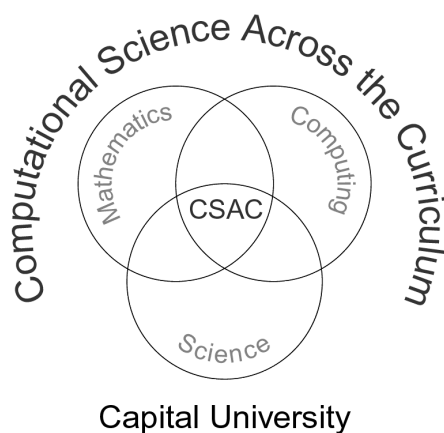


# A Guidebook for the Creation of Computational Science Modules



**W. M. KECK FOUNDATION**

*Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation, Battelle, or the W. M. Keck Foundation.*

*This guidebook was modeled after and borrows substantially from the ChemConnections developer resource pages <http://mc2.cchem.berkeley.edu/modules/index.html>.*

*Thanks, also, to Dr. Brownstein who provided important references and comments, a couple of which are used verbatim.*

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## Introduction.

Computational science is a field at the intersection of mathematics, computer science, and science (hereafter, broadly defined to include biology, chemistry, engineering, environmental science, finance, geology, medical science, neuroscience, physics, and psychology). Computational science offers an interdisciplinary approach to scientific research and provides an important tool, alongside theory and experimentation, in the development of scientific knowledge.

## Goals and Objectives.

The *problem* at the undergraduate level is a lack of educational materials for computational science. Much of the development of these computational science methods have been confined to specific disciplines within the sciences. The commonalities in modeling and visualization approaches between many disciplines provides a unique opportunity teach undergraduate students about this interdisciplinary field of study. The *objective* of this project is to develop course materials (in a modular format) that culminate in a comprehensive, interdisciplinary curriculum for computational science at the undergraduate level.

The proposed project targets national needs to enhance students' knowledge base in computational science, and to improve student attitudes and appreciation of mathematics and science as creative, collaborative, and interdisciplinary fields of inquiry. The goals and objectives for this project are:

### Primary Goal:

- To develop materials that constitute an interdisciplinary computational science curriculum

### Secondary Goals:

- To emphasize an interdisciplinary, team-based approach to science problem solving
- To cultivate undergraduates' understanding of the creative nature of computational science
- To improve written and oral communication related to scientific and technical projects
- To facilitate student use of current and emerging computing technologies
- To increase the number of students who pursue graduate degrees in science and mathematics

## Pedagogical Approaches.

This integrated curriculum is important because it emphasizes critical thinking skills, problem-solving techniques, and a team approach to undergraduate student research. Modules will use inquiry-based pedagogy focused on a problem-oriented approach. Through the inquiry-based pedagogy, instructors will use problems as the context for developing theoretical concepts. Instructors will facilitate student learning by: a) presenting students with a problem to solve; b) having students formulate possible solutions; c) stimulating students' thinking by asking questions; d) having students discuss their solutions; and e) having students assess their work by comparing and defending their solutions. This pedagogical strategy is endorsed in the recent Boyer Commission Report (Boyer, 1998).

In addition to the inquiry-based pedagogy, modules will be structured around collaborative

learning (i.e., peer instruction). Mazur (1997) developed, tested, and demonstrated the efficacy of peer instruction for an introductory physics course; this methodology serves as a model for the proposed modules. The strength of this approach is that students are not passive repositories for information; they must manipulate and verbalize their understanding as they defend their position to their peers. For each course, we will develop a set of conceptual questions to serve as a resource to aid instructors in assessing students' conceptual understanding and to facilitate peer learning.

The computational science modules should challenge higher thinking skills in students and demonstrate the integration of the disciplines. This type of learning may be frustrating for the students. This frustration can be addressed through thoughtful consideration of required previous knowledge and by creating an environment where students are encouraged to take risks and attempt creative solutions. Thus, as you consider the students' experience of the module, keep in mind the following pedagogical techniques and decide which subset of these techniques will best help you achieve the learning objectives for your module. A brief list of sources related to these techniques is available in the reference list.

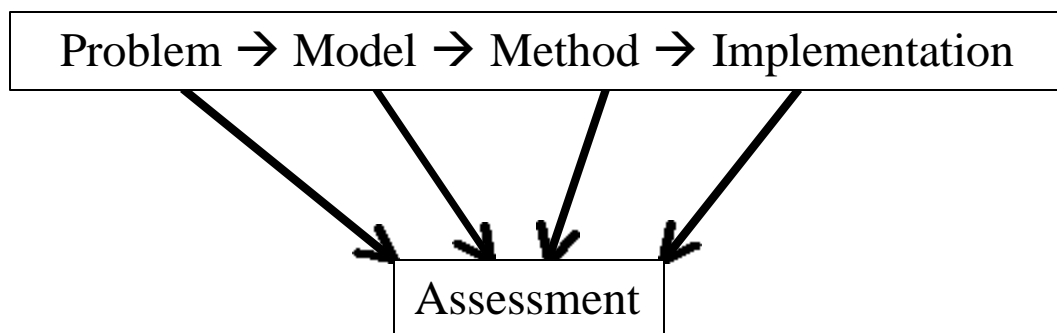
- ❑ Guided inquiry (or structured inquiry) can be used in the classroom or laboratory. In the classroom, students may be supplied with data or observe a demonstration. Through discussion in class and/or through investigating outside resources, the students learn about the modeling and computational techniques. It can be particularly intriguing to supply students with an anomalous or counter-intuitive example. In some modules, students begin by observing something interesting or generating some data. They must then discover the scientific principles behind their observations – it is this process of discovery that necessitates the use of computational tools.
- ❑ Open-ended inquiry emphasizes the process of doing science. The instructor does not have a specific outcome in mind, but rather sets up a situation where students can be creative while learning science. An open-ended question would encourage students to use both their prior knowledge and outside resources to investigate an area of interest. In the computer laboratory, students may begin by proposing a question they would like to investigate, designing experiments, collecting the necessary data, analyzing the data, and defending their results. Students are evaluated on how well they have completed the steps of the process, not on whether they got a specific result in the experiment.
- ❑ Cooperative learning (or collaborative learning) involves carefully structured group activities. The activity is structured so that group members are interdependent (they must all participate to succeed) and individually accountable (all members are responsible for learning). Part of the structure includes an evaluation that allows the students to reflect on what worked well in the group, what didn't, and how the group process could be improved. Careful structure is the key to the success of a cooperative activity.
- ❑ The interactive classroom encourages active participation of students, interaction between students, and interaction between faculty and students. Some examples are:
  - In-class problem solving in small groups.
  - Turn-to-your-neighbor activities (explain what you observed in the demo, summarize the key points that have been covered, etc.).
  - Getting students up front (to solve a problem on the board, to participate in a demo).

- Two-minute paper (can be used at the end of class to assess what questions the students still have, good for providing instructor with feedback).
- ❑ Writing to learn. Many of these activities come from the writing-across-the-curriculum movement. Some examples are:
  - Write what you know about... (used to get students thinking about a topic, to assess student's prior knowledge, and to document the student learning process).
  - Journal-keeping.
  - Two-minute paper (used to get quick feedback from students about their concerns or questions).
- ❑ Lecture can be used when students have questions they need an "expert" to answer. That expert does not have to be the instructor, but could be one of the students in the class or an outside consultant. Lectures can also be used to motivate and develop enthusiasm.
- ❑ Concept-mapping is useful for helping students make explicit connections between the things they're learning. According to Ruiz-Primo and Shavelson (1996): “A concept map is a graph consisting of nodes representing concepts and labeled lines denoting the relation between a pair of nodes. A student's concept map is interpreted as representing important aspects of the organization of concepts in his or her memory (cognitive structure).” Students link together concepts with "logical connectors" that explain the relationships between the concepts. This may be particularly useful in helping students make connections between their own experiences and the computational science they are learning in the classroom. There is some empirical evidence that concept-mapping “effectively promotes meaningful learning and metacognition” (Materna, 2001 see also, Ruiz-Primo, Shavelson, Li, & Schultz, 2001).
- ❑ In-class debates allow students to practice using scientific arguments to support and defend a stance they may take.

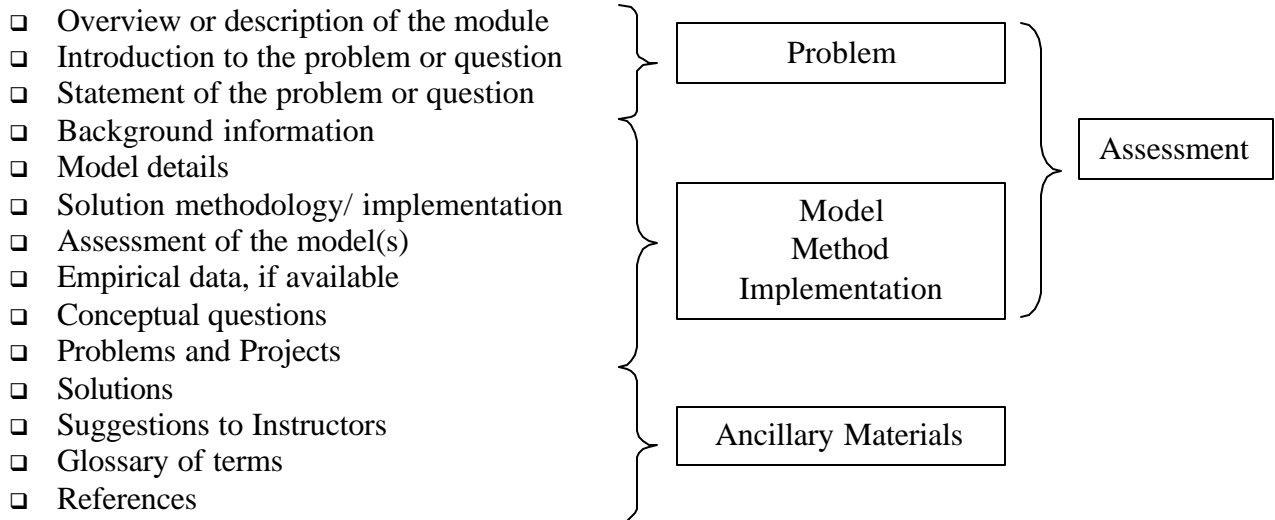
### What is a module? An Overview.

For most courses, a module will be grounded in a story that asks an important question and entices students into wanting to know the answer. The questions should be answerable through computational science techniques.

We conceptualize a module in the following way:



The module includes the following sections. When you author the materials, each of these sections should be under its own heading and each section is described in more detail below.



Class sessions explore various aspects of the overall question by breaking it down into essential sub-questions. Students work with relevant information through a variety of activities (e.g., in class, in the laboratory, with media, and as homework) to develop an answer to the immediate question. The module should culminate in a product such as a paper, poster presentation, debate, or experiment that provides an opportunity for students to communicate their solution to their peers.

Modules should be flexible so that they can be imported into a wide variety of courses and can accommodate a variety of teaching and learning environments. While some of the models will build upon material learned in earlier modules, there should be some modules that are independent.

### **Everything You Ever Wanted to Know about the Guts of a Module.**

#### *Overview or description of the module including the prerequisite knowledge*

Consider this an executive summary of the module. Clearly state the goals and objectives of this module for students – write the module goals and objectives in a way that facilitates evaluation of their attainment. Be specific without creating a laundry list of concepts. Identify what the students should expect to learn and, where appropriate, how this module is connected to other modules in the course and/ or other modules in other courses. For example, in the course *Computational and Applied Mathematics* students learn about the analytic and numeric methodologies for solving differential equations (i.e., numeric solutions for PDEs). They encounter this again in the groundwater-modeling module within *Computational Environmental Science*. This connection should be made explicit so that both students and instructors can begin to generalize to new situations the tools and techniques they learn. Common connections will probably be between elective courses (*Computational X* courses) and core courses such as *Computational and Applied Mathematics*, *Computational Science I & II*, and *Scientific*

*Visualization.* This section should also indicate the intended audience for the module and where it might typically fall in a sequence of courses in your discipline.

As you write this section, consider the following questions:

- ❑ Is the course in which I am going to use the module for a general science audience or for specific science majors?
- ❑ How many computational science, science, and mathematics courses should students have had prior to this course? Provide a short list of the basic concepts students need before taking the course. This should not be a list of concepts covered in your module.
- ❑ Do I envision using the module as a stand-alone component within the course, as an integrated component of the course, or as an add-on to the course?
- ❑ Do I intend to use the module in the classroom, in the laboratory, or in both?
- ❑ Where in the course do I intend to use the module? (e.g., beginning, end, an intermediate point, or throughout as part of an integrating theme or framework for the course)
- ❑ What resource/background material will students need to make sense of the material in the module?
- ❑ What knowledge should students have by the end of the module?

#### *Introduction to the problem or question*

This is the story. The module question, and its accompanying story line, provides a contextual framework and springboard for guided inquiry and exploration. The module story line is held together by a series of sub-questions. This template provides a simple structure for inquiry that conveys the module story line, its organization, and the direction of the associated inquiry. Variation is expected in how the inquiry is done between and within modules.

#### *Statement of the problem or question*

The problem or question flows from the story. The problem or question provides a context for understanding and applying specific computational science concepts.

#### *Background information – scientific, mathematical, and computer, where appropriate*

This section should provide adequate background for students to follow construction of the model. Some examples:

- ❑ When exploring a groundwater model, students must learn about the local geology, become familiar with appropriate terminology, and review the mathematical methods to be used. This module would be linked to appropriate modules in a course on mathematical modeling and/or *Computational and Applied Mathematics*.
- ❑ For the module on the spread of disease, students acquire background in epidemiology and the appropriate terminology.
- ❑ For the module on brain mapping in a *Computational Neuroscience and Psychology* course, students review brain structure and function, needed mathematical concepts (i.e., matrix algebra), and techniques from *Scientific Visualization*.

*Explanation of the model(s) used to solve the problem or answer the question*

A step-by-step creation and rationale of the mathematical and computational model(s). Include definitions of the variables, interrelationships among variables, and how those relationships are expressed mathematically.

*Solution methodology/ implementation*

A mathematical analysis, or the solution process, and the selection/ rationale for the appropriate computational technique(s). Use of appropriate software packages for the implementation and visualization of the solution. Authoring of code, where appropriate.

*Assessment of how well the model solves the problem or answers the question*

Students should understand that a model is only as good as the assumptions that underlie it and the data used to construct the model. To determine the value of the model, students should compare the predicted values of the model with actual data (if available) or with theoretical predictions. Consider employing a variety of techniques for assessing the model. Projects can flow out of the students' assessment as they determine when the predicted values don't match with actual data. Students should consider how the simplifying assumptions affected the model predictions and how the assumptions should be refined to acquire a better fit between predicted and actual values.

*Empirical data*

Whenever possible, provide sample data, plots and figures, or outline a method for having students collect such data. These data will be used to assess the validity of the model(s) that they produce.

*Conceptual questions to examine student's understanding of the material*

This section includes a selection of questions appropriate for end-of-module and/or end-of-course assessment. Include some in a format that can be easily graded. For example, common student responses to an open-ended question can be converted into the choices for a multiple-choice question, perhaps with a follow-up question asking students to justify the answer they selected. Where possible, include questions with links to other modules.

*Problems and projects*

Provide a number of practice problems/questions using computational science skills and thinking skills developed in the module. These are likely to be used for homework.

The module ends with a culminating activity, often project-based, for assessment of student learning of computational science concepts and/or scientific thinking skills. Full written reports should be expected for more involved homework and projects. In these reports, students should

explain all of the steps of the solution methodology and assessment – this will provide an opportunity to sharpen their technical writing skills.

As you develop problems and projects for the module, keep in mind four of the goals of the project:

- ❑ To emphasize an interdisciplinary, team-based approach to science problem solving
- ❑ To cultivate undergraduates' understanding of the creative nature of computational science
- ❑ To improve written and oral communication related to scientific and technical projects
- ❑ To facilitate student use of current and emerging computing technologies

### *Solutions*

These will be supplied to the instructors who choose to adopt the materials. Keep in mind that some of the conceptual questions, problems, and projects may have more than one answer. These solutions should clearly indicate the steps toward the assigned problem solutions. Include software or model output along with the answer documentation.

### *Suggestions to instructors for using the module*

Include a brief paragraph that emphasizes the importance of planning ahead and of choosing a pathway through the module that is appropriate for students. Demonstrating via a course calendar how to schedule class time and out-of-class assignments will facilitate adoption by other institutions. Include a brief description of the course format and how the module fits into the course as a whole. Note that instructors will need to generate a syllabus or schedule for their own students; here you provide a few models to convey the need for such a student guide and the range of time periods and approaches possible for a single module. You may provide an annotated list of exceptionally useful materials related to the module: books, articles, web sites, special collections of data, etc. One to two pages – be realistic and choose the few items most useful to instructors.

### *Glossary of terms*

Provide a list of new or important terms with appropriate definitions for students.

### *References – both cited and for additional reading*

Include a list of original references to journal articles, books, reports, and websites required as background reading for the module. Suggest background textbook reading about science, mathematics, or computer concepts covered in the module.

### **Tips, Tricks, and Traps.**

- ❑ Developing a module is a dynamic process that may lead to minor or major changes in the initial design. As the team members, outside evaluators, and students review the materials you create, they may suggest refining small or large components of your work. Because the

goal is to create the best materials that we can, you should consider the suggestions that others provide a blessing, and not an attack on your work... in other words, go with the flow.

- ❑ When including computer code, be sure to fully document the code so that students and less experienced instructors will understand the purpose of the commands.
- ❑ Avoid using highly specialized software, particularly expensive packages – dissemination of the materials will be greater with software that is either widely available or relative inexpensive.
- ❑ Avoid extensive formatting of the documents that you author.
  - Using a common word processing package (i.e., Word or WordPerfect) will make it easier for student workers to convert the files to PDF (and any other formats we select) and will make it less likely that information is lost in the conversion process.
  - Use Times New Roman for the font throughout the module.
  - Main titles should be in 18-point font and centered with one additional line both above and below.
  - Subtitles should be in 16-point font and left justified with one additional line both above and below.
  - Text should be in 12-point font, single spaced and left justified paragraphs with a blank line separating each paragraph. Do not indent the first line of the paragraph.
  - Equations should be centered and numbered, if appropriate – use Math Type
  - Include diagrams, graphs, and images in digital form and embedded within the text document
- ❑ See **Appendix C** for software used in the Capital University Computational Science program and for additional information concerning web resources on computational science.

### **Assessment, Assessment, Assessment. (Oh, did I mention assessment?)**

Although many faculty cringe at the thought of having to do assessment, for the purposes of this project, you should consider assessment to be an integral component for ensuring high quality materials.

For all modules, two types of evaluation (formative and summative) will occur in three overlapping phase: *Phase one*: Developed materials will be reviewed by co-PIs within the same discipline or who are creating materials for the same course. *Phase two*: an Evaluation Team of national experts will review developed materials. *Phase three*: Developed and reviewed materials will be class tested. The purpose of the formative evaluation is to assess the development of the modules (*phases one and two*). The purpose of the summative evaluation is to determine the effectiveness of the developed modules (*phase three*). The goal for the assessment is to engage in a reflective conversation with each other, with the outside evaluators and with our students.

A matrix of evaluation activities and assessment materials appears in **Appendix A**. This matrix includes the evaluation questions, methods of data collection, timing of evaluation activities, and the type of evaluation. The assessment materials provided in **Appendix A** were originally developed by professional evaluators to assess the Computational Science materials developed

for Capital University's NSF CCLI grant (DUE 9952806); these assessment materials have been modified to accommodate the needs of this project.

### **Dissemination.**

All developed materials will clearly identify the contributions of the W.M. Keck Foundation. Course materials will be platform independent and available in multiple versions (computer languages, computer algebra systems), thus encouraging a wide national impact. The modular approach increases their ease for adoption as either a whole course or a subset of modules depending on the hardware and software availability at the adopting institution.

Dissemination will occur in three overlapping stages. The *first stage* will begin within the granting period. All authored materials will be Web-based. A dedicated web site will be built for depositing the materials and will include a statement of the W. M. Keck Foundation's contributions to the project.

The *second stage* of dissemination will begin once materials have been created. This will involve presenting our model materials and organizing workshops at national academic conferences and disciplinary societies. At each of these presentations, the W. M. Keck Foundation will be acknowledged as a major contributor to the project. The presentations and workshops at national meetings of the various mathematics and science societies will focus on the innovative materials and the aspects of the comprehensive Computational Science curriculum.

During the *third stage* of dissemination, co-PIs will author articles about the developed materials to be submitted to peer-reviewed, pedagogical journals. Support of the W. M. Keck Foundation will be acknowledged in each of these manuscripts.

### **Timeline for Activities.**

The timeline for activities can be found in **Appendix B**.

## Appendix A. Assessment

<b>Summary Matrix of Assessment and Evaluation</b>				
Question	Data Collection Method	Respondents	Schedule	Eval. Type *
Do the materials facilitate students' understanding of computational science concepts and procedures?	Review of course materials	Evaluators	Prior to using materials	F
	Questionnaire	Students	During class testing	S
Do the materials reflect the interdisciplinary nature of computational science?	Review of course material	Evaluators	Prior to using materials	F
	Questionnaire	Students	During class testing	S
Do the materials facilitate students' ability to work effectively and solve problems in small groups?	Questionnaire	Students	During class testing	S
Do the materials facilitate student use of current and emerging technology?	Review of course materials	Evaluators	Prior to using materials	F
	Questionnaire	Students	During class testing	S
Do the materials stimulate critical thinking?	Review of course materials	Evaluators	Prior to using materials	F
Do the materials provide exercises that require oral and/or written communication related to scientific and technical projects?	Review of course materials	Evaluators	Prior to using materials	F
How have students' attitudes toward science, math, and computing changed?	Questionnaire	Students	During class testing	S

\* *Evaluation Type: F = Formative: addresses the development of the project, S = Summative: addresses the outcome of the project*

**Student Questionnaire: Pretest**

*Please use the 7-point scale to indicate your agreement or disagreement with each statement.*

		<i>strongly disagree</i>									<i>not applicable</i>	<i>don't know</i>
		<i>disagree</i>	<i>neutral</i>	<i>agree</i>	<i>strongly agree</i>							
<b>BELIEFS</b>												
<b>1</b>	Generally, I feel secure about attempting computer science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>2</b>	I study computer science because I know how useful it is.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>3</b>	Knowing computer science will help me earn a living.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>4</b>	I am sure I can do advanced work in computer science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>5</b>	Generally, I feel secure about attempting mathematics.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>6</b>	I study mathematics because I know how useful it is.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>7</b>	Knowing mathematics will help me earn a living.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>8</b>	I am sure I can do advanced work in mathematics.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>9</b>	Generally, I feel secure about attempting science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>10</b>	I study science because I know how useful it is.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>11</b>	Knowing science will help me earn a living.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>12</b>	I am sure I can do advanced work in science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>13</b>	Generally, I feel secure about attempting computational science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>14</b>	I study computational science because I know how useful it is.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>15</b>	Knowing computational science will help me earn a living.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>16</b>	I am sure I can do advanced work in computational science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>
<b>17</b>	I have a good understanding of what computational scientists do.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>					<b>N/A</b>	<b>DK</b>

		<i>strongly disagree</i>	<i>disagree</i>	<i>neutral</i>	<i>agree</i>	<i>strongly agree</i>	not applicable	don't know
<b>18</b>	It is clear to me how computational science is connected to other disciplines like math, sciences and computer science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>19</b>	Computational science is relevant to real world issues.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>20</b>	I understand the methods of computational science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>21</b>	I enjoy working in groups.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>22</b>	When I am working in a group, I am comfortable in a leadership role.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>23</b>	When I am working in a group, I usually participate actively.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>24</b>	When I am working in a group, I feel that I have important things to say.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>25</b>	I feel that my contribution to group work is valued by the other members of the group.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>

**PART 2: Background Information**

- 26** What is your age? \_\_\_\_\_
- 27** Which of the following represents your year in college?
  - 1. First year
  - 2. Sophomore
  - 3. Junior
  - 4. Senior
  - 5. Senior +1
  - 6. Graduate Student
  - 7. Post-professional degree
- 28** What is your gender?    1. Female                      2. Male
- 29** What is your intended major? (please choose only one)
  - 1. Biology
  - 2. Chemistry
  - 3. Computer science
  - 4. Education

- 5. Environmental science
- 6. Finance
- 7. Geology
- 8. Mathematics
- 9. Psychology
- 10. Physics
- 11. Other

**30** What is the field of your intended career? (please choose only one)

- 1. Science / Engineering
- 2. Medical / Dental / Other Health Care
- 3. Teaching K-12
- 4. Business / Policy
- 5. Social sciences
- 6. Humanities / Arts
- 7. Undecided/Other

**31** How many college computational science courses had you taken before this one?

- 1. 1 course
- 2. 2 courses
- 3. 3 courses
- 4. 4 or more courses
- 5. 0 courses

**32** How many more computational science courses do you plan to take?

- 1. 1
- 2. 2
- 3. 3
- 4. 4
- 5. 5
- 6. 6 or more
- 7. 0

**33** How many more courses do you plan to take in math and science?

- 1. 1
- 2. 2
- 3. 3
- 4. 4
- 5. 5
- 6. 6 or more
- 7. 0

**34** What are the last 5 digits of your student ID number? \_\_\_\_\_

**Student Questionnaire: Posttest**

*Please use the 7-point scale to indicate your agreement or disagreement with each statement.*

<b>BELIEFS</b>		<i>strongly disagree</i>	<i>disagree</i>	<i>neutral</i>	<i>agree</i>	<i>strongly agree</i>	not applicable	don't know
<b>1</b>	Generally, I feel secure about attempting computer science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>2</b>	I study computer science because I know how useful it is.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>3</b>	Knowing computer science will help me earn a living.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>4</b>	I am sure I can do advanced work in computer science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>5</b>	Generally, I feel secure about attempting mathematics.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>6</b>	I study mathematics because I know how useful it is.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>7</b>	Knowing mathematics will help me earn a living.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>8</b>	I am sure I can do advanced work in mathematics.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>9</b>	Generally, I feel secure about attempting science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>10</b>	I study science because I know how useful it is.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>11</b>	Knowing science will help me earn a living.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>12</b>	I am sure I can do advanced work in science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>13</b>	Generally, I feel secure about attempting computational science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>14</b>	I study computational science because I know how useful it is.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>15</b>	Knowing computational science will help me earn a living.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>16</b>	I am sure I can do advanced work in computational science.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>17</b>	I have a good understanding of what computational scientists do.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>

		<i>strongly disagree</i>	<i>disagree</i>	<i>neutral</i>	<i>agree</i>	<i>strongly agree</i>	not applicable	don't know
<b>18</b>	It is clear to me how computational science is connected to other disciplines like math, sciences and computer science.	1	2	3	4	5	N/A	DK
<b>19</b>	Computational science is relevant to real world issues.	1	2	3	4	5	N/A	DK
<b>20</b>	I understand the methods of computational science.	1	2	3	4	5	N/A	DK
<b>21</b>	I enjoy working in groups.	1	2	3	4	5	N/A	DK
<b>22</b>	When I am working in a group, I am comfortable in a leadership role.	1	2	3	4	5	N/A	DK
<b>23</b>	When I am working in a group, I usually participate actively.	1	2	3	4	5	N/A	DK
<b>24</b>	When I am working in a group, I feel that I have important things to say.	1	2	3	4	5	N/A	DK
<b>25</b>	I feel that my contribution to group work is valued by the other members of the group.	1	2	3	4	5	N/A	DK
<b>SKILLS AND ABILITIES</b>								
<b>26</b>	This course helped me gain abilities in giving oral presentations.	1	2	3	4	5	N/A	DK
<b>27</b>	This course helped me gain an understanding of the main concepts of computational science (i.e., math, science, and computing).	1	2	3	4	5	N/A	DK
<b>28</b>	This course focused on answering real world questions	1	2	3	4	5	N/A	DK
<b>29</b>	This course was organized so that we were encouraged to discuss ideas.	1	2	3	4	5	N/A	DK
<b>30</b>	The structure of this course enabled me to discover some of the ideas of computational science for myself.	1	2	3	4	5	N/A	DK
<b>31</b>	This course provided opportunities for me to construct models.	1	2	3	4	5	N/A	DK

<b>LEARNING</b>						strongly disagree	disagree	neutral	agree	strongly agree	not applicable	don't know
	1	2	3	4	5							
32 Student presentations in this course helped my learning.	1	2	3	4	5	N/A	DK					
33 Instructor presentations in this course helped my learning.	1	2	3	4	5	N/A	DK					
34 Discussions in this class helped my learning.	1	2	3	4	5	N/A	DK					
35 Hands-on activities in this class helped my learning.	1	2	3	4	5	N/A	DK					
36 Written assignments in this class helped my learning	1	2	3	4	5	N/A	DK					
37 Reading materials that the instructor created helped my learning	1	2	3	4	5	N/A	DK					
38 Other reading materials helped my learning	1	2	3	4	5	N/A	DK					
39 The feedback we got helped my learning	1	2	3	4	5	N/A	DK					
40 I understood why we did each module	1	2	3	4	5	N/A	DK					
41 I understood most of the ideas presented in this course.	1	2	3	4	5	N/A	DK					
42 By the end of this course, I felt able to apply the concepts presented.	1	2	3	4	5	N/A	DK					
43 This course helped me get better at seeing alternative approaches to a problem.	1	2	3	4	5	N/A	DK					
44 This course helped me feel more comfortable with the idea that some questions have no single right answer.	1	2	3	4	5	N/A	DK					
45 I enjoyed taking this computational science course	1	2	3	4	5	N/A	DK					

## **PART 2: Background Information**

- 46 What is your age? \_\_\_\_\_
- 47 Which of the following represents your year in college?
1. First year
  2. Sophomore
  3. Junior
  4. Senior

- 5. Senior +1
- 6. Graduate Student
- 7. Post-professional degree

**48** What is your gender?

- 1. Female
- 2. Male

**49** What is your intended major? (please choose only one)

- 1. Biology
- 2. Chemistry
- 3. Computer science
- 4. Education
- 5. Environmental science
- 6. Finance
- 7. Geology
- 8. Mathematics
- 9. Psychology
- 10. Physics
- 11. Other

**50** What is the field of your intended career? (please choose only one)

- 1. Science / Engineering
- 2. Medical / Dental / Other Health Care
- 3. Teaching K-12
- 4. Business / Policy
- 5. Social sciences
- 6. Humanities / Arts
- 7. Undecided/Other

**51** How many college computational science courses had you taken before this one?

- 1. 1 course
- 2. 2 courses
- 3. 3 courses
- 4. 4 or more courses
- 5. 0 courses

**52** How many more computational science courses do you plan to take?

- 1. 1
- 2. 2
- 3. 3
- 4. 4
- 5. 5
- 6. 6 or more
- 7. 0

**53** How many more courses do you plan to take in math and science?

- 1. 1
- 2. 2
- 3. 3
- 4. 4
- 5. 5
- 6. 6 or more
- 7. 0

**54** What are the last 5 digits of your student ID number? \_\_\_\_\_

**Evaluation of Materials (To be completed by Co-PIs and Evaluation Team)**

Date \_\_\_\_\_

Module Title \_\_\_\_\_

*Please use the 7-point scale to indicate your agreement or disagreement with each statement.*

		strongly disagree	disagree	neutral	agree	strongly agree	not applicable	don't know
<b>CONTENT</b>								
<b>1</b>	All sections are clearly identified.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>2</b>	Objectives of the module are clearly stated.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>3</b>	The software employed is NOT outdated.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>4</b>	All resources that are cited give credit to the author.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>5</b>	The materials provide the reader with avenues for further research.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>6</b>	The information within the module is consistent with the stated objectives of the module.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>7</b>	The information is organized such that it will be easily understood by students.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>8</b>	The content of linked sites is worthwhile and appropriate.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>9</b>	The course content is free of bias (i.e., sexual, racial, or ethnic, etc).	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>10</b>	A contact person or address is identified for the module.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>CONTENT VALIDITY</b>								
<b>11</b>	The scientific information for the course is accurate.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>12</b>	The mathematical information for the course is accurate.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>13</b>	Charts and/ or graphs are clearly labeled and easy to read.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>
<b>14</b>	Charts and/ or graphics aid in reaching the stated objectives for the course.	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>N/A</b>	<b>DK</b>

- |           |   |          |          |          |          |          |            |           |
|-----------|---|----------|----------|----------|----------|----------|------------|-----------|
| <b>15</b> | The source of data is referenced.   | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>N/A</b> | <b>DK</b> |
| <b>16</b> | The information is free of grammatical, spelling, and other typographical errors. | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>N/A</b> | <b>DK</b> |

#### **AUDIENCE ENGAGEMENT**

- |           |   |          |          |          |          |          |            |           |
|-----------|---|----------|----------|----------|----------|----------|------------|-----------|
| <b>17</b> | The module content promotes inquiry learning.   | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>N/A</b> | <b>DK</b> |
| <b>18</b> | Students are encouraged to think and reflect.   | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>N/A</b> | <b>DK</b> |
| <b>19</b> | Critical thinking skills are needed to analyze and synthesize information.                                    | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>N/A</b> | <b>DK</b> |
| <b>20</b> | Students are encouraged to continue exploration and research with additional hypertext links on the web site. | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>N/A</b> | <b>DK</b> |
| <b>21</b> | When appropriate to the module, data sharing with other students is encouraged.                               | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>N/A</b> | <b>DK</b> |

**22** Please provide other comments, questions, or suggestions:

## Appendix B. Timetable for Implementation

<b>PHASE I</b>			
<b>Timeline</b>	<b>Activity</b>	<b>Course</b>	<b>Personnel</b>
May 2002	Meeting to refine format of materials/ coordinate efforts.		All Co-PIs
June/ July 2002	Material Development		
	Vector Spaces and Subspaces	<i>C &amp; A Math</i>	Baker
	Statistical Mechanics	<i>Comp Chem</i>	Baldrige
	Tools for Genomics, Proteomics	<i>Comp Chem/ Bio</i>	Becktel
	Gene Finding	<i>Comp Bio</i>	Daniels
	Pattern Formation in Biological Systems and Stochastic Models of Cell Growth	<i>Comp Sci II</i>	de Pillis & Radunskaya
	Thermal Conduction	<i>Comp EnvGeo</i>	Grosfils
	Modeling Temporal Aspects of Behavior	<i>Comp N &amp; P</i>	Karkowski
	Spatial Data Analysis in Environmental Science	<i>Comp EnvGeo</i>	Lahm
	Volume Visualization	<i>Sci Vis</i>	Machiraju
	Friction and Faulting	<i>Comp EnvGeo</i>	Reinen
	Mathematics in Neurophysiology	<i>Comp Bio/N &amp; P</i>	Romstedt
	Atomic Structure of Single Electron Elements	<i>Comp Phys</i>	Shields
	Simulation of Animal Behavior in Searching for Food	<i>C &amp; A Math</i>	Shiflet & Shiflet
		<i>Comp N &amp; P/ Bio</i>	
	Image Reconstruction in Image Tomography	<i>Comp Sci II</i>	Soares
		<i>C &amp; A Math</i>	
	Performance for Steady-state Heat Diffusion with LAPACK, I	<i>Par &amp; HP</i>	Stewart
	Flood Prediction	<i>Comp EvnGeo</i>	Thorbjarnarson
	Artificial Neural Networks	<i>Comp N &amp; P</i>	Torello
	Elementary PDEs: From Analytic to Numerical Techniques	<i>C &amp; A Math</i>	Vakalis
August 2002	Evaluators review developed materials		Evaluators
<b>PHASE II</b>			
<b>Timeline</b>	<b>Activity</b>	<b>Course</b>	<b>Personnel</b>
Sep '02 – May '03	Class testing and dissemination of materials		All co PIs
	Material Development (1/2 the module developed)		
	Eigenvalues and Eigenvectors	<i>C &amp; A Math</i>	Baker
	Visualizing Protein Structures and Computing Properties	<i>Comp Chem/ Bio</i>	Becktel
	Modeling Tumor-Immune Interactions	<i>Comp Bio</i>	de Pillis & Radunskaya
		<i>Comp Sci II</i>	
	Thermal Conduction, Part II	<i>Comp EnvGeo</i>	Grosfils
	Scheduled Reinforcement Contingencies of Behavior	<i>Comp N &amp; P</i>	Karkowski
	Watershed Data Analysis and Visualization	<i>Comp EnvGeo</i>	Lahm
	Cash Flow Analysis	<i>Comp Fin</i>	Lawson
	Friction and Faulting, Part II	<i>Comp EnvGeo</i>	Reinen
	Diffusion Across Cell Membranes	<i>Comp Bio</i>	Romstedt
	Electrostatic Potentials Using the Laplace Equation	<i>Comp Phys</i>	Shields
	Modeling Blood Cell Population	<i>C &amp; A Math</i>	Shiflet & Shiflet
		<i>Comp Bio</i>	
	Principal Component Analysis of Satellite Imagery	<i>Comp Sci II</i>	Soares
	Performance for Steady-state Heat Diffusion with LAPACK, III	<i>Par &amp; HP</i>	Stewart
	Modeling Aggression	<i>Comp N &amp; P</i>	Torello
	Parallel Shortest Path Algorithms on Distributed Memory	<i>Par &amp; HP</i>	Vakalis
	Machines: A Comparative Analysis & Calculating the Electrostatic Potential in Parallel		
May 2003	Creation of Annual Report		Vakalis & Karkowski

<b>PHASE III</b>			
<b>Timeline</b>	<b>Activity</b>		<b>Personnel</b>
June/ July 2003	Material Development		
	Linear Transformations & Curve Fitting	<i>C &amp; A Math</i>	Baker
	Quantum Mechanics and Kinetics	<i>Comp Chem/Phys</i>	Baldrige
	Predicting Protein Structure and Function from Sequence	<i>Comp Chem/Bio</i>	Becktel
	Gene Identification	<i>Comp Bio</i>	Daniels
	Optimizing Chemotherapy Protocols with Dynamic Programming and Genetic Algorithms	<i>Comp Bio</i>	de Pillis & Radunskaya
	Volcanic Ballistic Trajectories	<i>Comp EnvGeo</i>	Grosfils
	Extension of Groundwater Flow Modeling	<i>Comp EnvGeo</i>	Lahm
	Imaging Pipeline	<i>Sci Vis</i>	Machiraju
	Object-Order Projection Visualization	<i>Sci Vis</i>	Reed
	The Influence of Mechanical Layering in Rock Deformation	<i>Comp EnvGeo</i>	Reinen
	Gas Exchange in Living Systems	<i>Comp Bio</i>	Romstedt
	Diffusion-limited Aggregation	<i>Comp Phys</i>	Shields
	Tomography	<i>C &amp; A Math</i> <i>Comp Sci II</i>	Shiflet & Shiflet
	Image Reconstruction in Emission Tomography: Iterative Inversion	<i>Comp Sci II</i>	Soares
	Performance for Steady-state Heat Diffusion with LAPACK, II	<i>Par &amp; HP</i>	Stewart
	Environmental Pollution	<i>Comp EnvGeo</i>	Thorbjarnarson
	Neural Networks: Applications in the Behavioral Sciences	<i>Comp N &amp; P</i>	Torello
	Modeling Traffic Flow	<i>Comp Sci II</i>	Vakalis
August 2003	Evaluators review developed materials		Evaluators
<b>PHASE IV</b>			
<b>Timeline</b>	<b>Activity</b>	<b>Course</b>	<b>Personnel</b>
Sep '03 – May '04	Class testing and dissemination of materials		All co PIs
	Material Development (1/2 the module developed)		
	Fourier Series	<i>C &amp; A Math</i>	Baker
	Visualizing Protein Structures and Computing Structural Properties	<i>Comp Chem/Bio</i>	Becktel
	Using Fourier Transforms to Understand Heart Conditions	<i>Comp Bio</i>	de Pillis & Radunskaya
	Volcanic Ballistic Trajectories, Part II	<i>Comp Geo</i>	Grosfils
	Modeling Scheduled Reinforcement Contingencies of Behavior	<i>Comp N &amp; P</i>	Karkowski
	Watershed Data Analysis and Visualization	<i>Comp Env</i>	Lahm
	Option Pricing	<i>Comp Fin</i>	Lawson
	The Influence of Mechanical Layering in Rock Deformation, II	<i>Comp Geo</i>	Reinen
	Diffusion Across Cell Membranes	<i>Comp Bio</i>	Romstedt
	Electrostatic Potentials Using the Laplace Equation	<i>Comp Phys</i>	Shields
	Modeling Blood Cell Population	<i>C &amp; A Math</i> <i>Comp Bio</i>	Shiflet & Shiflet
	Processing Images Corrupted by Noise and Its Relation to Signal Detection	<i>Comp Sci II</i>	Soares
	Performance for Steady-state Heat Diffusion with LAPACK, III	<i>Par &amp; HP</i>	Stewart
	Modeling Aggression	<i>Comp N &amp; P</i>	Torello
	Diffusion in Biology & Pharmacokinetics: Analysis of Drug Distribution in Living Organisms	<i>Comp Sci II</i>	Vakalis
<b>PHASE V</b>			
<b>Timeline</b>	<b>Activity</b>		<b>Personnel</b>
June 2004	Meeting to: <ul style="list-style-type: none"> <li>Report what was completed during the year</li> <li>Conduct final evaluation</li> <li>Final revision of modules and updates to consortium web site</li> </ul>		All Co-PIs and Evaluators
	Creation of Final Report		Vakalis & Karkowski

## Appendix C. Resources for Computational Science

### Partial List of Software used in Capital University's Computational Science Program

Software	Description
<b>General Proprietary Software</b>	
Maple ® <a href="http://www.maplesoft.com/">Http://www.maplesoft.com/</a>	Maple is a powerful symbolic mathematical solver
Mathematica ® <a href="http://www.wolfram.com/">http://www.wolfram.com/</a>	Mathematica is the integrated technical computing system for both numeric and symbolic calculations, visualization tools, and a complete programming environment.
MatLab ® <a href="http://www.mathworks.com/">http://www.mathworks.com/</a>	MATLAB integrates mathematical computing, visualization, and a language to provide technical computing.
Spreadsheets – Excel ®	Ubiquitous in many PC environments and allows for solution of statistical and computational problems.
STELLA ® <a href="http://www.hps-inc.com/">http://www.hps-inc.com/</a>	An icon-based model building and simulation tool using system modeling approach.
<b>Public Domain Software</b>	
VTK ® <a href="http://public.kitware.com/vtkhtml/index.html">http://public.kitware.com/vtkhtml/index.html</a>	The Visualization ToolKit (VTK) is an open source, freely available software system for 3D computer graphics, image processing, and visualization.
Python ® <a href="http://www.python.org/">http://www.python.org/</a>	Python is a programming language. It has efficient high-level data structures and a simple but effective approach to object-oriented programming.
US Geological Survey <a href="http://water.usgs.gov/software/">http://water.usgs.gov/software/</a>	Water Resource Application Software -- Public domain software for Environmental Science and Geology.
<b>Specialized Proprietary Software</b>	
AVS/Express ® <a href="http://www.avs.com/">http://www.avs.com/</a>	This object-oriented development system for UNIX/Linux and Windows lets you create scientific and technical visualization apps.
GIS Arc-View ® <a href="http://www.esri.com/">http://www.esri.com/</a>	Geographic Information System software
Minitab ® <a href="http://www.minitab.com/">http://www.minitab.com/</a>	Statistical analysis package
NAG ® <a href="http://www.nag.com/">http://www.nag.com/</a>	Numerical Algorithm Group Library
Surfer ® <a href="http://www.goldensoftware.com/">http://www.goldensoftware.com/</a>	Three-dimensional mapping software

### Undergraduate Programs in Computational Science

Institution	Degree Offered
Australian National University	Bachelor of Computational Science
Capital University <a href="http://capital2.capital.edu/orgs/CSAC/">http://capital2.capital.edu/orgs/CSAC/</a>	Minor in Computational Science
Carleton University	Bachelor of Computational Chemistry
Clark University	Concentration in Computational Science
Florida State University	BS in Computational Science and Information Technology
Illinois State University	BS in Computational Physics
Michigan State University	BS in Computational Mathematics
National University of Singapore	BS in Computational Science
University of Nevada, Las Vegas	BS in Computational Physics
Oregon State University	Bachelor of Computational Physics

Princeton University	Undergraduate Certificate in Applied and Computational Mathematics
Rice University	BA in Computational and Applied Mathematics
Salve Regina University	Minor in Computational Science
San Diego State University	Mathematics with emphasis in Computational Science
State University of New York Brockport	BS in Computational Science
SUNY Brockport	BS in Computational Science
Syracuse University	Minor in Computational Science
University of Buffalo (SUNY)	BS in Computational Physics
University of Chicago	BA and BS in computational and Applied Mathematics
University of Wisconsin – Eau Claire	Minor in Computational Science
University of Wisconsin – La Crosse	Minor in Computational Science
Wofford College	Emphasis in Computational Science

### Undergraduate Courses in Computational Science

Institution	Course(s) Offered
Boston University (home of the Boston Univ. Center for Computational Science, founded in 1990)	Parallel Algorithms and Programs; Introduction to Parallel Computing; Parallel Computation for Engineering; Advanced Scientific Computing in Physics; Computational Physics
California Institute of Technology	Introduction to Scientific Computing; Concurrent Scientific Computing; Introduction to Concurrent Programming; Freshman/Sophomore Computational Physics Laboratory; Algorithms and Applications of Physical Computation and Complex Systems; Advanced Computational Physics Laboratory
Duke University	Computational Methods in Biomedical Engineering
Elizabeth City State University	
Indiana University of Pennsylvania	Numerical Methods for Supercomputers
Indiana University – Purdue University at Indianapolis	Scientific Computing I; Scientific Computing II; High Performance Computing
Michigan State University	Vector and Parallel Programming
New Mexico Institute of Mining & Technology	Introduction to Parallel Processing; Introduction to High Performance Computing
North Carolina State University	
Oregon State University	Introductory Scientific Computing; Computational Physics
San Diego State University	Advanced Physical Chemistry; Chemistry on Supercomputers; Introduction to Computational Programming and Visualization; Supercomputing for the Sciences; Introduction to Computational Physics; Computational Physics; Computer Simulations in the Physical Sciences; Scientific Imaging and Visualization in the Earth Sciences
San Francisco State University	Supercomputing and Fractal Graphics
SUNY Institute of Technology at Utica	Scientific Computing
United States Naval Academy	
University of Colorado	High-Performance Scientific Computing 1 & 2
University of Houston-Downtown	Parallel Computing
University of Minnesota	Introduction to Parallel Computing; Computational Methods in the Physical Sciences I; Computational Methods in the Physical Sciences II
University of Rochester	Computational Physics I

**Graduate Programs in Computational Science**

(\* denotes specialty degrees/programs)

<b>Institution</b>	<b>Degree Offered</b>
University of Arizona	* PhD minor
Baylor College of Medicine	PhD in Structural & Computational Biology & Molecular Biophysics
University of California at Davis	* PhD in Applied Science with emphasis in Computational Science
University of California at San Diego	* PhD in Scientific Computation Graduate program in Computational Neurobiology
Carnegie Mellon University	MS in Computational Finance
Chulalongkorn University	MS in Computational Science
Clemson University	MS in Computational Science and Engineering * PhD specialty
Florida State University	MS in Computational Science and Information Technology
George Mason University	PhD in Computational Science and Informatics
George Washington University	MS in Computational Science
Georgia Tech	MS in Quantitative and Computational Finance
University of Houston	* Graduate certificate in Computational Science
University of Illinois	* PhD specialty * Graduate certificate in Computational Science & Engineering
Indiana University at Bloomington	* PhD minor in Scientific Computation
Iowa State University	PhD in Bioinformatics and Computational Biology
Louisiana State University	Dual Physics PhD/Computer Science MS
Memorial University of Newfoundland	MS in Computational Science
University of Michigan	* Joint PhD in Scientific Computing
Michigan State University	MS in Computational Chemistry
Michigan Technological University	PhD in Computational Science and Engineering
University of Minnesota	MS and PhD in Scientific Computing PhD in Computational Chemistry PhD in Computational Neuroscience
Mississippi State University	MS in Computational Engineering PhD in Computational Engineering
North Carolina State University	* MS and PhD in Scientific Computing and Computational Mathematics
Old Dominion University	* Graduate certificate in Computational Science & Engineering
University of Pennsylvania	PhD in Computational Biology
Princeton University	PhD in Applied and Computational Mathematics
Purdue University	* MS and PhD specialization in Computational Science and Engineering specialization in Computational Finance
Rensselaer Polytechnic Institute	* Graduate certificate in Computational Science & Engineering
Rice University	MS and PhD in Computational Science and Engineering MA and PhD in Computational and Applied Mathematics
San Diego State University	MS and PhD in Computational Science * Graduate certificate in Computational Science
Stanford University	MS and PhD in Scientific Computing and Computational Mathematics
State University of New York Brockport	MS in Computational Science
Swedish School of Economics and Business Administration	MS in Computational Finance
Syracuse University	MS in Computational Science * MS and PhD Certificate in Computational Science
University of Colorado, Denver	* PhD in Applied Mathematics with Computational Math option

University of Houston	* Graduate certificate in Computational Sciences
University of Minnesota	MS and PhD in Scientific Computation
The University of Texas at Austin	MS and PhD in Computational and Applied Mathematics
University of Utah	* Graduate certificate in Computational Engineering & Science
Utrecht University	MS in Computational Science
University of Wisconsin	MS in Computational Science
Worcester Polytechnic Institute	* MS and PhD specialization in Computational Engineering in Electromagnetics and Acoustics

### Graduate Courses in Computational Science

Institution	Course(s) Offered
Boston University	Advanced Computer Architecture
Colorado State University	Fundamentals of High Performance Computing; High Performance Computing and Visualization
Cornell University	Introduction to Scientific Computation; Computer Graphics and Visualization; Software Tools for Computational Science
The Ohio State University	Applications of Parallel Computers
University of Oregon	Computational Science
Vanderbilt University	Supercomputers in Scientific Computing; Computational Physics

### Undergraduate Curriculum Web Resources in Computational Science

\*\*Partial List\*\*

Resources	Description of Resources
<b>Biology WorkBench</b> <a href="http://peptide.ncsa.uiuc.edu/">http://peptide.ncsa.uiuc.edu/</a>	The goal of this project is to promote the use of molecular data in the identification and exploration of biological problems with an evolutionary perspective throughout undergraduate biology curricula.
<b>BioQuest</b> <a href="http://bioquest.org/">http://bioquest.org/</a>	Curriculum consortium to promote curriculum innovation by serving a national role as a networking resource for individuals to share, distribute, and enhance cooperation among on-going and future biology education development projects. Includes the BioQUEST Library, BQ Notes, BioQUEST Website.
<b>ChemViz</b> <a href="http://chemviz.ncsa.uiuc.edu/">http://chemviz.ncsa.uiuc.edu/</a>	Online chemistry visualization tools.
<b>CSAC at Capital</b> <a href="http://capital2.capital.edu/orgs/CSAC/">http://capital2.capital.edu/orgs/CSAC/</a>	Computational Science Across the Curriculum at Capital University. Resource for Computational Science modules at the undergraduate level in Math, Physics, Environmental Science, Behavior Sciences, Chemistry, Biology, Scientific Visualization
<b>EOT-PACI</b> <a href="http://www.eot.org/">http://www.eot.org/</a>	The mission is to develop human resources through the innovative use of emerging information technologies to understand and solve problems.
<b>Krell Institute</b> <a href="http://www.krellinst.org/">http://www.krellinst.org/</a>	Materials and links to curriculum at graduate level and K-12 in Computational Science.
<b>NPACI</b> <a href="http://www.npaci.edu/">http://www.npaci.edu/</a>	The mission of the National Partnership for Advanced Computational Infrastructure (NPACI) is to advance science by creating a ubiquitous, continuous, and pervasive national computational infrastructure: the Grid.
<b>San Diego SuperComputer Center– Computational Science Repository</b> <a href="http://www.sdsc.edu/CSR/">http://www.sdsc.edu/CSR/</a>	Repository of Computational Science curriculum
<b>Shodor Foundation</b> <a href="http://www.shodor.org/">http://www.shodor.org/</a>	The Shodor Foundation is a non-profit research and education organization dedicated to the advancement of science and math education, specifically through the use of modeling and simulation technologies.



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