Sigmund Abeles

EXTERNAL EVALUATOR'S REPORT TO THE CONCORD CONSORTIUM AND THE NATIONAL SCIENCE FOUNDATION ON THE SCIENCE OF ATOMS AND MOLECULES: ENABLING THE NEW SECONDARY SCIENCE CURRICULUM PROJECT

January 31, 2010

Preface

The Science of Atoms and Molecules: Enabling the New Secondary Science Curriculum proposal was submitted to the National Science Foundation on March 13, 2006. After review by the Foundation, the proposal was accepted and the grant (No.ESI-0628181) was awarded on September 22, 2006 to be effective on October 1, 2006 and to expire on September 30, 2009.[1] A no-cost extension was given to the project to allow it to continue until March 1, 2010. In addition, the team received a RAPID supplemental grant to focus on classroom research with SAM biology classes. This grant will be complete in September 2010.

This is the third and final external evaluation report (2008 – 2009) for the The Science of Atoms and Molecules: Enabling the New Secondary Science Curriculum (SAM) project. The first year (2006-2007) of the project was devoted to organizational matters and the preparation of materials. The evaluation report prepared for that period reviewed those activities and the progress made toward the goal and objectives as stated in the proposal to the National Science Foundation. In the second year (2007 – 2008), the materials developed during the first year were tried out in courses in physics and chemistry in four high schools and a middle school. These schools were Portsmouth High School in Portsmouth, Rhode Island; Belmont High School in Belmont, Massachusetts; The Hockaday School in Dallas, Texas; and Glastonbury High School and Smith Middle School in Glastonbury, Connecticut. In the third year (2008-2009) the participating schools were Portsmouth High School in Portsmouth, Rhode Island; Belmont High School in Belmont, Massachusetts; The Hockaday School in Dallas, Texas, and Woonsocket High school in Woonsocket, Rhode Island. One teacher in Glastonbury High School continued in the program.

The physics and chemistry units were developed by Concord during in 2007-2008. The biology units were added to the program in this last year (2008-2009). Woonsocket, Rhode Island was added to the list of schools in this last year while the Glastonbury schools discontinued their participation as a district. However, as noted, one of Glastonbury's teachers in chemistry continued to use selected units. The latter part of the 2008-2009 academic year was used by Concord to reduce the data it had acquired during the term of the SAM project. A penultimate report was submitted by Concord to the National Science Foundation in June of 2009 that included a report on the data reduced until that time. The extension until March 1, 2010 permits the further reduction and analysis of the data obtained over the life of the project. In addition, the extension provides for minor revisions of the physics and chemistry activities as well as an extensive upgrade of the SAM website.

The SAM project had Drs. Boris Berenfeld and Robert Tinker as its co-principal investigators. Dr. Berenfeld was responsible for the curricular materials. However, in 2008-2009 Dr. Berenfeld retired. His duties as co-principal investigator were taken over by Dr. Frieda Reichsman. Dr. Tinker remained involved in the design of the models as well as maintaining oversight of the entire project. Dr. Leon Lederman was an advisor to the project and was involved in materials review. Other staff members who had been active in providing support for the project include Amy Pallant, Director of Research; Dr. Qian Xie, author of the Molecular Workbench program who was responsible for software development; and Dan Damelin, curriculum writer. Dr. Barbara Tinker served the Project Manager for the first two years of the project. At the beginning of July, 2008, Ms. Amy Pallant became the Project Manager.

Once again, this reviewer thanks all the staff of the SAM Project at Concord for their fine cooperation, openness to all his questions, and complete candor in their responses. He also appreciates their providing all requested written records, including their annual reports to the National Science Foundation, and access to the materials in the Project's database in a timely and efficient fashion. Further, and importantly, he thanks participating teachers and students for their forthrightness in responding to his questions at the interviews at their schools. Finally, thanks are offered to the SAM advisory committee for engaging him in their conversations at their three meetings at Concord.

In order to provide a sense of continuity for the activities that took place in all three years of the project as well as to give the reader a review of the project's stated goals and objectives, some of the material from the first two reports – such as the project's goal and objectives - will be restated here. Complete copies of these first two reports have been submitted to the Concord Consortium and to the National Science Foundation and are available from them.

Goal and Objectives for the SAM project

The goal of the SAM project has been adhered to quite faithfully over the three years of its life. As stated in its proposal this goal is as follows:

"The goal of this project is to provide the materials and professional development resources that schools need to implement high-quality secondary science curricula with a unifying theme of atoms and molecules. Students will acquire a progressive understanding of the centrality of atomic-scale phenomena and their implications. Materials will be presented in a form suitable for all students. The project will also offer the support and professional development that teachers need to use the materials and integrate them effectively into their courses." [1]

The project's objectives are as follows:

1. **Student and teacher materials.** The project will produce 24 instructional activities, eight for each of four strands that cross all three courses of physics, chemistry, and biology. In each strand and course, there will be two activities, each requiring two-class periods. The activities will contain scaffolded computational models that permit students to learn core atomic and molecular content through guided exploration of the models. Instructional goals, student assessments, and teacher materials will be included."
2. **Formative testing and revision.** The materials will have formative testing in 18 physics, chemistry and biology (PCB) classrooms in four diverse sites nationwide. The materials will be revised on the basis of the findings of these field tests.
3. **Summative assessment.** Summative testing will assess student learning of the materials over two years in physics-chemistry and also in chemistry-biology sequences. Evidence will be sought for curriculum changes that the materials enable.
4. **Technology.** The molecular dynamics software will be upgraded to support the functions needed in the student materials and the ability to monitor and assess student performance remotely will be added.
5. **Professional development.** An online course, website, and written materials will be provided to support teachers who adopt the materials.
6. **Dissemination.** The project will actively disseminate the materials and research findings through presentations, professional papers and

meetings. Materials for caregiver and administrators will be provided and all materials will be disseminated electronically. To ensure that the materials are publishable, the project will work closely with a prospective publisher. [2]

Progress to meet Objective 1 - Student and teacher materials

The evolution of SAM's activities .

The content of the program includes activities involving the use of interactive molecular dynamics and light and photon models. These activities concentrate on concepts in the physical and life sciences. The project makes strong use of computer-modeling techniques.

The content of SAM has hardly been static. Continual review by the staff, discussion with participating teachers, and advice from consultants and the SAM advisory committee has led to changes in the activities as the project progressed. The tables below show changes in the topics of the activities over the three year period.

The specific activities to be offered by the project as presented on December 4, 2006 at the initial meeting of the advisory committee – and as shown on SAM's website at that time - appear in Table I. Some, but not all of those listed, were available for use at that time.

PHYSICS	CHEMISTRY	BIOLOGY
Motion and Energy		
E1. Conservation of Energy*	**E3. Phase Change**	**E5. Diffusion**
E2. Temperature	**E4. The Gas Laws**	**E6. Active Transport ***
Charge		
C1. The Coulomb Force	**C3. VDWs Attractions**	**C5. Protein Folding**
C2. Dipoles *	**C4. Molecular Geometry***	**C6. Molecular Recognition**
Atoms and Molecules		
A1. Atomic Structure	**A3. Chemical Bonds**	**A5. Macromolecules**
A2. Electron Orbitals*	**A4. Reaction Rates and Catalysis**	**A6. DNA and Proteins**
Light		
L1. Excited States and	**L3. Photochemistry ***	**L5. Photosynthesis ***

Photons*		
L2. Spectroscopy	**L4. Infrared Spectroscopy***	**L6. Vision***
Table 1		

Those activities starred were to be new to the project. The others were to be drawn, with modification, from the Molecular Logic (MOLO) and Molecular Literacy (MOLIT) projects which preceded SAM.

As the project progressed the content of some activities saw changes. Some activities were combined and others were added. The activities shown on SAM's website as of June, 2008 are shown in Table 2. As of the winter of 2008 the biology activities, for the most part, had not as yet been added to the website as they were not scheduled for tryout until the 2008-2009 academic year.

	PHYSICS	**CHEMISTRY**	**BIOLOGY**
Motion and Energy	**Atoms and conservation of energy** **Heat and temperature**	**Phase change** **Gas laws**	
Charge	**Electrostatics** **Electric current**	**Van der Waals forces** **Molecular geometry**	
Atoms and Molecules	**Atomic structure** **Newton's Laws**	**Chemical bonds** **Chemical reactions**	**DNA to proteins**
Light	**Energetic states and photons**	**Spectroscopy**	

Table 2

A new organizational chart for the activities including the biology activities – Table 3 - was presented to the Advisory Committee for its perusal at its meeting at Concord on May 12, 2008.

	Physics	Chemistry	Biology
Motion and Energy	**Atoms and Energy** **Temperature**	**Phase Change** **Gas Laws**	**Diffusion and Active Transport** **ATP Biological Energy**
Charge	**Coulomb Force** **Electricity**	**Van der Waals Attractions** **VSEPR – Molecular Shape**	**Protein Folding** **Molecular Recognition**
Atoms and Molecules	**Atomic Structure** **Newton's Laws**	**Chemical Bonds** **Chemistry Reactions 1 and 2**	**Macromolecules** **DNA to Proteins**
Light	**Photons** **Spectroscopy**	**Photochemistry** **Fluorescence**	**Photosynthesis** **Vision**

Table 3

The activities shown in Table 4 were those available on the SAM website – and for trial in the schools - in the Fall of the 2008-2009 academic year. [3]

	Physics	Chemistry	Biology
Motion and Energy	**Atoms and Energy** **Heat and Temperature**	**Phase Change** **Gas Laws**	**Diffusion and active transport** **Cellular respiration**
Charge	**Electrostatics** **Electric Current**	**Intermolecular attractions** **Molecular**	**Four levels of protein structure**

		attraction **Solubility**	**Molecular recognition**
Atoms and Molecules	**Atomic Structure** **Newton's Laws at the atomic scale**	**Chemical Bonds** **Reactions and stoichiometry**	**Lipids and carbohydrates** **Proteins and nucleic acids** **DNA to proteins**
Light	**Excited states and photons** **Spectroscopy**		**Photosynthesis**
Table 4			

As can be seen from the above transitions, considerable thought was given to the topics of the activities to be offered. As of October, 2009, the SAM project had prepared the 23 activities shown above. Combining and reorganizing some activities brought the total number to one less than that stated in the proposal's objective.

The format of the activities has also evolved. Each activity is now presented in a series of pages. Each page consists of a particular concept and includes narrative, a modeling activity, and embedded multiple-choice and written assessment questions. Breaking up the lesson in this fashion allows the concepts to be addressed in a sequential manner. It also allows for a 'break' depending upon how far the student has progressed in a given classroom period. [4]

Finally, as a result of continued trials, observations and comments from teachers the content of a number of the biology activities has been changed further. This new Table – Table 5 – which includes these activities and, in some cases their new titles, is slated to appear on Concord's new website. The rationale for the changes in the activities is shown in the Appendix.

	Physics	**Chemistry**	**Biology**
Motion and Energy	**Atoms & Energy** **Heat & Temperature**	**Phase Change** **Gas Laws**	**Diffusion, Osmosis, & Active Transport** **Cellular Respiration**
	Electrostatics	**Intermolecular**	**Four Levels of**

Charge	**Electric Current**	**attractions** **Molecular Geometry** **Solubility**	**Protein Structure** **Protein Partnering and Function**
Atoms and Molecules	**Atomic Structure** **Newton's Laws**	**Chemical Bonds** **Chemical Reactions**	**Introduction to Macromolecules** **Lipids and carbohydrates** **Proteins and nucleic acids** **DNA to proteins**
Light	**Excitation & Photons** **Spectroscopy**		**Harvesting Light**
Table 5			

As of this writing, this reviewer understands that the staff at Concord plans to revise the two remaining biology activities, Cellular Respiration and Diffusion, Osmosis and Active Transport.

Teachers Guides

Teachers guides have been written for 22 of the activities. [5] As of January of 2010 the guide for Cellular Respiration had not been completed. Each teacher's guide - with some modification in particular guides - presents the following categories of information.

- An overview of the activity
- Learning Objectives
- Possible Student Pre/Misconceptions
- Models to highlight
- Possible Discussion Questions
- Connections to other SAM Activities
- Activity Answer Guide

- SAM Homework Questions – With Suggested Answers for Teachers

Each of these categories provides extensive information about its topic. Not only are the answers to the assessment questions given, but explanations are included. Hints as to instructional techniques including some suggested demonstrations are included. One category – Connections to other SAM Activities – makes use of curriculum mapping techniques to relate an activity to other activities that have concepts that either precede or are derived from concepts in the activity being presented. A larger interactive curriculum map of all the activities can be obtained from http://riitest.concord.org/pubs/activityMapImages/activityMapForWeb/actvityMap.htm In the mind of this reviewer the interactivity of the map is a particularly attractive idea and should be applied to other curriculum maps which, because of their complexity, are often quite cumbersome.

Progress to meet Objective 2 - Formative testing and revision

Over the course of the project five school districts have been involved. These were

1. Glastonbury High and Middle School, Glastonbury, Connecticut
2. Portsmouth High School, Portsmouth, Rhode Island
3. The Hockaday School, Dallas, Texas
4. Belmont High School, Belmont, Massachusetts
5. Woonsocket High School, Woonsocket, Rhode Island.

In the last year Glastonbury withdrew its middle school. Physics was offered in the eighth grade there and it was felt that some of the physics activities were too challenging for students at that grade. However, at the high school a chemistry teacher continued to use selected activities.

Materials have continued to be tested and revised since the beginning of the 2007 – 2008 academic year. The objectives undertaken during this last year (2008-2009) of the project were to

- field-test the activities in the participating school districts,
- revise the Molecular Concept Inventories based on the results from last year's tests.
- review the test results to determine changes in student performance,
- interact with teachers to obtain their views as to strengths of the activities and areas of possible change, and continue to revise the instructional activities as necessary.

All of these objectives were addressed by project staff and produced data in the following areas:

1. Courses in which the activities were offered
2. Number of classes in which the activities were offered
3. Number of activities that were offered by class and by subject
4. Ways in which the activities were presented
5. Percentage of time and where the Molecular Workbench was used
6. Use of the activities in determining student grades
7. Class periods used to present the activities
8. Time of year in which the activities were used
9. Placement in PCB sequence
10. Methods of using computers in presenting the materials
11. Pre- and Post-testing of activities and reduction of data
12. Electronic recording of student work for each activity
13. Classroom observations on such topics as implementation, development of student understanding, confidence with the technology, student engagement and teacher-student interaction
14. Teacher judgment of activities via an online feedback form
15. Teacher focus groups and their recommendations
16. Reduction of data from multiple-choice and written assessment embedded in each activity.

These data give a detailed picture of activity placement, method of use and success. In addition information is gained about student learning through the embedded assessments and the pre and post-tests. Detailed statistical information, as well as attendant inferences can be found in Concord's penultimate and final reports. [6]

Progress to meet Objective 3 - Summative assessment
Work was continued on the Molecular Concept Inventories which were used as the summative assessments of the year's work in physics, chemistry and biology. Concord has been in touch with professional test organizations and consultants to seek advice on the composition and format of its test items and has revised these assessments based on the expert review.[7]

This year (2008-2009) Concord has provided a summary assessment for a given activity in the final page of that activity. This is in addition to the multiple choice and open-ended assessments in the body – previous pages – of the activity. The assessment on the final page does not provide the answers while the assessments on the previous pages do. To avoid the 'click till I get the right answer syndrome' on these non-summary pages Concord has added explanations to a selection when it is incorrect. This can serve the dual objective of assessing while providing instruction and provides a record of the students' performance in the activity. Such an approach deserves further investigation.

Analysis of last year's (2007-2008) data in physics and chemistry showed that the assessments were in need of revision. The p values were skewed toward the difficult and, therefore, were in need of work. As indicated in its final report Concord has recognized that modifications to these assessments were needed. [7] The revised tests were administered again this last year (2008-2009). The p values in chemistry for Hockaday, Portsmouth and Glastonbury were at the .05 level or better indicating an improvement in pre- to post-test performance. The p values in physics for Portsmouth and Belmont similarly were at or better than the .05 level. Woonsocket, which entered the program this year and which had some difficulty with the technology, did not fare as well with no significant change in its test results in this field. As mentioned above, the biology units were new this year and did not undergo the revisions that had been afforded to those in physics and chemistry. The honors section at Woonsocket and the college prep section at Belmont showed significant improvement on the pre- and post-assessments. The other biology sections at these schools and at Hockaday and Portsmouth did not. [8]

As has been mentioned in other reports for this project, this reviewer feels that the assessment aspect requires further analysis. There are many classroom variables that can affect test performance. For example, test placement; other methods of providing instruction in similar content; and the option of using the SAM activities as supplements or replacements; all can affect student performance on the MCI. Concord staff has been sensitive to these variables. Yet these variables may – and probably do - have an affect on test performance. This reviewer feels that keeping the assessments as close to the SAM activities as possible makes for the best determination of their effectiveness. This approach is used by Concord through the embedded assessments in each activity.

Work on the embedded assessments has continued. Again, as stated in its Year Three report Concord has stated,

"We are looking particularly at whether there were questions in which:

- no students scored in high numbers
- a majority of students score zero
- questions did not match the learning goal
- distracters were unfair." [9]

As a part of its summative data gathering Concord has compiled records of student reports giving information about their progress through the

activities. As of June, 2009 approximately 12,500 such reports have been electronically transmitted to Concord. Of this number approximately 5940 were in chemistry, 4150 in physics, and 2145 in biology.
The use of electronic data gathering provides an important way to determine student reactions to particular concepts.

Progress to meet Objective 4 -Technology

Throughout the project the molecular dynamics software has been continually upgraded to support the functions needed in the student materials. These changes have enhanced the attractiveness and accessibility of the web page and the activities. The ability to model physical processes at the atomic and molecular levels provides an important means for students to conceptualize these processes.

In the final year, the SAM activities provided for electronic monitoring and assessment of student reactions and performance as they make their ways through the activities. This has provided large amounts of data to the Concord researchers as well as a new reporting and grading system for the teachers.. This technology continues to develop and is becoming more powerful in assisting Concord researchers as well as participating teachers to view and analyze the progress of students in greater detail. Currently the software autoscores multiple-choice questions, and allows teachers to view particular embedded assessment questions. It does not score image or open-ended questions. This reviewer looks forward to the time when evolving computer-based scoring of open-ended written responses might be interpolated into the program.

Progress to meet Objective 5 - Professional development

Professional development has been ongoing throughout the project and consists of the following:

- A website. As described above, a website http://sam.concord.org/ has been developed and is operational. Staff has indicated that a major revision of the website is currently underway. It will recast the site to serve non-project teachers who find the SAM materials online.
- Written materials. Many written materials above and beyond the activities themselves have been written and made available for review and instruction. As noted above, a series of Teachers Guides has been written and are available at SAM's website.

- Summer workshops have been held for teachers and department heads. Participants were given the opportunity to learn about the overall operation of the project, how to use the Molecular Workbench platform as well as to try a number of the activities that had been developed at that time.
- An online tutorial on how to use the Molecular Workbench for modeling has been made available as an additional MW activity. It is readily accessible from the SAM website.
- Staff reports it is preparing a new tutorial that will introduce teachers who find SAM on the web to the pedagogy, philosophy, assessment tools and integration of the activities with each other via the four central themes (Motion and Energy, Charge, Atoms and Molecules, and Light). Although an online course was an original objective for the website, the advisory board and the Concord Staff discussed this and determined that it is more appropriate to provide a tutorial that allows self-pacing and does not require a moderator, which is not sustainable beyond the life of the project. In addition, those who come across SAM on the web are unlikely to enroll in a course, and are more likely to use the components of a tutorial that fit their current needs.

5. Progress to meet Objective - Dissemination

Dissemination of SAM's philosophy, methods and materials have taken place throughout the life of the Project, but predominantly in Phases II and III. Dissemination of the materials and research findings have taken place through

- Presentations,
- professional papers,
- meetings,
- materials provided for administrators,
- materials disseminated electronically, and
- the development of a close relationship with a prospective publisher.

SAM's Home Page

SAM’s Home Page has been revised this year to accommodate the changed content. The Home Page of SAM (http://sam.concord.org/) is replete with information about the project and leads the reader to a number of sites that provide assistance in navigating through it. In addition, Concord staff has indicated that the Home Page will be revised further to reflect the changing audience - from teachers who are involved in field-testing to those who find the SAM resources online.

This page currently provides the following buttons on its Task Bar:

- **Home** This page provides a portal to the project’s varied support structures as well as general information about the project. Its button provides information about
    1. the project’s philosophy
    2. example lessons on heat flow and molecular self-assembly
    3. a link to the database of over 200 activities
    4. a link to the Molecular Workbench
    5. additional information about the SAM project

- **Database** In addition to the activities designed specifically for SAM, this database also provides access to activities developed for the Molecular Logic (MOLO) and Molecular Literacy (MOLIT) projects. These activities give the student a total of close to two hundred activities from which to choose.
- **Research** Considerable research has been done in the use of molecular modeling. This button provides the student with entry to the following publications:

    1. The Science of Atoms and Molecules – an article by Dr. Tinker regarding the underlying philosophy of the SAM project with links to support material and activities.
    2. Characteristics of Models – an article describing the characteristics, strengths and weaknesses of models.
    3. Taming Science Models for Classroom Use – an article by Dr. Tinker and staff describing modeling in classroom situations to support student concepts about the molecular world.
    4. Molecular Dynamics in Education - This article points to the importance of student-model interaction as opposed to only viewing computer models. The article gives examples from the various sciences of biology, chemistry, and physics to demonstrate this view.

  This Research page also gives the reader the opportunity to see the original SAM proposal as well as an article on secondary school science reform that contains an extensive list of references and links the teacher to articles describing the movement.

- **Software** The Software button leads the teacher and student to sites containing the necessary software needed to run Molecular Workbench and other aspects of the project.
- **Help** This button links to a page that provides assistance with running the software and an e-mail link to Concord for its assistance with the activities. It also contains a trouble report for pilot teachers.
- **Activities** The Activities button leads the teacher and student to an outline of the specific SAM activities in physics, chemistry and biology as detailed on pages 6 - 8 of this report.
- **Teachers** This secure page is for teachers. Originally, this page contained the following links that contained the italicized materials. As a result of revisions based upon experiences with participants, the content of these links has been changed and are shown in normal print below.
    1. <u>My MW Space/Activities</u> *This page provides for the teacher's profile, models they have devised, reports they submit and comments. It also provides a molecular concept inventory which in test form surveys student knowledge of some of the physics and chemistry related to SAM.*
       This page now contains a link to the Molecular Workbench page that shows the following buttons
        - My profile
        - My models
        - My reports
        - My comments
        - Contact the MW team
        - The Molecular Concept Inventories in physics, chemistry and biology
        - An article titled Introduction to Modeling
        - A matrix of the theme activities.
    2. <u>Feedback</u> *This page provides feedback forms that have* been *created by the project. Basically, in Likert form it requests information about what the teacher is teaching, at what level, how the materials relate to their program of studies and instructional techniques, and student reaction to the activities.*
       This page now includes teachers' reactions to particular pages in an activity as well as to the teachers' guides. After choosing an activity the teacher is asked to respond to the following questions about it, making use of a Likert scale with an area for comments.

- What were you teaching at the time you used the unit?
- I liked this unit enough to use it again next year.
- In general, my students understood what was expected of them when working through the unit..
- The level of difficulty of this unit was appropriate for the class in which I used it.
- Describe how you used the activity in your classroom
- Did you have any technical difficulties with this unit?
- Were students frustrated or stumped by any interactive portion of the unit? How could it be improved?

Then questions were asked about specific pages in the unit.

- How could the text and any diagrams on this page be improved?
- How could any models on this page be improved?
- How could the questions on this page be improved?

Questions about the Teachers' Guides followed.

- Rate how well the Teacher Guide conveys an overall sense of purpose and direction.
- What is your opinion of the Teacher Guide's suggestions for discussion questions and model highlights?
- Do they adequately help students think about the phenomena that are introduced in the activity? Explain.
- Describe how you reviewed the activity or what you discussed with the students while doing the activity.
- Describe how you helped students make connections to other SAM activities.
- Did you notice students transfer knowledge from one SAM unit to the next?
- Describe how you used the Teacher Guide.
- Did you use the homework sheet provided?
- Please list and describe any suggestions for additional Teacher Guide discussion questions.
- Please list and describe any suggestions for additions or changes to the student homework sheet.
- Please list and describe any suggestions for additions or changes to the Activity Answer guide.
- Describe anything else you liked or disliked about this unit and your suggestions for improving it.

As can be seen from the above questions teachers were given significant opportunity to forward their impressions of the units in some detail.

3. Resources *This button leads to a survey for new SAM teachers, permission forms for students and teachers and another opportunity to report problems.* It now also contains what before was a separate button that provides teachers with a Trouble Report to provide information about problems.
4. Discussion *This button will provide a forum for teachers to discuss their experiences with the materials with their colleagues.* As of this writing this button has not been put into action.
5. MCI Physics *The molecular concept inventory for physics. This is essentially a test of some of the basic concepts in physics that are a part of the SAM project*. This inventory is now a part of the My MW Space/Activities page above.
6. MCI Chemistry *The molecular concept inventory for chemistry. Again, this is a test in chemistry regarding some of the basic concepts in chemistry covered by the SAM project.* This inventory is now a part of the My MW Space/Activities page above.
7. MCI Biology. *In a manner similar to the assessments for physic and chemistry this concept inventory covers the significant concepts in biology.* This inventory is now a part of the My MW Space/Activities page above.
8. Launch MW *A button to launch the Molecular Workbench.* This link to the Molecular Workbench remains the same.

Upon opening the Molecular Workbench, the user is provided with buttons for participants as well as those who may wish to learn more about the project. These are as follows:

- A ‘What’s New’ button that leads the reader to key characteristics of molecular modeling
- A button leading to an article discussing the value of molecular modeling
- A lesson on heat flow that serves as an example for other activities in SAM
- A sample of a lesson from the Molecular Logic project, once again showing how the use of the Molecular Workbench acts as the platform for the SAM Project
- A button serving the same function as the Database button mentioned above
- A button leading directly to the home page for Molecular Workbench

- A button leading to a brief discussion of the SAM project

Further, a tutorial for the increased scripting capacity of Molecular Workbench has been developed and is available. http://mw2.concord.org/tmp.jnlp?address=http://mw2.concord.org/public/tutorial/mwscripts.cml

Clearly, the reader is given a number of leads that will assist in an understanding of what the project wants to accomplish, what its organization and content is, what its methodologies are, and how it intends to determine student success as they move through the landscape of the project.

Management of the SAM project.

The management of the SAM project by the SAM staff has to be viewed as excellent. One thing that particularly has impressed this reviewer is the attention paid by the Concord staff to the comments and recommendations provided by teachers, students, consultants and the advisory board and ,of course, their partners in the project. As can be seen from the results of the questionnaires below, the results articulated in Concord's reports, this reviewer's visits to schools and to Concord, there has been considerable contact between Concord staff and participants. There have been three advisory board meetings to show progress of the project and to seek advice on content changes, pedagogical approaches and project dissemination. This has led to a constant revision of the materials provided by the project. Even in this no cost extension period (fall 2009 to winter 2010) revisions and updates continue to be made.

The SAM project was organized to address a number of tasks that grew out of the objectives stated in the proposal.

- Select the appropriate content and pedagogy to provide for the activities that make up the body of the program.
- Continually update software to provide a platform for the activities and the computer modeling necessary for the instructional materials.
- Create, review and revise the embedded multiple-choice and written assessments.
- Recruit the schools to take part in the project.
- Review how the materials are used by classroom visits from Concord staff.
- Prepare and disseminate teachers' guides to provide support for each activity.

- Create a website to lead teachers and students to the activities and to provide information about the philosophy of the project, obtaining the necessary software, contacting the staff, and downloading and working with the activities.
- Provide for focus groups from participating schools to discuss their progress with the project.
- Prepare and analyze the results of a pre-test and post-test in each of the subject areas – physics, chemistry and biology to determine student achievement.
- Research the progress of the project to determine how activities are used in class regarding such pedagogical issues as
    1. means of introducing and reviewing concepts,
    2. time required to go through a given activity, and
    3. distribution and use of computers in a classroom.

As noted in Concord's penultimate report, the activities titled "Solubility (Chemistry) and Cellular Respiration (Biology) were completed and made available to schools late in the 2008-2009 school year, past the point where they occurred in the curriculum. The Molecular Recognition activity (Biology) was underutilized because many teachers believed that the content "was beyond their needs." These latter observations are confirmed in this reviewer's questionnaire. As can be seen in Table 8 below, there was no response to questions about the Molecular Recognition activity. Cellular Respiration was not included in the questionnaire as it was unavailable at the time it was sent out (May and June, 2009).

This is a generous number of tasks that, as of this writing, have been essentially completed.

Results of Evaluator's Year III (2008-2009) Questionnaire

This reviewer sent a questionnaire to the teachers in the SAM project again in Year III. The return dates for the questionnaire were May 15, 2009 and June 1, 2009. Responses were received from 14 teachers in the following schools.

- Belmont High School
- The Hockaday School
- Portsmouth High School
- Woonsocket High School

Of the 14 teachers who responded to the questionnaire, three used only the physics activities; three used only the biology activities; six used the physics and chemistry activities; one used activities in chemistry and biology; and one used activities in physics, chemistry and biology. As with any questionnaire making use of a relatively small number of respondents (about 47% of the teachers reported by SAM as participating in the program), the results should be viewed as indicative rather than definitive.

Once again, this reviewer would like to thank all who gave so generously of their time for their forthright comments and candid observations.

Again this year, the questioning of the teachers was divided into four areas. However, additional questions were added to the SAM activities section to gain teachers' perceptions of the additional activities and the teachers' guides.

1. My School and Classes
2. Technical Issues
3. The SAM Activities
4. Concept Coverage and Relation to Local Materials and State and National Standards.

In addition to their comments, a Likert scale was used to give a quantitative flavor to some of their responses. The scale ranged from 1 (poor, weak, strongly disagree, not appropriate) to 5 (excellent, strong, strongly agree, quite appropriate).

1. My Schools and Classes

Three of the four school districts participating in the SAM project last year were a part of this year's cohort as well. The Glastonbury Public School District, with the exception of one teacher in its high school, decided not to participate this year and, thus, was not a part of the 2009 questionnaire sent out by this reviewer. However, he was interviewed in the spring of 2009. Since Glastonbury starts with physics in the eighth grade they felt that some of the activities were too challenging for students at that level. However, a chemistry teacher who used the activities in that field last year felt they were appropriate and continued to use them in the ninth grade this year. As a result of Glastonbury's departure the Woonsocket, Rhode Island Public High School was added.

The demographics of <u>all</u> the schools which participated during the project were as follows.

- **Glastonbury High School** is a suburban high school of 2010 students. It is 85.5% white, 3.5% African-American, 5.1% Hispanic; 5.8% Asian-American and 0.1% Native-American. Teachers felt the composition of their classes reflected those percentages. The courses in which the SAM activities were offered were college preparatory chemistry and chemistry.

- **Belmont High School** is classified as a suburban school of approximately 1200 students. Chemistry teachers felt their chemistry classes consisted of approximately 75% white students, 10% Asian-American; 5% Hispanic; 5% African American; 5% Native-American. The physics teacher reported the make-up of her class was approximately 80% white; 20% Asian-American. The chemistry activities were used in honors and college prep courses. The physics activities were used in a freshman honors course.

- **Portsmouth High School** is a suburban high school of approximately 1000 students in grades 9 – 12. According to interviewed teachers, their classes are about 97% white with the remaining 3% minority. The activities were used in chemistry, pre-AP chemistry, Chemistry in the Community, physics and Physics First classes.

- **The Hockaday School** is a private all-girls school with grades that range from K to 12. The upper school (grades 9-12) has 443 students. Of these, 30% are described as being "of color". The teacher scored diversity as 4. The teacher-student ratio is 1:10. The SAT range for the 25th to 75th percentile is 1810 to 2170. The average score for the SAT is 1518.[10.] This would place these students at Hockaday in a relatively high achievement cohort. The activities were used in the physics class.

- **Woonsocket Public High School** has an 8 – 12 grade structure. Its school population in 2006-2007 was 1920. The number of students in grade eight was two; in grade nine, 625; in grade ten, 528; in grade 11, 379; and in grade 12, 386. Its ethnic representation is 64.7% white, 20.2% Hispanic, 8.0% African-American, 7.1% Asian-American, and 0.1% Natïve-American.

One of the questions on the spring of 2009 questionnaire to teachers in the SAM project was to list the courses in which they offered SAM activities. It should be noted that while some of the titles were different, the content of the courses (e.g Honors Chemistry in one school, Chemistry in another) were similar. Also, similar titles from one school to another might involve different levels of instruction or content. The course titles listed were as follows.

College Prep Biology
Honors Chemistry
College Prep Chemistry
AP Environmental Science
Physics
Chemistry
Academic Biology
Physics First
Academic Physics
Oceanology
PreAP Chemistry
Honors Biology
Biotechnology
Chemistry 1
Honors Chemistry 2

The questionnaire also asked teachers the number of students in each of these courses. Again, recognizing possible content or level of instruction differences in course with similar titles, the courses in which the activities were offered in terms of student exposure to the activities were as follows:

Course Title	Number of Students
Chemistry	277
Honors Chemistry	122
Academic Biology	96
Physics	84
College Prep Chemistry	64
College Prep Biology	60
AP Environmental Science	55
Pre AP Chemistry	54
Physics First	33
Honors Biology	30
Oceanography	22
Biotechnology	19

Table 6

Of the courses listed above the student enrollments were greatest in chemistry (56.4%), followed by biology (20.3%), physics (12.8%), AP environmental science (6.0%), oceanography (2.4%) and biotechnology (2.1%)

2. Technical Issues

The responses to the statements in this section were based upon a Likert Scale with 1 representing strong disagreement with the statement and 5 representing strong agreement. In addition, teachers were given the opportunity to provide comments relative to the statements and many did so. A number of their comments are included in the following descriptions.

Belmont High School

Four teachers at Belmont High School responded to the questionnaire. The average of their scores follows each topic.

- Teachers at Belmont High School felt it was relatively easy to download, install and run the software (i.e. Quicktime, Java) needed to operate the SAM database. Score 4.3
- Response of the Concord staff with regard to questions about SAM's operation and content quite good. Score 4.5
- Generally speaking the graphics in the activities were quite good. Score 4.5
- Overall, the level of difficulty of the activities was appropriate. One teacher felt the level of difficulty was hard for her lower level students. Score 4.0
- The format of the summary sheets still caused some difficulty. Score 3.5
- The SAM Home Page was effective and provided a useful path to get to the activities. Score 4.8
- Teachers found that the models provided in the activities were excellent in helping students understand the concepts presented. "They not only help the kids understand the activity, they help them understand the science, and are useful for later application." Score 4.8
- Belmont High School had some difficulty with the MCI tests. It was felt they required some work. One teacher's comment. "I feel that this initial test was way beyond what the students already knew. They were guessing on the majority of the questions and it did not give me an idea of the more basic

concepts that they may have learned in the middle grades."
Chemistry score 1.3 Biology score 1.8

The Hockaday School

Four teachers at the Hockaday School responded to the questionnaire.

- Two teachers had little difficulty using the software for SAM, but two did have some. The problems seem to be local. "SAM has always run very slowly on my laptop, and for many (somewhere between 30-40%) of my students, it will not load at all on their laptops. We have worked on this issue with our IT staff for the past two years with no success. No amount of Java reloading or file cleanup has fixed the problem. Accordingly, my students often encounter frustration with completing the units which impedes their learning and causes them to develop negative attitudes toward SAM. When our ONE computer lab on campus is not occupied (which doesn't occur very frequently due to use by our lower and middle school) I use it because SAM works wonderfully on the desktops, but I often cannot arrange this." Overall score 3.3.
- Two teachers did not contact Concord for assistance. One had difficulty with the technology and one said the experience was excellent.
  Score 3.5.
- The graphics in the activities were very well received. Score 4.5
- All four teachers found that the level of difficulty of the activities was appropriate for their students. Score 4.3
- The format of the summary sheets showing student responses to questions was felt to be reasonably acceptable. Score 3.8
- The SAM home page was found to be useful in navigating through the program. Score 4.3.
- Teachers found that the models included in the activities were quite helpful in helping students understand the concepts in the activity. Score 4.5.

Portsmouth High School

Three teachers from Portsmouth High School responded to the questionnaire.

- The responses of the teachers regarding their ability to download and access the software was uniformly high. Score 4.7

- One teacher had no need to contact Concord. The other two were very happy about their contacts with, and assistance from, Concord staff.
  Score 5.0
- In general the graphics in the activities used were quite satisfactory. Score 4.7
- In general the level of difficulty for the activities was considered be quite appropriate. Score 4.3
- The format of the summary sheets was considered to be good if somewhat long. Score 4.0
- Some teachers were now using the RI-ITEST home page – a scale-up project from Concord. The use of the SAM home page still scored quite high. Score 5.0
- The use of models in the activities was rated quite highly. "I found the models included in the activities useful in helping students understand the concepts in the activity." Score 4.7

Woonsocket High School

Three teachers from Woonsocket High School responded to the questionnaire. This was the first year the school participated in the program.

- Teachers experienced difficulty in downloading SAM software largely because of centralized control of classroom computers. One teacher remarked.   "We cannot download anything ourselves as teachers. We have to put in a work order and have our tech staff do it. I am still waiting for them to update the desk computer in my classroom so I can use it to run the SAM software." Other teachers also experienced difficulty.
  Score 2.0
- Responses from Concord staff to the questions and concerns of the teachers were timely and effective. Score 4.0
- In general, the graphics in the activities were quite satisfactory.
  Score 4.0
  While the level of difficulty for each activity will be seen in the Table below, teachers at Woonsocket felt that generally, the level of difficulty of the activities was high. "The level of difficulty was way beyond the thinking skills of an academic class (non-college prep). The reading level made it difficult for even my honor students."
  Score 2.0
  Teachers were positive about the format of the assessment sheets but had some concern about the effectiveness of their use as

assessment tools. “The format itself was helpful but the students’ responses to the questions were not a good assessment tool. Since students could just click on the choices until they got it correct, it was not a good evaluation tool.” Score 3.3.

- Reaction to the SAM Home Page and the ability to navigate to the activities from it was positive. Score 4.0
- Teachers felt the models in most of the activities they used were effective in fostering learning of the concepts. “Most of the models gave a great visual representation of the concepts.” Score 3.7

3. The SAM Activities

The Tables below are compiled from the responses of the teachers to the questions regarding their experiences with, and feelings about, particular activities. The questionnaire was administered (May 15, 2009 and June 1, 2009). As of the latter date the biology activities Cellular Respiration and Molecular Recognition had not been used.

Each activity used by responding teachers was reviewed focusing on the following categories.

- Appropriate Language
- Clarity of Concepts
- Flow of Ideas
- Understandable Graphics
- Useful Embedded Multiple-Choice Questions
- Useful Embedded Written Response Questions
- The Activity Enhanced the Learning of My Students
- The time necessary to do the activity was appropriate for my class(es)
- I found the teacher’s guide for the activity to be helpful
- I will use this activity again

Again, in addition to their comments, teachers were asked to judge each category on a 1 (poor) to 5 (excellent) Likert Scale. A compilation of the responses from all teachers and schools appears in the Tables below.

<u>Physics</u>

Activity/Score	1. Atoms and Conservation of Energy	2. Heat and Temperature	3. Electro-statics	4. Electric Current	5. Atomic Structure	6. Newton’s Laws at Atomic Scale	7. Excited States and Photons	8. Spectroscopy

Appropriate Language	4.0	4.0	4.0	4.0	3.3	4.0	5.0	4.0
Clarity of Concepts	4.0	3.5	4.0	4.0	3.7	4.0	5.0	3.8
Flow of Ideas	4.0	4.0	4.0	4.0	3.7	4.0	5.0	4.0
Understandable Graphics	4.0	4.0	4.0	4.0	3.7	4.0	5.0	2.8
Useful Embedded Multiple-Choice Questions	4.0	4.0	4.0	4.0	3.7	4.0	5.0	4.0
Useful Embedded Written Response Questions	4.0	4.0	4.0	4.0	3.7	4.0	5.0	1.8
The Activity Enhanced the Learning of My Students	4.0	4.0	4.0	4.0	3.7	4.0	5.0	3.3
The time necessary to do the activity was appropriate for my class(es)	4.0	3.5	4.0	4.0	3.7	4.0	5.0	3.3
I found the teacher’s guide for the activity to be helpful	4.0	1.5	2.7	4.0	3.3	4.0	5.0	4.0
I will use this activity again	4.0	4.0	4.0	4.0	3.7	4.0	5.0	3.3

Table 7

Chemistry

Activity/Score	9. Phase Change	10. Gas Laws	11. Inter-molecular Attractions	12. Molecular Geometry	13. Solubility	14. Chemical Bonds	15. Reactions and Stoichiometry
Appropriate Language	3.4	4.3	3.3	3.5	4.5	4.0	4.5
Clarity of Concepts	3.4	5.0	3.6	3.5	4.5	4.0	4.5
Flow of Ideas	3.4	5.0	3.6	3.5	4.5	4.2	4.5
Understandable Graphics	3.6	5.0	3.6	3.5	4.5	4.2	4.5
Useful Embedded Multiple-Choice Questions	3.4	4.3	3.6	3.5	4.5	4.0	4.5
Useful Embedded Written Response Questions	3.4	4.3	3.4	3.5	4.5	4.2	4.5

The Activity Enhanced the Learning of My Students	3.4	4.3	3.6	3.5	4.5	4.2	4.5
The time necessary to do the activity was appropriate for my class(es)	3.6	4.3	3.6	3.5	4.5	4.2	4.5
The time necessary to do the activity was appropriate for my class(es)	3.4	4.3	3.6	3.5	4.5	3.5	4.5
I found the teacher's guide for the activity to be helpful	3.1	3.7	3.6	3.3	2.5	4.2	2.5
I will use this activity again	3.6	4.3	2.8	3.6	4.5	4.3	4.5

Table 8

Biology

Activity/Score	16. Diffusion and Active Transport	17. Four Levels of Protein Structure	18. Molecular Recognition	19. Lipids and Carbo-hydrates	20. Proteins and Nucleic Acids	21. DNA to Proteins	22. Photo-synthesis
Appropriate Language	4.2	4.3		4.3	4.0	4.2	4.0
Clarity of Concepts	4.2	4.0		4.3	4.0	4.2	4.3
Flow of Ideas	4.2	4.0		4.0	4.0	4.2	3.7
Understandable Graphics	4.4	4.0		4.0	4.0	4.0	3.3
Useful Embedded Multiple-Choice Questions	3.8	3.5		4.3	4.5	3.6	3.7
Useful Embedded Written Response Questions	3.8	3.5		4.0	4.5	3.6	3.7
The Activity Enhanced the Learning of My Students	4.2	3.3		2.0	4.0	3.8	3.3
The time necessary to do the activity was appropriate for my class(es)	3.6	2.8		3.0	3.5	3.0	3.7
I found the teacher's guide for the activity to be helpful	3.4	3.5		3.3	3.5	3.2	2.7
I will use this activity again	3.8	3.5		4.5	5.0	4.4	4.0

Table 9

As can be seen from the physics, chemistry and biology tables, there were variations in teacher perceptions of various aspects of the activities. However, overall the scores in most areas were 4s and 5s – or very good to excellent. Seven of the eight physics activities received average scores of 4 or 5. Four of the seven chemistry activities received average scores of 4 or above. The remainder of the activities in chemistry received scores between 3 and 4. As can be seen from their values, chemistry teachers felt the embedded multiple-choice questions could use some work and could be made more effective in evaluating student learning. The embedded written assessments were found to be more valuable.   The biology activities were found to be most difficult. The two biology activities that were found to be best for enhancing student learning were Proteins and Nucleic Acids (4.0), and Diffusion and Active Transport (4.2). Those that were found to be more challenging were Lipids and Carbohydrates (2.0), Four Levels of Protein Structure (3.3) and Photosynthesis (3.3). It should be pointed out however, that with the exception of Lipids and Carbohydrates all biology activities were on the positive side of the midpoint on the Likert scale.

Of interest was the important perception as to whether teachers felt that the activities enhanced the learning of their students. The average score for the chemistry activities was 3.9 or close to very good.   For physics the score was 4.3 – between very good and excellent. Clearly, teachers' perceptions of the activities as a whole were positive and - in terms of their ability to foster student learning – quite good. In chemistry, the activities that were scored most favorably were Gas Laws, Intermolecular Forces, and Chemical Bonds. The activity perceived as most difficult was Spectroscopy. In physics, Newton's Laws was perceived most favorably with the other physics activities very close behind. In biology, - the score was 3.2 – just above good and lower than for the other two subjects. Again, this score may be the result of the first year biology tryout and before revisions to its activities.

Activity	Average Score
1. Atoms and Conservation of Energy	4.0
2. Heat and Temperature	3.7
3. Electrostatics	3.9
4. Electric Current	3.9
5. Atomic Structure	3.6
6. Newton's Laws at Atomic Scale	4.0
7. Excited States and Photons	5.0
8. Spectroscopy	3.4

9. Phase Change	3.5
10. Gas Laws	4.5
11. Intermolecular Attractions	3.5
12. Molecular Geometry	3.5
13. Solubility	4.3
14. Chemical Bonds	4.1
15. Reactions and Stoichiometry	4.3
16. Diffusion and Active Transport	4.0
17. Four Levels of Protein Structure	3.6
18. Molecular Recognition	0.0
19. Lipids and Carbohydrates	2.1
20. Proteins and Nucleic Acids	3.8
21. DNA to Proteins	4.1
22. Photosynthesis	3.8

Table 10

Table 10 shows the average of all ten scores for a given activity. Averaging all of these scores for a given subject shows that, overall, the activities for chemistry (4.0) were found to be most appropriate followed closely by physics (3.9) and then by biology – not counting Molecular Recognition which had no responses - (3.6). It should be recognized that both chemistry and physics were in their second year of tryout while biology was in its first. Thus, it is possible that their higher scores reflect the revisions that were made after their first year of tryout.

4. Concept Coverage and Relation to Local Materials and State and National Standards

What follows are statements on the questionnaire related to this general area and teacher reactions to them.

1. SAM activities are correlated with concepts taught in my class(es).

   - Belmont High School Score – 4.0
   - Portsmouth High School Score - 4.7
   - Hockaday School Score – 3.7
   - Woonsocket High School Score – 4.0

Once again this year, teachers felt that the concepts in the SAM activities were appropriate for the content in their courses.

2. SAM concepts are related to those in the student text

   - Belmont High School Score – 4.0
   - Portsmouth High School Score - 4.0
   - Hockaday School Score – 4.0

- Woonsocket High School Score – 4.0

One Hockaday teacher indicated that a textbook was not used. The Hockaday score omits the count of that teacher.

3. The concepts covered in the SAM modules I used are related to those in our state's science standards.

   - Belmont High School Score – 4.0
   - Portsmouth High School Score - 4.0
   - Hockaday School Score – 5.0
   - Woonsocket High School Score – 4.0

Only one teacher from Hockaday responded to this question. The Hockaday score is based upon that teacher's response. The other teachers indicated, as was the case last year that they, as a private school, did not use the state standards.

4. The concepts covered in the SAM modules I used are related to those in the National Science Education Standards.

   - Belmont High School Score – 4.0
   - Portsmouth High School Score – 4.7
   - Hockaday School Score – 4.3
   - Woonsocket High School Score – 4.0

5. Overall, I found the SAM pre-test appropriate for the concepts I teach in my course.

   - Belmont High School Score – 4.3
   - Portsmouth High School Score - 4.3
   - Hockaday School Score – 3.7
   - Woonsocket High School Score – 2.0

With the exception of Woonsocket High School, which was new to the program this year, the reaction of teachers to the revised SAM pre-test was more favorable than their reaction to the initial version of the test.

6. I used the assessments in the activities to help me assess my students' progress.

   - Belmont High School Score – 2.3
   - Portsmouth High School Score – 3.3
   - Hockaday School Score – 3.0
   - Woonsocket High School Score – 2.0

7. I intend to use the end-of-year assessment prepared by SAM to help me give my students a grade.

- Belmont High School Score – 1.7
- Portsmouth High School Score – 2.3
- Hockaday School Score – 2.3
- Woonsocket High School Score – 1.0

As can be seen from the responses to questions #6 and #7 teachers did not make much use of the SAM activities in the assessment of their students' progress or grades.

8. I intend to use SAM in my classes again next year.

- Belmont High School Score – 4.7
- Portsmouth High School Score – 4.3
- Hockaday School Score – 3.7
- Woonsocket High School Score – 3.3

Overall, the participating high schools indicated they intend to use SAM activities again next year. The experienced high schools – Belmont, Portsmouth and Hockaday - showed stronger scores in this regard than Woonsocket which is new to the program.

Summary

Overall, this reviewer believes the SAM Project to be a most worthwhile endeavor. As can be seen from the narrative above, the project has made substantial progress since its inception. It has met and, in many cases, exceeded the objectives set forth in its proposal to the National Science Foundation. As mentioned above, the management at Concord is well-organized, creative, technically proficient, research oriented and, importantly, responsive and sensitive to the needs and concerns of participating teachers and students. As can be seen from the evolution of the content of the activities Concord staff has listened to the experiences of participating teachers and to the suggestions of its advisory committee and has made changes that have improved the applicability of the materials. This has worked for most, but not all, of the activities. Several of the activities, as noted above, were felt by some teachers to be either too difficult or lay beyond what was offered in the classroom. However, as can be seen from the questionnaire above - as well as from this reviewer's discussion with teachers and students – in large part the activities were appropriate and helped learning.

Over the course of the project this reviewer has had the opportunity to visit with 16 teachers in participating schools. In addition, he has sent out two online questionnaires - one in each of Years II and III. The results derived from these interviews and questionnaires plus the considerable amount of information received from Concord staff provide the substance for this report.

As can be seen from the enrollments in the various courses in Table 6 above chemistry appeared to be the subject of choice for the use of SAM activities followed by biology and then physics.

.

Once again, in this final year, participating teachers were quite pleased with the cooperation they received from Concord's staff. In my discussions with them over the years of the project, teachers said that their recommendations relative to the content and pedagogy of the activities were listened to and the changes made improved their instructional effectiveness.

Teachers found that the concepts in the SAM activities were consistent with national and state standards, as well as the concepts they addressed in classroom and texts.

As was the case in year 2007 – 2008, teachers felt that the Molecular Concept Inventories in physics, chemistry and biology leaned toward being difficult. The inventories were revised for the 2008-2009 school year based upon previous year's results; however they were still challenging. Staff has indicated that a review of the items will be made this coming year with an eye to making them more appropriate. Once this is determined, new items will be written. This reviewer feels that the information gathered from items used on the previous administrations of the inventories – along with the proposed item review and a cadre of knowledgeable item writers - can provide a basis for the types and difficulties of items to appear in the inventories to come.

The embedded assessments in each activity consisted of two kinds – a series of multiple choice questions and a series of open-response questions. All of the multiple choice assessments, with the exception of those on the last page of the activity, give the student either a Try Again or Correct response. As several teachers have noted this can lead to a point and click approach until the correct answer is obtained. The final assessment for the activity does not provide answers to the student and thus can be used as an assessment of achievement in the total activity. Experience has shown that the embedded multiple choice assessments in the activity can also be used as a learning device. As a result many of these items now have an explanation if either a correct or an incorrect answer is selected. Since each of the student's responses is recorded this still allows the items to be used for assessment purposes.

A change in the format for collecting written responses to embedded questions allows for these responses to be gathered at one place. This makes it easier for the teacher to see how the class as a whole reacts to the question. A rubric for the answers to these questions is provided in the teacher's guide for the activity. This reviewer feels that the embedded assessment items should be reviewed in a manner similar to that proposed for the Molecular Concept Inventories.

The software for the Molecular Workbench continues to be improved. This powerful piece of software gets better with each succeeding project. SAM has been no exception. Most schools found the software easy to obtain and put to use. For those reporting difficulty, the problems were usually local with access through district centralized control the main concern. To this reviewer the ease of use of Molecular Workbench and its power to provide models that permit students to learn core atomic and molecular interactions while changing many of the parameters that affect these interactions is especially attractive. A number of teachers have commented that the Molecular Workbench has helped them provide instruction in the concepts underlying atomic and molecular level interactions that would be much more difficult to provide without it.

A hope of the project, although not an objective, was that it might contribute to the materials that could assist in the development of a revised secondary school sequence from (often) biology, chemistry, physics (BCP), to the more logical physics, chemistry, biology (PCB) sequence espoused by Dr. Leon Lederman and others in Project ARISE.[11] Under such circumstances one might suspect that there would be more use of SAM materials in the courses in physics. Such does not appear to be the case in the participating schools as of this year. However, as was mentioned in last year's report, curriculum change is not easy. While the PCB approach is used in an increasing number of schools progress in this cohort appears to be modest (Table 6). The use of SAM materials on a larger scale - such as that beginning in the state of Rhode Island with Concord's participation - should contribute to a greater understanding of the mechanics and the progress of this change.

Finally, this reviewer believes that the overarching goal of the project - namely to use instructional technology through computer modeling to assist students understand basic concepts in the sciences at the micro level and through them their applications at the macro level - should in no way be underestimated. It is a highly significant and an important contribution to the student's perception of the natural world and, thus, a valuable contribution to the improvement of science education.

References

1. .The Science of Atoms and Molecules A Proposal to the National Science Foundation from the Concord Consortium. October 17, 2006.p 3.
2. op cit. The Science of Atoms and Molecules p 5.
3. http://sam.concord.org/
4. http://sam.concord.org/teachers/
5. http://sam.concord.org/teachers/teacher-guides/
6. SAM Research Findings Year 3. Concord Consortium, Concord, MA 01742
7. E-mail from Amy Pallant 08-28-09
8. Report from Amy Pallant Compiled Scores 12-15-09
9. SAM Research Findings Year 3. Page 16. Concord Consortium, Concord, MA 01742
10. SAT from Wikipedia. http://en.wikipedia.org/wiki/SAT
11. Lederman, L. M. *Physics Today* 2001, 54, 11-12.

Appendix

Biology Activity Revisions

The SAM biology activities have been revised during the no-cost extension period. These will appear in the next matrix of activities as shown in Table 5 above.

Many teachers cited the length of several biology activities as problematic. Due to the tight schedules for computer labs, teachers tended to schedule the SAM activities for a double period and then attempt to do the entire activity in one sitting, rather than scheduling two separate days as recommended for SAM activities. This resulted in students feeling overwhelmed by the amount of material covered in a single day. Removing some of the most advanced material that teachers tagged as beyond their curricula has shortened these activities.

In addition, the revised activities feature links to new, optional "ChemLink" pages to help students make the connections between the biology they are learning and the underlying chemistry that they learned in the previous year. For example, the Lipids and Carbohydrates activity has two timely ChemLinks, one on Polarity and another addressing Hydrogen Bonding in Water. Each ChemLink page briefly reviews the relevant chemistry concept using models and graphics. The links appear in the activity in a “just-in-time” fashion, providing the support in chemistry at the spots where biology students are most likely to need it.

New activity: Introduction to Macromolecules

The reduction in size and scope of the two macromolecules activities (addressed below) required removing from them an overview of polymers. This concept is fundamental to three of the four classes of macromolecules, so a new, optional activity, Introduction to Macromolecules, was added to SAM to help teachers to introduce the features of macromolecules in general, including their polymeric nature.

Revised Activities

Macromolecules: Lipids and Carbohydrates, Nucleic Acids and Proteins (formerly Proteins and Nucleic Acids)

Teachers indicated that at 11 and 12 pages respectively, both of these activities were far too long for the amount of time allotted in the curriculum. The revised activities are 7 pages each. Lipids and Carbohydrates has been refocused on solubility to lay a foundation for the critical role of water in cell and molecular biology. Nucleic Acids and Proteins has been re-ordered to reflect the flow of genetic information, and reinforces the role of solubility by briefly examining protein folding.

DNA to Proteins
This activity was extensively revised to increase the level of exploration of the transcription and translation models. Students now direct transcription and translation by choosing the correct bases or amino acids based on the DNA and RNA sequences. The original overly extensive instructions have been replaced by succinct challenges with hints providing pointers where students might need extra help.

Four Levels of Protein Structure
This 13-page activity was shortened to accommodate both time and content level constraints. The activity focuses on the connections between the four levels of structure - and places less emphasis on the details of amino acid charge distribution while emphasizing the theme of water solubility and protein folding that has been introduced in the macromolecules activities.

Molecular Recognition
The title of this activity was off-putting to teachers because it sounded too advanced. It has been re-titled Protein Partnering and Function to make it more approachable and to clarify the applicability of the activity.