

# Performing as Scientists: An Improvisational Approach to Student Research and Faculty Collaboration

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**Abstract:** The project described in this article is less about the content area, computational cell biology, and more about the educational practice of the students and faculty involved. Over the course of the past four years, Dr. Raquell Holmes has worked to create curricular resources that support the integration of modeling methods in biology education. For three of those years, students have been involved in the research required to develop chapters for a textbook in progress. This research experience for students is similar to other research experiences which include students identifying primary literature, participating in lab meetings, generating reports, and giving presentations. A unique feature of this research experience was its explicit focus on creating a group-learning environment. Students were hired based on their interests in the project and their willingness to work in groups. We describe the process that lead to the creation of a group-learning environment that supports the development of both students and faculty as researchers and academics. We understand this to have been a cultural, performatory process and introduce both the metaphor and practice of performance, particularly improvisation, in undergraduate education and research.

**Keywords:** undergraduate research, cell cycle, performance, improvisation, groups

## Introduction

In this article, we present how we created the research ensemble and our experience as student and faculty of creating an improvisational collaboration. The details of the schedule of our work completed each week have been documented in a suggested course outline developed at the BioQUEST Curriculum Consortium Workshop on Systems Biology (Holmes et. al., 2004). Here, our interest is in conveying the creation of a learning environment. We have intentionally broken the text into the different perspectives of the co-authors. The faculty perspective reflects the voice of Dr. Holmes. The Student Perspective, the voice of Ms. Qureshi, one of the student participants. Other sections reflect our joint opinion and description of the project design, performance, and learning.

### *Faculty Perspective*

Over the past four years, I have worked with four groups of undergraduate students on the creation of a textbook for cell biologists. The approach that I have to working with students and creating learning environments has been informed over the past 15 years by my work in supplemental education youth programs, professional development workshops, organizational development and training in performance based approaches to education. Through this, I have learned to see all of human life activity as performance. By performance, I do not mean the measuring of success as in “a car’s performance” or the identification of particular skills, but rather the activity of performing, as on a stage. In performing, actors, people, and students act both as who they are (students, non-experts, novices) and who they are becoming (scientists, experts, discoverers, graduate students).

The view of life as performance is an extension of work by the Russian developmental psychologist,

Lev Vygotsky. Vygotsky's work is visible in K-12 educational practice, theory and research and yet is less visible in discussions of college science education. Vygotsky identified learning and development as occurring in the "zone of proximal development". Some are interested in Vygotsky and his "zones of proximal development" as a way of looking at stages (Bodorova and Leong, 1996; Rogoff, 1984; Wood, Bruner and Ross, 1976). I am interested in this work as a view to co-learning and becoming. A commonly used example for understanding the ZPD as a joint activity is the early learning and development of babies. When a baby babbles with the family, those who "know" how to speak do not respond, "No, goo bibble does not mean anything." Or "You need to learn to speak." Instead they creatively accept and complete the meaning of the baby's babbling. Meaning is jointly created. Both parents and baby grow and develop individually and as a family. It is this co-creative, social activity that we see as performance. Performance is the process of learning together and creating an environment in which learning and development can occur. Parents relate to both where the baby is and that the baby is developing, becoming (Newman and Holzman 1997). The baby is related to as a speaker even as it is becoming a speaker.

I am interested in the process of becoming in the context of science and science education. In this context, Vygotsky presents a view in which learning occurs first socially and then individually (Vygotsky, 1978, p51). The importance is not in the faculty member creating an environment in which the students learn to become scientists, but rather that students and faculty member together create an environment in which science is done. Faculty and students are developing and learning. Products are created, but the products are one aspect of the larger activity of creating the group. The students were invited to create a working environment in which as a group they would become modelers and textbook writers. The language of theatre, particularly improvisation, is helpful to understanding the collaborative and co-creative process of building a learning environment. Co-learning, co-creating and becoming occurs in improvisational performances.

#### Language of Performance

Improvisation is often understood as theatrical spontaneity. However, to the professional performer, improvisation refers to a set of techniques and skills that are used to create a scene in the absence of a script. Basic skills of improvisational theatre include creating the ensemble (group) through listening, making and receiving offers, and "yes and". The ability to listen to what has been said by fellow performers is critical to being able to respond to what

they contribute. Contributions by performers are referred to as offers. The statement "The bird sat in the tree" is an offer. The responding performer must listen to what was said, accept the contribution and make their own offer in return i.e. "It was a humming bird." To continue to build an improvisational story, the performers say "yes, and". The performer does not take the time to evaluate the previous statement for rationale, feasibility, value for the story. Instead, the performer says "Yes, and it was the weirdest humming bird I have ever seen". "Yes, and" is both a philosophy and improvisational tool. It both builds the group as an ensemble and the group's "story".

The improvisational challenge in biology education and research is to create collaborative, scientific conversations that include the current understanding of the field, while saying "yes, and" to contributions of novice scientists in the performance.

#### Job posting

A job listing was posted for students interested in learning to create models and simulations in cell biology topic areas. The job required a minimum of 5-10hrs a week. No previous experience was required but a preference for students who had taken cell biology or biochemistry was expressed (See Job Listing below). Approximately eight students applied for the position. Students in the first research group suggested that students did better (willing to ask questions, could define their own directions) when they had some exposure to the biology. This was the second or third time that this position had been listed.

#### **Job title: research assistant**

Students will be responsible for running simulations of cell biological processes: calcium dynamics, cell cycle or signal transduction. Students will learn to create models and run simulations with pre-existing software. The simulations recreate results of previously published scientific studies. This job has flexible work hours, and requires a minimum of 5-10hrs a week with an hour and a half spent between 9 and 5 for team meetings. No experience required. Preferred background: one semester calculus, cell biology or biochemistry. Commitment through May or August (summer increased hours) also preferred.

#### Interviews

##### *Faculty Perspective*

Students were interviewed for the research assistant position. Students came from very different backgrounds: biology, engineering, computer science, psychology, and anthropology. They also came from different academic levels: freshman to graduate student. They were introduced to the goal of

our project, to create a textbook that teaches biologists about modeling. As an example of the work being done, I presented students with a draft chapter describing the process of modeling and the framework for modeling a specific process, e.g. the cell cycle. I emphasized to students that we would be learning the subject of modeling together. I had taken on the task of creating a textbook unlike previous books in the area; a text that could assist cell biologists like me to understand and do computational cell biology. Although I had experience with the topics we were investigating, I was not an expert. If the student joined the project, s/he would be my graduate student in the process of creating the materials. Performing as graduate students, these undergraduates would participate in conversations, asking questions, seeking answers and helping to define what we needed to do to advance the overall project. This is part of relating to the students as researchers even as they are becoming researchers.

We discussed the project, their interests in the topics and overall approach, learning through conversation, working as a group and not having the answers up front. In the course of these conversations, students would decide for themselves if they wanted to or were able to participate in the project.

My job as director in the interview was to identify ways that students could participate if they wanted to in the research project. At the conclusion of the interview, I asked each student a series of questions that would help me organize the cast, the research group. These questions grew out of the needs of the project and were designed to help me think about what the students would need in order to work as a group rather than individualistically. A sample of questions is provided.

### **Interview Questions**

Have you ever worked in a group? What do you think about working in a group?

Do you have a computer at home?

Have you ever made web pages?

What is your favorite and least favorite biology topic?

What do you think about learning something that does not have a specific answer?

What interested you in this job?

### *Student Perspective*

"I was simply looking for a research assistantship and saw a posting for this job at the career office website. Having no research experience and never having gone for an interview like this before, I showed up with a smile on my face hoping for the best, having no clue what to expect. "

Coming out of the office that day I felt that even if I never got a position, I was still satisfied with what I had accomplished that day. Not only had I gained insight into upcoming scientific methods that I had never heard about before, but I had had my first real job interview, and had come out of it having positive feelings about it. After waiting anxiously for about a week thinking whether or not my good feelings regarding the interview had just been one-sided or not, I was elated to read the good news in the email that was sent, telling me I had a position in the research group, and was invited to join Dr Holmes in the research for her textbook."

### The Group

All students who were interested were accepted into the research group. However, not all students were able to participate. Family issues arose, schedule conflicts, etc. The students that accepted and able to participate were undergraduate women. The first task was to meet as a group. Emails were sent to determine a time in which the entire group could meet.

### Creating Our Research Environment

In our culture and particularly in the sciences, our activity (conversation, writing, exercises, etc.) is often over-determined by what we consider to be true or correct. In order to discover possibilities and new ways of understanding, we need the freedom to explore and reshape our current understandings of what exists or is known. In order to create materials together, we (students and faculty) needed to break out of our traditional roles and learn to research together. Arenas in which we as adults are not constricted to our societal roles in life are in theater and play (Nachmanovitch, 1991; Newman, 1996). Improvisational exercises and games help build a playful environment in which we can learn to do new things. We used such games at the beginning of our group meetings to build an environment for playing with our understandings and the scientific materials (texts and concepts).

### First meeting

In the first group meeting, we used an "icebreaker" or group building game which has been called by some "truth or pretend." We introduced ourselves to each other by saying three things about ourselves. One of the three things had to be a lie. Technically, the next part of the game is that people guess what is true and what is not. As part of building the group we used this cultural game to challenge ourselves to work with what each person says, whether it is true or not.

As a group, we developed a work strategy that included meeting times and making sure people had the materials they needed for the project. This was

part of building a collective understanding of how we would work together.

At the end of the first meeting, we reviewed the process of creating a computational model, the biological topic (cell-cycle) and left with reading materials for our future conversations.

#### Overview of Modeling Process

Biological process  
Characteristic Experimental Results  
Concept Maps: Components, Reactions  
Writing equations: math and parameters  
Computer programs for modeling

ASSIGNMENTS: Reading for biological topic.  
Chapters 2, 3 of Murray and Hunt 1993

#### *Faculty Perspective*

I took for granted that the students both did and did not have the ability to model biological systems, just as babies do and do not have the ability to speak. In some ways, that was the point. I also assumed that readers of the textbook that we were creating both do and do not have the ability to model. The challenge for our group and the text were the same, create a context and approach by which non-modelers familiar with biology can become modelers. The context for the students was our research group.

My posture was, if students who were currently immersed in the details of mathematics, chemistry and biology could not understand or work with the information provided then it was unlikely that I was providing, describing or presenting what was needed to make the materials accessible to a novice audience. In the course of discovering what the group needed, it would become clearer what needed to be included in the chapter.

In our meetings, I would present my understanding of the biological system and the mathematical models that we were trying to create or teach others to create. I would also explicitly tell students where I still had questions.

Which of the two cell cycle models (Tyson, 1991; Goldbeter, 1991) do we want to introduce to readers? One is more detailed in its coverage of cell cycle factors and direct linkage to current experimental research (Tyson, 1991). The other is simple in that it has fewer factors but still covers the major components and behaviors of the cell cycle (Goldbeter, 1991).

Where do the parameter values (concentrations, rate constants) used in the simulations come from? Do they make sense

to us? Do we agree with the values or the ones selected?

These are the same questions that one asks in the process of creating models. They are not known a priori. As modelers, we decide the level of complexity or detail needed to address the question we are posing. We also determine what parameter values are appropriate or consistent based on experimental findings and current knowledge in the field. Addressing these questions was part of our group process of becoming modelers.

I tell students the steps of the process that I have gone through to understand mathematical models: identify the biology in the words of the research paper, match the words to the equations and terms, and develop an understanding of the reasons those terms or rate equations are used. I do not expect the students to do exactly what I have done. I provide these steps as a guide to getting started.

#### *Student Perspective*

"I have taken many science courses at the university, including introductory biology, chemistry, physics, and organic chemistry among others. They have all emphasized problem and research based inquiry in some way. However, this was a learning experience unlike any other I had experienced. From the very beginning, the professor emphasized that this project was going to be a collective effort and we would be learning from each other. I thought this would turn out to be just another tactic science professors are attempting to adopt in their courses these days to make their teaching more interactive, yet intuitively keeping the student firmly in the learner's seat and the professor rooted to his or her task of imparting knowledge and testing students. However, I soon began to change my mind when, to my surprise, I started getting the feeling that maybe I could help in the actual shaping of this project. My professor would give us information to read during the course of a week, and then call us in for a meeting at the end of that week.

Whereas I thought it would turn into a session of the professor getting our viewpoints and then informing us of the correct interpretation of the article we had read, I began to realize that my interpretation, if different from another member's, could hold equal importance and both were equally valuable in terms of how we might use them in our project. Other than reminding us of the general direction we wanted to be heading, the professor did not intervene by giving an absolute answer to any of our questions. She left it to us and our conversation as a group to decide which aspects of the article were worth focusing on and would help achieve our goal.

It fully dawned on me just how important my input was in the direction of this project when I was

able to help answer a query we all had regarding a certain variable quoted in a paper. No one seemed to know where that variable came from until I told them what I had learned about reaction rates in my general chemistry course. We discovered that based on my explanation we were able to better understand one of the key points in the article. Later, I saw that my explanation had also been incorporated into the chapter. That was when I truly began to feel an ownership of this project and further stimulated my active involvement in the readings and conversations that took place. I have seen many of my modifications or ideas incorporated into the textbook. This gave me immense satisfaction and encouraged me to take the work even more seriously. I realized that each time I came up with an idea, it could very well appear in a published article that would be read by and inform many others."

#### *Faculty Perspective*

A key challenge was to develop the group voice that included students asking questions, raising concerns or challenges to what I, or others, would say. What I needed were students able to raise questions and look at the same materials as I with a critical eye. This was not something that I could create on my own. I could, however, lead in creating an environment where it is okay to be confused, have a different opinion, or not know something. I used myself and the text materials as building blocks for creating such an environment.

Most modeling papers do not provide all the information needed to recreate a model. If there was a question, it was likely that it stemmed from something not being said or written explicitly. It was our job to make it explicit. This is an important justification of student confusion or questions. It is too easy to believe that the reason they feel stuck or confused is because of their own limitations.

I tell students my own limitations as part of creating an environment that accepts limitations. I inform students that I have a familiarity and working language for mathematics, particularly differential equations, but my understanding is shallow. Students presently taking these courses (calculus) are much closer to the mathematics than I and needed to help shape what was said and meant in the chapters. I stressed that what I say is my current way of thinking about the material. What I say may change based on what we discover and talk about. I share these concepts (experiences and philosophy) with the students as part of creating an environment in which it is okay to be confused, to not know the answers, and to highlight the process of discovery and learning how to learn. The students are invited to participate as collaborators who have something to contribute

including newly developed skills from classes, opinions, questions, and novice views.

#### *Student Perspective*

"One key aspect of the research environment the Professor helped in creating was the comfort level. I felt completely at ease coming into the meeting prepared to tell everyone that I could not understand one or more points mentioned in the articles we had agreed to study, and felt I needed further discussions or materials to give me the information that would help me understand. This uninhibited learning attitude in me is not brought about in most other university courses, but sprung forth in my meetings with the research group because Dr. Holmes constantly emphasized that our questions and concerns would be most helpful for informing us what more needed to be included in the textbook. In other words, if we were having trouble with something, our readers would most likely also struggle with the same concepts, and therefore simply bringing those topics to the group's attention would be the first step towards our advancement of the project. Solving those problems or addressing those concerns would then be the second step. I took this stance to be an opportunity for me to carefully read the (often dense) literature provided to us and highlight all the areas that were too complicated or vague in the literature, and let the group decide if we would further investigate those concerns. Clearly I would not have done so had the Professor not repeatedly reassured us that this was expected and encouraged, and therefore it helped create our unique learning environment in which I was open to sharing my difficulties with the group and collectively coming up with ways we could enhance our understanding, thereby improving the quality of our textbook."

#### How are we doing?

##### *Faculty Perspective*

A few weeks into the project, the students and I were working successfully in individualistic ways despite our hour and a half weekly meetings. I would assign individual tasks to members of the group during our meetings. During the week, each would complete her task and return. The weekly meetings saved me time. I did not have to have separate meetings with each student. However, given my training in building groups and performance, I felt that we could have a stronger group activity in which we were together making use of what each person was able to learn, complete and contribute each week. It is in such group environments that the students and I could be stretched to develop and grow in our ways of thinking, talking and writing about the work. I also knew that this was not something that I could build. It had to be created by the group itself.

In the absence of building the group activity, I suspected that the work being completed by the students would not differ from any other class or classroom situation. For example, the faculty member presents a problem, points to a direction or method to address the problem, and the students follow that defined method or direction. Students had different skills: seeing detail, attention to method, or background knowledge of the biology. Were the students able to advance their understandings of the biology and modeling topics? Were they able to identify new issues? Most importantly, did they have the work conditions to do so? Rather than intuit or interpret the students' abilities, or the success or failure of the environment, I asked the students, "How are we doing as a group?" The question invites student evaluation of and direction to what we are able to do.

#### *Student Perspective*

"Another feature of our group learning process, that I felt differed from other learning experiences, was the atmosphere created in our meetings. Dr. Holmes often asked us how we felt we were doing as a group, how we were proceeding, or if there was any other way we wanted to work on this project that would be more supportive of our work together. She did not dictate how the research would be carried out, but gave us the materials and concepts that would help in our research. This gave us an opportunity to examine our roles and decide if we were comfortable with the pace or approach we were taking to obtain our conclusions. When given the opportunity to shape the project to our needs, we, the students, came up with the idea to meet together in groups of 2 or 3 prior to the weekly meeting with the Professor. We thought this would give us the chance to come up with a more enhanced understanding of the articles we were dealing with, along with a clearer picture of where to go next with this information. Therefore, although the Professor was constantly guiding our group, she was not directing its every step. We, the students, fully participated in determining what our next move should be in the research process and how to approach the material we were given to work with."

#### The overall production

We believe key features in the success of this project were the performances chosen by the participants. Students were asked to perform as graduate research students and the faculty member as a director and collaborator. The group met once a week for an hour and a half to discuss progress and determine the next steps. The students worked independently during the week to achieve the goals set in our meetings. In this way, the group created an environment in which questions could be freely posed. The group had the responsibility of determining how significant each

question or task was in relation to the creation of the text. Students developed skills as needed to address the question, "What do we need to understand so that we can teach others?" This included skills in reading and interpreting experimental results in research articles, and representing their results in graph and table formats. Together the group went from the simple concept maps describing cell cycle protein interactions to the identification of mathematical representations, discussion of rate equations and elucidating rate constants from research literature. (See Figure 1) This was an iterative, non-linear process through which a chapter on cell cycle dynamics was produced. The materials have also been used in professional development workshops for faculty (Investigating Interdisciplinary Interactions, BioQUEST 2005) and graduate students (Advanced Computing for Cell Biologists, 2005).

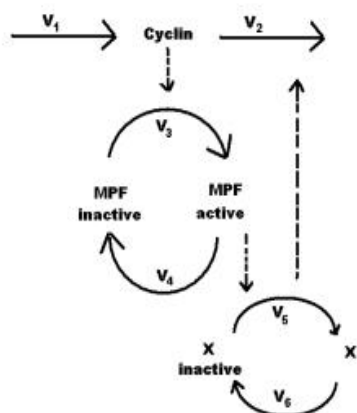
#### What's improv got to do with it?

In this article we relate to you our experience of how a group came to learn and grow together and how we understand this to be an improvisational performance. Improvisation, in the theatrical sense, is a process in which groups of people create an ensemble, listen to one another, and make and accept offers to create a scene. The scene in our case was to understand computer modeling of cell biology and introduce it to novice users. The improvisation in this context was to use everything available-our backgrounds, different levels of experience and attention to group efforts- to create a research ensemble of collaborators capable of writing a textbook and doing numerical models. None of us in the research group had ever undertaken such a task before, nor had any of us worked together prior to this project. We improvised how to divide tasks, what concepts to focus on, and how best we could improve our own understanding of materials given we were all starting from various base points. We accepted and related to each other as capable of doing the tasks we set ahead of ourselves. As a group we were able to accept help from the Professor, from each other, and draw information from published sources. As a by-product of this improvisational method we all learnt new skills and gained a vast amount of knowledge of concepts we had never formally been taught. .

To us, life itself is an improvisation. We are faced with the challenge of dealing with the unknown everyday and there is no manual to go by. We all take cues from those around us, whether in an educational setting or not. To go beyond what we already know how to do, and to do something new and developmental, involves self-conscious building with those cues collectively. What was new and developmental for us was working collaboratively across academic status and disciplines and producing

an introductory chapter on modeling the cell cycle. The method was improvisational and focused on group building. Our attention was on the group's understanding and not on whether any individual remembered the exact details of the cell-cycle process. As the environment was built by the

ensemble, we were freed to accept what each person contributed and to reshape it into a scientific narrative that reflected our growing collective understanding. The development of our understanding was not linear or individualistic; it was improvisational and group learning.



### Difference Equations

$$\text{Cyclin} = \text{synthesis-degradation} = V_1 - V_2$$

$$\text{MPF} = \text{activation-inactivation} = V_3 - V_4$$

$$\text{Inactive MPF} = \text{inactivation-activation} = V_4 - V_5$$

$$\text{X} = \text{activation-inactivation} = V_5 - V_6$$

### Ordinary Differential Equations

$$\frac{dC}{dt} = V_1 - V_2$$

$$\frac{dM}{dt} = V_3 - V_4 \quad \frac{dM_i}{dt} = V_4 - V_3$$

$$\frac{dX}{dt} = V_5 - V_6 \quad \frac{dX_i}{dt} = V_6 - V_5$$

### Mass Action Rate Equations

$$V_1 = \text{constant} \quad V_4 = k * \text{MPF}$$

$$V_2 = k * \text{Cyclin} * X \quad V_5 = k * \text{MPF} * X$$

$$V_3 = k * \text{iMPF} * \text{Cyclin} \quad V_6 = k * X$$

### **Figure 1. Legend**

Schematic of the conceptual model from Goldbeter, 1991 (upper left). Difference equations that describe the change in amounts of proteins are written as a function of the cellular processes (upper right). Ordinary differential equations that describe the changes in amounts of any given protein over time (bottom left). Rate equations for each cellular process (bottom right).

### References

- Bodrova, E. & Leong, D. (1996). *Tools of the mind: The Vygotskian approach to early childhood education*. Columbus, OH: Merrill.
- Goldbeter, A (1991). A minimal cascade model for the mitotic oscillator involving cyclin and cdc2 kinase. *Proc Natl Acad Sci*, 88, 9107-9111.
- Holmes, Flannery and Qureshi, 2004. "Systems approach to adopting, teaching and learning models". BioQUEST Systems Biology Workshop. [http://www.bioquest.org:16080/summer2004/project\\_template.php?project\\_id=92](http://www.bioquest.org:16080/summer2004/project_template.php?project_id=92)
- Nachmanovitch, S (1991). *Free play: Improvisation in life and art*. New York: Penguin/Putnum.
- Newman, F. (1996). *Performance of a lifetime*. New York: Castillo International Press.
- Newman, F. & Holzman, L. (1997). *The end of knowing: A new developmental way of learning*. London: Routledge
- Rogoff, B. (1984). Adult guidance of cognitive development. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Development in social context* (pp.95-117). Boston: Harvard University Press.
- Tyson, J. (1991). Modeling the cell division cycle: cdc2 and cyclin interactions. *Proc Natl Acad Sci*, 88, 7328-7332.
- Wood, D., Bruner, J. & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, 17, 89-100.
- Vygotsky, L. (1978). *Mind in society*. Cambridge, MA: Harvard University Press