



Integration of Computational Fluid Dynamics (CFD) into the Chemical Engineering Undergraduate Curriculum

A Report from the CACHE CFD Task Force

Richard D. LaRoche, Chair, CACHE CFD Task Force
DEM Solutions

Paper 19d

AIChE Annual Meeting, Philadelphia, PA

November 17, 2008



Outline

- CACHE CFD Task Force
 - Mission
 - Membership
- Integrating CFD into ChE curriculum
 - Michigan State
 - Florida / Iowa State
- Why hasn't CFD been adopted broadly in ChE undergraduate curriculum?
- Path Forward



CACHE CFD Task Force Mission

- Promote the use of CFD and related engineering software tools in undergraduate education
- Engineering software such as:
 - CFD – FLUENT, CFX
 - Multiphysics – COMSOL
 - Solid particle flow – EDEM
- Why?
 - Software tools can enhance undergraduate education in transport phenomena
 - Industry desires graduates that have background in commercial software tools



CACHE CFD Task Force Members

- Brigette Rosendall, Bechtel
- Bruce Finlayson, U. Washington
- Charles Petty, Michigan State
- Gavin Towler, UOP
- Jim Tilton, DuPont
- Jennifer Curtis, U. Florida
- Kurt Svihla, ANSYS
- Laura Dietsche, Dow
- Paul Sechrist, UOP
- Richard LaRoche, DEM Solutions
- Rodney Fox, Iowa State
- Shane Moeykens, ANSYS
- Tom Hanley, Auburn
- Venkat Raman, U. Texas
- Willis Bell, Eli Lilly
- Matthew Godo, Intelligent Light



Task Force Activities

- Monthly WebEx meetings
- Define teaching module specifications
- Survey existing CFD teaching module material
- Create a working list of proposed teaching modules
 - Academic lead
 - Industrial mentors
- Explore why past CFD teaching module projects have fell short of goals
- Explore funding possibilities where CACHE can assist

Michigan State University

344b: Integrating Computational Transport Phenomena into the Undergraduate Chemical Engineering Curriculum

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2006 AIChE Annual Meeting

San Francisco, CA

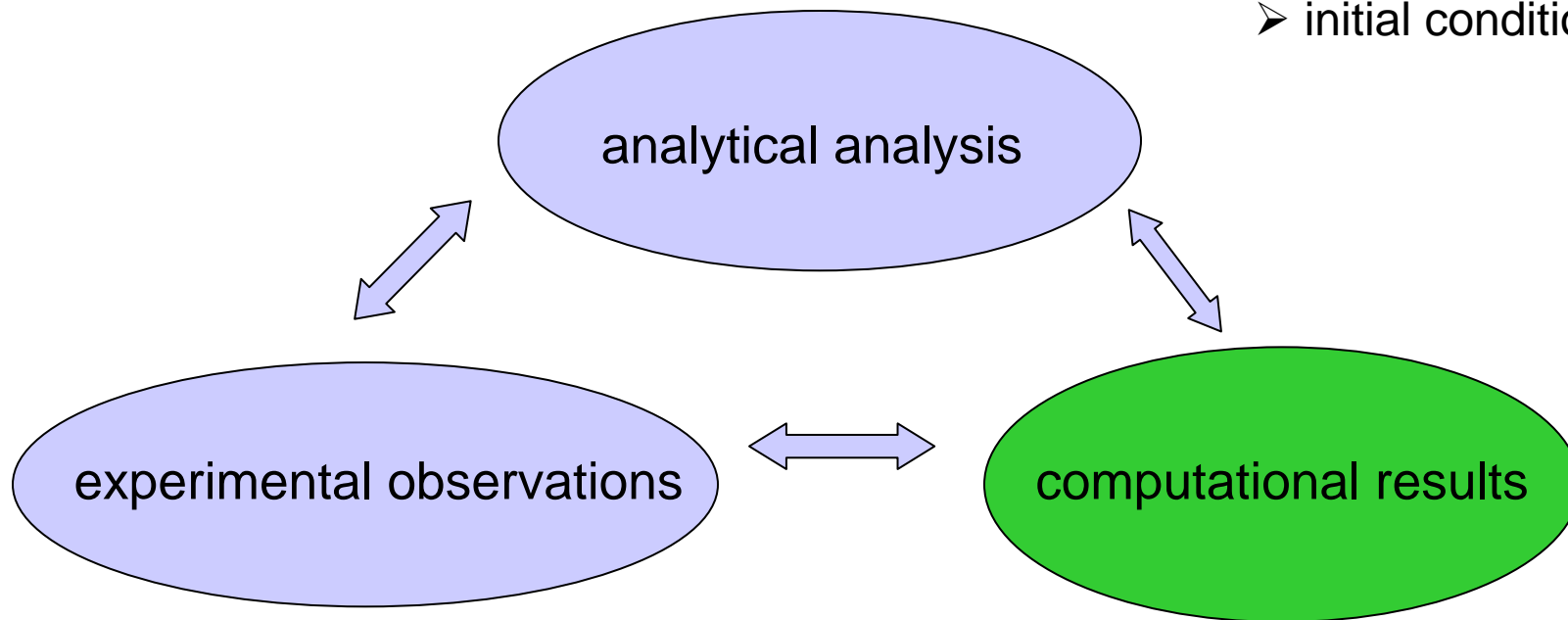
Scope of the CTP Training

- **Freshman** --- Frontiers in Chemical Engineering, Professor D. Miller
Dimensional Analysis --- unsteady state heat transfer
- **Sophomore** --- Introduction to Transport Phenomena, Professor B. Ofoli
Developing Flows --- entry length at low Reynolds numbers
- **Junior** --- Fluid Flow, Professor I. Lee
Engineering Analysis --- flow losses and toroidal recirculation flows
- **Senior** --- Independent Study, Professor C. Petty
- **Group Projects** --- I/UCRC-MTP, Professors A. Benard and C. Petty

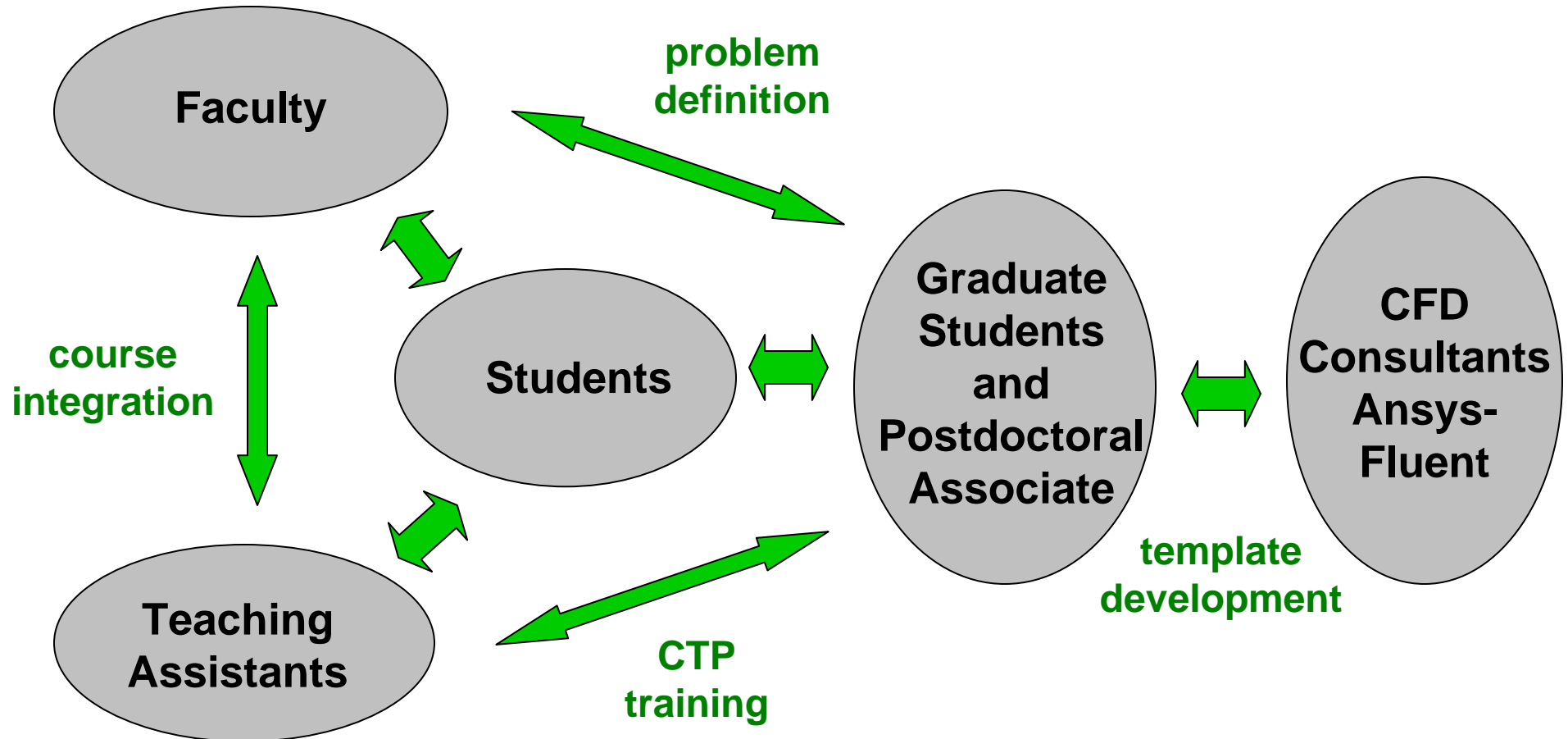
CTP Training --- Emphasis on Understanding, Discovery, and Excitement

Complementary to Course Lecture Topics Related to Momentum, Energy, and Mass Transfer

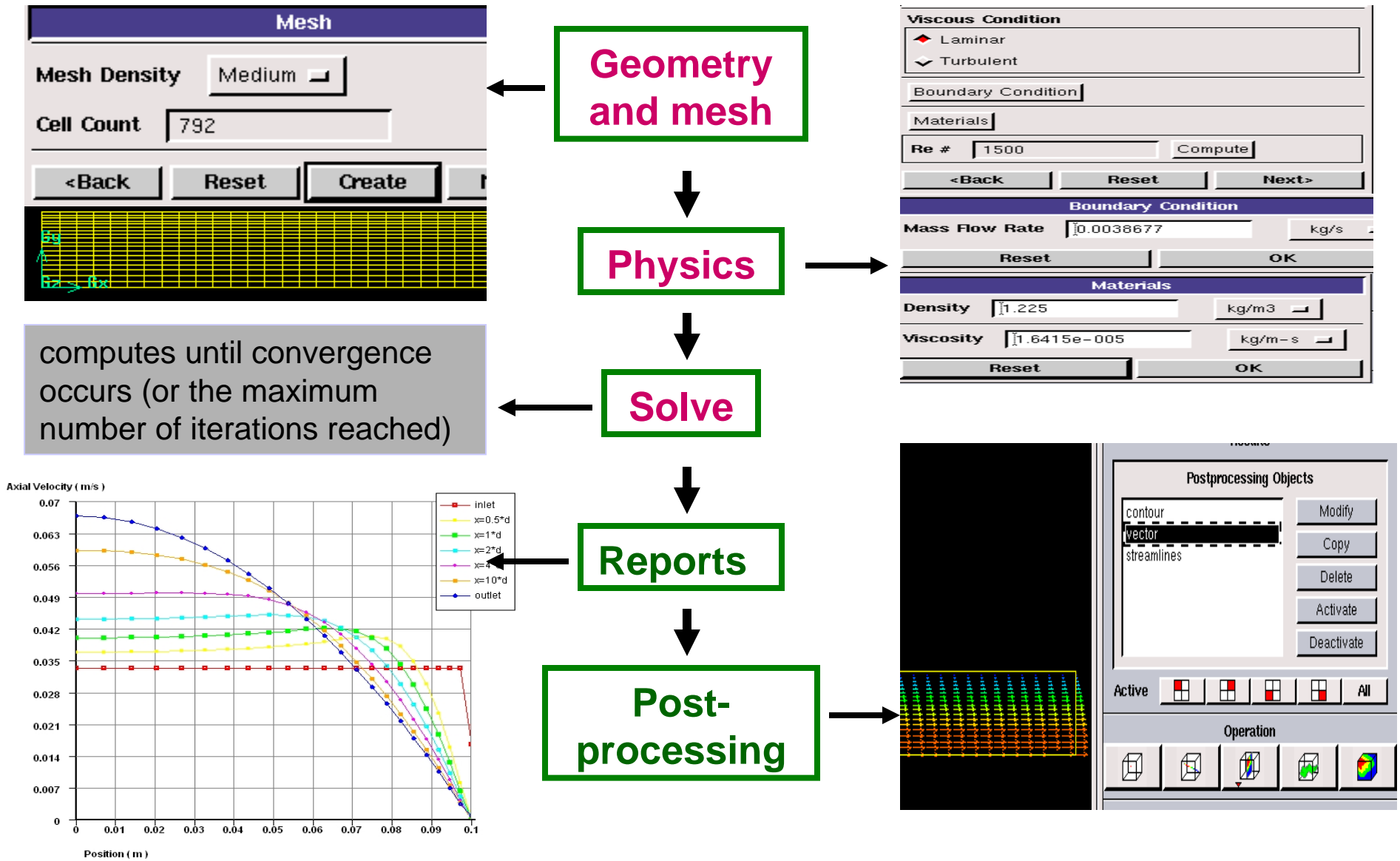
- geometry
- balance equations
- transport models
- material properties
- boundary conditions
- initial conditions



CTP Teaching Team at Michigan State University



Components of the Training Tool, FlowLab®



NSF Course, Curriculum, and Laboratory Improvement Grant – Adaptation and Implementation Program

*Enhancing Undergraduate
Understanding of Transport
Phenomena via Application of
Computational Fluid Dynamics*



IOWA STATE UNIVERSITY



Jennifer Sinclair Curtis

Professor and Chair,
Chemical Engineering, University of Florida

Research Area: CFD for Particle-Laden Flows

CFD Task Force Leader - Computer Aids in Chemical
Engineering Organization 1998-2004



Rodney O. Fox

Professor and Glenn Murphy Chair
Chemical Engineering, Iowa State University

Research Area: CFD for Reacting Flows

CFD Task Force – Computer Aids in Chemical
Engineering Organization, 2002 - Present

NSF Project Focus: Incorporation of CFD into Engineering Courses

First Course in Fluid Mechanics or Transport Phenomena

- Sophomore or Junior Undergraduate Students

Advanced Course in Fluid Mechanics or Transport Phenomena

- Senior Undergraduate Students or First Year Graduate Students

Chemical Engineering Applications Emphasis

NSF Project Scope

Development of Course Syllabi which Incorporate:

- CFD Lecture Material
 - Discretization of Governing Equations, Residuals, Convergence, etc.
- CFD In-Class Demonstrations/Visualizations
- CFD Homework Exercises which Compliment "Traditional" Lecture Material - Theory, Constitutive Equations, Empirical Correlations
 - Navier-Stokes Equations, Turbulence, Drag, etc.

NSF Project Scope

Development of Homework Exercises to Complement Existing FlowLab Templates

- Flow through an Orifice
- Developing Flow in a Pipe
- Sudden Expansion in a Pipe
- Flow over a Heated Plate
- Flow over a Cylinder

Learning Outcomes

- Students gain an understanding of the principles of CFD
- Students can model and solve CFD problems using FlowLab
- Students can analyze comparisons between CFD solutions and results of analytical solutions or empirical data
- Students gain an understanding of what problem-solving tools are available to address complex, real-world problems
- Students knowledge of fundamental concepts in fluid mechanics is enhanced via CFD

Assessment of Learning Outcomes

- Performance on Examination Questions
- Performance on Weekly Homework Assignments
- Student Self-Assessment Survey
- Comparison of Student Performance in Transport Course in which CFD is incorporated versus the same transport course in which CFD is not incorporated (same professor)



What are the Critical Success Factors to Deploying CFD in the ChE curriculum?

- Lack of CFD teaching modules?
 - More material is probably still needed but dissemination and integration into curriculum is not happening on a broader scale
- Key to success at Michigan State, Florida, Iowa State was having a resident student coordinator coupled with a faculty mentor
 - Graduate student teaching assistant or undergraduate honors project
 - This “student helper” assists faculty in implementing modules in undergraduate courses
- Central repository for dissemination and maintenance of teaching modules



Path Forward

- Informal and formal collaborations
- Workshops for student mentors
- Contribution of teaching modules
- Pursuing educational grant funding
- Pursuing national repository for teaching modules and best practices
 - Cornell – Swanson Engineering Center
- Interesting in participating?
 - Contact Richard.LaRoche@dem-solutions.com