NIA2 PROJECT IMPACT AND CASE STUDIES

The first part of this final project report addressed the three specific aims of the NIA2 grant and the extent which the PIs achieved those aims. This second part will look at the impact that NIA2 is making on the teaching and learning of neuroscience. It is subdivided into two sections. The first subsection looks at the big picture of the project's impact on both undergraduate and graduate education using all the various pieces of data we have managed to gather across sources. The second subsection reports five cases studies that give a detailed look at NIA2's use at five particular undergraduate institutions.

Overall Project Impact of NIA2 on the Neuroscience Education Community

As we have discovered, the neuroscience education community is clearly dedicated to pushing the "old-school" undergraduate education boundaries via NIA2 and other innovations. Many individuals with whom we communicated are members of the Faculty for Undergraduate Neuroscience (http://www.funfaculty.org/drupal/). One of the group's explicit goals is, "Disseminating innovations in undergraduate neuroscience education." In fact, this group named PI Ann Stuart its 2007 "Educator of the Year."

The Yale Journal of Biology and Medicine also positively reviewed NIA2. The published review (http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2442728) makes many of the same statements and observations as the users we spoke to, such as, "The journey through the book and CD allows readers to gradually build a solid foundation of neuronal biophysics, beginning with basic properties of membranes to more advanced concepts of synaptic integration and action potential threshold" and "readers can make manipulations which are impossible or difficult to do experimentally." In conclusion, the Yale reviewer states, "Overall, Moore and Stuart certainly have created a highly recommendable method for learning and teaching neurophysiology."

In the ***Data Collection Methods And Evaluation Overview*** section presented earlier, we outlined our data various collection methodologies. Many of these results have already been presented in Specific Aims #1 – #3. Other elements of these data sources, especially the surveys, classroom observations, and other communications, have been synthesized and summarized below in order to demonstrate how NIA2 is actually being used in the classroom. First we will address the *breadth* of NIA2 adoption: in what sorts of classrooms and in what ways is it being used, the reactions of both students and faculty, and recommendations for future use. Then we will present five *in-depth* case studies from our classroom visits and observations that tie implementation back into the specific aims and implicit learning goals discussed in the first part of the report.

How are the materials being used in the undergraduate classroom?

The NIA2 materials are being used in a variety of ways with undergraduates, graduate students, and post-doctoral students. We discovered that it has been incorporated in a broad spectrum of undergraduate courses, from introductory level to advanced, as well as for independent study instruction. It has also been used with graduate students, medical students, and post-doctoral students (e.g., SPINES 2007 and 2008). The Initial NIA2 Survey asked instructors several questions about their use of NIA2, especially with undergraduates, since that is the focus of the NSF grant. We have organized some of this data by institution to yield a set of snapshots of how NIA2 is being used around the country. The specific survey questions whose data are included in the institutional use examples are given below to provide context for the examples. In some instances, instructors did not answer every question posed by the evaluators. Whenever possible the instructor's own words are used, with minimal editing only to smooth transitions, since the information was originally answers to discrete questions. Below are the **Initial NIA2 Survey questions included in the institutional use examples**:

- In what ways have you used NIA2 materials with undergraduate students? (check all that apply)
- Please briefly describe the context and the undergraduate student population with which you used the NIA2 materials. Be sure to note whether the course was introductory, intermediate, or advanced.
- From your perspective, what do you feel your students gained from their experiences with NIA2?
- For a variety of reasons, there are often constraints that limit educators with regard to the depth of content they can cover in their courses. Has your experience with NIA2 allowed you and your undergraduate students greater access to neuroscience topics? Explain.
- If you could repeat your teaching experience(s) using NIA2 in the same undergraduate course(s) with the same students, what one thing would you change? Explain.
- If NIA2 were not available for teaching the content for which you are currently using it, what other resource(s) would you use to cover these topics with your students? Please explain.
- Overall, how would you rate your experiences using NIA2 with undergraduates?
- Based on your own experiences with NIA2 (whatever they have been to date), do you plan to use it in a future course? Or, if you are currently using it, do you plan to use it in a different course or in a different way? If so, please tell us about your plans. For example, what are the key aspects of NIA2 that make you want to use it for the course and in what way(s) do you foresee yourself using it (e.g., homework, labs, in-class demos, etc)?

<u>Undergraduate Institutional Use Examples from Initial NIA2 Survey</u>

- **Mount Holyoke College**: *I use tutorials from NIA2 in my neurobiology class. The class is for juniors and seniors. The course provides an introduction to neurobiology. Used at least one tutorial in class lab and I required students in a course to use NIA2 materials for homework, labs or projects outside of class. I spent less time lecturing on AP propagation down myelinated and unmyelinated axons since the students were exposed to this material in the tutorials. This left lecture time for other topics. The students also compared the results they generated during experiments in lab with the computer experiments they ran in the tutorials. The combination of approaches really re-enforced important concepts. I feel that the interactive tutorials allowed the students to work out biophysical problems. Some made use of the many references cited throughout the tutorials. If NIA2 were not available, I would create homework problem sets. Overall I would rate my experience as extremely positive. The students learn from and enjoy NIA2. The movies provide a way for students to see electrical events in neurons that can't be seen in any other way. If I could repeat the* *experience, I would use more NIA2 tutorials. In the future I will continue to use it for homework assignments and will show minimovies during lectures.*

- **University of Maryland***: I incorporated NIA2 in a variety of ways, including: (1) used at least one minimovie in class lecture; (2) used at least one tutorial in class lecture; (3) used at least one tutorial in class lab; (4) required students in a course to use NIA2 materials for homework, labs or projects outside of class; (5) had students use NIA2 as a self-tutorial; and (6) had students use NIA2 for independent study or research project not related to a specific course I teach. The simulations are very useful in (1) preparation for lecture and (2) review and consolidation of major concepts. Also, we can do experiments as simulations that are not otherwise possible. In the past, we had written our own simulations, these are much better -- deeper, more thorough, better graphics, etc. Overall, I would rate my experience as extremely positive. It's great! In the future, I plan to use NIA2 in all cellular neurophys courses and for review of key concepts.*
- **City University of New York**: *Undergraduate students in an intermediate course in comparative animal physiology had NIA2 available for use in lab. I asked them to complete the AP tutorial in preparation for a wet lab on the compound action potential. I think the students were better prepared for the wet lab having carried out the simulation in NIA2 first. I think the next time I use the program in the course (Fall 2008) my students will have greater access to neuroscience topics. The program had just been released when I used it in the lab last year and I didn't have a chance to fully incorporate it into the course. My overall experience was somewhat positive. If I could repeat the experience, I would have allotted more time for its use. The students found the interface a bit hard to use at first and could have benefited from more time with the program.*
- **University of Evansville:** *I used NIA2 in a senior level class PSYC 457 Advanced Neuroscience. Students in the course were required to use NIA2 materials for homework, labs or projects outside of class. I think it is a great opportunity for active learning. Alternatives for NIA2 are NONE, sadly. My overall experience was extremely positive. If I were to repeat the experience, I would have a more organized scheduling of NIA2 sections. In the future, I plan to keep it as a supplement to my advanced neuroscience course and to use some of the basic tutorials in my physiological psychology laboratory course. [Also from instructor e-mail: This semester is an independent study course with 4 students.]*
- **Dominican University**: *I've used NIA2: (1) as a classroom exercise at a large state university with an advanced neurobiology course offered to senior undergraduates and entry-level masters students; (2) as a classroom exercise and lab exercise with an mid-level seminar in neuroscience offered at a liberal arts college; and (3) as a classroom illustration in an upper-level behavioral neuroscience course at a liberal arts college. In these courses, students used at least one tutorial in class lecture, used at least one tutorial in class lab, and/or were required to use NIA2 materials for homework, labs or projects outside of class. Also, I often give lectures on neuroscience to a general audience in which I use a shape plot of the prorogation of an action potential that I modified from NIA/NIA2. I've modified some NIA2 exercises somewhat, depending on the audience. For classes I teach in psychology, I find that students are less prepared for some of the mathematical concepts (e.g. log plots in the equilibrium potential). In these cases, I've revised the exercise and questions to try to avoid concepts that would be over their heads. Hopefully, my students a better understanding of the basic physiological properties of neurons. Overall, my experience with NIA2 has been somewhat positive.*

- **University of Wisconsin Madison**: *I have used NIA2 for teaching undergraduates in three contexts: 1) Lectures to students who take the third in a series of 4 honor's courses in the Biology Core Curriculum, 2) A lecture to undergraduates who are taking honor's physics, 3) a student who is going through the tutorials with a little guidance from me in meetings once each week. In these contexts, I have used at least one minimovie in class lecture, used at least one tutorial in class lecture, had students use NIA2 as a self-tutorial, had students use NIA2 for independent study or research project not related to a specific course that I teach, and used NIA2 materials in a seminar that included undergraduate students. NIA2 made electrophysiology much more fun and dynamic for the students. The minimovies were particularly valuable for me not only because they are technically easy to deal with but also because the screen does not have buttons that distract students who have not been introduced to the program. The lack of depth that comes from the need of undergraduate courses to cover a wide range of material is indeed a big, and for me very frustrating, problem. Not only does one not have time to cover a challenging topic but if students spend only three weeks on cellular electrophysiology, other instructors do not want students to have to buy NIA2. One or two hours of Discussion sections where computers are shared by four students is simply too little time to use NIA meaningfully. I am seeking to teach a course in cellular electrophysiology for undergraduates and graduate students in which I can require all students to have a copy of NIA2. Overall, my experience with NIA2 has been extremely positive. I have used NIA2 only one year. The minimovies were fantastic. In the future I am hoping to teach a course for more senior neuroscience students in which NIA2 plays a central part. That is not entirely easy because I have to avoid overlap with existing courses whose instructors are set in their own ways of doing things.*

Other Undergraduate Institutional Use Examples

Additionally, via e-mail or other communications, the evaluators were told of the following uses of NIA2 in undergraduate classrooms. Since the information was not obtained with a structured survey, it does not have the same level of detail as the above discussions.

- **Grinnell College:** *I am using NIA2 this semester in my Neurobiology (BIO 363) class. I am more than willing to let you come and observe. The only problem is that I was not planning to have any specific sessions where students would all be using NIA together (and in the same room). Instead, I ask the students to work on the tutorials outside of class, treating them as assignments rather than class activities*.
- **Pomona College:** *We use NIA2 in a couple of lab sections of Psyc 143: The Human Brain: From Neuron to Behavior to reinforce principles of neurophysiology that are introduced in lecture. We use it every semester*.
- **Cornell University**: *NIA2 is used every semester as homework in BioNB 491/BMEP491 Principles of Neurophysiology. Students complete and hand in weekly assignments using NIA2 that the instructor comments on and hands back. Four of the assignments required completing two NIA2 tutorials while the rest were a single tutorial. The course syllabus with the list of assigned tutorials is available* in Appendix D. *[Based on the student feedback, this course required students to include images of the graphs in their reports. This issue was discussed in Specific Aim #1. Additional student comments suggest that there was a midterm project assignment in Spring 2008.]*

In Spring 2008, the Cornell University class filled out structured surveys similar to the ones used at SPINES. On the Initial NIA2 Survey we asked instructors what they felt their students learned from using NIA2. In this case, we asked these sixteen undergraduate students a slightly different question: "**What, if anything, do you feel you learned about neuroscience from using the NIA2 materials that you would not have been able to learn some other way (e.g., in a hands-on experiment)?**" Responses are shown below. It should be noted that these students did both traditional wet labs and NIA2 simulations in their course, and most liked the parallels they saw between the two modes of learning, as well as the opportunity to extend experiments using NIA2, which often would not be possible for them to do in the lab because of time, equipment, or skill constraints.

- *I think being able to easily change variables was the best part of the simulations. Even changing an ion concentration by half was sometimes difficult in the actual lab setting, and the simulations allow far more than that. If there were even more options, such as additional ion channels to manipulate and ionic concentrations, it would be even more useful (especially when trying to design your own simulation).*
- *I felt the simulations were better than hands on in the lab because it allowed for a large amount of reproducible results in a very short period of time using parameters that would be difficult to accurately manipulate during a lab period.*
- *Yes, I learn much better when I am able to test various parameters myself, so changing axon length and temperatures helped reinforce those kinds of concepts, whereas reading from a book does not work as well for me.*
- *Being able to check for channel openings and voltage flow across the cell very quickly just by changing parameters in the program.*
- *NIA2 was useful for learning how changes in ionic conductances affect the action potential and how toxins and other ions like barium can affect the action potential.*
- *The effects of different parameters (temperature) that are difficult to simulate in a lab.*
- *Because computer simulations are so fast and reproducible, it is much easier to see the effects of certain variables. For example, it is much easier to see the effects of heat on conduction speed when you are dealing with computer simulation. I believe I could have learned that with a hands-on experiment, but it would require more time to do so.*
- *The concepts that are learned apply knowledge present and extend it out to other situations where it may not be easy to extrapolate the abstract ideas. I felt like through using the NIA2 program I was able to synthesize ideas about neurophysiology as well as reinforce ideas of neuroscience which were previously learned but not totally understood. I believe it is an essential tool to develop a greater understanding of the material with the ability to tweak situations and potentially come up with ideas that are relevant to research currently being conducted.*
- *I don't think NIA2 teaches anything that a hands-on experiment wouldn't, but I do think that NIA2 does it more easily and quickly, with less resources involved. The ability to manipulate variables such as location of stimulus electrodes, or temperature, or ion channel density could not be easily or precisely done in a hands-on experiment. The simulations greatly increased my understanding of the importance of ion currents in AP generation and in changes in the membrane potential. Before the simulations, my understanding was hazy and superstitious, but I understand it much more clearly and logically now.*

- *The program allows results to be idealized and free from error that you would experience during an experiment.*
- *It was easy to view a variety of manipulations in a short period of time.*
- *The total control of cell parameters that allowed investigation beyond normal cell limits.*
- *Hands-on experiments wouldn't have provided the exact ion concentrations. It was nice to see the theoretical values.*
- *Variation of many parameters is much more easily demonstrated via simulation (i.e., changing the conductance, ion concentrations, membrane capacitance, and resistance).*
- *Several simulations allowed me to perform more manipulations on an axon than we had time for in the laboratory. It was nice to be able to supplement the real-time experimentation in the lab with a simulated version afterwards.*
- *The ability to change parameters at will allowed us to experiment with setups beyond what would be possible in an actual lab. Also allowed us to look at experiments that would be beyond my skill level in real life.*
- *The numerous possibilities! Experiments let you test only one thing at a time.*

Thirteen of the students read some of the pdfs of classic papers. Overall, they liked being able to see how the simulations were developed and how they replicated original results. One student said, "I would advise to try to include more publications in fact." Seven of the sixteen students in the class reported that they also explored additional tutorials beyond those assigned by their instructor. Five provided explanations of what they did, shown below. Most of the students explored the additional tutorials for a project in this course, while one did so to gain insight on materials in a different course.

- *I did a little bit of exploring of other tutorials while looking for possible simulations for the midterm project. Also, some of the tutorials reference other tutorials, and I usually tried out or at least about what the other tutorial had to say that was related to the current tutorial I was working on.*
- *For different parts of a complementary course, Introduction to Neurobiology, I used the tutorial materials at the beginning of the semester to simulate different scenarios in order to figure out answers to questions concerning abstract ideas and multiple conditions being analyzed concurrently. It provided a perfect resource to understand the ideas and questions being asked and furthermore allowed critical analysis of the question and ultimately the realization that many of the concepts being quizzed were inaccurate – the perfect resource and use for the program in my opinion.*
- *I looked into some of the simulations beyond what was assigned for use in the midterm paper to model some of the changes observed when neurotoxins were added to the preparations.*
- *I looked at all of the simulations (not all were required for class). I also looked at many of the additional classic papers that were available. None of these were required for my class, but they provided great foundational knowledge to help me make sense of the basic tutorials and the subject matter in general.*
- *I explored additional simulations and changed the settings for adding a simulation example in one of my class reports and went back to a few simulations to understand basic concepts that we explored in class labs.*

As all the comments above already suggest, most students liked using NIA2 in this particular course. They also told us that they would like to use something similar in other classes. Most would recommend the program to a friend who wanted to learn about neuroscience. On the other hand, some students did express a preference for learning concepts by doing traditional wet labs versus computer simulations, but almost half the class was neutral on the question. This may be due in part to the fact that students expressed frustration with not being able to print NIA2 graphs to include in their write-ups or download their data for additional analysis in Matlab (discussed in Specific Aim #1). Some results are summarized in Figure 12 below.

Rate your experiences using NIA2.	Strongly Disagree 1	2	Neutral 3	4	Strongly Agree 5
NIA2 was easy to use.	---	1 (6%)	3 (19%)	10 (63%)	2 (13%)
Being able to vary parameters and rerun the simulations helped me learn important concepts.	2 (13%)	---	---	6 (38%)	8 (50%)
When possible, I would prefer to learn neuroscience concepts by doing hands-on experiments in a lab rather than running computer simulations.	---	1 (6%)	7 (44%)	4 (25%)	4 (25%)
I liked using the NIA2 materials during this course.	---	1 (6%)	5 (31%)	8 (50%)	2 (13%)
I would like to use simulation-type labs or exercises, like NIA2, in other classes or workshops.	1 (6%)	1 (6%)	4 (25%)	7 (44%)	3 (19%)
I would recommend NIA2 to other students who want to learn more about neuroscience.	---	---	2 (13%)	6 (38%)	8 (50%)

Figure 12: Cornell Student Reactions to NIA2

Finally, we asked students, "**Do you have any other comments you would like to share about your experiences with NIA2?"** Five of them responded with both praise and some constructive criticism.

- *I think it is a valuable tool that should be used in conjunction with laboratory experiments, or at least demonstrations, in order for the student to be able to combine these experiences into their knowledge base. I give it a thumbs-up!*
- *I highly encourage students to use these simulations.*
- *Well done program, please improve the interface.*
- *The program was quite efficient and helpful.*
- *Please change the instructions and explanations so that they are a little clearer.*

<u>How are the materials being used in the graduate classroom?</u>

A few of the instructors who responded to the Initial NIA2 Survey were using the program with graduate students. Instructor's perceptions of the gains made by graduate students working with NIA2 were very similar to those noted for undergraduates. As seen below, one of them even explicitly said, "Same as for undergrads." This is consistent with our observations of participants at SPINES. Even graduate, medical, or post-doctoral students may be novices at some of the neuroscience concepts covered by NIA2. One of the instructors notes that biology students are often deficient at physics (and thus many of the electrical concepts inherent in neurophysiology).

Graduate Institutional Use Examples from Initial NIA2 Survey

- **University of North Carolina Chapel Hill School of Medicine**: *I have had students use NIA2 for independent study or research projects not related to a specific course that I teach. They gain a much better intuitive feel for the nonlinear electrical interactions that take place in neurons. If NIa2 were not available, I would have them use probably models taken from the ModelDB (Yale), which are NEURON -based and research-oriented. Overall my experience with NIA2 has been extremely positive. Students get involved with figuring out why things work (or don't), and do their own experiments with the models. Although the interface is unusual, the students seem to grasp it fairly quickly. In the future, I would like to incorporate it more into my course, both as a homework tool and for demonstrations of certain principles.*
- **University of North Carolina Chapel Hill School of Medicine:** *Students learned more because they had the opportunity to change things, observe effects, and think about why. Learning is more active. If NIA2 was not available I would have students read from books and do problem sets. Overall, my experience with NIA2 is somewhat positive. The ability to actively explore neuronal excitability is very powerful. The learning is active, so it is more effective. The only element of NIA2 that prevents me from being "extremely positive" is that I find the multiple-window user interface distracting at first. It takes some time to learn how to navigate through the many different windows and to get used to looking at all of them. The default positions and sizes are not always very helpful, either. Re-sizing and re-scaling is sometimes flawed and awkward. In the future, I plan to continue using it in class and in homework assignments.*
- **University of North Carolina Chapel Hill School of Medicine:** *I used at least one tutorial in class lecture, I required students to use NIA2 materials for homework, labs or projects outside of class, and I had students use NIA2 as a self-tutorial. No doubt about it, they develop a feel for the meaning of the parameters, equations, and interactions of all of these that is totally elusive in standard methods of teaching. The ability to manipulate the parameters and see what happens causes them to realize the significance of the parameters and their exact values. For most, they would put very little emphasis on values in their standard format learning. With NIA2, they come to grips right away with the notion that the exact value is important. If NIA2 were not available, I would give a longer-winded discussion of less material. I would have to be more basic and dumbed-down. Overall, my experience with Nia2 has been extremely positive. Among other uses, I have students prepare demos for the class using NIA2 with direction as to topic (the partially demyelinated axon, for example), but with very little direction beyond that. When a student develops a really good presentation ("And now what do we think will happen if we X and why?") through their own exploration, the effect on their curiosity and excitement and their transmission of the same to the other students is impressive. You'd almost never get that level of diving in from my students (graduate students) with text materials only. I want to use it in the future, but my problem is to have more time with it. A 2-month course in electrophysiology with NIA2 would be lots of fun. But the pressure is always to cut back so the students can be in the lab, so I need to find new ways to use it in less time.*

- **University of Maryland:** *I had students use at least one tutorial in class lecture, I required students to use NIA2 materials for homework, labs or projects outside of class, I had students use NIA2 as a self-tutorial, and I had students use NIA2 for independent study or research project not related to a specific course that I teach. Graduate student learning was the same as for undergrads: the visual interface supplements and reinforces key concepts. In the past we have written our own simulations, but NIA2 is much better. My overall experience has been extremely positive. In the future I plan to use NIA2 in all cellular neurophys courses and for review of key concepts.*
- **Emory University:** *My overall experience has been somewhat positive. I used at least one tutorial in class lecture and had students use NIA2 as a self-tutorial. They were better able to grasp voltage-clamp and axonal conduction as a result.*
- **University of Wisconsin Madison:** *NIA2 made it much more fun to teach material that is difficult for biology majors. Most such students have a good background in chemistry but a lousy background in physics. They are thus easily intimidated. Showing electrophysiology in action allows students to have fun with the topic.*

<u>Other Graduate Institutional Use Examples</u>

The graduate and post-doctoral participants at SPINES 2008, as well as the students in the Fall 2007 section of NBIO/PHYI/PHCO 722-723 Cellular and Molecular Neurobiology at University of North Carolina Chapel Hill (a required set of courses in the graduate neurobiology program) were also asked, "**What do you feel you learned about neuroscience from using the NIA2 materials**? Please give at least one specific example." Note that many of these students, who often have extensive lab experience, favorably compared what they learned using NIA2 to what they learn by conducting hands-on experiments. The concept of *current* threshold versus *voltage* threshold is another common theme among respondents.

- *I actually learned (and re-learned) quite a bit. As on example, I learned that a voltage threshold for generating an action potential (contrary to what I learned previously) really doesn't exist, it's really a current threshold. I think I generally learned that concepts taught in my lecture courses (likely in a certain simplified matter to ease understanding) weren't entirely accurate.*
- *Myelinated axons vs. an unmyelinated axon. I used to think of the action potential as jumping from node to node as originally taught. However, after the tutorial I learned that the action potential "appears" to jump as voltage change is able to occur all along the axon a lot faster due to low membrane capacitance.*
- *I learned how to view action potentials using phase plane plots and thinking in terms of threshold currents. I learned why hyperpolarizing a cell can make it more excitable, instead of just memorizing the concept. I finally understand reversal potentials. I gained a solid understanding of importance driving force and the factors that do and do not contribute to it.*
- *Patch clamping and how it's used to measure an action potential.*
- *Threshold to spike is determined not only by voltage, but the rate of change in voltage.*
- *I manipulated the kinetics of an action potential in order to visualize how sodium and potassium are involved. I manipulated sodium channels to experiment their role in tetrodotoxin.*

- *I learned how each component of the Hodgkin-Huxley equation fit together by being able to manipulate the different properties that made up that equation and seeing the resulting currents.*
- *How different the action potential runs on a myelinated axon vs. unmyelinated.*
- *The NA K Kinetics advanced tutorial was phenomenal. It was great to see how some of these toxins work on the channels.*
- *I learned about current thresholds rather than voltage thresholds.*
- *I learned better the principals that govern the propagation of an action potential down*
- *How calcium contributes to action potentials.*
- *I learned and reinforced a lot about channels, action potentials, and synapses.*
- *That there may be a current threshold instead of a voltage threshold we have to exceed in order to reach an action potential.*
- *Helped with visualizing traces, is clearer than an actual trace from a hands-on experiment.*
- *I feel that I understood action potential propagation concept freely.*
- *Freedom to do what I want and see what happens. You learn by <u>doing</u> and it is the best way to remember.*
- *You could change parameters so easily – it wouldn't have been feasible to do that many hands-on experiments.*
- *It is very helpful in understanding what is going on at the cellular level, specifically single cell, but it would be good if we could see the population level of measurement also.*
- *The ability to visualize potentials, voltage and capacitance graphs.*
- *It was easier to vary parameters than it would have been in a hands-on experiment.*
- *I do not perform these types of experiments so I was able to play with the parameters and see data.*
- *A lot concerning electrophysiology in a very short amount of time that wouldn't have been possible with hands on.*
- *It allows us to put up experiments that would not be possible, or physiologically possible, to demonstrate concepts.*
- *I majored in neuroscience in college, but still felt uncertain about electrophysics. I felt that NIA2 was very helpful for explaining it from the very foundation up.*
- *I could have memorized material, but this helped to actually understand how different properties contribute to the action potential.*
- *Almost everything I learned from NIA2 would be difficult to learn from a hands-on experiment.*

SPINES students were overwhelmingly positive about using NIA2 in their summer program. All but two also told us that they would like to use something similar in other classes, and all of them would recommend the program to a friend who wanted to learn about neuroscience. Again, there was a mix of responses when it comes to learning concepts by doing traditional wet labs versus computer simulations, but many of the students reported that they would not prefer wet labs to NIA2, which likely reflects in part the breadth and diversity of participants' lab experiences. See Figure 13 below.

Rate your experiences using NIA2.	Strongly Disagree 1	2	3	4	Strongly Agree 5
NIA2 was easy to use.	---	1 (4%)	2 (7%)	10 (36%)	15 (54%)
Being able to vary parameters and rerun the simulations helped me learn important concepts.	---	---	1 (4%)	2 (7%)	25 (89%)
When possible, I would prefer to learn neuroscience concepts by doing hands-on experiments in a lab rather than running computer simulations.	4 (14%)	10 (36%)	6 (21%)	6 (21%)	2 (4%)
I liked using the NIA2 materials during my MBL SPINES.	---	---	1 (4%)	4 (14%)	23 (82%)
I would like to use simulation-type labs or exercises, like NIA2, in other classes or workshops.	---	1 (4%)	1 (4%)	7 (26%)	18 (67%)
I would recommend NIA2 to other students who want to learn more about neuroscience.	---	---	---	3 (11%)	25 (89%)

Figure 13: SPINES Participant Reactions to NIA2

The graduate students in NBIO/PHYI/PHCO 722-723 Cellular and Molecular Neurobiology at University of North Carolina Chapel Hill were also very positive, and they were somewhat more inclined to prefer NIA2 to hands-on labs than the SPINES students. See Figure 14 below.

Rate your own experiences using NIA2.	Strongly Disagree 1	2	3	4	Strongly Agree 5
NIA2 was easy to use.	---	1 (5%)	5 (26%)	9 (47%)	4 (21%)
Being able to vary parameters and rerun the simulations helped me learn important concepts.	---	---	2 (11%)	6 (32%)	11 (58%)
When possible, I would prefer to learn neuroscience concepts by doing hands-on experiments in a lab rather than running computer simulations.*	3 (15%)	3 (15%)	7 (37%)	5 (26%)	1 (5%)
I liked using the NIA2 materials during this course.	---	2 (11%)	1 (5%)	11 (58%)	5 (26%)
I would like to use simulation-type labs or exercises, like NIA2, in other classes or workshops.	---	1 (5%)	4 (21%)	9 (47%)	5 (26%)
I would recommend NIA2 to other students who want to learn more about neuroscience.	---	---	4 (21%)	5 (26%)	10 (53%)
* Two write-in comments were made about this question: "So much easier than in lab with no troubleshooting!! And faster!!" and "For this stuff, not as much as molecular biology."					

Figure 14: University of North Carolina Chapel Hill Student Reactions to NIA2

Although Ann has some instructor duties for the Chapel Hill course, one of the major differences between the experiences of the SPINES students and almost everyone else we have discussed so far is that PI Ann Stuart was the sole, full-time instructor for the SPINES NIA2 sessions, and she did an exceptional job of verbally introducing and setting up the tutorials, as well as answering participant questions. Her enthusiasm is virtually unparalleled and is highly contagious. This unique experience – bright, dedicated, highly motivated students coupled with an exceptional instructor – is something most of us in education dream about (and perhaps even envy). After observing and participating in the 2008 SPINES sessions with NIA2, we asked the participants what they thought about the specific structure and content of their week-long experience.

In a typical NIA2 session at SPINES (9am to 12pm each day for one week), Ann Stuart gave a very brief introductory "lecture" about relevant tutorial concepts, introducing major ideas and mathematics relevant to the tutorials the participants would be doing. Everyone had a computer with a copy of the NIA2 CD, either their own laptop or a provided PC, as well as the printed lab manual. Sometimes the students explored the tutorials as a large group, going through step-by-step as guided by Ann, and at other times students did the tutorials on their own in pairs/small groups, after which everyone came back together to discuss their results, a process which was also led by Ann. Two TAs were available for questions about both content and the operation of the program. Small groups of about three students developed presentations outside of class that were given on the last day, using some of the advanced tutorials not covered together during the week.

As the data below show, the participants very much liked the manner in which Ann set up and led the tutorials. They were less enthusiastic about group work and presentations by their peers. See Figure 15 below. *[Note: After reviewing the survey layout and individual results, the "Does Not Apply" answers shown here are likely supposed to be "Strongly Agree" answers.]*

Rate each statement.	Strongly Disagree 1	2	3	4	Strongly Agree 5	Does Not Apply
I liked it when Ann led us through tutorials as a group.	---	---	---	1 (8%)	10 (77%)	1 (8%)
I liked it when Ann "set up" the tutorial by introducing the context of the simulation and main questions to investigate, as well as gave an overview of the various windows, before I explored on my own.	---	---	---	1 (8%)	10 (77%)	2 (15%)
I liked exploring a tutorial without any prior "set up" by Ann.	---	3 (23%)	7 (54%)	1 (8%)	1 (8%)	1 (8%)
I liked exploring tutorials in pairs/groups.	1 (8%)	2 (15%)	3 (23%)	3 (23%)	1 (8%)	2 (15%)
I liked exploring tutorials completely on my own.	---	3 (23%)	2 (15%)	2 (15%)	6 (46%)	---
I liked coming back together as a group to discuss the key observation(s) after exploring a tutorial on my own.	---	---	1 (8%)	1 (8%)	10 (77%)	---
I liked presenting a new tutorial's highlights to the group.	1 (8%)	2 (15%)	2 (15%)	5 (38%)	2 (15%)	1 (8%)
I liked seeing the other participants present the highlights of new tutorials.	1 (8%)	1 (8%)	3 (23%)	3 (23%)	5 (38%)	---

Figure 15: SPINES Participant Reactions to the Structure of the SPINES NIA2 Sessions.

Although the evaluators themselves also greatly enjoyed the structure of the SPINES sessions and learned a great deal about neuroscience during our week which greatly informed our case studies, we recognize that not everyone has the same learning style. In that spirit, we asked SPINES participants, **"If you could have structured the NIA2 lab sessions for this past week to optimize it for your own learning, what would a typical morning session have looked like? In other words, how do you think you would best learn the material from the NIA2 book and CD (i.e., mostly solo exploration, mostly group work, large group discussions led by the instructor either before or after the tutorial, etc)? Please be specific."** While many did suggest changes, and there was a definite disagreement in recommended approach between some of the "solo" versus "group" type learners, most appeared to think that Anne's approach was essentially the right one.

- *The sessions would probably have been similar, but I would have preferred to go through each tutorial in its entirety (not skip around to save time). Ideally we would begin each tutorial with a brief intro by Ann as to what to expect (any differences in this tutorial's set-up from the previous one, etc). Then, we'd work through the tutorial on our own with frequent consultations with neighbors if we got stuck or didn't understand a particular concept. Last, we'd finish each session by going over ALL the concept questions asked in each tutorial to make sure everyone understood the important take-home messages. I'm a particularly detail-oriented learner and without a lecture to accompany a given tutorial (if we also had a lecture component, as most Neuroscience classes do), I think it's a mistake not to go through EVERY section of the tutorials, as I've learned that sometimes we do not grasp new concepts as well as we think we do the first time we are introduced to them.*
- *1. Brief instructor introduction to provide context. 2. Mostly solo exploration with the option to collaborate with other students and/or instructor to address specific questions. 3. Large, instructor-led group discussion after solo exploration.*
- *There would have been more explanation of the phenomena outside of the context of the NIA program. More explanations of the concept using the board or some other medium than NIA. I think more modules with movies about what's happening at the synapse, or within the neuron showing the actual flux of the ions would be useful in conjunction with the 'movies' showing the progression of the current flow and voltage change.*
- *Large group discussions led by the instructor either before or after the tutorial or both.*
- *Mostly solo with instructor supervision.*
- *Led by instructor before the tutorial, followed by solo work to fully explore the tutorial's features.*
- *I think I would have like group exploration and discussion as we were going through the tutorials. During this course we mostly explored NIA2 individually.*
- *By the instructor setting up the basics of the tutorial and then us following them with questions for us to answer at the end.*
- *For the first half of each session I would like Ann to set up the background for the specific tutorial and a quick run through the tutorial; then the other half of the session each student would go through the tutorial on their own.*
- *I enjoyed it the way it was.*
- *I can't think of a better way than it was.*
- *I wouldn't change a thing.*
- *First led by the instructor, then left to explore additional experiments in a section.*

As with the undergraduate Cornell class discussed above, we finished by asking both the Chapel Hill students and the 2007/2008 SPINES participants, **“Do you have any other comments you would like to share about your experiences with NIA2?”** Their enthusiasm for the program, not just for themselves but for neuroscience education in general, was clearly evident. This is a strong reflection of the real positive energy and response we observed during the week we spent with the 2008 participants.

- *Liked it! [Note: This is the only response to this question from a Chapel Hill student.]*
- *Learning NIA2 with Ann was a definite plus. But I think anyone who takes the time to carefully navigate the program, even in her absence, will learn a lot. And, more important, the program helps students really understand and remember!*
- *I recommend NIA2 to all colleges especially at the undergraduate level.*
- *Great instruction tool for students of Neuroscience!*
- *I loved the program and it helped me to understand the basics that I struggled with when I first began to learn about cellular physiology.*
- *NIA2 is great. We should have used it for our synaptic pharmacology class back at my program and I will certainly use it when I have to teach it. I am sure if will be even fancier and more accurate by then.*
- *I am NOT from a physiology background; after initial catch up, NIA was VERY good at helping me understand the concepts.*
- *Ann and John have developed a powerful learning tool that has been integral to my education as a neuroscientist.*
- *I think it's definitely a useful tool for use in learning neuronal concepts! Great job Ann!*
- *This was one of the best ways to learn about physiology that I have seen.*
- *I felt that there were quite a few justifications in regard to the program being confusing. Fewer disclaimers and a less confusing interface would, in my opinion, lead to less frustration at the end of the day.*
- *Not at this time -- I love the program!*
- *Great program -- I will inform my institution of it. Thank you!*
- *Great program!*
- *Very neat program*
- *Ann was a fabulous teacher; her passion and knowledge really shine through in her teaching!! ☺*
- *This program is a great teaching tool.*
- *Excellent source -- as a teaching tool -- My only suggestion would be to add short answers to the questions asked in tutorials.*

<u>What do users like and dislike about NIA2?</u>

A free-response question on several surveys asked users at all levels (undergraduates up though instructors) **what they most liked about NIA2**, or what they thought was **the greatest strength of NIA2**. The emphasis among respondents was on (1) the ability to manipulate a large number of simulation parameters individually or all together to observe varied responses (i.e., the ability to “play” with the neurons); (2) the clarity and layout of the tutorials; (3) the links to history and real-world applications; and (4) its relative simplicity and user-friendliness. Many of the NIA2 users went beyond the tutorial materials for their own explorations. Overall, the layered structure of concepts (the way the program built upon itself) and the dynamic nature of the tutorials were highly praised. User responses that illustrate these points are included below.

- *There are at least two things that represent tremendous improvements over NIA1.5. First is the addition of many more visuals to the manual. The NIA1.5 version had relatively few visual aids; it was mainly text. My undergraduates need more visual guidance. Having just used NIA1.5 so far in my course, I found it necessary to use the projection system in the lab to show them how to navigate through the program. NIA2 has those visuals which are very helpful in seeing the layout of the panels and graphs. The other great strength is the expanded text that is much more systematic in its approach. My sense is that the early tutorials in NIA1.5 tried to mix learning about how to use the program with doing simulations. In NIA2 there is more of an introduction to the program, how to use it (again the visuals in the manual are very helpful here; p. ix-xiv)) and then you get into the basic tutorials. Also the expanded explanations throughout the tutorials make it much more user friendly. NIA1.5 assumed a lot of insight and grasp of what was going on. Perhaps graduate students could pick up on it. In contrast, NIA2 has filled in a lot of that assumed knowledge; necessary transitions that were not present in NIA1.5 are present in NIA2.*
- *The idea. It is an incredible tool that allows you to "play" with neurons and neuron channels, but is organized enough to be structured to help guide you through some of the more difficult concepts. Before I had to write all of this in some software like Matlab, and program every aspect in, if I wanted to play.*
- *I liked how I could go back to any of the simulations later on in the course and read through and retry several of the experiments to get a better understanding that I didn't have at the time was I originally doing the simulation. The fact that the tutorials also referred back to earlier simulations helped connect things together as well.*
- *The clarity in terms of the concepts and ability to follow the tutorials was essential to keeping me engaged and being able to get the most our of tutorials. Although some are repetitive, I believe there was a great deal of progression and building off of techniques that were learned.*
- *The rapid and elegant response to student interaction with the program*
- *That it provides realistic information about how and why neurons fire the way they do.*
- *User-friendliness of the simulations, and completeness of the models used.*
- *Ease of use and great documentation.*
- *Interactive and ability to change parameters - online learning.*
- *The active-learning paradigm. The ability to do "experiments" and learn from them.*
- *The ability to explore hypotheses about how the electrical excitability of neurons works, both within the context of the tutorials, and as a take-off from the tutorials. The tutorials are also very well written and designed.*
- *Being able to experience neuroscience concepts while controlling the relevant parameters is invaluable.*
- *NIA2 provides the opportunity to learn cellular electrophysiology more than superficially.*
- *The practicality and relative ease of learning about Neurophysiology to actually see its utility rather than relying solely on textbook has made it a great tool.*
- *The numerous possibilities that we can test in NIA2 are fascinating.*

- *It helped show how small changes in parameters can have large effects on the properties of the neuron.*
- *It was very easy to navigate and the directions were quite easy to follow. It was very simple, yet capable of presenting complex ideas and concepts, which I think is remarkable.*
- *Being able to change the parameters and see its effects immediately. Also, how it taught me more than just an intro neuroscience course!*
- *I liked being able to "practice" the concepts learned in class.*
- *I really liked how the tutorial would ask you to work through a problem, and you could check your answers right away by clicking a link. I find this more helpful than handing in assignments to a professor and getting feedback later in the week.*
- *The various simulation configurations that were available and the ability to manipulate many different variables and observe their effects.*
- *I liked the ability to see a simulation that showed me exactly what to expect during a real experiment and in a relatively easy to use, concise format.*
- *Has power to demonstrate/recapitulate the findings of fundamental concepts/experiments.*
- *The real-world applications relevant to the tutorial at hand.*
- *The layout of tutorials seemed to maximize my understanding by building on concepts in an appropriate manner.*
- *Being able to rerun the simulations until the concepts were very obvious to me.*
- *The simplicity of the program was able to make me feel like I was in an environment conducive to learning without feeling intimidated.*
- *Explains concepts and allows you to think through the various scenarios.*
- *The tutorials were well structured and organized. The goals kept me focused.*
- *Links to original papers and experiments to provide historical perspective. Ability to vary parameters to see how outcomes change. Ability to test potential experiments without the expense of setting up actual biological preparations.*
- *The ability to manipulate key concepts in an experimental fashion. Also, that we were led by the tutorial in how to manipulate the information to get the most out of them.*
- *I liked the flexibility built into the program. I liked that we can change many parameters including the properties of the cells we were looking at and actually see how these properties figure into the physiology.*
- *The way it takes you tutorial after tutorial and the linked pages that explains and goes into key concepts.*
- *I loved the background information coupled with actually running the simulations. I also liked the questions about why you got the results you observed on the simulation.*
- *The ability to alter parameters to really learn a concept by actually witnessing changes. It really made me appreciate the experiments that discovered early neuronal properties.*
- *The fact that you simulate real data for many real experiments.*
- *The flexibility of doing what I want and watching what happens.*
- *I liked how easy it was to change the parameters and worked on many in my own.*
- *The hands-on nature of NIA2 is appealing.*
- *The playability of the simulator.*
- *It made very abstract concepts more concrete.*
- *Ease of use and amount of explanation and guidance.*
- *The minimovies of electrical current spread over space and time.*

- *Complements reading.*

Virtually everything users **did *not* like about NIA2** (e.g., the multiple simulation windows) has already been addressed in Specific Aim #1. Those comments will not be repeated here. However, the Initial NIA2 Survey also asked respondents (primarily instructors) what they thought was **the greatest weakness of NIA2**. The difficulty of managing multiple windows was again mentioned by some individuals. Other responses that have not been covered in previous discussions are shown below. Some people responded that there are no weaknesses in NIA2, and in some cases the "weaknesses" were still considered to be an improvement over the prototype NIA1.

- *It is easy to perform many experiments using NIA2. This can sometimes be overwhelming for the students.*
- *At this point, I haven't spotted anything obvious, but I haven't actually used NIA2 yet with my students. I have just looked through it and compared the NIA1.5 modules with the NIA2 for the modules I use in my course.*
- *I can't find one.*
- *Requires a little bit of time to get on board with the interface.*
- *None.*
- *Sometimes the tutorial text is a bit confusing. NIA2 is much clearer than NIA1.*
- *Probably some aspects of the interface, which relies on the NEURON GUI. However, this doesn't seem to be a real problem.*
- *The videos were not that good--if they could be more "on line" like an oscilloscope it would be great.*
- *One has to make a significant investment in time to make full use of NIA. This is true for all learning, however. One does not learn without putting in effort.*

<u>What have instructors (and future instructors) learned from NIA2?</u>

Above we have discussed what instructors felt their *students* learned from NIA2. However, one of the most amazing and exciting parts of the NIA2 evaluation was discovering how much the instructors themselves, many of whom have been teaching and researching neuroscience for long time, learned about neuroscience from teaching with NIA2. One such example will be illustrated more in the case studies section. When faculty members were asked, "**Did you personally learn anything about neuroscience or the teaching of neuroscience from your experiences with the NIA2 materials?**" one person gave us a very enthusiastic, "Indeed I did!" This person went on to elaborate with two examples, telling us, "I had never thought about membranes that have only capacitance! I continue to be fascinated by propagation in axons with changing diameter, changing channel densities and changing myelination." Another individual noted, "In preparing for a class with simulations, I inevitably get sucked into a tangential direction and find myself exploring things of interest to my own research."

With regard to what they **learned about *teaching* neuroscience with NIA2**, instructors said:

- *Graphics help in explaining kinetics.*
- *I am not an electrophysiologist by training; it is only something of a hobby interest. But, I now teach it at a high level, and I really learned how to do that using NIA1 and NIA2.*

- *I learned that proper visualization of electrophysiological phenomena really enhances understanding.*
- *That students can handle a fairly complex software package/simulation tool well (at the graduate level anyway).*

In regard to what they **learned about neuroscience on a *conceptual* level**, the instructors told us:

- *I learned a different concept of saltatory conduction, i.e., that the AP does not jump from node to node. I got a better appreciation for the concept of threshold.*
- *The details of demylenation were explained.*
- *I thought the simulations showing action potential generation and propagation of myelinated axons was truly astonishing!*
- *The real meaning of threshold.*
- *Calcium effects on threshold*

<u>What recommendations do instructors have for future instructors?</u>

The Initial NIA2 Survey asked individuals, primarily current post-secondary faculty: **"Although the upgraded Neurons in Action 2 materials have been used/tested in a variety of settings, the NSF grant that is funding NIA2 explicitly targets undergraduates and undergraduate education. Given your personal experiences with NIA2 (whatever they have been to date), if an instructor was planning to use the materials in an undergraduate classroom, what advice would you give him/her?"** The advice they offered is as diverse as the current uses we have already described. All of them, however, recommend using it in some context, and they do not limit their recommendations to advanced students.

- *Even with the expanded introduction in NIA2 as to how to use the program and the "What is..." and more user friendly help section; I have found it useful for students to actually watch me navigate the different panels using a classroom/lab projection system. I've only used NIA1.5 in two offerings of a basic neuroscience course for undergrads, but in one offering, I had the students just watch as I introduced the different panels and layout of the program, how to change parameters and what those parameters did. The other time I had the students use the lab laptops to follow along and actually do what I was doing on the classroom projection system. I think the latter, which admittedly took more time, was more effective in the end. Let's face it, it was active learning. In the end, the students seemed to more readily pick up on what the program did and how to use it with that second approach.*
- *1) Use it to make sure your own understanding is spot on and/or teach yourself. 2) Use it for in-class demos to make points. 3) Use it to make problem sets for exams or homework; some real brain teasers can be developed that way and the screen capture allows one to put the image or the result directly in the exam. 4) Turn the students loose on it. Motivated undergraduates will beat my graduate students on it every time.*
- *I plan to keep it as a supplement to my advanced neuroscience course and to use some of the basic tutorials in my physiological psychology laboratory course. I would suggest they use NIA2 as often as possible, it stretches the students, challenges them to think, do and solve problems.*

- *Give them a lot of oversight... it's easy to misunderstand how undergraduates see the world of science.*
- *The instructor should try each tutorial himself or herself and then target those aspects of the tutorials most relevant to the course material.*
- *Assign it early on, and use the quiz/questions function. Require students to use NIA2 output for presentations.*
- *Undergrads need a little prep by the instructor beforehand. It wouldn't be good to have them use the simulations entirely on their own outside of class/lab.*
- *DO IT and do it soon. You will have a great time.*
- *Get the students on their own computer with a copy of NIA2 as soon as possible (vs. the teacher doing the simulations for them on a projector screen)*
- *Give yourself enough time to become familiar with the user interface. Give your students enough time to become comfortable with the interface, also. There are many excellent options in NIA2, but it is easy to not find them and to get lost in the somewhat complex user interface.*
- *To go slowly through the material, and in sequence.*
- *I have been very successful in integrating simulations within lectures, demonstrating with simulations the concepts I talk about within the lecture. This is really valuable.*
- *Do it for sure.*
- *My advice would differ depending on whether the course was an introductory one or an upper level neuroscience course. For an introductory course it is great to use the minimovies. For an upper level course, make full use of NIA2.*

The SPINES 2008 participants, many of whom currently teach or who said they plan to seek faculty positions where they may be in a position to teach neuroscience, were asked, **"If you were going to use NIA2 in an undergraduate course to teach fundamental neuroscience concepts, how would you use it in the classroom? Even if you have never taught before, please try to imagine what you might do. If you do not think the NIA2 materials are appropriate for undergraduates, please explain."** Most respondents indicated that they would use it in conjunction with some sort of lecture or other form of instructor guidance. Some would also assign it as homework, or for group projects. No one indicated that they thought NIA2 was too advanced for undergraduates.

- *Similar to what I recommended for SPINES: 1. Brief instructor introduction to provide context. 2. Mostly solo exploration with the option to collaborate with other students and/or instructor to address specific questions. 3. Large, instructor-led group discussion after solo exploration. I would start with basics and then moved to advanced. The advanced tutorials are much more interesting with a strong understanding of the fundamentals.*
- *I would use this tutorial as the only book in the course. This is a very good book to use to teach an undergraduate course, because it also explains and provides definitions and it allows the fundamental of each particular lesson to be seen through example simulations that are guided throughout the book.*
- *I would introduce the topic incorporated with a lecture.*
- *I think the NIA2 tutorials are appropriate for undergraduates, but would suggest the tutorials be led by an instructor. The tutorials help to visualize complex concepts and to better understand them.*

- *I think I would follow what Ann had done in our course. I would introduce NIA2 and go through one of the tutorials as a class. Then I would have students pair off in groups and work together. I would also walk around the class and promote discussion on the key concepts within the tutorial.*
- *I would give a lecture on the action potential and then go to show it. Then go into passive membrane vs. active membrane. Then into unmyelinated vs. partially myelinated.*
- *Each student would be assigned some of the classic papers and some background information for each tutorial. For the first half of each class I would set up the background for the specific tutorial and do a quick run through the tutorial; the other half of the class each student would go through the tutorial on their own. The advanced tutorials would be saved for the end of the course. Each student would get into groups and give presentations on a specific tutorial. Presentations would include background on the tutorial, and an explanation of the tutorial.*
- *Materials are a bit advanced, but a great teacher like Ann could teach it to kindergarteners and they would understand and be excited about neuroscience.*
- *As above, I would use NIA2 to illustrate points gone over in class during lecture. For time purposes, like Ann did, I might choose particular sections of a given tutorial that particularly highlighted certain points (but only because I had already touched upon the ideas learned by doing the parts of the tutorial I omitted in class). Still, I would probably suggest students work on those extra sections as a homework assignment, where they were free to use each other as resources. We'd then address any questions specific to the tutorials they did on their own prior to the next lab section.*
- *I would first lead into the preliminary experiment, get student excited and comfortable and then let them explore and then finally review to make sure everyone grasped the major concepts.*
- *I would use it in conjunction with different media. My problem here is that things are only presented in one way. There's one explanation for everything and if you learn through different channels than strictly visual, you can get lost within the modules.*
- *I would give lectures about specific topics and use the simulations to enforce different aspects of the lecture.*
- *I would copy Ann.*

<u>How can we get more instructors to use NIA2?</u>

On the Initial NIA2 Survey, we asked people how they heard about NIA2. Almost everyone had found out about the program directly from Ann Stuart or John Moore. A couple heard about it at a Society for Neuroscience meeting, likely also from Ann or a talk that she gave. Two said they got it from a colleague and another two found out from the publisher via a mailing or the web site. This sort of dissemination is not unusual in the early stages of an educational innovation, but eventually produces a group of users that is semi-closed group – “preaching to the choir”.

According to our own evaluation records and sales information provided by NIA2’s publishers Sinauer Associates, Inc., in Fall 2008, a total of 80 post-secondary institutions in the United States and several foreign countries have purchased NIA2 site licenses or individual copies. Overall, forty institutions have purchased some sort of site license for NIA2, which generally does not include print copies of the tutorials for the users, and thirty-seven institutions have purchased five or more individual copies. These are not mutually exclusive groups; in some cases an institution has purchased both a site license and individual copies. Eleven institutions who had purchased the prototype NIA1 upgraded to NIA2. Another fifty-one institutions that purchased a site license for NIA1 and have not yet made the switch to NIA2. It seems likely to us that many will choose to do so. A list of the institutions that have purchased NIA2 can be found in Appendix E.

Any number of ringing endorsements of NIA2 may be found among the previous comments. The enthusiasm for the program and its great perceived value is evident among nearly every user with whom we have communicated. But, how do we get even more people to use it? Two instructors discussed in the case studies below said they personally were surprised that NIA2 was not more widespread. Sadly, it is probably impossible for everyone to have the chance to experience Ann's teaching firsthand, though if the iTunes model (as discussed in Specific Aim #1) is implemented for future NIA tutorials, the PIs may wish to consider podcasts or short instructional videos with Ann's inspiring teaching that mimic the types of experiences that the SPINES students found so valuable. One instructor also offered the following comment about disseminating NIA2.

> *This is one of the most important teaching tools now available for understanding "Neurons in Action." I believe that the activation energy to test the program may discourage some and others may be unwilling to discover how much they have to learn. (I think those faculty who teach neuroscience but are not grounded in neurophysiology might be frightened away) I suggest that faculty that have successfully used NIA2 be asked to participate in a workshop for others.*

Case Studies

When we were first approached to take over the evaluation of the NIA2 project, as usual we began our process of creating the proposed evaluation plan by focusing on the state project objectives (or *Specific Aims* in this case). However, as we read more and more of the proposal, we realized that there were implicit learning objectives embedded within the descriptive text. For example under *Specific Aim 2*, when discussing the proposed new *Ca Action Potential* tutorial, the PIs stated:

> *Students will be able to appreciate how this extremely important second type of voltage-gated channel can underlie regenerative activity just as Na channels do. They will see that the kinetics of the Ca-dependent and Na-dependent action potentials are markedly different, and that both channel types can coexist, generating different types of action potentials appropriate for the function of the particular neuron.*

We felt, that if it were within our time and monetary budget for the evaluation, we would like to evaluate these implicit learning objectives as well. This spawned the idea of doing site visits where the new NIA2 were being used with undergraduates. We wanted to catch the complexity of each classroom, and look for details of how NIA2 was being used within that context. So within the tradition of *instrumental* case study research (Stake, 1995), we began making inquiries of various undergraduate instructors that Ann Stuart and Bruce Johnson

(Cornell University, past president of the Faculty for Undergraduate Neuroscience (FUN) organization) indicated were using NIA2. We wanted to find environments that would maximize what we would learn about how NIA2 was being used to further the neursoscience education of undergraduate students.

What follows then in this report are five case studies from University of Texas at Austin, Amherst College, Williams College, Emory University, and Agnes Scott College based on our 1-2 site visits at each institution. A brief description of each school and their respective academic programs within which NIA2 was used can be found in the **DATA COLLECTION METHODS AND EVALUATION OVERVIEW** section above under ***Data Collection Method 4*.**

Case Study 1: The University of Texas at Austin, Austin TX

The first site we visited for this evaluation was University of Texas at Austin. We put out some inquiries in early spring to see if anyone was using NIA2 in spring classes. We heard back from Nace Golding that he was using it all semester long in a lab course. He sent us a copy of his lab manual and we saw that he would be using some of the new NIA2 materials during the spring. In particular, he planned to talk about *Chattering Ion Channels* and have students work on the updated *Na Action Potential* tutorial. We also found out that there was another instructor at UT Austin, Jennifer Morgan, who had previously used NIA1 and was planning to use NIA2 in upcoming courses. We decided to interview her as well during this visit.

- **University of Texas at Austin Class Observations:** We must admit that this first site visit was a little daunting for us. We had worked through the tutorials on our own and had discussed them with our biology consultant, Mark Venable. However, we still did not have a substantial conceptual understanding of the ideas covered. In retrospect, it is amazing to us how much more we have assimilated after our experiences with Ann Stuart at Woods Hole. For example, as we look back over our field notes from this visit, we can see that the UT Austin instructor had a macro to micro approach to the neurobiological topics in his lab course. For example, students had just completed tutorials and wet lab experiences on the summation impact of multiple impulses in synaptic integration the week before arrived. While we were there, they stepped down a bit to talk about multiple channels in the *Chattering Ion Channel*s tutorial demonstration. Finally, students took an up close and personal look at the mechanisms behind a single Na channel's action potential.

  The class began with students doing presentations on group wet-lab report. These wet labs were extensions of the ideas introduced in the *Interactions of Synaptic Potentials* tutorial. The entire class had completed the first two experiments of *Laboratory 3: Excitatory synaptic transmission* in tandem. Then the five groups were each assigned a slightly different wet lab to explore, which the instructor referred to as "variations on the theme," designed to facilitate peer to peer learning. Here is a list of the experiments that they presented.

  Experiment 3: Variations on the theme

Group 1: Examine the role of calcium influx in the presynaptic terminal on synaptic transmission and short-term plasticity by manipulating extracellular calcium. Compare your results with your prior expectations.

Group 2: Investigate how vesicle availability affects synaptic transmission using repetitive stimulation under conditions leading to robust presynaptic calcium influx.

Group 3: One way to alter calcium influx into the presynaptic terminal is to alter the width or height of the presynaptic action potential waveform. Perform paired-pulse experiments during blockade of potassium channels known to contribute to the repolarization of the presynaptic action potential. If time allows, you can also discuss a way to confirm the effects of this blocker on the presynaptic fiber volley.

Groups 4 and 5: Record synaptic plasticity in different interneurons in the hippocampus. The excitatory drive to these neurons is provided (largely) by the same Schaffer collateral axons. Thus your results will give you some insight as to whether the probability of synaptic transmission is determined by the identity of the input or the target.

Some groups clearly understood of what they observed better than others did. It was interesting to note that the instructor did not readily give answers to students' *why* questions. Instead, he suggested various ways students could further explore them with additional experiments. Also we observed some common problems with wet labs. One group had potential sources of error in their measurements due to old tissue and another group had incomplete data due to computer issues, pipette issues and cell death during their experiments. It is interesting to note that several instructors have mentioned that they use NIA2 instead of wet labs for just such reasons. At the end of the presentations, the instructor discussed how students should set up the context of the lab in future reports and presentations so that one can make connections between the physiological context (i.e., understanding what part of the cell neurotoxin TEA affects and why) and their lab observations. The emphasis was on not just observing, but putting the observations in context and making connections.

After discussing the lab reports, the instructor lectured on the *Chattering Ion Channels.* This lecture was essentially a "highlight reel" of the objectives listed in the NSF proposal for this new tutorial. In particular,

They will see that when the channel is open, it has a fixed, measurable conductance: that is, the channel is either open or closed. (A common misconception of a pore slowly widening and narrowing to let through *more or fewer ions can be dispelled). The conductance plot will show that, in response to a large step depolarization, the number of openings of the channel increases so that the channel is almost always open. The concept of channel opening as a probability will be stressed in this approach (and, for the inquisitive student, linked to Hodgkin and Huxley's ideas about probability in the NIA2 Appendix).*

He began with drawing an action potential curve on the board and talking about the "anatomy" of the action potential. He explained what was happening physically in the cell at each part of the action potential curve (see Appendix F for a handout of these notes found in the Course Lab Manual *Section 3: Mechanisms of Action Potential Generation*). Next he drew an ion channel on the board and discussed what happens when a pore forms (see Figure 16 below, taken from one evaluator's notes).

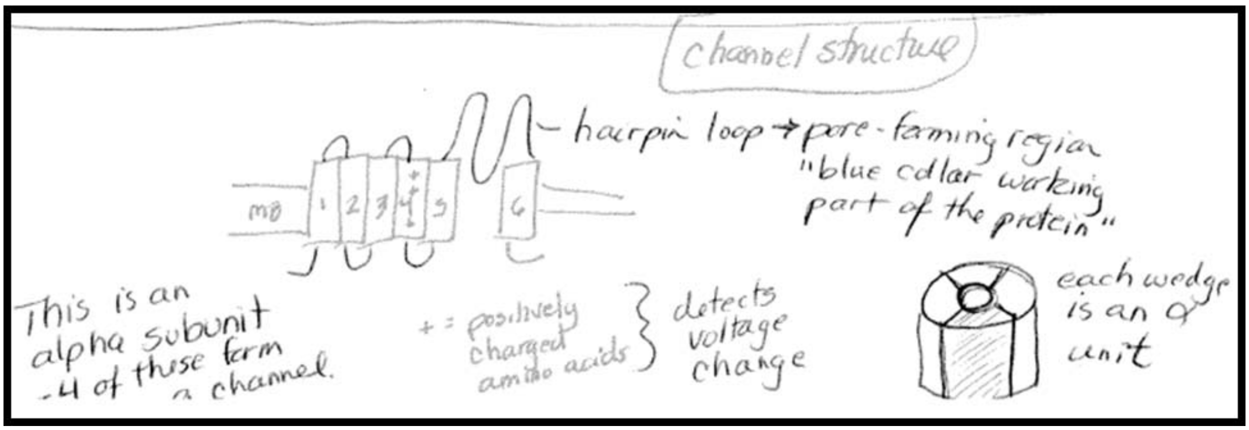

Figure 16: Ion Channel Structure from Evaluator's UT-Austin Field Notes

You can understand the sequence of what happens in a voltage-gated channel, but the structure can be difficult to describe. It is often because of this difficulty that people develop misconceptions of what is happening during the inactivation period of the action potential.

The instructor then spent a great deal of time distinguishing what happens in activation, inactivation and deactivation of channel. The pore is either open or closed; however, during inactivation the pore is blocked by a positively-charged "plug" of intracellular amino acids (see Figure 17 below), yet the channel is not closed at this time. It remains blocked until the membrane repolarizes. During the inactivation phase, recovery takes time. So there are two key concepts regarding time course in which an action potential takes place. First there is the *passive membrane property* which tells us that the membrane has its own time constant that acts as a "superthreshold" for the action potential. Second, the time constant also depends on the kinetics of the process. Na channels have an intrinsic speed in which they activate. However, K channels have a slower rate of activation (if they happened at the same rate, the positive ions of Na would cancel the effect of the negative K ions. Thus the cell would remain inexcitable). As the cell repolarizes, the channel closes and no longer allows Na ions to flow.

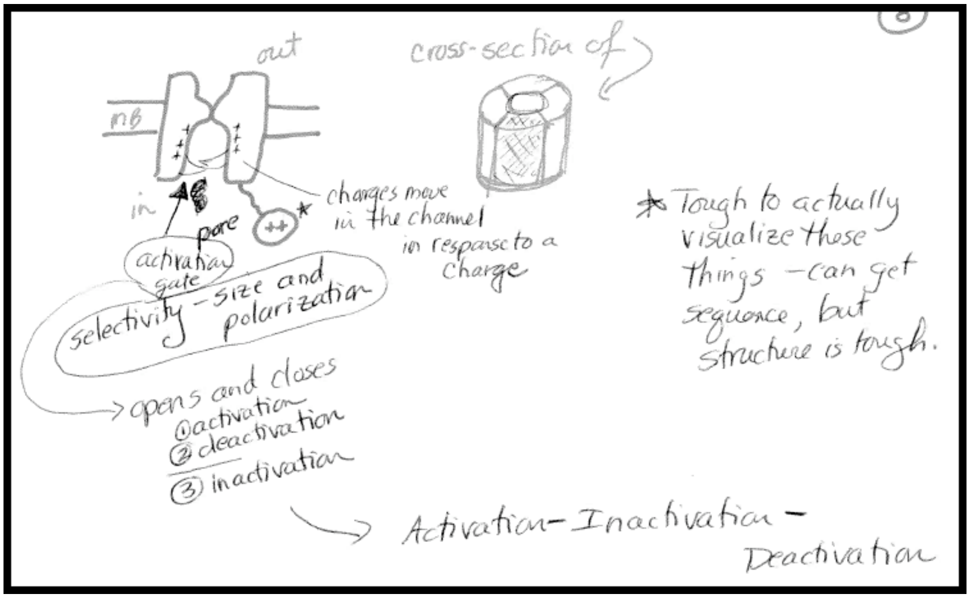

Figure 17: Activation-Inactivation-Deactivation Cycle Notes from Evaluator's UT-Austin Field Notes

This is the context that the instructor set up that lead into demonstrating the Chattering *Ion Channels* simulation. In this simulation, he controlled the voltage and looked at the current that flowed through. In this introduction, he reminded the students that they first looked at how current depended on time. Now, they were going to see how current depends on voltage as well as time. He wrote the following equation on the board:

$$I(v,t) = -g(v_m - E_n)$$

Here we see current, *I*, can be found by knowing the conductance, *g*, and the driving force (how far away the voltage is from equilibrium potential). Neurons are cells that average currents from thousands of ion channels. It is a "group mentality". He referred directly back to the action potential process they had just discussed and the varying rates of activation for Na and K.

So how do all of these different channels impact voltage? In the *Chattering Ion Channels* tutorial, he ran the simulation for Na alone and then K alone. He then ran Na and K together. We observed that there was a low probability of Na channels opening at resting potential. The *probabilities* increase as more and more Na channels open. He then asked the students, "What dictates the voltage at which an action potential occurs?" We need sufficient number of Na channels open to trigger regeneration.

At this point the instructor set up the NIA2 tutorial that the students were going to explore in lab, the *Na Action Potential*. He discussed the different toxins introduced in the tutorial and the mechanisms by which they affect neuron function.

- TXX from bacteria found in the ovaries of puffer fish. It blocks the channel from the outside.

- STX from Red Tide flagellates. It binds to the inside of the channels.
- Novacaine is a Na channel blocker. It settles in the pore.
- TEA blocks voltage-gated K channels.

He also talked about Information Theory and how action potentials code information. They code *how fast* an action potential can fire and the *duration* of the action potential.

Students were then given the NIA2 lab handout (see Appendix G). They did not have their own copy of the NIA2 book. UT-Austin has NIA2 installed on the lab computers, but they also have a site license that allows five copies to be in use for work outside of class. Students broke up into their lab groups and began working on the *Na Action Potential* tutorial in the laboratory. Each group contained three or four students.

Here are some of the observations of the student work groups that we made as students worked on the *Na Action Potential* tutorial:

- All five groups struggled to varying degrees with the first simulation. They were supposed to explain what was happening with the "kinky" part of the graph. They had difficulty actually identifying the correct "minimum current". See a detailed discussion of this in Specific Aim #1 (f) **Project "Detour" -- Restructuring the Interface and Other Tutorial-related Issues**. The instructor noticed that the students had "stalled" on this part. He walked around to the groups and kept pointing to the equation $I(v,t) = -g(v_m - E_n)$ that was written on the board. However, the students became even more confused because they were trying to apply that equation to the wrong point on the graph. Students had to get over this graph interpretation hurdle before they could start meaningfully varying parameters and making observations as outlined in the NIA2 tutorial. One of the five groups took *substantially* longer than the others to figure this out.
- Students had a difficult time describing what they observed in the graphs in words. They had a hard time translating the observed function into a verbal description of what was happening in the Na channel.
- After the misconception with the graph interpretation was cleared up, students were able to think about the graph in terms of the current equation on the board. It still took some time. One student said, "I never thought about driving force in a graph." Eventually the instructor was able to help them make the connection themselves to the idea that the current *must* change in response to both driving force and conductance, and further pushing them to see for themselves the idea of minimum driving force occurring at a specific point on the graph. For example, no matter how large the conductance value is, when driving force approaches zero, then current will also approach zero.
- The group that Jill primarily observed used the "keep lines" feature without being prompted to facilitate comparisons of changed parameters to the baseline. They were very systematic in their approach to the simulations. This same group had many animated discussion about what they were observing, more than most of the other groups. In one section of the lab, they were asked to compare the effects of anesthetics that block both Na and K (lidocaine and procaine) versus those that

block only Na (tetrodotoxin or saxitoxin). There was a vigorous debate about the observed effects. In the simulation, students decreased the Na channel density to the point where an action potential was no longer generated (from 0.04 S/cm^2 to 0.03 S/cm^2). However, when K was removed (i.e., also blocked) then the action potential returned, even though the Na level was still at the decreased 0.03 S/cm^2 level. One of the three participants disagreed about the relative merits of blocking only Na versus both K and Na both, even though the graphical evidence of what happened when K was blocked were on the screen right in front of him. He had to be talked into it by the other two group members, both through verbal arguments and repetition of the simulation to demonstrate the effects of K.

- Once the group that Mary Beth observed got past their difficulties with the first simulation, they basically flew through the rest of the tutorial. When asked to explain what was happening behind their observations, they were rather vague with their responses. Usually the response was "I think it has something to do with …" There did not seem to be a great deal of depth in the discussion as with the group that Jill observed.

At the end of the lab period, students were reminded that the next lab would be a wet lab, Laboratory 4, which went along with the simulations they did in the *Na Action Potential* tutorial. See Appendix H for a copy of Laboratory 4.

- **University of Texas at Austin Informal Interview with Instructor Nace Golding:** Nace's own research informs what he does in the class, because he knows what to expect. He sometimes replicates the results of his own research with this class. There is a freedom when exploring questions that he may not know the answers to himself. The students in this course have already taken the Introduction to Neurobiology course. The BIO 365L laboratory course is an elective. The time separation between the two courses sometimes creates difficulties for students. They seem to have forgotten all that they learned in the lecture course. He has a mix of students: methodical (thinking while they go along) versus those that "jump in and do" with little reflection. He uses both detailed and short answer items in the lab to accommodate the different learning styles of his students.

  When Nace first began to think about offering this course, his colleagues told him that is would be next to impossible to do with undergraduates. He is teaching this course at a level somewhere between an undergraduate- and graduate-level course. It has been a trial and error endeavor. At first he started introducing several ideas primarily in class lecture, but students were not able to internalize those ideas for themselves. He would get the typical response that most educators have experienced: "I understand this in class, but …" So through the trial and error process, he has ended up with the process we observed during our visit: short lecture (sometimes accompanied by demo in NIA2), simulations in NIA2, accompanying wet lab, homework, and student group presentations. He said that "repeated exposure" to the concepts was needed to understand these complex ideas. From what we observed, we agree that this layered approach might be the right way to approach such a level of mature thinking.

Including NIA2 in this course has been a good idea. Nace has had some "catastrophic failures" in past wet labs, and w observed evidence of such 'failed' labs in the students' presentations of their own work during our visit. Some of these undergraduates work in other research labs on campus, so there is a diversity of lab experience in the class. However, NIA2 does not care how much lab experience a student has, so students can get the concepts they need.

Despite out initial concerns about what we might take away from this visit due to our own (at that time) lack of experience with the materials, UT Austin has been the case we often refer back to when discussing NIA2. It is interesting to note that John Moore's bio on the NIA2 web site (http://neuronsinaction.com/about/authors) says that, "Neurons in Action reflects his career in neurophysiology where experiments and simulations were carried out in parallel." If that is the case, then Nace's supposedly "impossible to do class" is really an incredible example of this philosophy in action. Though the students certainly struggle at times with both the simulation and wet components (which is arguably a good thing in advanced education), they are in a sense living out exactly what NIA2 was ideally intended for.

- **University of Texas at Austin Informal Interview with Jennifer Morgan:** Jennifer Morgan has known both PI John Start and PI Ann Stuart for a very long time. Ann was her undergraduate advisor at University of North Carolina Chapel Hill, and she got her Ph.D. from the Neurobiology Department at Duke where John was a professor. She has the unique perspective of having been around since the birth of NIA. We did not get to observe her teach with NIA2, but we discussed with her prior experiences using NIA2 at a different school, as well as her plans for incorporating NIA2 into a future course at UT Austin.

  Jennifer used a pilot version of NIA2 at Bowdoin College Fall 2006 in Introduction to Principles of Neurobiology, though in her own opinion she probably did not really tap the new capabilities of NIA2 versus what was available in NIA1. She designed the course to be more of a systems-level approach, though she had something of a battle with students who expected it to be more of a psychology course. There were several wet labs required, so she fit in NIA2 where she could. She said she felt sad that she had to pick and choose from the materials. She wanted use be able to use the entire thing. About 25% of course grade was based on write-ups from NIA2 labs, and exams had novel problems with applications of concepts.

  In her approach to using NIA2 in this course, Jennifer really took her lead from the way she had seen Ann Stuart teach at MBL. First she introduced her students to the program by running the *Membrane Potential* tutorial in class as a demo. She used about 2/3 of lecture time to do simulations from various tutorials throughout the semester, designing for each a series of 'tests' and asking her students to predict what would happen when she ran the simulation. The same week and the week after the initial introduction, the *Threshold* tutorial was done together as an exercise. She felt she had to teach this particular concept with NIA2 because most textbooks approach this concept this incorrectly as an *absolute* membrane potential and not a value that is dependent on current. In fact, most textbooks never mention current in the context of threshold. According to Jennifer (and others we have spoken to, as discussed earlier), you can never really understand threshold from a textbook because it is a static, ‘flat piece of paper’. She then used simulations to look at nerve properties in space and time, talking about resting membrane potential before she brought in NIA2 for *The NA Action Potential* tutorial (2-3 weeks into the class). At this point, the students knew a little about the passive properties of action potentials. She had them look graphs and asked about what they expected to see, based on what they had learned so far. This is another strategy she copied from Ann: she turns the tutorial into a real-world situation where suppose you have a toothache. You need a filling and they numb you with Lidocaine (Na blocker) or Novocain (a general blocker). Which works better, and why? Then they run the tutorial. Students were often surprised by the results that they got, so they had to go back and work through them logically, not only on the action potential concepts but the tutorials in general. Finally, students did the *Refractory* tutorial, leading up to a capstone-type “design your own experiment” project.

For the last NIA2 labs of the class, student created and ran their own experiments using NIA2. Students had one week to derive a hypothesis, then a second week to figure out how to do the experiment. They actually did the simulation at the end of the second week. She discovered that the students loved to make up "clinical type" problems and hypotheses that they could then test using NIA2 simulations, and they very much enjoyed being on control. It was their favorite part of the course experience. This activity was a particular challenge for Jennifer. She had to check to make sure what capabilities were available in NIA2 to conduct the experiments students had devised. In total she had six groups who picked real-world experiments, such as a grandmother with Alzheimers. Since the death of neurons can affect synaptic properties, so she pointed the Alzheimers group to the synaptic integration tutorial. Only one group was a “miss” for their first idea – they couldn’t find a tutorial to fit. The groups wrote lab reports about their experience.

One particularly interesting occurrence during this course was that while two groups of students were working on their projects, they needed to use the idea of “inter-nodal space”. Jennifer contacted PI John Moore, and according to him neither group interpreted it correctly according (it was decided that the concept was vaguely defined within the NIA2 text). The interpretations significantly impacted how the groups’ experiments were designed. Because of this discussion, the definition was fixed in subsequent releases of NIA2. Jennifer gave these students extra points for contributing to the education of other students by helping identify this issue to the designers.

When discussing her class, Jennifer spoke about the realities of teaching the current generation of students. When doing the tutorials together, Jennifer first led her students as a group through the various windows before turning them loose to work in groups. Every student had his or her own computer (site license). Among her students, a level of competition to get the answer “first” developed. In Jennifer’s opinion this is an advantage, as it forced them into an interactive and dynamic learning environment that they did not necessarily like, but which made them think. She said it was important pedagogically to do something active and get students comfortable talking about topic.

In her experience, students expect to be entertained in a passive "give it to me" way. They do not like think for themselves and be challenged to something with the information they are given. The dynamic, interactive nature of NIA2 works well for the mentality of this "video game generation." Another real strength for this population is that NIA2 has many real-world examples. The typical 18-19 year old is mostly only interested in him- or herself. Currents are far removed from what they typically think about, but the real-world problems, highlighted by the projects she devised, made it real for this group. "Kids really lock in there!" Jennifer said. So what did they learn? She gave us her impressions of this in the Initial NIA2 Survey.

> *The students gained insight into the parameters that affect various aspects of the action potential. They specifically learned that rate of current change, not strict voltage change (amplitude), is what determines whether a neuron will fire. They also learned that the action potential does not "run" down the axon as a narrow depolarization, but rather spreads over a large distance. They learned that the spacing and size of synaptic inputs on a dendrite (or multiple dendrites) determines the neuron's likelihood of firing. Because NIA2 is interactive, and because the students can change the important parameters, the students learned these important features of excitability by trial and error. It would not be possible to do this with a non-interactive book or slide format.*

In general, Jennifer said that she believes NIA2 is good for stepping undergraduates through the process involved with some neurobiological concepts, but that it can be intimidating. Instructors have to go slower with them because they need time to process, and even then only one-half to two-thirds of the class will be on track. Also, while other instructors have used NIA2 as out-of-class assignments (e.g., the Cornell example discussed previously), she thinks her students would have been bored doing tutorials for homework because "they wouldn't know why they needed to be excited." The context or set-up and debate are an important part of the process. This supports our observations that students do not readily have the ability to interpret the output of NIA2, especially graphs. They need guiding questions and debate to get them going in the right direction. She has notes for herself that go step-by-step through what happens, another habit she picked up from Ann Stuart, who she said "has step-size thinking" toward guiding how to most effectively change parameters to observe the intended results. This approach, of course, means that instructors have to do a lot of prep work ahead of time learning the program for themselves and creating guided discovery questions. In her opinion they also need a decent background in neurophysiology. For those that do not have those skills, she would like to see a NIA2 Teacher Manual. She also recommended demo classes (AIA -- Ann in Action) to prepare faculty to teach with NIA2.

Jennifer plans to use NIA2 again in undergraduate courses. When using NIA2 with introductory-level students, she would proceed much as she did at Bowdoin: first demo in class, then have a lab where you walk through the program with the students, followed by having the students work on tutorials in groups. If at all possible, she would have students run the simulations on their own computers during the lecture component, as in the lab, because they are more "plugged in" that way. Specific plans at UT Austin include a Cell Biology Lab course, where she hopes to do one unit from NIA2 (perhaps the synapse tutorial). Her final choice will depend on what the current course looks like. She feels the top students at UT are comparable to those at Yale (where she used NIA1) and Bowdoin, though the middle students may not be quite the same.

Like so many of the other instructors we spoke to, Jennifer sees NIA2 being useful to her own research and learning. She has learned a lot about neurophysiology from NIA2, and would start with NIA2 if she had a new problem before programming and modeling herself in NEURON. In her opinion, NIA2 is a great tool to introduce professors to the concepts of modeling, noting that it could really help someone who does not do this sort of thing all the time. She said, "I feel like I want to do more with it," both for herself and her students.

Case Study 2: Amherst College, Amherst MA

We were interested in Amherst as a case study because it is an institution that solely caters to undergraduate students and because the instructor there was using three tutorials that had either been revised or were new to NIA2: (1) *Neuromuscular Junction* (revised), (2) *Postsynaptic Inhibition* (revised), and (3) *Interactions of Synaptic Potential*.

- **Amherst College Class Observations:** The BIOL-35 Neurobiology class was broken up into two different lab sections, which met on consecutive days. We were able to observe both labs. As noted in the Data Collection section of this report, the instructor was away at a meeting both of these days. A different undergraduate Teaching Assistant monitored each of the two labs. At the start of the period, students came into the computer room with their lab handout and began working on the tutorials as directed. The handout included a master set of instructions (see Appendix I) and copies of the NIA2 book pages for each of the three NIA2 tutorials mentioned above. Students did not have their own copies of the NIA2 CD. Instead, the program was installed on a server in that lab. Students had access to the lab during other times of the day if they wanted to review or explore on their own.

  Lab Section 1 Observations: What we saw in this course was significantly different from what we saw at UT Austin. First, there was no contextual introduction or set-up given by the Teaching Assistant or explicit connections made in class to other work. Also, instead of having prearranged lab groups, students spent the whole time working alone. It was *very* quiet in the room and thus difficult to ascertain what students were thinking. Given this independent-working atmosphere, it was difficult even to ask them questions because it would break the silence of the lab. Students did not ask one another questions and rarely directed any questions to the Teaching Assistant. Students appeared to actually read the materials instead of simply plunging ahead and "doing" the simulations. We did see something interesting here that we did not see in the lab at UT Austin. When students went to the links that answered the "why do you think this happened" type of questions in the tutorial, we saw them recording that linked information (which is not in the printed tutorial text they had copies of) in a variety of ways: by hand in their notes, taking pictures of the information with their cell phones, or copying and pasting the prose into a MS Word document and emailing it to themselves. It took about an hour and 20 minutes for the first student to complete the lab.

Because of the limited verbal discourse within this lab, we **informally interviewed Lab Section 1 Teaching Assistant** via e-mail to get her reaction to NIA2 and what happened in the lab during our observations. We have included a transcript of the questions and the TA's responses (in italics) below:

> (1) Compare this course including the NIA2 labs with your own experience in the Neuroscience course. Do you feel the labs are an added benefit with regard to (a) understanding course content and/or (b) the ability to add concepts that you didn't see in the course without NIA2?
>
> *Using the NIA2 program certainly added to an understanding of concepts discussed in the course and provided a good introduction to topics that weren't covered. While NIA2 helped students to visualize certain phenomena, it also created some confusion when the presentation of the material did not match course content.*
>
> (2) Describe the students in your lab section (majors, level in school, demographics)
>
> *The students in my lab section were primarily neuroscience majors, with some psychology and biology majors as well. Most of the students were in their third undergraduate year, though some were in their second or fourth. The vast majority of the students were women.*
>
> (3) What ideas from the NIA2 labs are students struggling with in particular?
>
> *Students were particularly confused by NIA2's explanation of the h, m, and n probabilities associated with ion channels.*
>
> (4) What are the most frequent kinds of questions you are asked by students during the NIA2 labs?
>
> *The types of questions I was asked typically fell into two categories. The first type were "How to" questions about navigating the technical aspects of the program. In other words, questions related to how to locate a particular window, alter settings, etc. The second type were generally related to the provided explanations for observed phenomena. While in general the explanations were very helpful in guiding students through the experiments, they sometimes derailed students from their own thinking through of the questions. If the answer wasn't presented in the same manner as it was presented in class, my role was to act as 'translator',*

explaining the provided explanation in a way that would resonate with what they observed and what they had learned in class.

Furthermore, students often had a difficult time linking what they observed with the provided explanation. For example, the explanation might say something like, "Note the early dip in potential...", but it would be unclear to which early dip this referred. I think a feature to improve the program would be to either incorporate more images into the explanatory text (i.e. a screen shot of the potential with an arrow pointing to the particular dip) or to incorporate more text into the experiments (i.e. allow the user to scroll over a curve with pop-up explanations at critical junctures).

We found out from the instructor in a later interview that students were introduced to many of the tutorial concepts in lecture first. Students then explored them with NIA2 in the labs. However, sometimes there were discrepancies in language, notation, and in one case (see Informal Interview with Steve George below) a difference in the concept itself. We thought it was very interesting that the TA considered herself a "translator" between instructor lecture and NIA2 experiments.

Again, for **Lab Section 2 Observations,** the Teaching Assistant gave no introduction or set-up for the lab. However, this time, the TA wrote a note on the class white board to remember to keep lines in the graphs and close windows after each tutorial. Although still somewhat quiet, there was more interaction between students in this lab section. We each focused on different areas of the computer room. Mary Beth observed one young lady as she went through the tutorials. The student spend a lot of time on the "why this happens" links. She did not see the connections on her own, though. She asked a few questions of the neighbor sitting to her right, but for the most part worked independently. Mary Beth noticed that the student did not do the entire second tutorial. The separate handout from the instructor gave directions as to which parts of the tutorials to do and which to leave out (see informal interview with Steve George below). Also, there was an additional exploration added by the instructor. The student said that running the simulations definitely helped her to "see what was happening". In fact, the understanding she gained from previous NIA2 tutorials helped her on her last test (see Appendix J for a copy of this test). She said this learning experience was "better than just reading" about the topic.

Jill observed a couple of students on the other side of the room during this lab section. The students rearranged the windows on their desktop to keep track of everything. They also hand-sketched various graphs in their notes as they went through the simulations. These students seemed to push the limits of the parameters to "see what happened". There were only a couple of difficulties encountered by these students, both in the *Neuromuscular Junction* tutorial. First, students had been told something different in lecture about the concept of "subthreshold reversal potential" than what they observed in NIA2. For an explanation of this discrepancy, see Informal Interview with Steve George below. Second, there was an issue with graphical interpretation when the students were exploring the “*How do voltage-sensitive channels affect the shape of an EPP or an EPSP*?” part of the tutorial. In the NIA2 text, students are told

> *The next experiments will use a patch containing HH Na and K channels rather than a passive patch. In the muscle fiber, depolarization of the postsynaptic end-plate region must gate the Na and K channels in the surrounding membrane to elicit an action potential and cause contraction.*

As they produce their graphs, they are asked in Question 4

> *Can you explain the shape of your subthreshold EPP in this active membrane? If you are puzzled about EPP or EPSP shapes observed experimentally when recording from intact muscle fibers or neurons (rather than a patch), a detailed explanation is available in this link.*

Figure 18 below shows the explanation given when students follow the link given in the question above. Although the explanation says that all graphs are “plotted from zero” in order to compare the *shapes* of the graphs, students could not seem to comprehend what was happening. The HH Channels graph (in red) that they had just plotted on its own in their simulation was completely under the horizontal axis. Now, in this explanation, it is sitting on the horizontal axis. It took some time with the TA to realize that the HH Channels graph had been shifted vertically upward. The students seemed somewhat irritated by this, and even when they finally understood about the shift, they still found it very confusing.

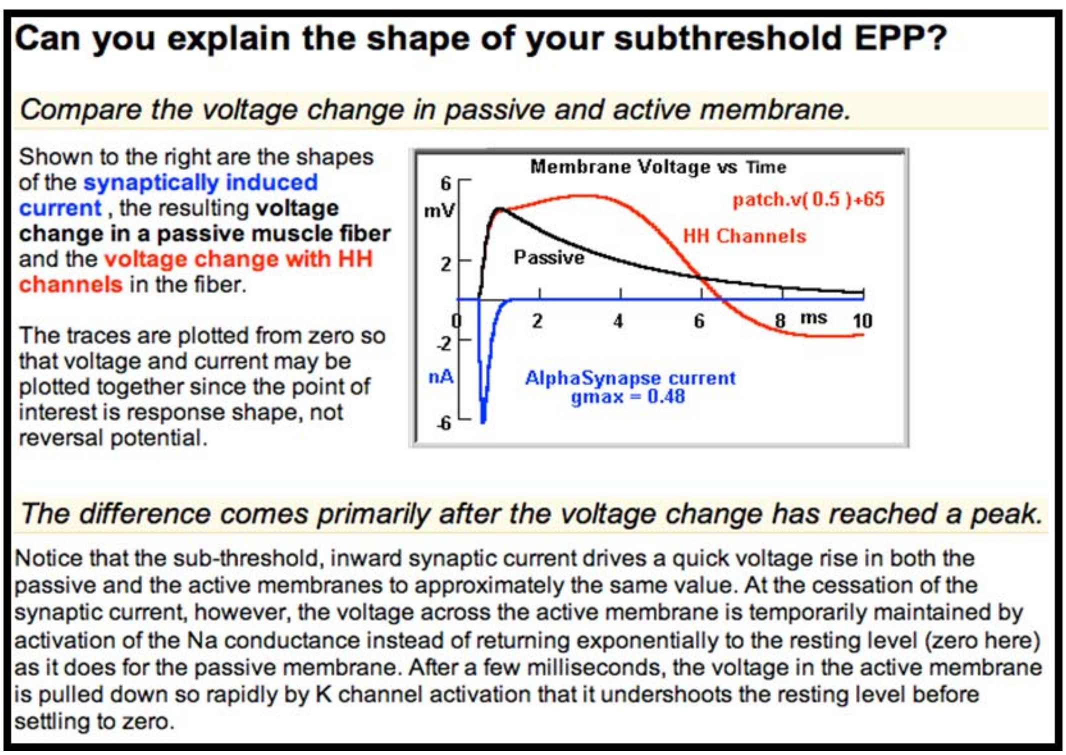

Figure 18: Students struggled with this graph in the Neuromuscular Junction Tutorial.

- **Amherst College Informal Interview with Instructor Steve George:** We were fortunate to be able to talk to Steve George after he returned from his two-day meeting. He gave some background information about BIOL-35. The students in Amherst's neuroscience major take more behavioral courses than other biology majors. Most are premed juniors and seniors. The *Introduction to Neurology* class does not use NIA2. The curriculum is simply too packed with content, due to anatomy labs, and includes some psych majors. In the BIO 35 course, he also gets some physics (BIO 35 counts toward their major) and regular biology majors.

  Before NIA2, Steve used a free online simulation by Francisco Bezanilla at http://nerve.bsd.uchicago.edu/. It has several sections, and the relevant part used for class was "Nerve." The year before, Steve used a software package called HH and NIA2 in his class. In the current class, he is just using NIA2. Prior to using NIA2, he presents all of the technical vocabulary in lecture and asks students to read the original Hodgin-Huxley papers on their own. Then he wants students to discover concepts on their own with NIA2. As we indicated above, students were making the observations, but struggling with the electrophysical reasons "why" they were happening. The concepts are then assessed in the course. Students are given exams (see Appendix J) that are like "evening-long problem sets". Students are allowed to use any resource they wanted to use, including NIA2, to answer the questions.

  As for the lab we observed, he said that the discrepancy students observed between lecture and their observations in NIA2 was that the "subthreshold reversal potential" actually occurs at resting potential instead of threshold. We asked him to send that to Ann and John. We do not know if he has contacted them about this issue. He also explained why he had students omit parts of the *Postsynaptic Inhibition* tutorial. He said,

  > *Re: why the last sections of Postsynaptic Inhibition were omitted from this week's lab (these were the sections on "Excite a cell by disinhibiting it," and "Are there changes in excitability following an IPSP?", pp. 65 and 66). (1) These basically repeat the 'anode break excitation' simulation on p.110 which we already did in the previous lab on electrical excitability. (2) The psp's are simulated by constant applied currents, which don't accurately reflect the time course of synaptic currents, so this isn't as realistic as the other parts of the synaptic simulations.*

  Finally, he talked about the additional simulation that he had students do in the lab. He wanted students to see that "depolarizing synapses with Erev above Vrest but below threshold can be inhibitory." From his experiences in this course, he feels that NI2 is "really hitting its stride" as in instructional tool. He rather enthusiastically said, "Jeepers! What can't NIA2 do?"

  After this second case study, we again saw that students often struggle a great deal with making connections when trying to answer the "why" questions in NIA2. In order to get through with the lab quickly and because students have very limited experiences with thinking about concepts at this level, we saw students clicking on the answer links without taking a lot of time for reflection. We again recommend that the authors think about doing some STOP & REFLECT sections that have graduated questions that direct students to the answer without just presenting it to them after just asking "Why does this happen?"

Case Study 3: Williams College, Williamstown, MA

Our interest in Williams College started with the following forwarded e-mail from Ann Stuart:

From: Ann Stuart [mailto:aesnia@gmail.com]
Sent: Thursday, May 15, 2008 3:58 PM
To: Jill Thomley
Subject: another happy NIA user

Hi Jill--

We received this email today from Steve Zottoli, Williams College. He will be in Woods Hole at the same time as you two will.

--Ann

On May 14, 2008, at 2:33 PM, Steve Zottoli wrote:

Dear John and Ann,

I want to share the good news that I followed through on a promise to Ann. When she brought a complementary copy of Neurons in Action to me last summer at the MBL, I promised that I would do more than look at the cover! First, I attended the session that both of you held for the MBL community on Neurons in Action. Second, after your inspiring presentation, I opened the cover and started to read but other obligations took me away from actually playing with the tutorials. Realizing that another year might go by without any follow-through on my part, I decided to use Neurons in Action as the text for my upper level Neurobiology course. This commitment forced me to actually load the CD and start my journey. What fun! In my typical fashion I did not read anything but immersed myself in the tutorials. I quickly realized that I had the power to do experiments that led to more experiments and sometimes questions that I could not easily answer. What more could an experimental scientist wish for!

The students were assigned a tutorial each week that coincided with the lecture material. As questions arose in the classroom concerning my lectures, I challenged the students to answer them by doing experiments with me on the big screen. The students were given challenge questions and were encouraged to use Neurons in Action to answer them (the equivalent of problem sets/. My most memorable experience was when a student raised her hand and rather than directing a question to me she asked the question to Neurons in Action!

I have yet to see the course reviews and will share the results with you later. At this point I wish to congratulate you both on one of the best teaching tools available for neuroscience. I also commend you for providing such an interactive tool for an affordable price. I applaud your selfless dedication to education.

Thank you,
Steve

Steve Zottoli is a faculty member in the Neuroscience Department at Williams. We could not help but be intrigued by this individual's story and enthusiasm. We did meet Steve in person at Woods Hole during the summer of 2008. He told us a little more about his experiences with NIA2 in the BIOL 304 Neurobiology course and his plans for using it in NEURO 201 Introduction to Neuroscience during Fall 2008. The fact he was using it in two such different contexts made us want to visit and see what was happening for ourselves.

- **Reflections on William College's BIOL 304 Neurobiology with NIA2:** This is an upper-level course, and students have already had an introduction to neuroscience in the prerequisite course NEURO 201. NIA2 was the sole text, though students read original research literature as well. There were 12 students in the course (seven were women, four were African American and one was Hispanic). Student response to NIA2 varied. Steve said, "The response was bimodal. Some students prefer the boundaries set by the text (one student dropped the course because there was no text!) probably because this is how they have been taught to date. Other students thrived on NIA2 and the way it allowed questions to be answered through experimentation. I feel that the latter group were the stronger students."

  Within this course, this instructor used the following NIA2 materials:

  Minimovies

  - Very Near Threshold Stimuli
  - Passive Spread of a Depolarizing Stimulus
  - AP Initiation in a Motoneuron

  Basic Level Tutorials

  - Introduction to Neurons in Action
  - The Membrane Tutorial
  - Equilibrium Potentials
  - The Na Action Potential
  - Threshold: To Fire or Not to Fire
  - Voltage Clamping a Patch
  - Chattering Ion Channels
  - The Neuromuscular Junction
  - Interactions of Synaptic Potentials

- The Passive Axon
- The Unmyelinated Axon
- The Myelinated Axon

Advanced Level Tutorials

- Na and K Channel Kinetics
- Axon Diameter Change
- Site of Impulse Initiation
- Synaptic Integration

As stated in his e-mail above, Steve used tutorials as demonstrations in lecture, ways to answer student question in class, and venues for student exploration on their own. He actively encouraged the students to look at other tutorials that related to various student presentations made in class. When he teaches this course again, he will use more tutorials that are matched to the content of original research papers to ensure students understand what they are reading in the papers.

While were at Woods Hole, Steve introduced us to an undergraduate student who had been in this BIOL 304 Neurobiology course. This student served as Ann Stuart's teaching assistant when she introduced NIA2 to the SPINES participants. We were somewhat awed to watch this undergraduate, who had only used NIA2 for one semester, turn around and comfortably answer questions from doctoral students and post docs. That was an indication to us that Steve's NIA2 BIOL 304 Neurobiology experiment had been quite successful. This underscores what we have heard from other instructors about the ease with which students can familiarize themselves with the software package. We feel that this could have only been accomplished through the extensive interface redesign.

This student took sometime to talk to us at Woods Hole and answered a student survey for us. For her own exploration of NIA2 in the course, she focused on the Basic Level tutorials. She really enjoyed using NIA2 and said she would strongly recommend it to other students. Here is what she had to say about her experiences with NIA2.

> **What did you like the *most* about NIA2?** *Intellectually stimulating and easy to use with just a little bit of knowledge of neurobiology. It gives you lots of opportunities to do experiments.*
>
> **What did you like the *least* about NIA2?** *The text can be organized in a clearer way (but the content is very good)*
>
> **What do you feel you learned about neuroscience from using the NIA2 materials?** *I learnt a lot from the tutorial. It not only helps me answer my/professor's questions, but also keep generating new questions as I experiment. Learning with NIA is like a positive feedback, but it's a bit frustrating to know that there is always more questions out there that you cannot answer.*

This student has highlighted one of the strongest aspects of NIA2, the ability to generate more questions.

- **Reflections on William College's NEURO 201 Introduction to Neuroscience with NIA2:** We made plans to visit Williams College in fall 2008 in conjunction with a trip to Amherst College. Steve was only using the NIA2 materials for a single 1.5-hour lab in his course and we were unable to visit during that time. We visited with Steve, Martha Marvins (adjunct professor who helped set up the labs for the NEURO 201 course), a Teaching Assistant (and Williams College Alumus considering graduate school options), and two students from the NEURO 201 course.

  NIA2 was only used once for the NEURO 201 course. They took the *Introduction to Neurons in Action* and *Equilibrium Potential* Tutorials and made a 1.5-hour lab as a review for Test 1. They focused on topics students had already covered in class. Martha took a lot of time to cut and paste portions of these two tutorials, as well as provide very detailed instructions as to how to use NIA2 (see Appendix K for this lab handout). It was tough to decide what to use in one-off kind of experience.

  The two students we interviewed thought it was worthwhile to do. It definitely helped them get ready for their test. One student said she took extra time with the lab. She came back the next day to explore "why did that happen?" She said that 'facts from the lecture came alive with the graphs. You *could see it*!'

  We sent a **follow-up e-mail interview to the NEURO 201 Teaching Assistant**. Here is what she said about the students' NIA2 experience:

  > *In our class, we focused on the basic labs to help the students review topics we had covered in class to help get ready for an upcoming exam. I think a lot of the non-science majors (not necessarily just English majors) really benefitted from the program because it was hard for many of them to calculate what was going on in their head. It made it much easier for them to think about and answer questions like if the concentration of Na+ (for example) is raised, what will happen to the threshold of the cell. Things like that were not as easy for them to think about with just the formulas, but when they had to program to use to see what happened in different situations and they then had to think about why and relate that back to the formula, it made it easier to do.*
  >
  > *From the feedback I got from students in general, NIA2 tended to help them make sure they understood the topics. One of the main goals of the lab was to help them review certain concepts for their in class exam on Thursday. It seemed to me that the students using the program closer to the exam felt it was the most useful and understood everything the best. One factor in this was probably that this was the third time we had run the lab, so we were more prepared for the typical questions that would come*

up and we addressed them in the beginning. Another factor I'm assuming is the knowledge and motivation had going into the lab. On Wednesday, the students all had an exam tomorrow so for the most part they all understood a lot of the basics and were interested in solidifying their knowledge and really getting a lot out of the lab because they had the exam the next day. The differences were not as drastic from day to day as it may seem from my response, but I definitely think when the students were motivated to really understand the topics and not just to get through the exercises they got a lot out of the program.

The questions we received in the NIA2 labs could be divided into two main groups. At the beginning of the lab, they generally had some basic set-up/how to use the different screens of the program questions. The worksheet Martha Marvin made up tended to minimize these (she re-edited it after the other TAs and I tried doing the lab with it and told her where we experienced confusion). Also, the more days we did the lab, the fewer questions like this I found myself answering since the introduction to how to use the program became better in terms of covering what the students would need to know about the program for the lab. The other main type of questions came when students wanted us to explain an unexpected result or help them understand what a result meant with respect to one of the questions we had asked them to answer during the lab. These were more common as the lab period went on. Raising these questions seems to me one of the main values of the program, because it highlighted for the students (and us) things that they perhaps thought they understood but did not completely. Once they were raised, it became evident where their understanding of the topics covered in class was weaker and we could help them sort through this before the exam to make sure they really understood it. The other questions of this sort came when students either entered the wrong values in the wrong places by accident or were finished with the "experiments" we had instructed them to do and began to do different things with the program. They then wanted help understanding the results they got.

I can't remember any one topic that the students struggled with in particular, I think there was one question we asked them to answer in the instructions we gave them that did pose some difficulty for quite a few of them. I'm not entirely sure since we did the lab awhile ago now, but I think it was this question that gave people the most trouble, probably because it required them to remember several things they learned in lecture and was not an question they could answer entirely by using the program. Q3. For the same values of [K]o and [K]i, would EK be different in a mammalian vs a squid nerve? Why or why not?

My main suggestion would be to create some sort of instructions sheet tailored to what they are doing for the labs you want them to do that *encompasses the concepts you want them to explore in the program while making sure they don't get into the more difficult topics they aren't ready for yet. It seems like for introductory neuroscience students it would be easy to get confused using this program without guidelines because there are a lot of topics covered with more details than they need to understand the basics.*

We see from her comments that even at this introductory level, students wanted to understand why things happened the way they did in the simulations. Again, it is very difficult to help students develop deeper levels of thinking. And as noted at the end, when an instructor only uses NIA2 once in a class, it is so easy for students to get lost in the procedures and not focus on the ideas behind what they observe.

Steve said that Ann and John have done a great service for neuroscience. Using NIA2 with this introductory level course was much more difficult than using it in the advanced class. The next time he teaches this class, he will add more demonstrations from NIA2 in the class lecture before the lab that students are required to do.

<u>Case Study 4: Emory University, Atlanta, GA</u>

The course we observed at Emory University was BIO 360L/NBB 301L: Neurobiology Simulation Lab. It met for two hours one night per week. According the course syllabus (see Appendix L**)**, the course is described as

In this lab course, students will explore topics in cellular and small network neuroscience by performing virtual electrophysiology experiments on the computer. The content of the course matches material covered in the Introductory Neurobiology course, BIO 360 / NBB 301, and will help students understand neurons and neuronal networks in greater depth

The required materials for the course were:

Neurons in Action 2: Tutorials and Simulations using NEURON, John W. Moore, and Ann E. Stuart, 2007 CD and Text. The course will loosely follow the content covered in BIO 360 / NBB 301, which uses Kandel, Schwartz, Jessell "Principles of Neural Science" (McGrawHill). Other course materials will be provided in class or on the Blackboard site.

Attendance for the course was required. Students would come and do the labs in groups during class time. Although students liked working on labs together, Emory University's policy states that grades should reflect individual effort, so students were required to write up individual lab reports. They were also given an extra problem set related to that week's lab. Of the 13 weekly problem sets, students' grades were based on the top 10 scores.

The 15 students enrolled in the course were also enrolled in a large lecture Introductory Neurobiology course of 80 students. We asked why only a few students took this Simulation

Lab course. We found out that because of the many requirements for the Neurobiology major and the fact that the lab course only gave the students two of the four elective credits needed for the program, many students found it difficult to fit the course in their schedule. Also, the instructors said that given the long hours required for grading and creating novel problem sets (it usually took around four hours or more to create one problem set), they just did not have the time to offer this course for all 80 students.

We chose this particular site for a case study because they were using some of the new materials specifically mentioned in the NIA2 proposal. As we mentioned earlier, we felt that the implicit learning objectives mentioned within the Project Description needed to be directly evaluated. On the night of our visit, the class was doing the *Coincidence Detection* lab, which was created for Specific Aim #2 ("**New tutorial for modeling a simple network.**"**)** of the NSF proposal. As stated by the PIs in the proposal, the learning objectives for this tutorial were (bold face is our added emphasis)

> *We will focus on a well-known sensory problem: the localization of a sound in space (Carr and Konishi, 1988; Oertel, 1999). Sound localization is essentially a problem of "tuning": the tutorial will* ***lead the students to discover the various ways in which a simple neuronal circuit can achieve tuning**.* ***The students will build on their knowledge of how to achieve a window for coincidence detection, developed in the Postsynaptic Interactions Tutorial.***

This tutorial also illustrated the PIs' goal of "**Relating NIA to health and physiology.**" (see Specific Aim #1 part (d)). Therefore, within one site visit, we were able to observe students working with several ideas from the new NIA2 materials.

- **Emory University Class Observations:** There were approximately 15 students present for the BIO 360L/NBB 301L: Neurobiology Simulation Lab course on the night that we attended. The students were arranged in groups of 3-4 around square tables. Students either had their own laptops or one provided by the University in front of them.

  The class began with about 30 minutes of lecture by the instructor. The instructor introduced how the auditory system works. In particular, he talked about how the brain detects a particular sound's location by the length of time between inputs received by both ears for that sound. To put these time intervals for sound into perspective, the instructor referenced the students' prior *Temporal Summation* lab experience (using the NIA2 *Interactions of Synaptic Potentials* simulation). Students found that the interval for two subthreshold EPSPs triggering an impulse was about a millisecond. In comparison, the instructor asked the students to calculate the time it would take for the sound (using speed of sound = 343 m/sec) to travel the maximum distance needed to reach both ears (approximately 10 cm). This gave them the idea that the maximum difference between the time sound hits one ear and then the other is approximately .9 ms. The interaural time delay is on the order of 100 microseconds, which is much less that the intervals the students looked at in the *Interactions of Synaptic Potentials* tutorial.

This discovery led the class to think about the mechanisms in such a specialized neuron that would narrow responses to very small time intervals. One student suggestion was to add K channels. This would provide more leak conductance and thus a shorter EPSP. The instructor drew a circuit diagram and looked at the impact of different types of channels (See Figure 19 evaluator's field notes below).

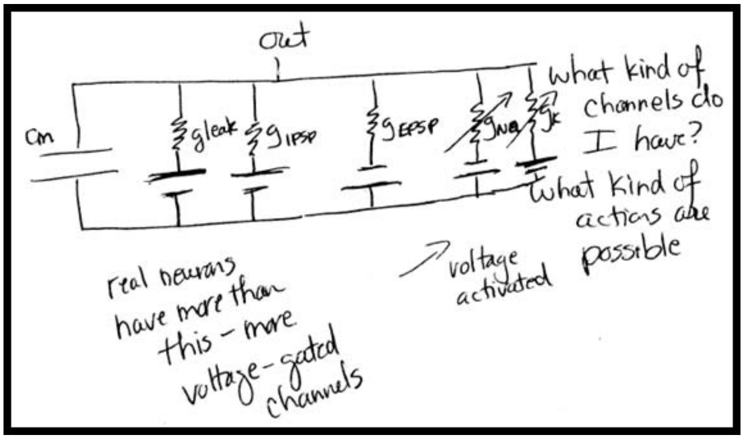

Figure 19: Basic Channels Circuit Diagram Used in Emory Class

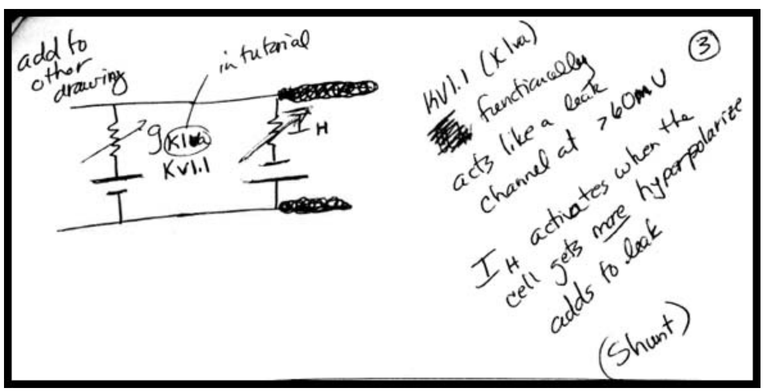

Figure 20: Circuit diagram Used in Emory Class to Introduce New Channels for *Coincidence Detection* Tutorial

This is very interesting in the fact that the PIs specifically mentioned wanting to include more electrical circuit diagrams within NIA2 (see discussion of Specific Aim #1 above). We found that the underlying mechanisms behind this tutorial were effectively demonstrated with this type of diagram. In Figure 19, the instructor talked about all the channels that had been explored earlier in the course. After discussing findings by Bal and Ortel (2001) (see class handout in Appendix M for reference to this paper), two new conductances, I_H and Klva, (see Figure 20 above) were added that are instrumental to the coincidence detection process in the auditory system. NIA2 was used to illustrate how they impact conductance and thus the *coincidence detection window* (CDW). Within the *Coincidence Detection* tutorial simulation, the instructor went into NIA2 and found the hidden Neuron Main Menu. He found where he could introduce parameters so that he could plot I_H –outward current (i_hcno: which is the current thru IH) over time and plot I_K – inward current --(i_klva) current over time on the same axes. Are they depolarizing or hyperpolarizing? What happens? The opposing currents create a lot of extra conductance called a "shunt" without changing the membrane potential (overall current). This mechanism gives the cell a short EPSP, which allows for the tiny CDW. Some students followed along with the instructor on their own computers.

Students were then asked to work in their groups on the *Coincidence Detection* tutorial. Each group was assigned one of the four parts of the coincidence detection tutorial. The instructor asked the students to increase the temperature in the lab from 6.7° C (stated in the NIA2 tutorial) to 32° C to better model mammalian coincidence detection. They had 10-15 minutes to work on their simulation.

In one group, all three students worked on the problem individually and got disparate answers. They spent time exploring why this happened. They compared parameters and looked at specific values that might be suspect. They did not find any major differences in their parameter inputs, so they felt like it must a problem with opening and closing windows in NIA2. They shut NIA2 down and restarted it and everything worked fine. Since some of the students had been following along with the instructor's demonstration earlier in the lecture, it is possible that they had multiple windows open within the simulation. It is interesting to note that students did not have to ask the instructor or the TA about this problem. It is obvious that they had either encountered something like this before or had been paying attention to the various warnings the PIs put throughout the tutorials about the window issues.

In another group, students worked together on the problem. They checked with each other at each step about which parameters to change. One of the evaluators asked the students about the need to change the temperature to 32° C. The students were engrossed with quickly changing parameters and they responded that they were not supposed to change the temperature in their part. All but one of the students was successful in completing the simulation as originally stated in the tutorial. The other student was perpetually lost throughout the process.

After completing their parts of the tutorial, the class came back together to report and discuss their findings. The instructor recorded each group's results and made comments regarding how the windows were narrowing (see Figure 21 below).

Parameter	Coincidence Detection Window
Default	240 μs
"Faster Synapses"	170 μs
I_H + Klva	120 μs
Both "Faster Synapses" and I_H + Klva	* The group did not produce correct results because they did not change the temperature. The instructors told the group that it would be faster … ≅ 100 μs

Figure 21: Group Results From *Coincidence Detection* Tutorial

After they discussed the results, the instructor said that it was not enough to just have the simulation values. In the lab report, the instructor wanted students to interpret their results in connection with the physiology. He wanted them to explain why their results must be true. He then assigned homework (see Appendix N). The instructor stated there are many "tricks" for narrowing the CDW. The homework explored how adjusting the amount of channel conductance impacts the CDW.

As we reflect on these observations, we noticed that the auditory coincidence detection context was never explicitly referred to as a simple network problem. As mentioned in the discussion of Specific Aim #2, the NIA2 materials do not make this connection either. The process in the *Coincidence Detection* tutorial so closely parallels the single input source process from the *Interactions of Synaptic Potentials* tutorial that we missed this network nuance until we really investigated it within the evaluation of the proposal's Specific Aims. We feel that students might also miss this big idea. It may be interesting to ask students if they understand the difference (other than the auditory system connection) between the processes in the two tutorials. If the PIs are interested in bringing the simple network idea to the forefront of student understanding, we feel they will need to make explicit references to it in the tutorial.

Before we went to Emory, we went through the *Coincidence Detection* tutorial on our own. However, we must admit that we had limited knowledge of the auditory system context. After the great setup and explanations by the instructor at Emory, we had a much better understanding of what we were doing and the significance of the tutorial. We think it would be very helpful for the health-related tutorials to have deeper contextual materials for the students. Also, it was an excellent idea to get the students to think about how much smaller the time intervals would have to be for the neurons connected to the auditory system. By starting with the windows from the two subthreshold EPSPs in the *Interactions of Synaptic Potentials* and actually calculating the time it takes for sound to travel to both ears for comparison was a terrific lead-in for this tutorial. Finally, although the idea of a circuit was not specifically used in the *Coincidence Detection* tutorial, the instructor's use of it in his lecture helped us, and hopefully the students, make connections between the new channels being added and those that had already been discussed in previous tutorials. This instructor truly seemed to integrate the explicit and implied learning objectives presented in the NSF proposal within this class.

- **Emory University Student Focus Group Comments:** After students completed the lab, we used the remaining class time to have a focus-group discussion with all the students in the class. The instructor remained in the room, but that did not seem to have any effect on the responses we received from students. They began by expressing an overall satisfaction with what they were learning from NIA2. However, they had a couple of issues that frustrated them. For example,
    - When you keep traces, it is sometimes hard to distinguish between the various trials. They would like to be able to use 'color picker' to paint various graphs different colors in order to be able to identify each trial correctly. The instructor mentioned that students have had points deducted on homework problems

because they had mislabeled graphs and therefore came up with incorrect conclusions.

- They would like to export data from the models into a spreadsheet. As of now, students are using STATS button (crosshair on graph) to get points off the graph. This is especially difficult if you change to a faster time course because you get less data to work with.

These frustrations are minor when thinking about the benefits. One student explained that they were "learning by doing". Information given in the large lecture course was often gained by reading the static facts in the book. With NIA2, one can see what is happening. An example of this was when they saw the "rebound", or the action potential in the opposite direction. That was surprising. Some students said they went beyond what was assigned in class. They found themselves asking "what if …?" and doing experiments in NIA2 on their own. Overall, the students felt they definitely had better understanding of the lecture course materials from their NIA2 experience. In fact, one student concluded the discussion by saying that the other students in the main course (who were not in the lab course) were at a *disadvantage* by not having the NIA2 experiences. There was general agreement by other students with this statement.

- **Emory University Faculty Interviews, Surveys, and Follow-up Correspondence:** We collected data from Emory instructors Astrid Prinz, Ron Calabrese, and Dieter Jaeger via informal interviews, surveys, email correspondence, and artifact collection. This section will summarize what we learned about how NIA2 came to be used at Emory and current implementation.

  Many neurobiological concepts are best understood through the use of mathematical models. However, the instructors at Emory did not want students to have to struggle through the actual equations (like they would need to do in Matlab). They looked for some software packages where the equations were hidden, but students could observe phenomena via graphs and interpret the results. Along with NIA2, they considered using *Neurodynamix* and *winpp.* One instructor said,

  > *Neurodynamix is a nice program but has no nice set of tutorials set up in a way that the students can easily do them. The text support of NIA2 is much better as are the graphic outputs.*

  They currently have a NIA2 site license for their lab and students have individual copies.

  Even though students do not have to type in any equations into NIA2, they still need quantitative skills to think about, work with, and interpret the mathematical models. Emory has just changed its mathematics requirement for this Biology degree. The required course used to be Calculus I. However, they have created a new BioMath course that teaches modeling. It is a two-course sequence. We do not know much about the content of these new prerequisite courses, but we do wonder if students get any experiences with rates (such as dV/dt). Rate concepts occur throughout NIA2. Without the calculus background, this might present a conceptual challenge to some students.

Within the current course, time is always an issue. However, one instructor made the comment that it would be next to impossible to explore all the concepts they cover in the course in a wet lab environment. Wet labs are just not feasible; there are too many students, not enough facilities, and always glitches with wet labs. So NIA2 truly helps them make the most of their time. It still takes about *four* hours to create a new homework problem set for the students in the lab. Some tutorials are "closed" so that you cannot get to other NEURON parameters in order to expand what one can do in those tutorials. They really would like more access to the NEURON main menu in all tutorials to get some more flexibility with their students' homework experiences. Time is also a major deterrent to using NIA2 with all the students in the lecture course. They get the more "computationally literate" students in the lab course and even they have non-stop questions about NIA2. The learning curve would be much greater for those who are not as computationally literate. Thus the time to deal with those issues would be greater. When you add that to the consideration that it takes approximately *six* hours to grade the homework for their current 20 lab students, the time costs for 80 students would more than they could afford to give for the lecture course.

Overall, the instructors using NIA2 at Emory are very happy with what they are seeing from their students. One of teaching assistants for the lab course even gave a poster presentation at the annual *Society for Neuroscience* conference about his experiences with NIA2 and teaching undergraduates about neuroscience (see Appendix O). The instructors said they inevitably get the technical difficulty questions regarding NIA2 operations, but they also get the "why" questions about the concepts. That is what they want. Students struggle with their preconceived notions about certain processes. One instructor noted that students sometimes follow their intuition and they interpret what they see from the models incorrectly in terms of they had expected to see. Instead, they should be modifying their expectations based on what they observed. We suggest that there needs to be little more "scaffolding", or building guided learning of the "why" explorations with a few more supported questions instead of sending them to a link that explains the *why* for them. Perhaps this will help students slowly modify what they believe to be true as they step through the questioning process.

When asked what they would like to see from future NIA versions that would support undergraduate neuroscience education at Emory and beyond, they had a few suggestions:

- As mentioned above, one instructor would like for the PIs to "create an 'expert' button that gives you access to more control variables. In several tutorials some important control variables can't be changed, which limits the range of potential homeworks and experiments."
- They would like to have tutorials that address the systems-level concepts taught at the end of the lecture course. Since they are trying to parallel the lecture course in content covered, they really would like "several systems-level tutorials. Important topics they cited include: 2.1) Receptive fields [e.g. vision]. 2.2) surround inhibition [e.g. thalamus] 2.3) epilepsy [e.g. cortical network.] 2.4) central pattern generation [e.g. lobster ganglion]. They would add to these ideas a tutorial on

neuromodulation and second-messenger cascades, which they are currently covering with a custom-made WinPP program that is very unpopular with the students.
  - They would also like to have more institutions using NIA2. They feel that many people do not know about it right now. They are sure that instructors could see the utility of NIA2 within an hour. So, please keep up the marketing.

We were quite impressed with how NIA2 is being used at Emory. Their approach in the lab course truly embodies the educational ideals hoped for by the PIs in undergraduate neuroscience education. It somewhat disappointed us that the large lecture Introduction to Neuroscience students were not being exposed to concepts via NIA2 unless they took the lab course. We feel that the instructors could use demonstrations or minimovies in the large lecture. It was interesting to hear a student say that the other students were at a *disadvantage* from not using NIA2, instead of the lab course students being at an advantage. Perhaps someday the NIA2 dynamic learning experiences will be integrated into the education for *all* neuroscience students at Emory.

Case Study 5: Agnes Scott College, Atlanta, GA

Agnes Scott interested us as a case study because the Biology/Psychology 250 Foundations of Neuroscience 1: Excitable Cells and Synapses instructor was having student do extended NIA2 projects that related to specific health issues. Also, since there is currently an increased national emphasis on getting more women involved in STEM disciplines, we really were interested in the neuroscience education efforts at this private liberal arts women's college. The class we went to observe is a part of a relatively new Neuroscience major in which the majority of the teaching faculty are from Psychology.

When we first started discussions with this instructor about the evaluation, she sent us a copy of her course syllabus (see Appendix P). We could quickly see that about half of her class laboratory experiences were from NIA2. In fact, she listed NIA2 as her lab manual for the course. The tutorials she covered with the entire class were:

- Introduction to Neurons in Action
- The Membrane Tutorial
- Equilibrium Potentials
- The Na Action Potential
- Threshold: To Fire or Not to Fire
- Voltage Clamping a Patch
- The Neuromuscular Junction

After these group exercises, the instructor had "Action Projects (w/NIA2)" listed as part of the lab experience. We asked her to send us more information on her plans for this project. She told us that the project evolved as the semester went along. Initially, her plan was to have students go beyond the tutorials listed in NIA2. However, during the lab, she realized that students were good at "doing" tutorials, but she was not sure that they were getting the deeper understanding of the concepts and the bigger connections behind what they were observing. She wanted them to have time to think about ideas deeply and let them truly sink in. With this in mind, she decided to have students use the advanced tutorials as project ideas.

Here are the objectives for the Action Project as stated in the assignment (see Appendix Q for a copy of the project assignment):

> *The objectives of this lab project are for you to develop an independent, creative project, and to share your accomplishment with the rest of us. You will use new NIA2 exercises as the starting points for your talks, but you will be expected to go beyond the lab exercises and present your own protocols and information from linked publications or others that you find. At some level these presentations will be exercises in teaching for you because the rest of the class will not have tried your tutorial and you will need to make the simulations, experiments, and the neurobiology clearly understandable to the class. Use the evaluation sheet attached to reflect on your presentation and to help judge how to make it strong.*

Students were given a timeline of dates to have various pieces of the project completed as they worked through the semester. By October 8th, students were to have explored several of the project ideas below and chosen one for their Action Project topic:

Action Project Options

- *Chattering ion channels (p 43).*
- *GABAergic synapses (p 67) target for psychoactive drugs, search for drugs and inhibition.*
- *Partial demyelination, the problem in MS (p 89).*
- *Extracellular Ca sensitivity of the Na channel (p 95), and dynamic view of threshold (p 99).*
- *Na and K channel kinetics, drugs (105).*
- *Local anaesthetics, trauma and AP conduction (p 119).*
- *Simplified multiple dendrite cat motor neuron and integration (127).*
- *Simulation vs real experiments APs invading terminals (133).*
- *Focus on Hodgkin and Huxley classic 1952 papers (choose one).*

The students were allowed to select more than one choice as to what they would like to do for their projects, but the instructor made the final decision and assignments using these preferences to ensure that everyone was working on something different. Most students got their first choice. The projects were presented in mid-November.

- **Agnes Scott College Class Observations:** There were four students in this class (a fifth had initially enrolled and dropped due to other pressures in her schedule). Normally the class has around 16 students enrolled, but this was an "off" semester in the course cycling within the program. Due to a miscommunication, we did not arrive in time to see the first student's presentation on "Components of Na and K Channel Excitability". However, we have included a copy of her presentation slides in Appendix R . Students were given a copy of the grading rubric for their presentation before they began. A copy of this rubric can be found in Appendix S. We will briefly discuss two of the three remaining presentation and then focus on the "Extracellular Calcium Sensitivity of the Na Channel and Dynamic Threshold" presentation. We chose this particular presentation to highlight in depth because it used one of the new NIA2 tutorials described in the NSF proposal and we had not encountered students who had worked on it before.

The other two presentations were on "Gabaergic Synapses: Target for psychoactive drugs, search for drugs and inhibition" and "Partial Demyelination: the problem with MS". The student's presentation on Gabaergic Synapses was actually based on an in-depth look at the *Postsynactic Inhibition* tutorial (see Appendix T for slides from this presentation). The student ran NIA2 simulations during the presentation (not shown on the slides) to help the audience see her observations for themselves. She used Ohm's Law to explain why there is no current when resting potential is equal to the reversal potential. The Partial Demyelination presentation came from the tutorial of the same name (see Appendix U for complete presentation slides). During most of the presentation, this student used screen captures to portray the major ideas from her exploration rather than running tutorials as the other student had done. Unfortunately, she encountered a glitch when she transferred the files from her computer to the podium computer. She lost about three-quarters of her presentation slides. So, she ended up having to run the simulation live. She really did not seem to be as comfortable with NIA2 as the others. Her conceptual understanding of the topic was not strong. One thing she observed in this tutorial is that NIA2 does not allow the user to change multiple channels and that was something she had wanted to explore for her project.

The Extracellular Calcium presentation was probably the best of three that we observed. This student started by introducing what extracellular calcium is and referred to Hille (1991) (see reference in presentation slides in Appendix V) to illustrate the effects of extracellular calcium on Na and Ca channel activation. She talked about how some early theories had difficulties explaining the process by which these effects occurred. She then discussed the current theories for this process that involve voltage-gated channels. Her discussion was very similar to the one we one referenced above from UT-Austin.

The student's exploration of the NIA2 tutorial led her to look at the HH equations and Moore-Cox equations. HH does not factor in the extracellular Ca and the Moore-Cox equations do. So, Moore-Cox models more closely align to experimental results. HH graphs have an "anomalous hump". She demonstrated how one can mimic hyper- and hypocalcemia in the NIA2 tutorial with the Moore-Cox equation. During this part of the presentation, she explained what happens to "threshold" for hypercalcemia, hypocalcemia, and normal conditions. She ran the NIA2 tutorial multiple times during this part to illustrate for the audience the concepts she presented.

The *Extracellular Calcium* tutorial directed then her to the *Dynamic View of Threshold* tutorial to take a closer look at what happens to threshold. She did a good job using the phaseplane plot to explain what happens to the rate of change of velocity (dv/dt) over velocity. She showed how one can use this phaseplane graph to define the threshold (where an action potential is generated) and relate it to the battle between Na and K currents. However, as she indicated on her slides, she had to do this exploration by adjusting extracellular K, [K]o. We were left wondering why students could not also adjust extracellular Ca as well (since this *Threshold* tutorial was suggested at the end of the *Extracellular Calcium* tutorial). She said she still had some questions about "why": "Why is the threshold half as big when stimulus amplitude is negative?" She ended with a discussion of the physical problems that can result in a person from hypocalcemia and hypercalcemia.

- **Agnes Scott College Focus Group Discussion with Students and Instructor:** After the presentations were done, the students were asked to stay and talk to us about their NIA2 experiences. The instructor stayed during this discussion but did not seem to influence student responses. The students discussed some of the issues they ran into while they learned to use NIA2. There were printing frustrations with various windows (similar to Bruce Johnson's class above in the Overall Impact section). They also did not like the fact that a parameter will not change if the mouse is not over the number in the parameter panels. They tried to change colors of traces to keep them straight, but too many times it caused the program to freeze. Like other students and instructors we have talked to, they wished there was a way to label the lines automatically. They also would like to have some sort of 'cheat sheet' with instructions about to how to save and export graphs. They agreed that it would be nice to be able to save a graph by itself when you need it for presentations. The only conceptual issues they specifically mentioned were the lack of details given in explaining the phaseplane plots and in the exploration of the "kinky" graph in the Na Action Potential tutorial (see UT Austin observations above for additional comments about this particular graph).

  Overall students were complimentary of NIA2. On student said "it made it more real" because you could interact with NIA2. The instructor said that NIA2 actually helps the student learn. Like other instructors have noted, a wet lab has so many variables that could go wrong. In wet labs you could do the lab wrong and the student does not really know if she is getting the correct data or not. It is tough for beginners to know if they are getting the lab right or not. NIA2 does not have as many complications. The only thing this class's instructor would add is

  > *I also wanted to suggest some pharmacology exercises--such as adding imaginary drugs that closed or open K, Cl, Na, Ca or mixed ion channels--and get students to find whether the drug opened or closed channels (using Ohm's law with constant low amplitude current pulses) and to figure out reversal potentials for the responses which would point to ions involved. They could then test their notions by changing ion concentrations. This would be an exercise that sort of broadened the neuromuscular junction tutorial.*

While we certainly enjoyed all of our classroom observations immensely (it is one of our favorite parts of evaluation in general), this experience particularly spoke to us because of the way in which students were using the material and the depth of their engagement. It was true that some of the students were less familiar with the concepts than others, yet they all appeared to be interested in the problems they had chosen to explore. This echoes Jennifer Morgan's (UT Austin) comments about the need to personalize student's NIA2 experiences in order to engage them in the learning process. However, this engagement is not sufficient for learning. They can make the observations, as all these students did, but they need outside guidance putting it all together to get that depth of understanding that characterizes true learning.