Scientists – friends and family – helps her talking about her own work using embodied; plus; they’d be less likely ; helped her learn how to explain things in a different way; the only negative – some science colleagues see it as silly and frivolous, and how do you deal with the negative response – data helps – students ; if point out that scientists have different learning styles that gives it credibility; not always ready to listen;
9. What are the things one should beware of when using it? Helpful suggestions for other educators…?
Beware – don’t think you can be casual -; get feedback from other people; really understand why it is you are using and how you are going to use it deeply;
10. What is the future of SC in your opinion? Why is it beneficial to incorporate it into academia? What is its value?
In general there are more people thinking in these lines, NSF, NEA – endowment of the arts; collaborations like this are becoming more typical and less bizarre; there are conferences; a more acceptable mode; it will never be mainstream, but it’s ok; it’s important to have it as a resource and option;
Two things – idea of reaching to students who are kinesthetic learners, and reaching through art- the science-phobic students;
11. Have you thought of using SC in your research, and if yes, why would be feasible/impossible to use?
Harder to integrate it in the research; last week – one of her student; she had you embody the growth of a primary cilium organelle; it was helpful from basal body – centriole – that was useful in understanding of their understanding of that structure; moving into the research domain; when the visual model Is static or not as revealing, it helps to put it into; Consciously – not finding a way in which it informs;
1.3. Katja Kolcio

12. What is your dance background? Have you experienced this often perceived dichotomy between science and dance?
Dancing most of her life, folk and modern; always seemed a normal thing; dance as integral to the way she lived day to day, always interdisciplinary in the social sense, politics, anything ropology;
Never took science basic school minimum; only through dance, body mind centering she became acquainted with science, developmental movements;
Dance – the antithesis of science; she thought dance countered science; except for the fact that both use lab work central to their experiences and practices, thought it was interesting; always had a curiosity about science; she has assumption about connection she might not know, that’s why she started working with scientists;
Manju seemed to think similarly to Katja – interest in her way of thinking;

13. When was the first time when connecting dance and science just made sense for you?
Graduate studies in dance;

14. How do you use in science your dance teaching? Did your work this out from someone else, did you create the idea on your own, did you practice, or did you experiment with your class?
2 things – 1st – very basic level of science in dance because she has little knowledge of science; skeleton, alignment, breath, how the body functions in technique class; a bit in dance education, no unit on it;
2nd – MBB course – exception because she wouldn’t have done it without a scientists, she learned a lot of science; doesn’t happen normally;
3rd Barry Chernoff- environmental science- take it much deeper – respiration – what happens in nature –she talked about breathing; relationship with that; very exciting and interesting, but not without Bari;
Both were very important – why? – Bari – first, Katja countering the idea of the body as machine; never considered the relationship of the body in a relations of a larger ecosystem; it horrified her; if we paid more attention, we might live differently and might not encounter some problems; still figuring out how to make this part of her teaching; how strong blinders in a discipline if they are not looking around; one can forget if they don’t look out; same with Manju; how important it is to take off your blinders

15. Why did you decide to use this in your teaching? How long did it take you to develop this and implement it?
Bari – 3 modules; met about three times to prepare about an hour, not that hard;
Reasons – curiosity, with scientists clearly interested in art, the institution allowed it;
Wes had the “Creative Campus Program”; the department found someone else to substitute her regular class for interdisciplinary one; many people are interested but cannot find the time or flexibility; same for students;
Manju – hours and hours many 3x times more for every class; also met outside of the semester; and she read 3 textbook and she attended a science class before; that’s the difference between modules vs. collaboration;
They didn’t want to decide how they should belong together – wanted to ask the students how these fields should think about it; presented three models, but this is not the only way they can interact; a lot of people had a bias they don’t’ fit together
The future of scientific study and of us understanding what this is depends on finding more creative way in thinking about things; it would be inappropriate … They didn’t want to give a list, blinders; how can we use the mix to ask new questions, think in another way; what they wanted; at a college level it should be more than a mitosis dance, and what are the implications and what they might do with that; 3 ways in which they connect; 
1 representation; 2 experiment on the body; artists that practice growing extra body parts; let’s play… if you are studying cellular respiration, you can do a mediation around that; if working a circulatory system, you can have experiential learning – similar to my class; doing physics; 3 imagination – rather than modeling, how can it aesthetic question be raised, how do you ask this question beside that questioned; with dance into it – it is more quickly – to go those questions – for non-science people; how do scientific models get determined -0 because they are pleasing; science is not neutral, not objective, how do you make those choices; aesthetics and politics are very similar; 16. What difficulties have you had? Successes? How do you know what worked out, from students’ comments or your own perceptions or anything else? The way they constructed it – hard; Challenges – coming up against biases; against science and dance what they are supposed to be; same with science; intro class – on both disciplines – sitting In the classroom – comes with science; they wanted rigorous learning … if one is not meeting one’s expectations, it’s not as rigorous ; Funny how people don’t believe how rigorous Manju is or Katja; this kind of work takes away from the rigor; The students did not believe how well their dances were; they were pushing them; disconnect between what the students thought they got, and what the experts thought; and that’s why the evaluations were not so good, and Wes goes by that; from a scientific perspective they were making equally profound observations; Maybe if it is longer than a semester, in three months; students that keep working, different; Hard to figure out what questions are most fruitful; many of these dance science collaborations have had similar kinds of evaluations; 17. What are the things one should beware of when using it? Helpful suggestions for other educators…? The main thing – have to have a good relationship with someone when working; have to be invested in the collaboration; bottom-line; It helps to be very clear – students to know what to expect; day 1… Preparation takes more time than you think it would; especially with dance; if you want to breathe, you have to have time for it; you need extra time, lab; TA: 18. What is good teaching in your definition? How does (if) science incorporation fall into this category? Is connected teaching – whatever connects beyond, no blinders – talk about the relevance in a larger context; science is one way to do that – go beyond; she believes in interdisciplinary work not only science; 19. What keeps you engaged in the process? Would you keep using this and why/why not?
I would – every opportunity possibly can as long as schedule allows; the future of our education system depend on it; all she wants to do; Awareness that teaching now is not addressing the problems; students are not engage, don’t like school, ; standardizes test ; drip out rate is racially and economically divided; not thinking we are doing a good job with environment, gender, race discrimination; so many problems that are getting worse; not thinking that dividing disciplines is coming up with answers; disciplines – arguing; - those anything ropologists are screwing it; friction rather than collaboration; arguing but no problem solving; she thinks the right way is bringing things to the level of the body, connecting it to each person; (just like science can be connected to me) Interdisciplinary work does –connecting it; when doing it – exciting to ask certain questions to scientists – and the other way around; Never felt like a waste of time; she likes; when people care they are more likely to solve that problem; when feeling part of the system – then it is relevant; when dancing they feel they matter; depends on the dancing; *not all dance is good, it is potent, but it can be as bad; so one needs to take note of that; 20. What is the future of SC in your opinion? Why is it beneficial to incorporate it into academia? What is its value? It’s important to think about the body in whatever discipline because it’s always there; 21. How has it influenced your academic, social, personal life? Has it had any undesirable or positive consequences? Professionally – she gets a lot of attention and visibility; many people like how it sounds, but can’t have resources; gets invited to conferences, and talks at different universities; there is interest; She get to meeting interesting people outside of her field; she has a relationship to science – completely new broader understanding of what science is, and that broadens her world significantly; she wasted a lot of energy combatting the danger of scientism, and has greater appreciation for science; Valuing the science “truth” above the person’s experience or sanity; wanted to punch every doctor; 1.4. Lane, Robert Class experiences; the value of embodiment for students to interpret; students my not grasp things with images and words; some concepts – the opportunity to see the light is enhanced; He is believer of context dependent learning – ex. Rather than memorizing the anatomy of the body (med school) , to learn the anatomy in the context of a medical problem – to learn the anatomy that allows the med students to solve the problem – a lot longer lasting effect; Students can remember longer because it’s associated with the context Introducing dance in small amount in classes 22. When was the first time when connecting dance and science just made sense for you? The Ferocious Beauty Genome project; participated in advance in the discussions; came to realize that it was extremely stimulating to watch dancers think about and
express ideas about big ideas; that didn’t really lead to anything concrete to anything concrete; for another year
But he participated I none of her workshops (about 5 y); 1 thing – warm-up – exercise (no educational value) – Katja - to get the blood moving she everyone walked around the room to music, and eventually asked to do triangulations; he was not aware of an intentional exercise; but it immediately hit him had a very interesting application in a couple of his courses; today he does a lot of layers of this exercise and class discussion – meaning of this exercise in the context of his class; genetic networks and systems biology; and on higher level - emergence of order from chaos – a hard concept to grasp ; really important problem when one thinks of cellular organization ; every cell is chaotic, but life is emerging from a set of a small rules; - it is maybe the most powerful ( in terms of conveying and summarizing things) in his class; he does it even in intro bio.

a. To convey idea
b. To allow students to learn something in the context ;
c. 23. How do you use dance in your science teaching? Did your work this out from someone else, did you create the idea on your own, did you practice, or did you experiment with your class?
Coffman – you got a cell – thousands of molecules – which are influenced in discrete ways by environmental signals; the cell is not smart, but a lot of the information is processed in an a single output (eq) – it will stay there until a new shift of factors influences it to go into a new eq; how an entire system behaves; how a chaotic development- how that chaos – converges and gets integrated in a binary step – a coherent behavior of the cell that is recognizable and reproducible; Coffman figure that mathematically simple bullion functions (and, or, not) applied to a network of interacting proteins can explain this convergence; interesting – what Coffman figured out – that if you have 3 other proteins – will dictate how I behave - this and this but not this; remarkably – the line between order and chaos falls around the number of 3; If every protein is paying attention to two other – equilibrium is inevitable; this is why using dance is so important; 5 -infinite walk – impossible equilibrium; - computer simulated; most powerfully it can be demonstrated;
In a classroom a set of very complex equations by simply repeating this exercise with h3,4,5 things; changing this one parameter is sufficient to create order or chaos; in Coffman’s- there are many parameters; they can play with all of those by simply modifying the dance;

24. What difficulties have you had? Successes? How do you know what worked out, from students’ comments or your own perceptions or anything else?
Very successful - in class, student evaluation; the most telling reaction is the discussion afterwards – there are always students – with wide agreement who respond with “wow” – a Eureka moment; hearing about it less on evaluations – because they are on the whole course; anecdotal feedback – and that’s the goal; Negative feedback – 1 – students who are uncomfortable doing this kind of unusual thing in a science class; most have fun, but rarely It happens;
2- maybe negative; sometimes the exercise he dreams of it doesn’t work, but during the discussion the students get very involved how to improve it – but it’s still
successful because it makes them think deeply about the concept; from a pedagogical view – it’s still a success;
E.g. Protein folding – it didn’t really work because – for logistical reasons – who is the amino acids- the degrees of freedom – not fluid enough ; but they spent at least as much time how it might work better, not just about the dance, but about the forces the dance was intended to teach them; it was as useful as any class time;
25. What is good teaching in your definition? How does (if) dance incorporation fall into this category?
Both conveying or stimulating new ideas and new ways at looking at the world and inspiring students to want to learn more; in his experience what truly does this – is recognizing complexity and unknown; in contrast –teaching of textbook of knowns – is useful but not terribly inspirational; what got his soul to pursue unknown – the complexity, the puzzle; one of the benefits of simulating this process- makes it more accessible – much other job in conveying complexity;
26. Why did you decide to use this in your teaching? How long did it take you to develop this and implement it?
He went fast – rather inspires him and kind of the whole thing – he doesn’t try to implement in the classroom until this eureka moment; what happens now has evolved tremendously; feedback and learning from the event; additional thinking and reading and relates to the exercise; trulyfully 0 originally – an hour; since then – he put countless hours – directly and indirectly; used since 4-5 years ago; a year after F B;
27. What keeps you engaged in the process? Would you keep using this and why/why not?
Sure, it’s successful, as long as I love to teach, I will want to do things that are successful and fun for him and the students; doesn’t see an endpoint; will he use triangulation – he doesn’t know; but something; he has experimented with some exercises, some ex. Need some work – on the back point, but it is not rigid;
28. What is your dance background? Have you experienced this often perceived dichotomy between science and dance? No; played musical instrument his entire life, used to sketch and draw; he doesn’t see a conflict between dance and science; all human activities relate who we are, and why we relate; on that level – he doesn’t see any academic or intellectual activity as fundamentally different or in conflict; As for goals in arts counterproductive to goals in science –science must remain an empirical process and methodology; one way the science theory can be sabotaged – if scientists are too prone to non-empirical thinking and bias; there is a systematic way of obtaining truth in empirical world that isn’t necessarily the way into an introspective world such as dance;
29. What is the future of SC in your opinion? Why is it beneficial to incorporate it into academia? What is its value?
He agrees that the SC encompasses a broader territory than what he feels is most exciting and useful; for him the real value of embodying science principles or boil behavior is in modeling the process , not to learn it, but to model it – appreciating a very powerful truism; a few simple local rules can create order, beauty, a predictable reproduction. Behavior; that implies in thinking about DNA structure, protein running through a gel, signal transduction, almost every boil concept – experiment or theory he is engaged in order to truly understand how it works; requires true understanding; - hydrogen bonding, hydrophobic, bending angles – local rules;
What he really loves you can enact (pretending to be a naïve protein) and enact those local rules and watch the beauty unfold – if the local rules are constraining enough to remove chaos – and hence the strongest value in academia;

He understands – associate moves with context; others – used it to mimic some behavior; the most powerful value – emergent properties;

30. What are the things one should beware of when using it? Helpful suggestions for other educators…?

Recognize that you are losing control of your classroom for a moment- you don’t know how things are going to end up; more terrifying than a discussion – you can still moderate; it can be frustrating or embarrassing if the exercise doesn’t work as planned; one thing he does to mitigate this kind of outcome – he simulates the exercise on the computer- gives the same local rules – and write a little program; this has helped him see a problem – and he notices he needs something more;

Not every student is a good learner by reading a book or listening a lecture, solving a problem work in a lab, it’s also not the case every student getting out what you are hoping; not universally effective; with lecture it is invisible; whereas it is more visible when an embodiment ex doesn’t work – but also an opportunity – address those thought – to see when students that don’t see the value;

31. Have you thought of using SC in your research, and if yes, why would be feasible/impossible to use?

It honestly hasn’t be applicable: most of the classes he teaches are really in completely different orbit than his research; goals in course are far more broader and conceptual; class- developing concepts; res – pragmatic –explicit goals; occasionally – theory discussion; doesn’t mean it cannot be done; he hasn’t faced a conceptual problem for which he thinks embodiment would solve it; the he just does it on the computer;

32. How has it influenced your academic, social, personal life? Has it had any undesirable or positive consequences?

There is almost no impact outside of his professional life; he’s met a lot of new people – and he especially enjoyed to learn Liz and Elizabeth, and has also appreciated that these exercises have been inspirational to some of his former students and that is always gratifying; but no effect outside of his prof. life;

1.5. McQueen, Amy

33. What is your dance background? Have you experienced this often perceived dichotomy between science and dance?

Dancing since 5, didn’t start doing science until 16; when she started dancing in a different company, the director was very environmentally aware; studied coral reefs; the dancing followed; telling a story and raising awareness about issues environment; (1); dance is a nice tool for moving people, tell stories; 2 – using dance to learn principles of science, never thought of – learning, muscle memory, etc. ; 3 – idea of process of making a dance is so similar- makes her appreciate that running a lab is so much of an artistic endeavor;

Never experienced dichotomy

34. When was the first time when connecting dance and science just made sense for you?
2 – when came to Wes; Dianne – often talked about learning through dance, but not hard core; now, (last summer) Dianne is all about choreographer going through a scientific method to go to a final piece; thinking about correlation of dance leading dancers – reminds her of being a PI: have a vision of where the research is going, don’t know the aha; rely on students to provide you those moments; a lot of parallels – sometimes dancers were there, sometimes not, when together, got “aha” moments; the artistic process is so similar to lab work – to publish a paper; Liz did not deal with that;
It made sense to her – visual learners – movement learning embodying a concept can be very helpful;
Do mitosis – do meiosis - ; but if you could act it out 0 they get it;
It was harder for her – larger concepts- referring to Michael Weir; trying to teach larger concepts – more so than the simple concepts; she needed an example; the statistics; triangulation; doing it is very compelling, almost like doing an experiment;
Her physics teacher –embodifying an experiment –different than learning on papers; for educators – useful tool;
She saw Liz’s piece – so moving; it is so helpful to get a story across – Huntington’s, a science struggles; different way than just standing and talking
35. How do you use dance in your science teaching? Did your work this out from someone else, did you create the idea on your own, did you practice, or did you experiment with your class?
Manju, EJ (Elizabeth Johnson), the night before; once you come up with the two concepts the students need to take home; once decided on it then develop the exercises for the students, this is easy; but the concepts – some are too simple, some too complicated;
Protein folding – relatively straightforward; students can embody the chain; can also get to cool concepts- triangulation – system with constraints vs. not; had to plan good not to lose students for longer than 50 min;
Elizabeth Johnson – 5 min this, 8 min this… very well organized; video mixed;
sometimes fast, sometimes put more thought; never know what is going to work until you try, it’s always risky, Wes students are open, usually students are up for a change; she’s done little
Molecular biology-208 – one day, last two years – protein folding; show piece Huntington – though provoking;
First year – spindle checkpoint – chromosomes to signal that it’s not ok to divide; how does that signaling happen; tried to explore that, and the aurora kinase; that’s it; part of workshop;
In Cell Biology– they did something; the students did an independent dance without asking her; the flaw in the paper – sperm dynamics – they videotaped the experiments; competition in the sperm; videotaped kids in red and green shirts – you could see the experiment clearly; the 60 vs. 30% - ; the students showed it;
One year – didn’t work so well; checkpoint signaling; if they are fuzzy on the concept, then the whole thing is; having an anchor – what to embody, 2 what to play with; once this in place, then it’s a couple of hours;
36. Why did you decide to use this in your teaching? How long did it take you to develop this and implement it?
Because of colleagues, she is a dancer too, she should be all about it; doesn’t know she would have the energy hadn’t EJ come; she does use certain ideas in her class;
haven’t done walk and talk – thinks a good idea – wants to do; she did – stand up and turn around, and noticed- got so many more questions than before; and they were a little more engaged; did in cell biology– bring pairs of people –meiosis; doesn’t have the stamina; it’s nice to have an actual dancer come in; they love her ; she’d collaborate with Katja for experiment, an experiment in the dance field; The little exercises are very useful; if she though a concept can be embodied, she would do it;
37. What difficulties have you had? Successes? How do you know what worked out, from students’ comments or your own perceptions or anything else?
Surveys – had a number of students just tell them they liked it; she’d think they’d feel awkward; at least 3–4 students; even those less comfortable – they said they were less scared;
50 min – 5 min that did not worked, did not matter; some liked the video pat more; there things for everybody;
Amazing – 5 min – never how she thinks about her classes; it made a difference – changing activities; intense workshop;
38. What are the things one should beware of when using it? Helpful suggestions for other educators…?
The idea clearly – the overall idea; reiterating the concept a little bit with every exercise; students are coherent, it makes sense; even when you feel too simple, if they are not confused what you’re trying to do;
She went into it thinking it would be worse for student feedback; it will be enjoyable ; if something in class is not working, u need to jump onto something else; like politician ; try to move on without forcing something; having a diverse set of things, especially for the first time; want to come out from different perspectives; want to have video, exercises just to get them moving; want to try out high risk things – have a few, some fail, some work, but move on; take notes on what worked; having a toolbox full of thing; have more than one things
39. What is good teaching in your definition? How does (if) dance incorporation fall into this category?
She thought of her favorite teachers;
1- Engage your listeners, and keep it; have to be interesting; she didn’t know why she was even that; but she had a couple of teachers she really adored listening to; their clear enthusiasm, so clearly thrilled by science; connected on intimate level, and were very good at telling stories; they were part of science; they taught with story-telling mindset;
2- To be able to tell a story; capture humans attention;
3- That can be important, though her teachers did not use it; to be able to use different tools methods to capture student’s capacities – visual, audio; likes dance being another one of these students; doesn’t harm those who don’t need it, but helps those having harder time with textbook ;
Her teacher – high school unconventional methods of teaching – brought them to different environment- little textbook; he used those other forms; he went through great length to do that;
Dance can help even the simplest way- getting students to do something out of the box;
40. What keeps you engaged in the process? Would you keep using this and why/why not?
Totally used, even more; Laurel- mentioned walk and talk; essentially – breaking up the staleness of the period, taking a breath, just like running; she’ll think more and more; especially since she’ll be teaching 208 again, getting bored, but not the slides, changing the methods will make it more fun for her;

41. What is the future of SC in your opinion? Why is it beneficial to incorporate it into academia? What is its value?
In academia – not sure; we are in the midst of what could be a big change to how teachers students; more an more we shouldn’t be sitting learning lectures; more hands on; in science it’s easier – labs; how do you do it in art; what’s nice about dance and movement, music, without even bringing the scientific experiments you can bring a tool for hands on without having to set up a lab; it could be you are embodying, a process to learn about; or use to memorize something; it is a totally different way to engage your body; vs. typical sitting and listening;
If it’s true that students should not be learning by sitting, dance is one of those tools you can bring in cheap and use it to fulfill this need for hands on learning;

42. How has it influenced your academic, social, personal life? Has it had any undesirable or positive consequences?
100% positive, she is shy and awkward, never wanted to impose something weird on the students; always been presently surprised her students; Whether it changed her – dance w Dianne – could have invigorated connecting those fields; which have been separate since undergrad; something she could continue and explore; it seems like a valuable avenue to go; never thought to be the thing; but it seems a legitimate tool to engage the students at least for 1 or 2 classes wouldn’t do a whole workshop

43. Have you thought of using SC in your research, and if yes, why would be feasible/impossible to use?
Haven’t thought of it at all; this question would have without that summer; Referring to the process of Dianne workshop; building a hypothesis – if it works – hypothesis right; her dancing was informed by her science; So used to it – develop an idea – explore; if it’s thrilling, publish, if not something else; this was exactly how choreography worked; so struck by this; she did the choreography; 
Haven’t thought of the other way around; it’s not out of the realm;
On personal scale – it’s very fulfilling – that what we do in the lab is as creative as the artistic endeavor that all artists are doing; felt closer – to them, the dancers; feeling closer;
Trying to get some sort of truth, whether changing or not, getting to this beautiful moment where something works; and most of the times it doesn’t work; those two parts of her life have come together; work with EJ - ; (except for tap dance around);

Los Alamos – CERN – tea – tables – images of tea;
Hearing the scientists talk – whatever the moderator posed on the tale; one the questions – how much art and science are you? Amazing – people really think about them as two different things; never thought about them as two different things; now she is so much more sure – that at the level of PI you are an artist creating things; sometimes the truth you find I disproved later; it’s the same thing with social dance; it can be disproved later, even by yourself; the public – maybe the school – arts budget vs. sciences; kids tend to think dichotomy because parents, maybe;
So much can be changed by a teacher; thought she was not good at writing; if she hadn’t had super duper science teachers…
Dianne Eno – Fusion Danceworks 2011 – events; (website)
Dianne thesis – environmental arts – (Antiac) – PhD – her book;
Earth Dance institute; continuing the tradition of artists on the mountain;

1.6. Michael Singer

44. When was the first time when connecting dance and science just made sense for you?
Most of his experiences in collaborating – has been in him bringing his science into a dance class; using the content to inform the dance; he’s done one – ongoing with Liz on a science choreography module…
2 1st s – through discussions with Liz and then seeing the ferocious beauty
performance – 2004 -5 ; right when she first came and started that collaborative ; present as a listener and observer; when it 1st came to his attention
Fall 2008- he started to plan a collaboration with Nicole – co-teaching a module in her performance class in spring 2009; in her class wanted some ecological content as a part of the basis as developing the dance in that class; he wasn’t directly involved in the process involved with the movement;
What kind of info provided? Ecological info at variety of levels – personal experience as an ecologist – identity as an ecologist – representative scientist – assumptions different from other disciplines –presentations of fundamentally different perspectives – objective reality – questioning this assumption ; thinking about ecology as a way of knowing a particular place – went out to a field – and gave them a chance to learn about the plants – and what role these had in ecology and how they’ve been used by the people; they did their own personal way of interacting with this place;
The process of using ecology as a science to infer meaning from what you can observe; the communication between him and Nicole wasn’t that great – she wanted him to throw out various perspectives that they could grab onto; “what is her vision?” – she was reluctant to provide that – looking for content she could take – a bunch of stuff at a yard sale – raw material to work with; not really included in the development of the dance; at the end he was not sure how much the content he gave ended up in the piece;
After that – the following spring 2010 –module with Rachel Boggia – very different:
she had a science background and she understood where he was coming from, and there was really less skepticism what science could offer; not fighting this battle – collaborative communication; they co-choreographed a piece – he contributed more than he expected to – ideas of choreography – much more of a shared vision in creating the piece; the students showed less interest in the overall vision than doing their pasts in it. Input from the students;
It was something new for him, very exciting experience; rather than feeling as the token scientist – standing one; it was much more fluent and synthetic collaboration – he played the role of an artist – 3rd –fall 2010; Cassie Meador – her class his part was smaller – he was on sabbatical – he limited the amount of teaching; he was not given teaching credit; similar to his work with Rachel – good communication – clearly had some experience from a
scientific view; few meetings but very productive - thinking a lot of about the kinds of skills an ecologist or a naturalist has to read nature – observation and attention to certain kind of details – taking the students out to a natural area; initially very open-ended assignments, and then report back; then it became more focused on particular things you’d observe were you a naturalist or ecologist; chances for the students to perform movement and incorporate their ; never saw the end product; it felt really productive at the time;

In all three of the classes – when the students did movement – immediacy of the content – it felt very successful, it seemed the student enjoyed it; in Rachel’s class these moments built up and made something bigger at the end , in the other case less clear;

45. What is your dance background? Have you experienced this often perceived dichotomy between science and dance?
Background – informal one – took art classes in college, but always included aspects of visual art in his scientific career – macro photography of insects and plants he used to study; really nice photographs – engaging people – captivating; hobby – paint water color; no dance or movement; he’d been to dance performances; as a grad student he first started going to performances in the university- he could appreciate some , others found harder to relate to ; familiarity with observing dance; U Arizona – large U;

46. How do you use dance in your science teaching? Did your work this out from someone else, did you create the idea on your own, did you practice, or did you experiment with your class?

47. Why did you decide to use this in your teaching? How long did it take you to develop this and implement it?

48. What difficulties have you had? Successes? How do you know what worked out, from students’ comments or your own perceptions or anything else?
In each case he did have some personal interactions with the students – they thanked him ; generally positive feedback; he saw the student’s evaluations; not much detail about it; always looked at these things as an interesting side project, not central to what he does professionally; he teaches ecology and does research; they were not necessarily feedback into his mainstream, work;

49. What keeps you engaged in the process? Would you keep using this and why/why not?
He recognized in the first case – personality thing – communication problem ; by the time he was doing that, he had met Rachel and Cassie; he knew there were other people he had better communication with; he thought it was going to develop better; he separated the personal part from the larger idea;

50. Have you thought of using SC in your research, and if yes, why would be feasible/impossible to use?

51. How has it influenced your academic, social, personal life? Has it had any undesirable or positive consequences?

1. Teaching – it gave him some perspective on his own teaching in relation to other people’s teaching that was helpful ; one thing he recognized he was doing – providing active learning activities - seeing how that mattered in a content of a dance class, he understood how much that mattered in his science classes; one of the students the students really liked and benefited from – was combining their brains for physical way – combining their minds and bodies – thinking about something – and
trying to translate this into motion engaging these parts of the ; stronger emotional connection to the intellectual material; he understood why ;
He went skeptical – how do they incorporate intellectual work, how are the students learning ecology from a dance class? He saw that because the dance helps them engage emotional parts of their brain – with the content – he understood that any sort of active learning how it worked; the more emotional, positive- the better off active learning that is; now he stands to develop that better in his classes;
At a point where he does not want to sacrifice something he’s doing well with something risky; so far it hasn’t been that transformative, but enlightening to think about the process of pedagogy; he gets students – out – just by being outside- same emotional experiences like with movement; for what he teaches – taking them out; he does not know if doing movements in the class better than being out;
As for his research – no significant effect; the quality of the science that he is bringing, the rigor of the empirical work; personally it’s more fun to think of his research in other terms;

Easier to communicate his research to other non-scientists – before that he had done a lot of outreach talks; the best thing that plays with them – presenting the drama of the interactions – parasites – rich colorful way; mainly continued to do that;
52. What is good teaching in your definition? How does (if) dance incorporation fall into this category?
Both dance and other techniques can do – is engaging the students – complicated thing – the kind of things that will draw one are diff; the goal of teaching come up with methods that are likely to appear to a diverse audience and have very diverse way so of learning – visual kinesthetic – well known to educational literature; taken pedagogical workshops in the past; having them use their brains in a critical way than passive recipients in the content; If you are telling a good story – drama-identification – for brains set up to hear good stories; some of the best teachers- that really engaged you with good stories; but he doesn’t tell good stories all the time; but he also does exercises where the students are doing something; playing a game – that is meant to represent a certain concept; taking them outside - some would res; in every given class he does different things and hopefully every student will have found a way to be engaged; different kinds of assignments; not only one kind of exams; readings, lab reports, exercises, lectures, all things together – diversity of methods to engage them; being clear in your content; fair treatment; in a position of authority 0very sensitive in abusing that; empathize with them – increasingly harder; In a place like Wes- no need to worry about how smart they are, but how engaged; figuring out how to help the muse their brains in a non-accustomed ways, not always that easy;
53. What is the future of SC in your opinion? Why is it beneficial to incorporate it into academia? What is its value?
SC – of collaboration with Liz; trying to add one of those modules to the existent project; on evolution by natural selection; a couple of years –with Elisabeth Johnson; pretty close to putting something on the web; slow process – she in Arizona- so busy that communication is slow; he did this in his class and w. high schoolers too – movement to embody the concept / represent natural selection; drawn to this concept – as something SC could help teach; nearly everyone has an understanding of it, but most people who haven’t thought of it critically – misconception – not quite accurate;
education studies if there are preexisting misconceptions – can’t just feed them the correct version – and expect to replace the old with the new one; the idea- maybe by using movement – a good way to shake up people’s thinking – change the way they are processing it that they are more likely to kick out it; Why? – when he was observing students into these classes- emotional connection –working in other ways – maybe introducing movement; the idea- a association in the brain – solidly attached; different parts of the brain and new connections – the brain would be able to hold on to both ideas 0 and then make a choice; intuition on his part- not much known neurologically; one thing he knows from educational studies – have to challenge this ideas – what do you think would happen if this.. sometimes they become more open; but maybe the movement would be an alternative way; he doesn’t have enough experience in his classes – different between students response to this and ; CCY –summer programs – Center for creative youth; he knows nothing about the students; survey “they say understand that better” but it’s not the most reliable way; interested in trying because it seems fun and interesting; if they could make it work as a web module – clearer understanding ; appreciating the world and think about the kinds of things that happen in the environment; passion personal; Not something he thought about – the future of SC (general) – Rachel – vey experimental phase with it; hard to see which things techniques and types of interactions will emerge as more conventional ; even if conventional – idiosyncratically; ex. Conventions in pedagogy – lectures- content; unclear will it be a standard practice- who knows – to teach meiosis with movement; idios. – here and there –any systematic pattern ; not clear; take a little more effort and work – SC; it could be valuable –he doesn’t know – then he knows its valuable for students; and for him – because he likes to think about things in a different way; professionally - not much benefit- time is more valuable than his money; Only when the whole system is set up for this kind; but it certainly has a place – even when a small number of teachers and students; 54. What are the things one should beware of when using it? Helpful suggestions for other educators…? Hard, time consuming ; it’s not too inconvenient; maybe having the right kind of environment; incentives to do it; when the cost is not too prohibitive; it’s worth trying – because it’s another way of engaging students; it seems that it has been successful peeking the interest of students that were previously not interested in science; In his own experience- less clear - ; not his goal ether – to get them interested; in his classes –they have more interest; whether useful; SC – one of many things – testing it – not such high priority; It’s out there as a pedagogical method; best thought of in relation to other kinds of techniques to engage students; something to add to the toolkit; If he were to lead to movement exercises – not interested; not being comfortable leading a movement exercises; not a lot of confidence & background, he’d feel embraced ; it would make him feel vulnerable ; predisposed to certain ways of teaching predisposed ~ cert. ways of learning; hat opportunity to get trained – maybe could work; not worth sacrificing his pride; dancers ; Liz and EJ– hoping to initiate and scientists – do that, but that does not make much sense (except Laura –dancer and scientists) ; the success of it depends on how you
interact with the students – the likelihood that they are really going to buy it – its less; if you have Elisabeth – being able to break the ice down – special skills; If the dancers think it’s easy for scientists to take ver ; not; this is a very good role for dancers ; it needs to be collaborative; unless you are that; kind of teacher that can pull it off; it could be good for dancers – to bring dancers to academia; for scientists- it is great to work with someone from that background, assuming good communication; really enjoyed that kind of communication; it’s been fun; wouldn’t want to take that over; Huge potential – for dancers – to bring their skills to any professional setting – it fundamentally allows you to bring emotional connections – team building; the students are so much more cohesive because they interact on a physical level than in any other class; dancers can bring that for a lot of different settings; Generally – group dynamics in science – figure it out; in a dance class – it is the instructor – leading it very well; different sort of skill – people love – to feel – like they are part of the group – a bond with other people; and dancers can bring that; there are other ways but this seems like a natural way;

1.7. Michael Weir

How it all began … 2004 (before 2006 Ferocious Beauty)
When was you first contact with Liz and how did you react to it? What inspired you to continue this project? Why did you get excited about it?

Pam Tatge – meeting of directors or Arts; Liz presented; mentioned her next work; Dean at that time was Laura; Liz visited a bunch of times; no idea what we’d talk about; the guy acting Mendel walked in; talking about ; Not imagining what to expect; I previously viewed the intellectual processes very separate; parallels about how we think about problem areas; how we approach; noting parallels, but more the power of building exploring the bridge in classroom setting in a way of engaging in a deep way students; Not explicit very early, but became more apparent by 2006; analogous to a text book; this is what launched the Hghes Project; Embodied learning that made bringing this in class powerful; flexibility; but might work differently; Stimulating science thinking directly; but mostly ?cirricularly; how to model biology processes; deep modeling in bio; modeling not always explicitly discussed, it’s more implicit; the assumptions and the model componentnts are not as well defined as they could be; they could be catalyzed by dance experience; The next proposal – reminder;
What difficulties did you encounter? Communication, understanding, conceptualization?

The power of this interactions – avoiding jargon and honing on the general concepts; over the last concepts, to focus in teaching, because of collaboration with nonobiologists- computer; so it was easier to interact with them; no jargon communication is very hard; honing on the essence of ideas; valuable for students in classes; if faculty not as distracted on memo but on core concepts;
When did you first start calling it “science Choreography”?
No idea when, maybe at grant writing; at 1st performance; coining the terms; giving something a name is wise; there’s an actual framework; Embodied learning - connotations might be less useful descriptor; notions of bringing the body into a thinking process that catalyzes an effective deep modeling of that; it is more than the definition I found; the thinking becomes crisper and in some sense more accurate; 

What are you aiming to do with this? What are your goals? Is this where you see the value of your work? Any further implications?

1. When was the first time when connecting dance and science just made sense for you?
2. What is your dance background? Have you experienced this often perceived dichotomy between science and dance?
3. What is good teaching in your definition? How does (if) dance incorporation fall into this category?
   Good teaching encourages everyone In the room to develop deep thinking in a subject, a range of approaches, parallel, interdisciplinary thinking; to the extend SC can cat deep, powerful thinking – it can be very helpful; because SC is non-standard, and because some of the cutting edges of scientific thinking are not standard, the novelty of SC encourages one to think outside of the box;
4. How do you use dance in your science teaching? Did your work this out from someone else, did you create the idea on your own, did you practice, or did you experiment with your class?
   My most common use has been in small section of intro biology as a prelude to problem-based learning sessions; used “ask a question” – 3 questions; 1st thing – typically addressing concepts from the previous 2 class sessions; a valuable way discussing in pairs – opinions about important concepts, and then discuss it as a large group; works well with small section; this year are bigger (lower 50) and has been impractical in doing it with a larger group; constraints; a variant of the tool, no music;
   Last year – they did it every Friday; this year haven’t done it because of the class; the relationship between the number and the size of the classroom – that makes a difference; have to use the seats and the tables;
   For how long implemented In the class; 4th year teaching, may have started doing it 3 years ago (not sure the 1st year, the 2nd); as a transition out of that often have – local rule – form the groups for the problem based learning; ex. One of four person – who cannot role their tongue to be part of the group; nucleotide on the top right hand corner of syllabus - ; how you can arrange the ribosomes ; little challenges – transition to ask a questions; the reason – a lot of things in molecular biology– local rules – how things work, vs. how they are built;
   Modules of single class sessions – based around a segment of Ferocious Beauty; including the Mendel scene – as a question; the huge theme- how do I ask a question – bioinformatics classes - where they try to model genetic maps; the triangulation tool – Katja - local constraints causing emergence of a local behavior; also in genetics class (many years ago), for some had Liz /Elisabeth lead the class; Tried to model protein synthesis – the surprise how many wrong codons – another way exploring the rarity of the correct base [pairing; wouldn’t have thought of this process hadn’t they put it into motion;
It gradually evolved; synergistic interaction in planning; working out what kinds of activities would encourage thinking; time – at least extended meeting before the class and plan; an hour to plan; a lot of e-mailing; often use a power point outline; time – PowerPoint – varies – all he has to do is put into the frame; but has the goals in ; Using ask a question – easier; designing a full session is still not easy, never been; 5. Why did you decide to use this in your teaching? How long did it take you to develop this and implement it? 6. What difficulties have you had? Successes? How do you know what worked out, from students’ comments or your own perceptions or anything else? Occasionally people form the class – especially, in computer science might feel uncomfortable, greater tendency to discomfort compared with life scientist students; Elizabeth – deals wit ; people don’t have to participate; Surveys at the end of class; mainly informal discussions; at the end of class; haven’t been particularly systematic, generally not discussed in course evaluations; guess – perceived as a minor component of the course; generally do not get “this did not work feedback” 7. What are the things one should beware of when using it? Helpful suggestions for other educators….? It takes some time; it’s helpful to have a room with moving space, not crucial, but helpful; setting up a framework – PowerPoint – helpful in catalyzing the work, and can imbed videos – which can make the who thing more successful ; Refer to SC website; recommend starting small; one tool; evolving the tools for one’s own style of teaching is very appropriate; 8. How has it influenced your academic, social, personal life? Has it had any undesirable or positive consequences? 9. What keeps you engaged in the process? Would you keep using this and why/why not? He sees people engaging as active learners – reasons to continue doing it; he compares with this semester when they don’t do it; if you ask the students turn to their neighbor and talking -works; the act of moving – is related to them being more engaged; a bit of difference; because of that he will try to use it ; an issue of smoothness of transitions; ask a question – tends to discourage use of PowerPoint; element of disruption of flow ; when using PowerPoint with “Ask a Question” outline, ; once the students are sitting less likely to look at PowerPoint; using the prompts at the beginning – is problematic in terms of class order; 10. What is the future of SC in your opinion? Why is it beneficial to incorporate it into academia? What is its value? Future – as individual faculty deciding to explore parts of SC, having external finding catalyzed the development in the last few years; have Howard Hughes Grants cut off; many schools did not get funded; the development does require funding, the use is cheap; the catalyst would not be quite as transparent; a lot of work – work with choreographer and developing modules; 11. Have you thought of using SC in your research, and if yes, why would be feasible/impossible to use? Have you used SC as a research method yourself to discover something about science/your students/or inquiry of choice? Not using them ; there are aspects of our teaching where analytical methods – models – useful in curricula setting; where conceptualization and thinking approaches are
developed – a way to catalyze this; one teaching to one thinking – hence direct on research;

Having courses with focus on SC – open question; development of the approach works in small modules; the full course project might lose focus and vitality; a module is a modest investment within the class and can have a significant impact;

2. **Dance in Science Performance – interviews with winners of the “Dance your PhD” contest**

2.1. **Bohannon, John**

Michael Raynard – Brussels  
Dominance biology – 2 explanations most readers of science are from biology sciences; dominant field; 2nd – something different about biology; categories – sure to get social sciences; cover as broader range as phenomena; john makes the decision where the dance goes; if disputed – change; judging is completely external; john – promoting not biased;  
3 10 point scales – 30 most; science, art, and combination of the two; science is all right, no mistakes- by the end really understand the piece of science – could be a big picture, or something; art – full if beautiful piece of art - funny, beautiful, solid; how did they combine it in a creative way – did they really put the strengths together; pretty arbitrary;  
The winners convinced all different kinds of judges;  
Judges choice- John – bunch of Harvard scientists + local s scientists – Boston, science covered all fields;  
Pilobolos; Interpretive dance – background; dance be about something; scientific origin; one of 5 companies that make more than 1 mio a year  
Google blog ted Bohannon – ted – explanation; essay – modest proposal;  
Dance and rhetoric – people are hungry for;  
I am trying to study how scientists’ and dancers’ approaches differ when they create science-dance representations. Please do your best to answer the questions, if you cannot, please try to specify why.  
What is your dance experience? What is the place of dance in your life? And science? Love seeing dance; non-artistic way dancing; background theater; power of spectacle; what does it mean to catch someone s attention; combination – spectacle science and dance  
When did you decide to start the Dance your PhD (DuP) project?  
Started in Vienna before moving here; 5 years ago started ; big science party – helping; d=need dancing; how do you encourage scientists to dance; most in hell with PhD; why not into comedy; constantly explaining the PhD; never-ending explanation fest; force people to explain through dance; so much jargon; made people  
Turned it into an online contest; first 12 to 55 in some years;  
How do you evaluate the dances? Is there a scale / general impression/ a group of people? How objective/subjective is that?  
Who do you collaborate with?  
What kind of people participate in “Dance your PhD”? What is the average profile of a dancing scientist? What are they interested in? More women than man? A field of science more represented? Geographic area?
Mostly us and many Europe and Australia, Canada; pretty representative of universities; all have in common – exhibitionists; eth else diff. some background, some not; some humor some not; want attention and not afraid to be in stage; giant google search – friends, resources, sanity to create one of those things; do you love the idea; ridiculous; artists are more resistant In general than scientists; maybe thinking it’s mocking them; broader historical trend of seeing interpretive dance as not state of the art; prestige correlates with abstractness; Liz –; dance moved to abstract , feels like a throwback; somebody pocking their territory; more attention than work artist develop; artists don’t have a sense of humor more so than scientists; artists- provocative sense of humor – undermining what you understand; scientists are just goofy, child-like and naïve; broad trends – thinking out loud; never a bad word from scientists; money –not important; artists are judging by own metrics; not the kind of art; more folk; most jokes; some are arts; jokes that explain something complex and funny; comedy –art; distinction between art and entertainment; Karl Flink – discussion art vs. entertainment in dance; am I the creator; responsive-art; shaping ideas – entertainment; hip-hop- but nth to pour in – entertainment; how do you define the border;

TED - Explain a complicated thing with not much words – understanding science even with a PhD is difficult!!! With Dance is much easier; social issues; money; big picture; humor; A different kind of SC – telling a story – engaging in a social issue; using S representation to make a point about the importance of two different worlds that are so connected!

1. How did you get interested in the project, what was your motivation to get involved? Was there an initial event or lifetime experience that triggered your interest to put science into a dance?

2. How did you go about creating the dance? Please feel free to talk about (but not limited to) the choice of setting, dancers, choreography, science concepts, music, etc. How did you go about collaborating with other people? What made you choose them?

TED – script – got to the studio; dancers on the floor – read through it and see places that have visual potential – where are the moments; filmmaker – the scenes- strongest moments; spontaneously form furniture; mess with people’s expectations; cloud of human movement; eth connects; watching an animation; photons – humans; spectacle from beginning; no way to drift off; not to feel bizarre; not losing any moment; looped; refines the text; then music;

3. How did your creative process work? What were things you were having hard time with? What was easiest to do?

Personal – TED _ easiest – translating ideas from text to human movement; wonderful chem. With choreography; the hardest – learning how to deliver a piece of theater, memorize script and blocking; and make it look seamless with the dancers; part of the dance-
DuP – easiest – worried that you wouldn’t get good dances; every year is getting better; the hard thing- dealing with the website; 0 budget – no money- embedding the videos in the websites; don’t need money either; takes time; experience is awesome;

4. What is the place of your work (scientific and dance) in the world? What was the final design goal of your project, and has it changed over time?

Performance distributed in time and space- a talent show; everyone knows each other; the charm of a high-school contest; con

5. What prospects does your dance-science have – teaching, research, common knowledge, other? Influence on community? Bridging fields ; communities that have little contact; a lot of the scientists are secret dancers or have friends ; an excuse for them to go back into dance or something they’ve been curious about; Winner – sister and girlfriend to do it with him; any weird activity can do that; bringing family – anything that requires a teamwork – nth special about it ;

How and would you compare it to work done by choreographers such as Liz Lerman or projects such as F2F?
Technically – different between scientists and dancers creating SC; something over the weekend; no experience with choreography and lighting – not made by arts practitioners; intellectual core of professional choreographers are making out of science – not more sophisticated than scientists; set of ideas how to translate ; and what to focus on; if looking at that level only – Nickey .. Cambridge –biology – ravens – animal cognition; Mark Remberg – interpretation of Einstein’s theory
******* first moment when J combined arts and dance; what is the idea here; what ideas – just as sophisticated;

6. How has this work influenced your development as a person, scientist, or dancer? Would you continue in this direction and why/why not?

DuP - Evolve – modest proposal- TED - tons of offers – sucked you into the art world;
Change as a person – so satisfying to be able to make things with people- break from being a journalist; just dance; collaboration with Pilobolus – dances; do you feel more of a dancer – not comfortable taking on those names; liberties- with publicity presentation; have a hard a time respecting so a scientist – there is space for amateur scientist – a thing you do; a scientist -
Are the 6 questions I am addressing good for the scientists I want to interview? Their contacts?
How many people returned? How has the project expanded over the years? Only a few cases return; use the winners of all previous winners to do the first cut through; choose four 5 best and score them in the best; making sure judges don’t do too much work; they all care about ; survey of everyone – REMIND! Stories;
Community aspect is new – nth like traditional relationships; something one-to many – one artists –to many audiences;
2.2. Goldberg, Anne

1. How did you get involved in “Dance your PhD”? What is your dance background?
   Social science - 2010;
   Had danced for a year – took a class of improv dance; no background before; she hated interpretation; but she loved the improvisation – she had to feel - ; so she decided that people will improv for her DUP;
   She thought it was crazy at first; they decided to do it with a friend working on a similar person; not possible to do one dance for 2 PhDs – so they decided to one;
   She was in Poland doing installation about her PhD; interest in transforming science into other things; in Mongolian –she thought for 2 weeks about her dance; she had 1 week to do it all;

2. Did the lab participate or the lab leader? Were you mostly the leader or was it a common effort? How many were involved eventually? How did you choose the people to participate? Was it easy to find them?
   She decided to do the dance with friends and Lille in France; in Quebec – to share;
   people had no knowledge but who could understand it; gigs – did not feel at ease with their bodies; but knew the projects; this was difficult; two childhood friends and they brought a friend more; a little girl ; the gigs never answered;
   Improve is about expression something you know;
   The first meeting – the group 4-5 that was supposed to dance; by chance the people were in the same bar; so she had the chance to convince them; they thought it was crazy, but then they agreed; thought a park would be beautiful – worked with a filmmaker;
   Started with exercises.

3. What are the timeframes you used? How long did it take you to work through the process?
   The shooting went on for 2 days; a lot of fun; the girl never wanted to be left apart;
   the gigs gained a lot of confidence – they invented the beginning – the creation of a software; plus 2 more days for the editing; they all did it together – very intense;

4. How did you choose music, setting, etc.? How did you create the choreography? Who gave you feedback?
   She had decided to make a page about the park; two people were missing, but then others arrived; and another person decided to publicize it on the radio;
   She thought of the music that she listened to it – then they mixed; she put the music at the end; it was silent; a bit like magic – you would think it was made with music;

5. What kept you engaged in the process? What about it made it a pleasant/unpleasant experience?
   A very pleasing atmosphere; enjoyed a lot; the pregnant friend – was not dancing – but she helped with feedback and choreographing;
   Difficult –to believe in herself; lacking self-confidence; a bit afraid, but then it worked well; because it was pleasant, the challenge was that she worked in a bottom up way; she put a lot of confidence in people to dance things they had no idea of; and for the gigs to express to express things they know but never expressed in a dance form;
   “how non choreographers had non-dancer to express something they had no idea of”
Discussed a lot with the filmmaker friend about the bottom up method – opposite to film – how could it work vs. someone setting it; how people could improve and build something together in a free yet collective way; people were suggesting things – “that is beautiful, I like that”; she asked the people to develop their style – reflected what she studied too;

6. Did it affect the people you worked with and how (in the long term)?
Mostly in contact w people; they haven’t started dancing after that except for one girl who got inspired;

7. Did your participation affect your lab work? How?
Making the dance really affected her work – completely changed the way of her approach;
She contained with improv; a year later she was invited to work in a lab; she got very involved with improv; she got invited to teach about dance and science in some university; she works on a postdoc project- very involved with performative part – free culture – Mac culture, Linux, and windows comparison; work on that with movement;
Work with 2 people – 1 from Berlin who works on performance;
Karin - From London – works on science and dance;
http://fleurdasphalte.com/fr/humans/karine
LABAN - dance science; will get a link of their projects
https://wikifarm.koumbit.net/anne/ERSE
8. Any negative effects on your science career / or positive?
She got a lot of skepticism – her thesis director – he mentioned the dance at her defense with a big smile – she was looked upon as a crazy person; the year after – somebody told her – what are you doing in career; now she is a researcher; an artist and facilitator; she is better paid for their art work; and she has some recognition; installation – easier to understand; visualization of a process and concept; s
She worked in neurology department cognition – art and cognition and creation;
Send her link on John Wayne -

9. Would you keep getting involved in DUP or any other forms of dance, science, etc.? What does it depend on?
She was reviewer last year, and she will do the project again this year; talked to John to reframe the website so it is not blog-like and chronological; wanted to find a way to add tagging; inspired at TED; the public searching

10. What is your opinion about the Dance your PhD project? How do you see the future of this project? What are its perspectives? Any drawbacks?
The project is beautiful – sad that there are only four winners; she wishes there were a way to make it more collective, a sense of community of science-dancers; some beautiful dances – very said to lose these people; 10 best; there is something about transforming this contest into something more searchable – subject and type of dance;
People become inspired by each other; are there many ways to describe a cell process; hard to do it in practice; will need money for that;
What is the value? Should people do it? – yes, but not to win; she is critical of contest – she finds it sad because only the best will be elected, but she is not a competitive person; she hopes that people contribute but not to win the process; because it has to be fun – stay fun; For her it was a way to make a summary of her thesis and make sense of it; the “grandmother test” - when you can simplify it so it is understandable ; it was a “friend test” for her; it helps build up your confidence into the project and what it’s about; Very often – she sends the link for the movie dance rather than the written part;

2.3. Hsu, FoSheng

11. How did you get involved in “Dance your PhD”? What is your dance background?

I got involved in Dance Your PhD from seeing it online. The title drew my attention, and I like to dance. I do not have formal training in dance, I just dance for fun.

12. Did the lab participate or the lab leader? Were you mostly the leader or was it a common effort? How many were involved eventually? How did you choose the people to participate? Was it easy to find them?

If you watch my video, you will see that it was a solo act. It was not hard for me to find people to help me record the dance…I have many close friends and classmates who were willing to help, but I was the main project initiator.

13. What are the timeframes you used? How long did it take you to work through the process?

The thought process took about a week, on and off, it was mainly about whether or not I should do it or not. Once I decided that I wanted to do this, it took about 3-4 days, and the filming itself took 2.5 days.

14. How did you choose music, setting, etc.? How did you create the choreography? Who gave you feedback?

I spent a lot of time picking out the music – I chose music that was non-lyrical for a reason. I did not want the audience to be distracted by the lyrics. At the same time, I chose music that would draw peoples’ attention, and show different progressions of the process. The setting I chose is the place I work, and it was just easy access. As for choreography, part of it comes from having thought of myself as the bacteria, and imagining how it moves…however, when it came to actual filming, most of my movements were spontaneous responses. There were no rehearsals, it was a one-shot deal.

15. What kept you engaged in the process? What about it made it a pleasant/unpleasant experience?
What engaged me was that I was doing something new, interesting and fun. What made it pleasant was thinking about the work and dance at the same time as an integrative piece. It was a challenge to combine the science and dance, but it inspired and demanded use of creativity.

16. Did it affect the people you worked with and how?

Yes, for sure. It affected people in a big way – through media press… and our department became involved later. The word spread to the Graduate School and my video was posted on the school’s website…I believe it had an influence on other graduate students, I know for sure that it affected people I knew as they also wanted to do something similar.

17. Did your participation affect your lab work? How?

Not so much.

18. Any negative effects on your science career / or positive?

So far, it is pretty positive. It has allowed me to show others that I do not just know science, but I am also creative.

19. Would you keep getting involved in DUP or any other forms of dance, science, etc.? What does it depend on?

Yes.

20. What is your opinion about the Dance your PhD project? How do you see the future of this project? What are its perspectives? Any drawbacks?

I think this project is great for science, for the graduate students…as well as the professors. There have been some video submissions with professors’ participation. I think the Dance Your PhD project really helps spread the word about science to non-science majors, encourages innovation, and makes learning fun and creative.

Additional notes (e-mail communication):
. I have one question, on the question "would you keep getting involved" you said "yes," but I was wondering how exactly you are thinking to do so ( I assume beyond judging the new contests).
. Me: Have you set up some goals for yourself, or have you found some other venues to combine dance and science, etc.?

#A: What I mean about getting involved is getting involved in the science and art as a combined field…Participating in the Dance Your PhD allowed me to see the power of these two disciplines, as co-agents to producing a certain experience, understanding, or impact. This is something I wish to explore further, and it can come in many different forms. The possibilities for this synthesis is endless.

#Post-interview comment
Me: You said that participating in the contest had only positive effect on your work because it showed that you can be creative. Could you please elaborate on this? Who did it show this to, your colleagues or people not involved with science? Are there any stereotypes that go with scientists not being creative where you work/live? Do you/or the people with prejudice not find science a creative endeavor?

A: My video was shown to the school community, including the President and the Trustees of the school... so the word spread widely. I am not sure if stereotypes were changed... when my friends saw the video, they thought that I was so 'nerdy' for dancing for science... so maybe it did not change much stereotypes there... However, I hope that my video inspired the community to think that science can be fun as oppose to the traditional view of science as a nerdy subject, so in a way, yes, it touches on your question about stereotypes being altered/affected.

I do not quite understand your last question because not only do I feel that science IS but SHOULD be a creative endeavor...and as for prejudiced people who think otherwise, I have no clue what they are thinking so I cannot answer for them. I think science should be creative, and it is actually a trend. Especially these days, in this field, a lot of times you have to be creative.

I do have a question for you. You mentioned you have been collecting interesting data, and I was curious about what kind of data you have been collecting and if you would not mind sharing a peek with me after you've finished with your project...

2.4. Lade, Steven
1. How did you get involved in “Dance your PhD”? What is your dance background?
   winner – physics - Dresden did postdoc, now Sweden;
   Group of astronomers at his university – Australia organizing a DUP workshop; one-day event just for astronomers; but also for other astronomers; but then advertised this among the rest of the university;
   They had a morning with a physical theater artist from Melbourne how to create and use your body; then they had time to practice;
   He did partner dances; one semester of ballroom, salsa;
   The workshop led to perform his dance in the night next – Christmas party that was filmed; he didn’t plan to submit in DUP, but then he had the video and then submitted

2. Did the lab participate or the lab leader? Were you mostly the leader or was it a common effort? How many were involved eventually? How did you choose the people to participate? Was it easy to find them?
   He was alone;

3. What are the timeframes you used? How long did it take you to work through the process?
4. How did you choose music, setting, etc.? How did you create the choreography? Who gave you feedback? He spent some time to think about the music; a friend helped him edit the video before he sent it; Molecular motors – dance suitable; two things – they walk on actin filaments; it came up on the day – who was doing what molecule; he started with the concept; and oriented the dance to the audience; he got an instructors idea to look heavier; Group dance not solo and encourage discussion; Included some other students; he had the music before; the water molecules – emerged on the day; The dance was much more effective through that process in the day;

5. What kept you engaged in the process? What about it made it a pleasant/unpleasant experience? He went to the workshop – he wanted to practice his science presentation skills; he had gone to present your PhD in 5 min competitions; He thought it would be fun to try to communicate through science; It was fun all the way through;

6. Did your participation affect your lab work? How? It did help him a little to step back and think more broadly rather than bury in the details, helped in writing it; he was not aware of negative comments; Random scientists e-mailing him his paper; writing comments on his PhD – well done comments; www.stevenlade.net

7. Did it affect the people you worked with and how? He got most attention after; he already doing his postdoc; talking to people from his new group; they found it strange, but cool in a good way; e tried to persuade them to participate, but didn’t happen;

8. Any negative effects on your science career / or positive? no

9. Would you keep getting involved in DUP or any other forms of dance, science, etc.? What does it depend on? He was a judge last and this year; he will continue to advertise the project; he’d be happy to help others, but not submit anything else; Event in Dresden- Science Slam – to communicate their research in whatever way; he repeated his PhD dance; a carnival; he’ll be involved in science communication; a science journalist who was visiting the city; maybe the university has picked it up; http://www.mpi-cbg.de/scienceslam/beschreibung.html http://www.scienceslam.org/content/science-slam-dresden http://danceyourPhD.pbworks.com/w/page/1973183/FrontPage

Sam Davison - the artist, he has done some interdisciplinary work;

10. What is your opinion about the Dance your PhD project? How do you see the future of this project? What are its perspectives? Any drawbacks? A few different angles: Student participating – gets to think them about the project in a different positive way; For all participants in video – gets them exposed to dance, out of the lab, a social activity; lab bonding exercise; science communication thinking more generally Observers – a different way of connecting what’s going on in the science world – understand what’s going on if the dance is good enough; Would you recommend – yes

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11. How did you get involved
One other student found it – as a joke; the supervisor responded that her PhD would make a good dance; started talking about it at lunch time; one time sat down and did it; Picked songs first; then finally decided to do it;
Lab or leader involved in the process? Between her and the lab, but definitely a collaborative experience’ a whole meeting about every major decision, then broke down the joy;
*We did think it was funny, and it was put out there to our group as a chain email joke, but the contest and idea itself wasn’t a joke… I think John/ my friends may be offended saying “we took it as a joke”. Maybe a funny idea? I think the contest is anything but a joke. Some people in science do think it is a joke, which is really too bad and needs to be changed I think. So, I really don’t want the “joke” part in here, if possible! Thanks! ☺
12. How long from the time started to submission, under a month; individually not a lot of work; most 10 hours per person, majority of gr 6/7 h
13. Dance background? What kept you engaged in the process?
She does not dance at all; group are all friends, they enjoy doing things together; many people interested in science outreach; chemistry talks, etc. Excited about the project – didn’t think of popularize, but to show to friends about your research;
14. Amount people?
She knows the kids in advance, and saw the potential and decided they’d do it.
16 people total
15. Did it affect your work? How?
No change at all to them or her; because it was in august; much more time in summer – met during lunch time, did practices at night; didn’t really affect work; the more stuff you do in free time, the more motivated you are to do work;
16. Positive/negative effect?
Since then, had e-mails from parents because of the video and kids liked science; family members calling her and share excitement;
Lab relationship, the pi was supportive and excited; in a way solidified the relationship with undergrads in the lab; the pi did Negative effect –isolated the lab from the rest of the department; they also made another dance; rather that standing out for research; Most have moved on – but there was brief moment; some people thought it was cool, some not, they all watched;
* Not entirely, just by some. Can this be softened a bit? (like “became known by some for its dances and not…” The lab still has a good reputation among most scientists.
17. Since she’s not a dancer she wouldn’t do it; but she promotes it
18. Postdocs – hard to convince them to put something in; in Stanford; happy to participate in it; but she’s great at thinking of ideas as long as there is someone who is good at choreography; combining the arts and science is really awesome; definitely will combine this for the rest of her life; it’s not as boring; it’s so exciting to share science with the rest of the world and get them excited;

*58 All post-interview comments are noted with stars.
Interview— they sent the video to the whole lab in advance; some people thought it’s cool; they don’t think it’s bad but they’re not into it;

19. Supervisor now – very hard working and brilliant; she doesn’t seem to be outreach actively; but it might have made a difference;

2.6. Miller, Joel

20. How did you get involved in “Dance your PhD”? What is your dance background?
Danced at clubs, having good time; never had any dance training or school; although he has done a little bit of salsa (social dance); his girlfriend Trish is a professional contemporary dancer; she heard about it and posted it on his wall; she suggested they should do it; at that time they were in long-distance; he Perth – she Sydney; he headed over to Sydney and started there; filmed about half of it in Melbourne; his sister birthday; so he used a camera with a lot of photos; didn’t have a video camera; they did a lot of choreography, did not know whether it was going to be considered dance or not;

21. Did the lab participate or the lab leader? Were you mostly the leader or was it a common effort? How many were involved eventually? How did you choose the people to participate? Was it easy to find them?
It was just him, the advisor did not know until he won the contest; family and friends, nobody from the lab knew;
He was the only PhD student in the lab; small lab; never considered the lab because his girlfriend wanted to be involved, so they filmed on the east coast; his area – engineering – heavily automated; guys are more difficult to get involved in dance;

22. What are the timeframes you used? How long did it take you to work through the process?
A week in Sydney brainstorming; none of the ideas were going to work; the ideas were complicated; needed to simplify everything; he made the music; rather than doing a lot of characters, they decided to have less people; (he makes analogy with dancers moving simultaneously to make an impression of one thing); he had to script everything the day before the screen; 6 hours filming, 3 nights to edit it;

23. How did you choose music, setting, etc.? How did you create the choreography? Who gave you feedback?
To give the effect of flying he had to do a lot of jumping; very physical so he had to split the shooting; uploaded it on the night it was due; got lucky that it all worked;
Music? - all music without rights; friend – “the transients”; decided to use the song of a friend; expected to have a “yes” but then he controlled the use of his music;
The story line – cliché love story; where a man sees a woman that he’s never seen before and wants to meet her; opened space, park, and that’s what they worked with; the indoor scene – different; did not fit with the rest – made a joke about it; Had the story line down and knew what needed to happen; all of the moves were added on the spot; just before they shot;
24. What kept you engaged in the process? What about it made it a pleasant/unpleasant experience?
Difficulties – expected Trish to be very involved with the choreography – a lot of stuff on the spot; how concentrated on the story; he felt she dropped the ball; difficult them to figure out what t=he wanted; then they put the photos together (20%) – he was certain they were going to win;
A car got stolen and computer broken; on the way to the last shoot park while filming;
All in all – bringing his sister in – a great dancer; not trained one; the good thing about it – all of them involved; that got momentum of the people want to be involved;

25. Did it affect the people you worked with and how?
It is a history now; some in jokes amongst themselves; a bonding experience between them;

26. Did your participation affect your lab work? How?
He was on a holiday doing it, but after – the trip to Brussels; he did not plan that; why not make it useful for the lab, so he went to a trade fair; and spent a week in U of Birmingham in a lab with world leaders in his field; definitely positive on his work; and quite a few people that got familiar with his work because he generated;

27. Any negative effects on your science career / or positive?
No one said negative things; the university was not that interested in promoting the win; it took them a little while to realize it was a decent piece, but they did and promoted heavily; the university considers itself very academic; they saw the value;

28. Would you keep getting involved in DUP or any other forms of dance, science, etc.? What does it depend on?
The TedX conference – he has taken a lead position in the TEED – Perth chapter;
DUP is about communicating science in an interesting way that captures people’s attention; TED is like that too; and he is very interested in doing that do engage people; he has to work with other people to support him; (energy); in the case of TED X – it absolutely needs the input of other people; value in this; creative skills;

29. What is your opinion about the Dance your PhD project? How do you see the future of this project? What are its perspectives? Any drawbacks?
He is using the DUP for partying when it comes judging; more broadly – the project could become (and it is) a big thing; it may become too big and hey might have to work on country basis; much people enter in the last moment;
Value? - worthwhile in terms of getting a PhD student to get out of the lab; it helps the students take a step back and see their research from a story perspective; get to see the bigger picture; it is fun to describe your work in dramatic terms; a lot of value;
When people know about the work you are doing, that is; other people get involved if they understand; and opens it up to others;

A couple of people contacted him with regards to teaching; a university in the states; he doesn’t really understand how he could use dance to do his topic to do research;

Forwarded e-mail: [10:36:05 AM] DUPHD-Joel Miller: I'm writing to the School of Mechanical and Chemical Engineering in the hopes that you can put me in touch with Joel Miller, who I believe is a current or former graduate student. I would like to ask Mr. Miller for permission to use his winning "Dance Your PhD Thesis" video on an
educational website. The website, Little Red Schoolhouse Online (redschoolhouse.org), is a digital environment for teaching and learning college-level writing. The site is being constructed by the University of Virginia's Writing Program with the help of several graduate research assistants, including myself. Each lesson on the site begins with a vivid illustration of the principle we aim to teach in the lesson, and we find that Mr. Miller's video perfectly demonstrates the way that complex ideas are easier to understand if they are mapped onto identifiable actors or characters.

Thank you in advance for your consideration and for any help you can provide. I look forward to hearing from you!

Best,
Jean Franzino
jlf9y@virginia.edu
Research Assistant
Little Red Schoolhouse Online
redschoolhouse.org
Doctoral Candidate
Department of English
University of Virginia

2.7. Tan, Cedric

30. How did you get involved? What is your background?
Someone forwarded them on Facebook the contest; at that time has started; the postdoc was a dancer, and they decided to collaborate – her PhD – latin dancing; before this he was choreographic dances … ?
His first video;
The following year – the fly one; the winner;
Started dancing 2006 – age 21, modern dance; then he did ballroom and latin;
Did the lab participate or the lab leader? Collaboration and supervisor different art forms; a paper – help children understand science; the video is easy to understand;
Was there a leader or a common effort? He was the leader;
He has two supervisors; one in the attraction video; other Tom Pizzari

31. What are the timeframes you used? About 6 weeks for production + 1 m video editing;; 3times a week , 2 h / day;

32. How did you choose music, setting, etc.? How did you create the choreography?
The music, then dance moves; together with the message
He used scientists to give him feedback on represent; and dancers – friends who had different technical backgrounds and were doing things they are comfortable with; he changed the movements if they did not illustrate the concept; the team works together to create the moves;
33. What kept you engaged in the process? What about it made it a pleasant/unpleasant experience?
Do it with people, fun, sex, good team building; achievement – accomplishment to send the message across in a humorous way – o have fun; stressful – deadline & big team; different to coordinate, dispute, diff;

34. How did you choose the people to participate? Was it easy to find them?
How many were involved eventually? 3 people+ 4th video; peacock – plus supervisor; + 2 video ppl;
More people asking for a 4th production;
More people getting more interested; the latest video – college got funding to support the video;

35. Did your participation affect your lab work? How?
Just a way to disseminate science, not much effect on science; also doing ballroom; free time – PhD; quite busy, but rewarding;

36. Did it affect the people you worked with and how?
Closer relationship with lab people – awesome feeling, different – barbecue- vs. dance; not shy, body contact; bring together creativity; less stressful and you learn a lot about others;

37. Any negative effects on your science career / or positive?
Shy first; lee playful and childish- latest one – professional; people take him more seriously; now; it got popular; in the department; but then he won and things changed;

38. Would you keep getting involved in DUP or any other forms of dance, science, etc.? What does it depend on?
Yes; nothing that can stop him, unless lack of people to collaborate; as long as you can move your arm then I say so; getting bigger;

39. What is your opinion about the project? How do you see the future of this project? What are its prospective? Any drawbacks?
Thankful for this competition and let him continue with this work;
Science education and outreach – more emphasis – DUP a platform in communicating science; more publicity; in a creating science via the arts.
3. Movement Exploration Data (1st semester)
3.1. Transcribed and summarized survey responses

Bullet point summary of survey responses from presentation at the end of the first semester movement exploration (April 2012):

1. **Favorite part:**
   - Clearly articulated activities - made science meaningful;
     - the content
   - Social aspect -
     - Walk and talk – getting to know other people
     - supporting friends / seeing them dance
     - Interactions with others (strangers), physical and communicational
     - Team work during modeling
   - **Accessibility and active participation** of the audience –
     - being part of the show instead of watching;
     - Resourcing the dance making
   - **Creativity**
     - making up science moves
     - dance creation from scientific concepts
     - choreography
   - **Movement**
     - because of intimate connection to the concepts (emotional)
     - because of how it looked in the space (aesthetics)
     - Modeling because allowed an artistic view on science, which was never thought of before that (unusual connections)
     - Seeing the same concept of microtubule formation from different angles helped solidify the concept a lot (learning and understanding)
     - Moving helped understand the concepts observed afterwards;
   - **Atmosphere** –
     - Lighting – change of colors
     - Use of the space
     - Music – uplifting, important choice in SC
     - Video

2. **What excited you**
   - Interaction with peers:
     - "molecular interactions became anything ropomorphic and colored by human emotions which made them more memorable"
     - Talking to strangers
     - Group engagement despite the unexpected situation, attracting the audience that would trust me; large audience participation
     - Working together with the rest of the audience
   - **Active Participation**
     - Creating
     - Involvement
     - The opportunity to dance my feelings about science
     - Learning about the body through the body
Moving, dance
- The dancers (break dancing, embodying the energy and it was exciting to watch)
- In such a big space
- Dynamics of motion
- Observing interaction and motion

Chance
- Unique and original experience
- Experiencing something that would not happen outside of Wesleyan
- The Unexpected in the presentation
- That Wesleyan supports such kind of activities
- Interesting way to learn about science in general

Modeling
- How well it related to the video
- Its success considering the lack of background for the audience
- Science interpretation of the and cargo movement across microtubules

The atmosphere
- The lights; how they changed
- Music

Further application
- Strategy for younger children who are more “right-brained and creative learners”

3. Did something unexpected happen to you?

Interaction
- Amount of interaction
- Interaction with different people
- Collisions with “molecules”/people
- Care from the dance leaders about experience
- Meeting and dancing with new people

Participation
- Didn’t think they’d be comfortable, but are very glad they just went for it
- Embodying a molecule
- Felt in tune with music and wanted to dance
- Lack of self-consciousness
- Performing and getting energized
- Unexpected level of interactivity and fun

Modeling
- A single entity (molecule) vs. a process
- Embodying (becoming) a science object
- Creating molecular structures

Creating
- Dance move related to science
- The dancers incorporating quickly movements from the audience into a dance

Learning/Reflection
Understood certain molecular interactions much better
Started thinking more about the dynamics of the cell
Learning science in a fun way
Thinking about straight molecular trajectories
Learning something new

- The venue set up
  - Being cut off by the music in the middle of a sentence
- Enjoyment of themselves and the movement
  - Enjoyment but lack of science understanding
  - Begin to see the beauty in the processes we take for granted
- Potential
  - Potential in SC, although it was considered “silly”
  - Seeing an unsuspected connection between dance and science
- No – several people

4. Other comments:
- Potential
  - For choreography, inspiration for movement
  - TED talk – replacing presentation with dance
  - great middle school biology class program to get kids engaged; "I hope it serves as intro of science in primary education"
  - "loved it. should be used to teach kinesthetic learners scientific concepts;"
  - For development in many directions
  - For psychology project (research potential)
- Educational
  - Learned new way of thinking about science
- New, fun experience
  - Connecting dance and science
  - Innovative experience
  - Unexpectedly educational performance
  - Made people smile
  - Interesting and refreshing
- Event Organization, Choreography, and Dancing
  - Well organized; “care in planning is important; choice of microtubule + motor = excellent; motion of molecule - good choice for SC;
  - Great lighting
  - Great Music
  - Desire for helpful links in the program.
- Confusion
  - Unclear what the improvisation at the end represented scientifically (it did not, it was art)

Transcribed Survey Responses:
Semester 1 - 63 responses
1. What was your favorite part?
   - walk and talk 5; getting to know people;
- lighting 5; color; the charge of color - when temperature changed;
- use of space;
- music 7 (improv) ; very uplifting and involved the movements; "choice is very important in SC"
- video =5; (they were informative)
- atmosphere of the setting 2
- choreography
- creative ideas

- improvisation of dancers -17; "after given intro to SC made the final part feel very unique and natural; "individual dancers danced on their own, ignoring each energy; no interactions- no chemistry. then, there were small macromolecules assemblies working together, then lots more lovely interactions between molecules"; also interactive element; " I felt it was fitting culmination of what we had been exploring, and I could see some of the movements and better understand what they represented - especially after we had gone though the motion of "SC"; spontaneous choreography and the final dance - interesting because the former was impromptu; "after seeing + taking part in the earlier exercises, it was great to look at dance as a means of expressing other ideas, with grace and beauty" ; "because of opportunity to dance/interact with the dancers;

- the movement of all the dancers modeling; individual dance moves; group movements;
- dancers creating a dance based on moves based on scientific concepts; (never thought about that before!)
- dancers incorporating moves they were given on the moment; making our own choreography for the dancers; watching the 4 movements become a dance;
- "scientific concepts" dance sourced from the audience; incorporation of audiences' movements into the dance and how it worked; involvement of the audience;

- microtubule model 6; being cargo (2); being microtubule; modeling because there was a task; because it allowed everyone to work together 2; " microtubule chain recreation was very creative and it helped me look at science in an artistic manner. I never imagined such expression of science was possible"; the opportunity to see the concept in 3 ways ( videos and 2 dance models gave different viewpoints that helped its solidifying the concept for me"

- movement 1- because "I felt I could connect to hte context and concept more intimately" ; 2 -
- engaging and freeing; 3- movement - easier to visualize model of a system; movement with music;
- making up science move because of creativity
- talking to people (walk and talk) because there was a reason to interact with a stranger

- participation 3 ; involvement; participation in models and representations triggered high school biology/chem lessons because had to learn the dance move;
• accessibility - great for young audience; "made me feel like a part of the show instead of just watching"

• embodying molecules 4 ; most interactive and illustrative part; + - interactions
• interaction 3 ; made it easier to understand the principles behind the dance;

• break dancing;

• dancers' movement - looked just like molecules
• "the clearly articulated activities - made the science much more meaningful;
• the class contents;
• "supporting my friends and watching them dance"

2. What excited you?
• interaction 9; with peers; "that break the fourth wall"?? ; " molec. interactions became anything ropomorphic and colored by human emotions which made them more memorable" ; bouncing off people; talking to others 2 (lovely conversation with a stranger;
• moving; dance;
• chance
• dancing in such a big space
• amazing dancers;
• unique and original experience

• participating/creating moves/dance; 8; 6- the opportunity to dance my feelings about science;
• involvement 2 ; emotional intensity - motion really got me involved; moving about the dances
• walk and talk; "the hands-on participation"

• lights
• Learning things about my body though my body

• opportunity to experience something new that won't happen outside of Wes 2
• break dancing 3; really embodied energy and exciting to watch;

• how well the modeling related to the video inside of the cell;
• molecules moving faster/slower with music

• everyone's engagement, even though we had no idea what to expect. you attracted an audience that could trust you ??? ; energy and focus of dancers; large audience participation;

• seeing own gestures used in the improv.
• incorporating scientific concepts into a dance ; dance inspired by science; 3
• use of people as models - because it was uncertain how successful it would be as the audience had not known what to do previously; modeling larger dynamic systems;
• watching others 2 ; watching everyone interact to form a mock-system of a cell;
• the first activity - interactive dance based on externals and doing it really excited me (and seeing it done)
• the dancers interact with the audience
• working in sync with the rest of the audience;
• music
• entire PowerPoint - did not know what to expect coming in and even while the PowerPoint occurred, no clue what to expect next
• the rise of temperature
• microtubule synthesis ; seeing cargo movement along the tubes + interpretation;
• "Using this on younger children who are more right-brained and creative learners; combining physical experiences with lectures makes sense as a strategy;"
• communal participation;
• dancing
• learning
• "that Wes supports this type of thing"
• interesting way to learn about bio-science in general

3. Did something unexpected happen to you?
• interaction 3; physical contact with a bunch of people;
• amount of interaction 2
• participation 4 ; participating ; involvement; "I did not think I'd want to participate in the dancing but I'm really glad I decided to "just go for it"."
• being a molecule
• understood certain molecular interactions much better
• collided with another +/- molecule;
• the set up of the venue

• making a dance (move) related to science
• A.G. was really good at helping me adjust to and understand SC which was something I had never come across before; a girl came to me and asked if I was happy - nice and unexpected!
• felt in tune with music and wanted to dance
• started thinking more about the dynamics inside of the cell;
• enjoyed myself and moving with others
• SC to model individual molecules/particles. I thought it was supposed to model/embdy some phenomenon, not an object.
• Surprised by the lack of self-consciousness I encountered when participating with eo
• enjoyed it but did not understand the science too much
• science lesson
• unexpected how dancers incorporated the audiences ideas in one second;

• "performing"; got energized
• became an anemome; being a microtubule;
• learning more about science in a fun way;

• no 9; was expected; good experience

• overall surprise - never imagined how interactive and fun it was;
• molecular structure enacting

• meeting more people was a pleasure! dancing with other people you didn't know

• "thinking about STRAIGHT trajectories of molecules"

• "I actually saw potential in dance choreography, even though I initially thought of it as a "silly" idea"

• "saw a connection between dance and science that I had never thought about before"
• "I learned more about science" 2; learned something new;
• "I began to see the beauty in the processes we take for granted"
• "cut off in middle sentence by music level"

4. Any other comments?
• exercise potential for choreography; inspirations for movement;
• TED talk - replacing POWERPOINT with dance;
• narrow down the notion of science in performance;
• very educational
• well organized and great dancing
• new experience 2;
• fun
• great middle school biology class program to get kids engaged; "I hope it serves as intro of science in primary education" ; "loved it. should be used to teach kinesthetic learners scientific concepts;"

• awesome lights and dancers/ choreography
• professional dancers;
• good organization;
• many possible points to develop + expand;

• Amazing - I learned a new way of thinking about science;
• cool and interesting presentation that connected two fields that would usually not be associated; "cool seeing dance and science connect"

• great music;
could do model building step-wise, adding rules;
very innovative
a little too education for what I thought a dance performance would be; "nth like I would expect form a regular performance. exceptional"; not what expected;
fun! 2;
" I am not sure what the improv at the end really represented scientifically: I think improv might just be hard to use in SC"
Would love to see more complex models;
"would work as a good psych project"
:) 2
"care in planning is important; choice of microtubule + motor = excellent; motion of molecule = good choice for SC;
"interesting idea but I wish there had been more of it" // maybe put some useful links on the programme;
interesting; refreshing
"provide the construct of modeling at the beginning w. dancers + have of the def. are abstracts and based on the frame of mind you come from you here a different reference point"

3.2. Event Program

Science Choreography – bridging dance and science in the fields of education, research, and performance
Elena B. Georgieva

While historically science and dance have both helped shape our understanding of the world, nowadays they seem to be more dichotomized than ever. In my research process I concentrate on science-dance intermediary work that has emerged in the last 20 years and I explore some of it through movement. I am interested to study how dance and science inform each other in the fields of education, research, and performance to make something called science choreography\(^{59}\), a new term describing the embodied connection between the two. Thus I hope to better understand what science choreography is and how it works, with which I am aiming to define the status quo of the field and lay out a base for future research. In addition, by stressing the importance of developing this emerging field, with my own work I hope to popularize the concept of science choreography among the broader audience.

Today’s presentation aims to give you a taste of what science choreography is and what it can do. The focus will be on molecular motion:

* we will use embodiment to try to understand the molecular patterns and learn from our kinesthetic experience;
* we will build a molecular machinery model in a living cell and study how it works while assessing its limitations;
* and last, we will build a dance phrase based on our impressions.

At the end, you will be asked to summarize your reflections in a short survey (see additional page).

\(^{59}\) A term that originated from Prof. Michael Weir during his collaboration with Liz Lerman’s Dance Exchange.
**Dancers:** Julianne E. Edwards, Ashley Garrett, Shipra Kanjlia, Joyce C. Noble, Anju E. Paul, Chazelle E. Rhoden, Natalie Sacks, Dat T. Vu, Michael Yee

**Music:** Emotional Beat (Instrumental), Don't Cry (Smooth Beat), Enya and Enigma, Caspian – Moksha, Philip Glass Violin Concerto 2nd Movement

**Videographer:** D. Adrian Rothschild
Light design and execution: Elena Georgieva and Chazelle E. Rhoden

**Acknowledgements:** I thank my advisor Katja Kolcio, as well as the other Dance Faculty members, staff, and senior dance majors for their incredible support and helpful suggestions.
4. Teaching Exploration Data (2nd semester) –

4.1. Notes and observations on students from second semester

The body: where science and dance meet

A. Beginning
Describe your first day of class. What surprised you? What went well? What in your plan did not work? What kind of changes did you make on the spot? Will you need/want to revise the remainder of your course design as result of something you learned on this first day?
The goal of my first class was to get to know the students and introduce them to the concepts we will be working with this semester. The first class consisted of my TA and one student only, which was quite surprising considering the amount of people that were initially interested in it. However, I hope for my second class there will be more because I tried to find a time that would work for more than 5 people.
The things that went very well were the activities we did together. We started with a warm up and a motion that describes a letter of one’s name and went around the circle until we got all of the motions. Without repeating the moves, I then asked everyone to make a short sequence out of their movements and we then did those three sequences in a row multiple times. It was great when they took the challenge and engaged with the movement. What ended up happening, however, was the repetition of similar moves and very literal interpretations of shapes and letters.
The things that I did on the spot relating to this exercise were to include a walking part and do the whole sequencing with music. I then proceeded with a short stretch with prompts from everyone in order to cool us down and prepare for sitting down.
We then sat down and talked about best and worst things about science, followed by talk on the connection between science and dance.
We watched a snippet of the “Ferocious Beauty Genome” which we then discussed. Some of the troubles with that were getting it to work, therefore for next time I will make sure my equipment is working in advance.
I do not know if I will have to revise something in my plan yet because I still have not met most of my students. My goal is to get an idea of what their interests in science and dance are and I will design the course around that. Yet, my overall idea is to introduce students to choreographic concepts and translation of ideas from science to dance and the other way around.

B. Place
1. What are the characteristics of the physical space that influence how/what you teach?
I teach in a university underground dance studio that is quite big. It has piano, mirrors, bars, and a whiteboard, as well as technical equipment and projector. All of these influence the way I design my classes. For example, I try to show videos almost every class, I use i-pod, computer, and CDs. I have the choice to teach with or without mirrors based on what my goal is. The size allows me to ask them to go big in their movement and to really run in the space without being afraid of hitting someone/something else. However, it might feel lonely if we are very spread out,
therefore I ask them to often face a circle and create the feeling of inclusion throughout.

2. What are the characteristics of the culture of place that influence how/what you teach?
   Since the place is not familiar to any of the students and is university property, we have very clear rules about what is allowed and not in the space. There is a strong sense of respect in this term, not only towards the place but also towards me, the teaching assistant, and the rest of their classmates.

3. What are other structural characteristics of place that influence how/what you teach?
   The studio is a good travelling distance for the students, which means they are often late for class. This forces me to start late, and sometimes later if they want to go to the restroom before class for example. I am trying to make it more clear that the moment in which they come in the dance studio we start dancing.
   Being so far away from them also precludes me from making closer connections to them and being part of their normal school life. It has left me unable to make Wesleyan be part of their study environment.

C. People. Describe yourself and your goals in this context. What are you gaining from this experience?
   1. Who do your students think you are?
      A Wesleyan student, an adult, a teacher, a model? Based on my observations, I think they see me as a respectful authoritative figure, as somebody to look up to and somebody to learn from. Simultaneously I think they perceive me as somebody they can have fun with, somebody they can trust (at least I hope so), and somebody who is not judging them but rather is embracing what they have to offer. I believe they perceive me as somebody very enthusiastic about the subject I teach and also about them and their involvement and contribution to the common learning. I also hope they perceive me in this way because it is extremely important to me that the classroom is a safe space for us to share experiences, to learn, create, and to help each other have a full experience.
      Who do you think your students are?
      They are home-schooled teenagers, therefore I assume they are very respectful and more disciplined than normal high school students would be. This preconception has been confirmed later.
      The students are very independent thinkers, they seem to be used to being challenged and to embracing situations on the moment. They are willing to experiment, go out of their comfort zones, but are also very responsible for their own bodies and learning. This kind of class environment is highly stimulating because I feel I can “throw” anything at my students and they will experiment with it. I am not sure if it is entirely coming from them or the way I approach them, but the final result is the same: very productive learning environment.
      2. Describe two students in your class.
      One of the students is very energetic, she has some dance background, and she very quickly grasps concepts and ideas. She is somehow always positive and engaged. Another student is also very receptive, but her attention somehow wanders off quickly. She sometimes talks to other people from the class when we are doing an exercise and her attitude does not seem that jubilant throughout. However, every time
I approach her, she responds back with a smile and always seems to have actually heard what is going on.

D. **Interactions**

1. **How do you manage discipline?**
   I mostly try to keep them engaged throughout which helps a lot, i.e. they do not get distracted by “extra” time in which they do not have anything to do. But for the most part I do not have any trouble with discipline. Sometimes they start chatting with each other, but then I assume it is my lack of preparation to engage them and I try to find something extra, like a more challenging task if they were done with something first. Or when I see it is a common thing, I just give a water break and this usually resolves the attention problem.

2. **Feedback?**
   I try to share my excitement with their work throughout the class and how creative and smart they are. I feel like they are really present in our classes and I try hard not to lose their attention.
   When I give a specific movement exercise or task I try to go around and give individual attention to all of them. When I ask a question and there are many hands simultaneously, I try to make it clear that all will get a chance to talk and then I make sure to hear their opinion.
   I often admit when I make mistakes and in this way I try to give them the feeling that we are all learning together. One of our class rules is that there are no right or wrong answers, so anything they say I try to encourage.

3. **Transitions? Dynamic flow?**
   I plan out my classes long in advance so I know very specifically what the logical flow of my lesson is. In this way I ensure first, that the students clearly see the point of the exercise, that they have some previous information to grab onto, and that they something different. For example, I try to order the exercises/activities in a way that the energy and dynamic in the classroom changes: after an energetic running around, we would have something more calm, after a lot of talking, we would get moving again. Usually my lesson plans have more to offer than the class time allows me to do, which sometimes means that I ask them to work quickly and constantly keep track of time. Thus I also build a sense of challenge and rhythm.

4. **How do you connect your course and teaching to the outside world? How do you help your students see the connections of your course to their lives, both during the course and after?**

   From the very first class I asked the students to write out what their goals for the semester are and what they hope to get out of the class. I also asked them what the best and worst things about science are in order to have some information to hook onto as to how to make the course throughout relevant to their goals and expectations. I was lucky to get very specific answers and also more general desires such as “dance sometimes hurts,” and “I am here because I hope to meet new people and learn about how science and dance connect.” Some of the students shared they would love to be able to apply what they learn outside of class, for example to teach others. Some just wanted to move and dance, and some hoped to actually learn some science.
Based on these responses I focused the class on the body as the meeting place for dance and science. More specifically, in the class we learn how our body works, and what is good and bad for it and why. With this in mind I designed classes looking at scientific principles of how the body functions, internally and externally, what physics forces apply and how our knowledge about these processes can inform the way we move, dance, and choreograph. With this it is extremely easy to connect to our everyday life because I use their common knowledge and perceptions about things to extract universal principles that apply to my lesson plan.

Later in the semester I planned individual choreographic activities where they work on a science topic of their choice and about which they would like to make a dance. This will be entirely based on their own interpretations of their chosen topic and I am the moderator to give them feedback about what options they could explore and how they could enrich their choreographic experience.

With the course I hope I give them the skills necessary to engage in their own learning about dance and science, and about life in general. I hope they can more easily make connections between different areas of study after the course, and that improve their school work.

E. Middle and Ending of Class
The middle of the semester came too quickly before I realized it was the middle. With that came the end too because we basically stopped having classes since November. One of the things that bothered me was that students kept coming and going and there was no sense of uniform community for a good amount of the semester. We could not even see each other for a last time and finish the class in an appropriate manner. Everything felt so insecure but I know it was not my fault that the students could not come to class. Maybe the next time I organize a class like that I will make sure there is a real sense of commitment to it.

Although I was not able to teach all of the lesson plans I had prepared, I was happy to have been given the opportunity to meet all of these students and explore science and dance for a bit. I still think they got something out of the course and will continue engaging in dance and science with desire.

F. Extra notes
I worked with a TA this semester and I found this a very helpful experience. Although I know that in reality I might not be given the luxury to have a TA, it was useful to think of another person as a co-teacher. Sometimes I was not sure how to approach her, or what tasks to give her, but it worked out very well eventually. She was extremely supportive and helped me keep track of what was going on. It is interesting to note how guiding her made me be even more organized and made me think about my authoritative role.

In relation to that, I also had to plan a class for which I was gone. I realized a lot of the unstated rules and concepts in my lesson plan when I had somebody else look at it and try to decipher my “code.” For example, how a class begins and ends, what I expect from the students, what are the details they need to pay attention to, etc. In the future I will probably make a much more detailed description of my plans and make sure that anyone could repeat my class based on that. It will be also helpful for me to reflect on what worked well and what not. In fact, I had to repeat one of the lesson plans for a girl that missed class. It was interesting to note how I modified that
class when she was alone with me. Some concepts were related to group activities so I had to cut that part off, but it also allowed me to give her my full attention and expand on some things more.

4.2. Course Syllabus

Our Body – where science and dance meet
Wedn. 2:30 – 3:45 p.m. CFA Dance Studio
Wesleyan University

A course taught as fulfillment of requirement Dance Teaching Practicum at Wesleyan University.
Student population: middle to high-school home-schooled students from CT, US.

Instructor: Elena Georgieva, egeorgieva@wesleyan.edu, 860 – 807 – 5252; also on Facebook, and skype – farmel_f
Teaching Assistant: Yuko Fukuoka, yfukuoka@wesleyan.edu, 503 – 333 – 5636

Course description
The goal of this semester is to direct the student’s attention towards the body as a meeting point of science and dance. The questions we will address include (but are not limited to):

- What is the science that guides my body? What external and internal scientific principles are valid for me?
- How does knowing the science influence the way I move and dance?
- What is the dance that happens inside of me every day? How can we make sense out of it and represent it?
- What choreographic principles can inform the way I represent the science of my body?

The focus will be to learn about ourselves on physical level, explore ranges of motion, and how we can use our body to create utilizing the three basic choreographic principles of space, time, and energy.

We will take note of the dances that go within us, how we function, what basic anatomical principles we should be aware of when executing movement safely. As we familiarize ourselves with the body, we will learn how basic science principles such as gravity and force apply, how the skeleton is constructed, how the muscles work. Along this exploration we will learn about healthy practices and habits that we can apply to our everyday life.

The three main body concepts we will work with are release, strength, and lightness. We will explore these in the context of science (how do we explain what is happening?) and in the context of dance (how can we apply them?).

Class rules:
1. We are the owners of our own bodies and we should be aware of what is happening inside of us. We have to notice our zones of comfort and discomfort, and should engage in this action even when we opt out not to participate in an activity. We ask questions and try to answer them.
2. There is nothing right or wrong, there is not an image we are striving for, but we are trying to feel and understand how the body works. The class is a place for discovery and reflection, not for virtuoso performances.

3. We choose whether to participate or not. In either case, we should be positive and encouraging, and not disrupts others’ opportunity to learn and engage in the activity. When we give feedback we should say what we see, take note of patterns and what grabs our attention, and not judge, because everyone comes from different backgrounds and we have different skills to offer.

Homework and Assignments. Evaluation Policy.
- You will be given small assignments every week such as video watching, dance phrase creation, short written reflections. Although most of the work will be in class, these are aimed to help your learning and are not going to be graded.
- Your work in the class will be evaluated mostly on your in- and out-of class participation, motivation, as well as progress throughout the semester. At the end you will receive a written and spoken evaluation from me, as well as a certificate for taking the class.
- Midway through the semester (the week before Thanksgiving) I will ask you to fill out course evaluation as well as personal evaluation so we can improve the rest of the course together.

Music
- Feel free to bring your own i-pods, mp3 players, or CDs to class.
- Please contact me in advance with songs you like and you find inspiring for dance. I will download them and make a playlist that I will bring every time.

Space policies
1. No food, shoes, or wet clothing allowed in the studio.
2. Water bottles allowed and recommended so you don’t need to leave the classroom.
3. Socks are not allowed during movement sessions, but are recommended during discussion times. Pullovers / sweatshirts as well.

Attendance Policy
The class is taking place once a week, which makes attendance extremely important. While absences are strongly discouraged, I do insist that you contact me in advance when you are not going to be able to attend. Further, you have to make an out-of class meeting arrangement with me so you can catch up with the material.

Class Dates and Meetings:

<table>
<thead>
<tr>
<th>Week Number</th>
<th>Class Date</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3rd Oct.</td>
<td>Getting to know each other and our interests and goals for the semester</td>
</tr>
<tr>
<td>2</td>
<td>10th Oct.</td>
<td>Exploring: Definition of science choreography (science and dance) in the context of our body.</td>
</tr>
<tr>
<td>3</td>
<td>17&lt;sup&gt;th&lt;/sup&gt; Oct.</td>
<td>Exploring: Sequencing and Patterns, how is the body connected/disjointed</td>
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| 4   | 24<sup>th</sup> Oct. | Exploring: Gravity and forces 1 – Newton’s Laws, friction, center of gravity  
(Physics Unit 1) |
| 5   | 31<sup>st</sup> Oct. | Exploring: Gravity and forces 2 – energy, work, pendulum motion, dance phrase encompassing all of the principles  
(Physics Unit 2) |
| 6   | 7<sup>th</sup> Nov.  | Exploring: the chemical environment inside of us – water, minerals, carbohydrates, pH (Biology Unit 1) |
| 7   | 14<sup>th</sup> Nov. | Exploring: Processes inside of us – the immune system – a dynamic dance  
(Biology Unit 2) |
| 8   | 21<sup>st</sup> – Thanksgiving Break – we might not have a class. I will specify by week #7. | Choreography |
| 9   | 28<sup>th</sup>      | Choreography |
| 10  | 5<sup>th</sup> Dec. – Last Class | Choreography |
| 11  |                      | Final Presentation – |

**General Class Outline**

- Warm-up and Intro to the concepts of emphasis for the day
- Analysis of Movement & Concepts
- Exploration of Movement & Concepts
- Stretching / Cool down
- Discussion / Reflection Time. Future goals / plans.
4.3. Lesson plans
4.3.1. Body Parts

Objective for the course – familiarize ourselves with our body, its range of motion, its ability to execute varied movements in relation to gravity and space (and time).
/ended up doing only standing upper body parts ;

Warm-up – Body Parts
1. We stay in a circle, allowing enough space between students to move. 20 min
Each of us is going to introduce a movement about a part of our body and pass it around the circle in repetition of 10. We want to note how this affects our body, which is easy, which is not, which might be harmful, and which not.
   i. Head
   ii. Arms and shoulders
   iii. Hands and fingers
   iv. Toes, feet, and ankles
   v. Knees and hip
   vi. Core, back, and torso
   vii. Combination – arms and legs
   viii. C – upper body
   ix. C – lower body
   x. C – left side
   xi. C – right side
   xii. C – opposition – right upper, left lower
   xiii. C – opposition – left upper, right lower
   xiv. Extra choice
2. We repeat the exercise but on the floor, trying to extrapolate the movements we came up with. Notice how execution is different. What is easier, what is more difficult, what is new, what feels more comfortable? 10 min
For interest of time we might split in #1 & 2. The #1 will start with a body part, and the #2s will choose a second movement for it.
3. Progression in space – everyone spread around the room and does several kind of movements based on my call for which body part; 5 min
Switch, switch, switch, freeze;
4. Move across the floor – initiating body parts (following list from above)– music accompaniment; 10 min
5. Stretching 10 min
Why is it good to stretch? What do we aim with it?
How do we stretch?
What do we stretch?
Go around with different body parts (1&2).
6. Watch a video 10 min
   a. Talk about bodily processes that could be described in our body
   b. Become familiar with the “Dance your PhD” program
   c. Talk about the Liz Lerman dance and the science choreography website
7. Class Discussion at the end. Homework – write out all of your science background – all of the classes you’ve taken and for how long. 7 min
What worked for you?
What was really hard?
What was your favorite part and why? And the least favorite?

4.3.2. **Body parts in sequential movement**

Objective for the course – familiarize ourselves with our body, its range of motion, its ability to execute varied movements in relation to gravity, space, and time).

Class Goal:

**Warm-up – Body Parts**

8. We lie on the floor around the room, allowing enough space between students to move. We try to extrapolate the movements we came up with during last class. 15 min Each of us is going to remember a movement about a part of our body and all of us repeat it. We want to note how this affects our body, which is easy, which is not, which might be harmful, and which not.

  xv.  Head
  xvi.  Arms and shoulders
  xvii. Hands and fingers
  xviii. Toes, feet, and ankles
  xix.  Knees and hip
  xx.  Core, back, and torso
  xxi. Combination – arms and legs
  xxii. C – upper body
  xxiii. C – lower body
  xxiv.  C – left side
  xxv.  C – right side
  xxvi.  C – opposition – right upper, left lower
  xxvii.  C – opposition – left upper, right lower
  xxviii. Extra choice – whole body;

9.  Sequencing and connection — grab a partner - pull each other? How is our body connected? 7 min

What happens to the rest of the body when we move our arm, leg, or core?

10. Progression in space and time – everyone spread around the room and does several kind of movements based on my call for which body part; They can do it up, on the floor, or middle way… 7 min

Switch, switch, switch, freeze;

11. Move across the floor – initiating body parts (following list from above) – music accompaniment; 10 min

3 times from the floor, then go up and try the same (3 times), and then switch between levels up and down (3 times) – How can we do this? Up-down, down-up, lower/higher.

12. Stretching 10 min

Why is it good to stretch? What do we aim with it?

How do we stretch?

What do we stretch?

Go around with different body parts (1&2).

13. Discussion:

What worked for you?

What was really hard?

What was your favorite part and why? And the least favorite?
14. Watch a video 10 min
a. Merce Cunnigham – body parts! http://www.youtube.com/watch?v=ra2T_iMXQVM
b. Garth Fagan – body parts; http://www.youtube.com/watch?v=y32mOnYzOkk
c. Urban Bush - sequencing; http://www.youtube.com/watch?v=iv0j_uwfs1w

15. Homework – write out all of your science background – all of the classes you’ve taken and for how long. 10 min
a. Talk about bodily processes that could be described in our body
b. Become familiar with the “Dance your PhD” program
c. Talk about the Liz Lerman dance and the science choreography website

4.3.3. Physics 1 & 2

Gravity and Forces of Motion
The Body – the meeting place for science and dance

To do list
- Make a worksheet with terms
- Homework sheet
- Get a pendulum (use my poi?)
- vmiглас@wes – responsible for physics things ;
- Stopwatch
- Choreography… one movement per slide combine at the end;
- Chunky Move video
- Send Yuko book title...
- Science Saturday Announcement...

Class Goals
- understand basic physics principle that determine how the body can move in space in relation to gravity
- Apply these principles on our body
- Learn how they relate to body parts and connectivity
- Learn how to use them in our advantage to make our motion more efficient, smooth, controlled
- Explore new ways to move – resiliency, lightness, force
- Create a dance phrase with all of these principles
**Warm up**

- Disjointedness vs. connectivity –
  - shake it 8-4-2-1 times – each limb
  - Try to isolate movement
  - To connect to the whole body
  - Try different body positions (bent on the floor)
  - Try different body parts (somewhere in space), explore levels again, switch on every call!
- Trust circle – people falling onto each other...

**Gravity**

- Mass vs. weight
- What is gravity? How do we think of it in a body context?
- Force = mass * acceleration (g)
  - g is always the same for every object (compare two different objects falling down/ compare hands/ppl falling down).
  - Opposing forces –
    - anti-gravity
    - friction

**Speed**

- Constant speed -> no acceleration;
  - How do we measure the speed? – how far/s;
  - Frequency – e.g., how many moves per second; count the beats of a song / minute;
- Positive vs. negative a; (walk across the room with increasing speed vs. slide on the ground)
- Friction – (pull a friend exercise) determines a;
  - Static vs. kinetic; which is bigger?
  - What does friction depend on? The floor, the weight, the angle of the force. \( F = \mu mg \cos(\theta) \)

**Warm up – Forces that affect us**

- Going through different media – 5-7 min
  - Walking on a cloud
  - Being in water
  - Walking on glass or needles
  - Being in peanut butter
  - Being in jelly
  - Jumping on the moon
  - Falling from the sky
  - Walking on boat
  - Rolling in cotton
- How did our behavior change? How was movement quality different? – 1 min

**Momentum**

- \( p = mv; F = \frac{p}{t} \)
  - What would happen if \( v \) or \( m \) increases/decreases?
  - Grab a friend while running / grab a sock game;

**Changing levels in physical terms**

- Pain – what is it caused by?
  - How we increase our time of impact? Slide, have bigger surface, fall on something soft, have someone/our body grab us;
- Greater mass – smaller force, less pain;
- How can we increase our time of impact? Slide, have bigger surface, fall on something soft, have someone/our body grab us;
- Small mass – greater acceleration; small acceleration, greater mass; \( Ft = 1f \)

**Energy**

- Pendulum – changing momentum = impulse = change in momentum...
  - What if the distance of the string is shorter/longer?
  - If we want to move the whole body how would it relate to connectivity and momentum?
- Conservation
  - Potential vs. kinetic (height vs. motion)
  - How it relates to work?
- Goal – learn how to “harness” energy

**Phrase**

1. falling limbs - up or on ground -8-- W, g
2. swings upper body, w. jump – pendulum-8-4, Ep, Ek
3. falling backwards – 4 – Ep – Ek
4. walking quality16&16- v, a, f
5. Melt on ground –8- Ft
6. Leg swings from side to side & Roll – F – f – p
7. Push to sit on ground and push yourself through the space – F, f, p
8. Push to sit up & to get up F - 3rd law, Ek-Ep
9. handstand – pendulum – connectivity, Ek - Ep
4.3.4. The Environment

Theme of the course – The body – where science and dance meet

Objective for the class –to familiarize ourselves with the environment in which our body exists and how it affects us. What is our internal environment? How does change in the environment change us? How can we change the environment? What is our nearest spatial environment? What is minimal? How can we play with it?

The internal environment consists of … blood, which is made of cells (our parts) and the liquid they move in (the environment). What does the environment contain/what properties does it have?

1. Water – liquid, in motion; warm;
2. Salt – dissolved (not crystal), ionized;

1.1. the water in motion - dance – - give them the six motion types – embody it and switch a card; music background; (rhythmic music) ; walk for 16 , 8 wih arms, 8 with legs find a partner - 8; (demonstrate) http://en.wikipedia.org/wiki/Molecular_vibration; http://www.chemtube3d.com/vibrationsH2O.htm

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Summary

- Newton's Laws
  - 3rd – opposing force
  - 2nd – body in motion or stillness
  - 1st – F = ma
- Phrase Learning
- 3 Forces in dancing;
- Watch a video – Chunky move http://www.youtube.com/watch?feature=player_embedded&v=vKXlczs2Y8;
- Handout quizzes;
1.2. sour – facial expression, minimal dance; salty, butter, sweet; counts of four – switch face on counts of four – sit in a circle; (1min)

pH – def. – water dissolving; embody this in molecule sense; draw on white board; -

- partner exercise – 2 groups of three people; or someone in center of room, people associating,

dissociating – at random time; (1min)

improvisation – modeling of the concept – feeling how water feels; explore levels; space –

boiling;

(rules- always vibrating, always moving, never staying at the same place, always interacting
with other molecules and the environment;) (2 min)

acidic vs. basic – which parts of our body; Stomach – acidic; skin too; intestine- basic –

dissolve protein; bile – acids; neutral environment – how do we describe this- equilibrium of
dissociation and association; equilibrium as a static / dynamic balance ... ;

task – make a minimal phrase of 8-16 counts describing the acidity of the different parts of
your body; (2 min) + 2 min show


Bring a pH indicator to class...; bring some vinegar; some soda or try at home – give the kids
pH paper.

1.3. How does temperature affect the way we act? Try out vibrations; dissociation; pH?

2. Salt - embody it’s name, sound, structure (square) & vibrations; ionization – having a hat
that’s to obig for you – missing just the hat of the costume... ;

improv – too much salt in a tiny space vs too little – dynamic balance of the blood
environment;

3. Nutrients – sugars – bringing energy - bigger molecules – how do we describe it =
function, sound, feeling, structure – 6 membered rings – up and down – legs and arms out –
stable vs. unstable structure- range of motion in and out of it;

Structure building – bodily range of motion, its ability to execute varied movements in
relation to gravity, space, and time).

Homework – teach a sibling, parent, or grandparent one of the concepts we learned in class.

Note on a piece of paper what was easy and what not. Did they get it? What do they think?

Thinking question – what else is there in the body? What is environment?

4. Discussion : (1 min)

What worked for you?

What was really hard?

What was your favorite part and why? And the least favorite?

What did you learn today?

How does it relate to moving our body?

4.3.5. The immune system (not done in class)

The life inside of us and how we protect it: the immune system

Goals:

1. Why do we have one/what does it do/what is made of?

2. Learn about how cells of the immune system “see” and respond to a foreigner

3. Learn how what kind of partner work/contact we can make in a dance through the

exploration of these science concepts.

1. Warm-up: Walk and Talk (10 min)

How was your weekend?
What was the most exciting thing you learned from last class? How did the video relate to what we learned last class?
What are the smallest living units we are made of? How do they look like?
What is the immune system and what does it do?
Repeat without words… How do we communicate something without words?
What if we cannot use our gestures or mimics? (5 min)
2. Discussion – go over the questions; how did you explain what you wanted to explain? Difficulties? What is the task of the immune system? How do pathogen get inside of us?
What is the purpose of our immune system?
Why do we have one?
What does it actually do?
- Protect body from “dangerous foreigners”
- Distinguish self from non-self
- Kills pathogens
- Prevents infection
- Generates memory
- Prevents disease
- Kills tumor cells
- Keeps us healthy
To protect us… we are going to explore how it does its job through movement;
3. What if that thing is urgent and we need help? How do we make someone pay attention to us and do what we ask them to do without words?
How can they respond?
a. Have them stay in two columns facing each other; go over the vocab; (10 min)
How do we work with a partner and what kind of contact can we have between them?
- simultaneous, delayed, not responding
- Mirror, contrast, repeat
- Exaggerate, diminish, adequate
- Passive vs. active vs. semi-active
b. Have a group exercise (call and response) – split them into groups of (three) four, rotate each of them to be the messenger, give them cards with tasks/tell them what response to have to the messenger. (15 min)
Your response should be one of each category per # of messenger (person):
1. simultaneous, delayed, not responding
2. Mirror, contrast, repeat
3. Exaggerate, diminish, adequate
4. Passive vs. active vs. semi-active
Your call should be:
1. One time
2. Persistent
3. Fast
4. Slow
Rotation goes base do on the categorie s below, sample card looks like:
It is choice of students how to respond.
The immune system detects an antigen (invader, microbe, virus, foreigner) and tries to signalize to the rest what is going on by going to the place where the other cells are (the lymph nodes). If appropriate, it tries to activate the rest and point them to the direction of the invasion. The response and how we deal with the pathogen depends on how successful the messenger was. There could be local response from the innate immune system, and there could be a global from the adaptive one. The latter leads to memory, so if the pathogen comes again, the response is fast.

4. What if we want to calm someone down? (10 min)

5. Conclusion (improv) –

   1 vs. 3 pathogens, 1 a messenger, (2-3) a group that is responding, and a control person 1.

   Is something foreign?

   Is something dangerous?

   What’s the best way to deal with it?

   a. “Should I respond?”

   b. “How strongly should I respond?”

   c. “Should I ignore it?”

   The default (“normal”) response is to respond strongly

   d. Controls must be induced to prevent the default response
5. Data not discussed in thesis
5.1. Dance in science research
5.1.1. Comments from interviewed Wesleyan professors

Singer: As for his research – no significant effect; the quality of the science that he is bringing, the rigor of the empirical work; personally it’s more fun to think of his research in other terms;
Cohan. Before – “Global change and infectious Disease” – he wanted to do a simulation of lime disease of ecology; why a forest full of deer mice – vs. more species; set up the model ; diff. properties of the infectiousness; 2 mistakes – 142 students – too many; since they were trying to collect data, it was very important that students were rigorous how to follow the rules; and the data was not so good; then he realized that it is something visual and physical to enact an idea, collecting data, bad idea, it might be easier to do on the computer; have smaller group – focus; It doesn’t seem easier to use people to simulate a data; it’s easier to do it mathematically; understanding concepts from movement – physical metaphors;
McQueen: now, (last summer) Dianne is all about choreographer going through a scientific method to go to a final piece; thinking about correlation of dance leading dancers – reminds her of being a PI: have a vision of where the research is going, don’t know the aha; rely on students to provide you those moments; a lot of parallels – sometimes dancers were there, sometimes not, when together, got aha moments; the artistic process is so similar to lab work – to publish a paper
Grabel - Harder to integrate it in the research; last week – one of her student; she had you embody the growth of a primary cilium organelle; it was helpful from basal body –centriole – that was useful in understanding of their understanding of that structure; moving into the research domain; when the visual model Is static or not as revealing, it helps to put it into; ; Consciously – not finding a way in which it informs;
Lane - It honestly hasn’t be applicable : most of the classes he teaches are really in completely different orbit than his research; goals in course are far more broader and conceptual ; class- developing concepts; res – pragmatic –explicit goals; occasionally – theory discussion; doesn’t mean it cannot be done; he hasn’t faced a conceptual problem for which he thinks embodiment would solve it; then he just does it on the computer; /
Weir: Not using them ; there are aspects of our teaching where analytical methods – models – useful in curricula setting; where conceptualization and thinking approaches are developed – a way to catalyze this; one teaching to one thinking – hence direct on research; Having courses with focus on SC – s open qn; development of the approach works in small modules; the full course project might lose focus and vitality; a module is a modest investment within the class and can have a significant impact;

5.1.2. Interview with David Odde
I really enjoyed our conversation yesterday! Here is a link to Bob Hammel's documentary about The Moving Cell Project http://vimeo.com/30346802. Another link to see a bodystorming in action is at: http://www.ias.umn.edu/collabs11-12/MovingCell.php#Events
5.2. Science in Dance Research, Choreography, and Education:

5.2.1. Interview with Rachel Boggia

55. What is your dance and science background? Have you experienced this often perceived dichotomy between science and dance?
Danced since she was 5, ballet, tap, jazz, acrobatics; father science teacher, exposed to science education from very young; in high school go dance in summers, or science, 1 summer; in college she did dance, Cunningham, it has this kind of objectivist approach to choreography; she found this similar to science method – rather than aesthetics; ended up being a science major; she wanted to be a medical doctor; a lot of practical work, neuro-pyschologist, and ecologist, plant work; a lot of lab experience; NYU medical center; hospital for joint disease; didn’t enjoy lab work as much ; she felt she had more passion for dance; went to graduate school in Ohio State; enjoyed every moment of it;

56. When was the first time when connecting dance and science just made sense for you?
At Cornell made dances about atomic structure; pretty basic –

At Ohio state the head of the biology department (2003), Dr. Fischer – teaching biology for non-majors; she responded to research of different learning styles; she commissioned Rachel to make a dance piece about DNA translation; she made this funny dance and challenging ; after she was asked to more – worked with videos; so she could distribute them; she made three – translation, Krebs cycle (marching band ), photosynthesis (football team). Ended up being pretty popular in her classes. What mostly came out – they broke up the lecture and incited ppl’s curiosity; people liked them, they were memorable; they’d remember the lectures, or at least the videos better.

Other scientist, Nandini Tr., physicist – superconducting work; asked her to make a piece about electron behavior ; performed this in Columbus major science museum; they performed the dance and explained to the audience what each person represented; then guided dance party; She was learning a ton about science; every time you need to translate, you find your gaps in understanding; dancers were learning a lot too; wasn’t very happy with the aesthetic of the dances; she didn’t feel happy to make a dorky dance; hard to make an interesting dance and science pedagogy; still finds this tension in her work

In Wes she found all these people bringing science and social research and dance ; really excited, spurred by Liz Lerman, excited by the amount; her favorite collaboration with a scientist – Prof. Singer - ; how we make knowledge in their fields and methodologies; instead of focusing on science pedagogy (conveying knowledge through dance), they used performance to understand where each individual stood between science explanation , relationship to nature, ; what is it to allow us to examine the different ways to interact with nature– science, literature, documentaries, physical experience;

She really liked the piece, it was not trying to teach the audience, but approached relative to nature from different perspectives; students had a lot to say;
At Bates – another piece for super conduction; she didn’t like how simplified the movement had to be to be clearly read; so she wanted to collaborate with a playwright – so combined words and dance – movements and change, but then that fell through;

A couple of pieces based around particles and waves, nature of light, interested in comparing approaches to choreographic translation to science knowledge; two pieces – one a dancer – embody both nature of light; another piece – separated particles in one and waves into another student group;

Because of her aesthetic as a choreographer she finds it troublesome and challenging; corny to have human things represent non-human

What is the research method of scientists vs. choreographers;

1. subjective – objective

Most choreographers accept their personal view, while science is trying to be objective; the dichotomy she sees – positivist vs. not; some scientists don’t believe there is an objective reality either;

Before it was this kind of niche things, not understood why she did it;

57. Why did you decide to mix science and dance in your teaching? How long did it take you to develop this and implement it?

If you pick an example – and tell me about the process;

Semester long experiences; she’s been doing this for 9 years on and off mixed into other kinds of work; it is incredibly deep feel; she tries to step in from a different angle; each time she learned something about science, choreography, and herself as an artist; what she really learned that the making process is the most educational; rather than sitting and watching a dance about science, having students work through it – students had very interesting questions that even scientists could not answer; as a choreographer you need to know how to transition work, and scientist might not know;

ex. Mitosis – in what order do these chromosomes form – they don’t know …

She thought Katja (Kolcio)’s class – in 2010 – so interesting – learning about biochemistry through choreography – and that’s exciting, making, not watching;

On body level – very clear connection between science and dance – also neuroscience – muscular patterns; neurology of aesthetics, perceptions, liking; a friend studying the perception of the performing art;

Motion Bank… forgot name; biannual meeting between dancers and scientists – in Germany;

58. What difficulties have you had? Successes? How do you know what worked out, from students’ comments or your own perceptions or anything else?

The most successful moments were either working with students choreographers or at Wes where she was able to create environment where students really learned something about science and reflect on science and how to make decisions about their relationship to concepts like global warming;

Another – science museum – surprised audience;

Difficulties – about how to make a hybrid, to create something that needs – that somehow respectfully hold the complexity of both the dance form and the scientific method; good piece of dance and represents science well; the questions of choreography that are going to lead fruitful answers; same in science- they have to find the fruitful questions in their research.
59. What keeps you engaged in the process? Would you keep using this and why/why not?
At the moment – she focuses more on learning about choreography before she wants to tackle such subjects; but she thinks to go back; one thing that keeps her in – the scientists are curious and open-minded people; she enjoys spending time with very creative people like scientists; she feels strongly our culture really values scientific knowledge and holds it on pedestal for experts to understand; she believes dance is a display where people can people can put their bodies in relationship to any process, just like I said, the body meeting place for science and dance- this place for big abstract ideas to; place for objectivity and subjectivity that come together; the fact that you are processing through movement, changes the way you can relate to that knowledge; and the way u can actively respond, and can reflect on your relationship with it in your own way dance provides us with a really (modern dance) reflective relationship with it; important to scientific knowledge; w

60. What are the things one should beware of when mixing science and dance in the classroom? Helpful suggestions for other educators…?
To understand how time to spend; how knowledge is made and outcomes valuated in the fields; when she gets a chance – luxury to spend a lot of time to talk about those things; it is two different bodies of knowledge, it takes a lot time to bring them together; how do you spend the first part of a semester, body principles, educational process into building body awareness; understanding the basic premises of both fields; quite challenging – to move between the practices of scientist to those of a dancers; body mind set-up is different; s
For someone – make it a seminar and work with students from both fields or have a lot of time because anybody can learn these ways of understanding the world; but if you want to move forward, need to have understanding of both fields;

61. What is good teaching/choreography in your definition? How does (if) science incorporation fall into this category?
Relates to… good t is enough info to interact with other people working on the same problem ; some of the basics of the shared language ; provides clear framework for students to relate to; provide space to have work into their own minds and perspective and bring in their rich life experiences; doesn’t believe in teaching that is isolated from the lived expectations of the students;
Science is about honesty, about asking a question and honestly looking for the answer; wants to encourage the same thing for her arts students; everywhere she taught- liberal arts – giving people a way of modeling what it’s like to bring together contradictory ideas and create actions; creating a performance could be how you could act in the world; simplified model of the real world what you need to bring together different ideas of what truth is; what phenomena is; and ten do something positive – make a performance;

62. What is the future of SC in your opinion? Why is it beneficial to incorporate it into academia? What is its value?
Surprised how many different weird people are interested in this relationship; when she started – no one else; in the past years, many many people; a lot of opportunities for high level artists and scientists - how does your understanding about the world help understand us, what does it teach me.; excited to see science acknowledging the role of the whole body in understanding the environment around us; dancers are experts; scientists seeing dancers values; also in k-12 – inclusion – moving as a way
to processing knowledge; helps people who have hard time sitting still, can empower people to feel more comfortable in the science situation; in college, sitting privileged people who sit and read; but real scientists go through the fields, do all of these active thing, schedules not prepare people to do all of these stuff; not that dance prepares people to hike;

One thing that dancers are really good at, is making something of what they have, responding to the situation; seen people that are very respected have hard time adapting in a change, dancers are used to be flexible, really valuable

63. How has SC influenced your academic, social, personal life? Has it had any undesirable or positive consequences?

Definitely became more friends with scientists; the dancer of it, both can get watered down, of any collaboration – when you try to bring disparate ideas, neither gets represented very fully or effectively; the other danger or side effect, dance, which is not as well respected as science; dance is seen as cool because of its relation to science and not its own right, but it is@! ; not neglecting things; the solution is having – 1 finding the right questions – sometimes simpler than the one we find sexy, and to finding the right collaboration; when she works with scientist, they are so much more curious than popular culture represents them, they are much more inquisitive, and dancers too, never met a dumb dancer in her life; having time to appreciate and understand each other’s perspective; learned a lot about it in Wes;

5.2.2. Transcription of Liz Lerman talk

University of Michigan 2007- Dance meets Genetics
http://www.youtube.com/watch?v=SgNps1Rcbug&feature=related

Pluto – change of status; everyone made models; When you embody something it changes your relationship to the meaning; changes are coming fast and they have deep meaning; how are we going to handle that? Where do we work those things out – many adversarial places; one of roles in art – a place and tool to deal with changes in meaning; the tools are in science and art – but not enough time to spend together…

big question is not enough in 1 discipline; the big ideas require more fields – designers and videographer; didn’t know she’s making a dance about genetics; use of genetics in art – upset people; info – shock – knew nth about it; as a parent should know – reproduction; U of Santa Cruz; Human Genome Project – wanted her to make this dance; U of Chicago – diabetes – if you can make people understand that science is beautiful, I’d do anything; esthetic questions – how do people get information – what role can beauty play in perceiving information? How much to give to the audience?

Mendel – science right – disagreement; education and learning goes both ways – art representational of the science- therefore people that would not get the science; how much info – debate; Wesleyan – Laura Appel – fruit-fly – addressing Gregor (Mendel) directly – section to show him what happened; design – act 1 – info – all scientists names- people cried – emotional connection, scientists talking to Mendel; ; act 2 – 3 stories; johns Hopkins science and Artists; Melon institute of Art; Elizabeth – pictures – confusing but inspiring to do something; diagrams; exchange – two way; collaborative – metaphor – poetically thinking about the work made
scientists get out of their box; William University – marker is not good one needs a whip – best characters – to make the best piece; the work is not about performance but also about community engagement; pull from the same body of knowledge and work with presenters to address their needs; i.e. working with local artists – many people who got excited – and resistance- high-art people – little interest; other problems – shootings – genetics not my world; genetics – work that’s both personal and scientific – Negros – social poems & spoken word; part of remembering and exploration through our own bodies; won’t be a waste of time- resistance- info; emotional engagement- thinking about a person with whom you’d like to share; notice details, trace the pattern - Liz – does not like purity of the dance form – maybe have to preserve some things, but now the artists have a different power; breaking the laws; comfortable sharing writing tools; who should know this info – Charles Darwin; artists responsibility to remedy issues; aging, perfection and diversity and ancestry - sections; working in communities- hard; genetics & ethics; understanding from artist perspective what the place is; Elizabeth showing Huntington’s movement- what is it like to be observing this; the sense of feeling uncomfortable; looking at tough questions; qn – artists asked: when did it become the opposite direction – the scientists? Scientist-choreographer The disability person – two separate lives; the two identities started to cress- arts and accessibility; ready to talk about mutation and how it is so beautiful and important; “How is science beautiful? What is beauty to you?” the scientific method??!! Testing?! http://sciencechoreography.wesleyan.edu/dances-about-science/cells-the-universe-inside-us/