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Computational Science Concept Map

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The Need for Computational Science

“The current system does not provide the broad range of interdisciplinary knowledge that tomorrow’s engineers and scientists in SBES require. **To succeed**, they must acquire **substantial depth in computational and applied mathematics**, as well as in their specific engineering or scientific disciplines.”

(SBES Report, 2006).

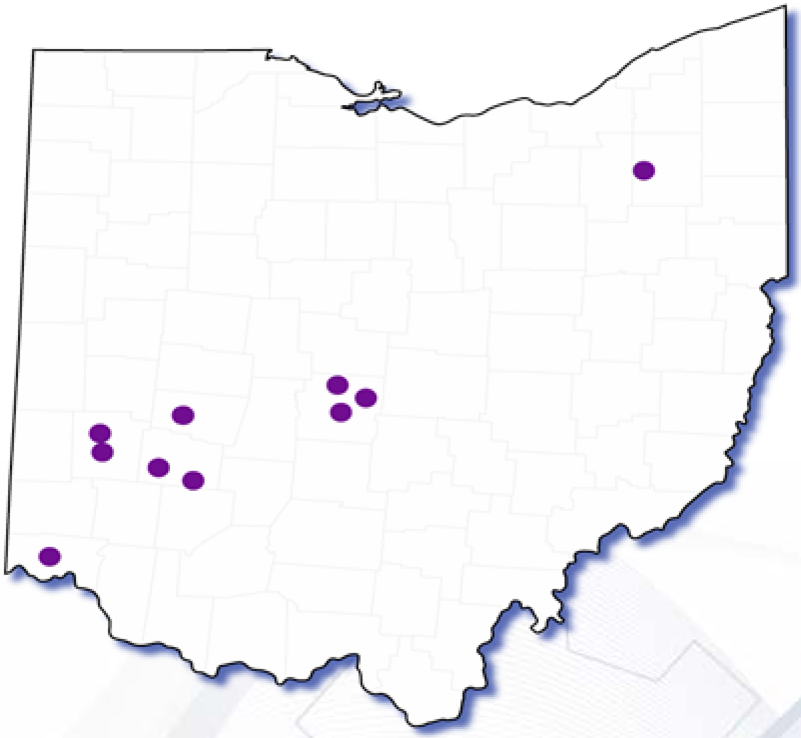
Biotechnology companies including Genentech Inc. and Gilead Sciences Inc. can't find enough scientists to hire, threatening to slow one of the industries bolstering U.S. job growth. (Financial Post Canada, May 23, 2007)

Ohio Context

- Faculty dispersed across many departments and colleges
- Faculty committed to disciplinary departments
- Only a few institutions had implemented a comprehensive program
- Existing courses taught irregularly
- Excellent potential for share program
- Strong push by the Ohio Board of Regents and industry

Undergraduate Minor Program

- **Funding from NSF**
- Participating (2 and 4 yr):
  Capital University
  Central State University
  Columbus State Community College
  Sinclair Community College
  Kent State University
  The Ohio State University
  University of Cincinnati
  Wittenberg University
  Wright State University
- **Program started-up in Autumn 2007**



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Major Conceptual Questions

- What are the minimum computational science skills that undergraduate students should have?
- How should those skills be linked to the major field?
- How should those skills be incorporated into the undergraduate curriculum?

Undergraduate Minor

- Faculty defined major competencies
- Competencies reviewed by business advisory committee
- Faculty created instructional modules
- Designed shared minor program

Competencies for Undergraduate Minor
Topic
Simulation and Modeling
Programming and Algorithms
Differential Equations and Discrete Dynamical Systems
Numerical Methods
Optimization
Parallel Programming
Scientific Visualization
One discipline specific course
Capstone Research/Internship Experience
Discipline Oriented Courses

Simulation and Modeling Competencies

- Explain the role of modeling in science and engineering
- Analyze modeling and simulation in computational science
- Create a conceptual model
- Examine various mathematical representations of functions
- Analyze issues in accuracy and precision
- Understand discrete and difference-based computer models
- Demonstrate computational programming utilizing a higher level language or modeling tool
- Assess computational models
- Complete a team-based, real-world model project
- Demonstrate technical communication

Programming and Algorithms Competencies

- Describe the fundamentals of problem solving
- Understand and write Pseudo code
- Write code in a Programming language
- Use subprograms in program design
- Use different approaches to data I/O in a program
- Understanding and use of fundamental programming Algorithms
- Explain various approaches to Program Design

Differential Equations and Discrete Dynamical Systems

- Describe the solution methodology for first order linear differential and difference equations
- Describe the solution methodology for systems of linear first order differential and difference equations
- Describe the solution methodology for differential equations using the Laplace Transforms
- Describe the solution methodology for non-linear differential equations
- Describe the solution methodology for non-linear difference equations

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Numerical Methods

- Understand number representation and computer errors
- Analyze methods for solving non-linear equations
- Describe techniques for solving systems of linear equations
- Describe interpolation and approximation methods
- Describe numerical methods for Ordinary Differential Equations
- Describe numerical methods for Partial Differential Equations
- Describe Monte Carlo Methods

Optimization

- Describe and use Optimization techniques
- Implement linear and non-linear programs

Parallel Programming

- Describe the fundamental concepts of parallel programming and related architectures
- Demonstrate parallel programming concepts using MPI
- Demonstrate knowledge of parallel scalability
- Demonstrate knowledge of parallel programming libraries and tools

Scientific Visualization

- Define SciVis needs; relationships to human visualization; basic techniques
- Overview of computer graphic concepts
- Describe approaches to visualization for different scientific problems
- Utilize software to implement grid representations of data
- Use visualization software to display an isosurface
- Use visualization software to complete a volumetric rendering
- Utilize visualization software to visualize a vector dataset
- Explore examples of image processing (several examples)

Integrated Approach

- All materials delivered using project-based learning approach
  - Encourages active learning
  - Aids in understanding complex processes and theories
- Capstone experiences
  - Computationally oriented course in major discipline
  - Research or internship experience

Detailed Information

- Minor program competencies
  - http://www.rrscs.org/minor/competencyfinal.pdf
- Current courses
  - http://www.rrscs.org/minor/courses.shtml
- General information
  - http://www.rrscs.org/minor/index.shtml

Next Steps

- Will be evaluating course materials and competencies as courses are taught
- Working on more detailed competencies for the domain courses in biology, chemistry, physics
- Will post updates and materials to the website
  - http://www.rrscs.org (probably under the minor program

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Acknowledgments

- Funding
  - National Science Foundation - SCI-0537405
  - National Science Foundation – DUE-0703087
  - Ohio Board of Regents funding from US Department of Education U215K040292
- Garrison Walters, Vice-Chancellor, Ohio Board of Regents for his foresight and support of this statewide effort