Education for the future

Morten Hjorth-Jensen[1,2] Anders Malthe-Sørenssen[1]

Department of Physics, University of Oslo[1]

Department of Physics and Astronomy, Michigan State University, USA[2]

September 2 2015,

This talk is about how we perceive the role of education; present and future

- **Research-based education**, from undergraduate studies to a PhD: The Computational Physics group at the University of Oslo as example
- Future challenges and directions

The role of computations, from education to society

Computations of almost all systems in science are central to our basic understanding of nature and technological advances.

Examples

- quantum physical systems in nanotechnology and the characteristics of new materials
- subamotic physics at its smallest length scale
- simulating galaxies and the evolution of the universe
- cancer treatment and how the brain works
- predicting climate changes and this week's weather
- simulating natural disasters
- semi-conductor devices, quantum computers,
- assessing risk in the insurance and financial industry
- and many many more

Modeling and computations as a way to enhance algorithminc thinking

Algorithm : A set of instructions to solve a problem.

Algorithmic thinking:

- Enhances instruction-based teaching
- Introduces research-based teaching from day one
- Triggers further insights in math and other disciplines
- Emphasizes validation and verification of scientific results, and integrates ethics
- Ensures good working practices from day one!

What does computing mean?

Computing means solving scientific problems using computers. It covers numerical as well as symbolic computing. Computing is also about developing an understanding of the scientific process by enhancing the algorithmic thinking when solving problems.

Computing competence is about:

- derivation, verification, and implementation of algorithms
- understanding what can go wrong with algorithms
- overview of important, known algorithms
- understanding how algorithms are used to solve complicated problems
- reproducible science and ethics
- algorithmic thinking for gaining deeper insights about scientific problems

All these elements (and many more) aid students in maturing and gaining a better understanding of the scientific process

Computing and research-based education

A computational approach allows us to introduce research concepts and engage students in research from *day one*.

How do we define it?

It is coupled to a direct participation in actual research and builds upon established knowledge and insights about scientific methods.

Research-based education

What should the education contain?

- Theory + experiment + simulation is the norm in research and industry
- Modeling of real, complex systems with no simple answers
- Insight and understanding of fundamental principles and laws
- Visualization, presentation, discussion, interpretation, and critical analysis of results
- Development of a sound ethical attitude to own and other's work
- Enhanced reasoning about the scientific method

This is what we do in the Computational Physics group at UiO!

Computational Physics group at UiO; our visions

A particular strength of physics students is their ability to **pose and solve problems** that combine **physical insights** with **mathematical tools** and now also **computational skills**. This provides a unique combination of applied and theoretical knowledge and skills. These features are invaluable for the development of multi-disciplinary educational and research programs.

We develop a social and scientific learning environment

The main aim is that students should realize their own potentials and creative power

- Students come with different dreams, ambitions, aspirations and topics they wish to study, our approach is to tailor the education to all these aspects
- Our motto: foster students who are better than their supervisors - that's progress!
- Students and teachers help each other
- Students with different backgrounds and needs can thrive socially and scientifically
- No competing environment, but a drive and enthusiam for sharing and developing knowledge

We develop a social and scientific learning environment

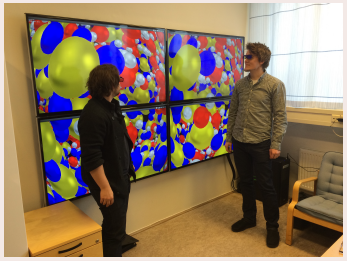
- We target bachelor, MSc and PhD students
- Project-oriented work where students develop and mature their own ideas, with an individually tailored approach to each student
- Office space with desktops to every student and large common room for recreational activities (meals, gaming, movies)
- Many students collaborate on similar thesis topics and publish in top scientific journals

Features of the Computational Physics group

- Our students have made significant contributions to the Computing in Science Education (UiO education prize in 2011) by developing exercises and participating in educational projects at the MN faculty
- Our students have also developed educational tools and applications for understanding complicated physical problems
- A group of PhD students is now developing new textbooks for Computational Life Science
- 2005-2015: $>$ 60 students have finalized their master's theses and 60% have continued with PhD studies
- Many students don't want to leave the group after finishing their studies

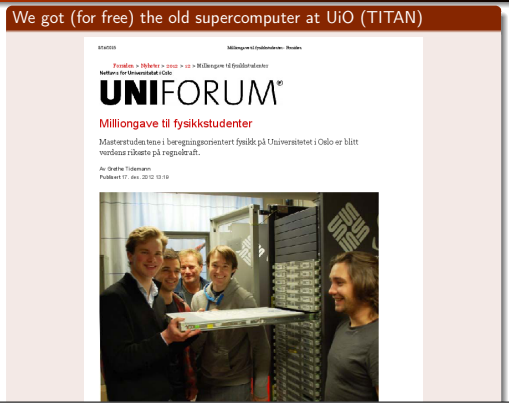
Investing in equipment for students

Using research funds for visualization tools



Building a supercomputing cluster

We got (for free) the old supercomputer at UiO (TITAN)



Forsiden > Nyheter > 2012 > 12 > Milliongave til fysikkstudenter

Nettavis for Universitetet i Oslo

UNIFORUM

Milliongave til fysikkstudenter

Masterstudentene i beregningsorientert fysikk på Universitetet i Oslo er blitt verdens rikeste på regnekraft.

Av Grethe Tidemann
Publisert 17. des. 2012 13:19

Undergraduate student publishes in PNAS

Using research funds for visualization tools

6/27/2013 Begynnerstudent gjør oppsiktsvekkende oppdagelse - Fysisk institutt

UiO : Fysisk institutt

Begynnerstudent gjør oppsiktsvekkende oppdagelse

Bachelorstudent gjør ryktet om middelmådig norsk forskning til skamme ved å få sin forskning publisert i et internasjonalt topp-tidsskrift.

Henrik Sveinsson. Foto: Oda Hveem

Vanligvis deltar ikke studenter i forskning før etter 4-5 år på universitetet. Nå er fysikkutdanningen ved UiO endret slik at studentene raskt blir i stand til å forske på reelle problemstillinger. Studentene får mulighet til å være med i toppforskning gjennom et prosjekt som kalles "Grand Challenge".

Henrik Sveinsson er en av studentene som har deltatt i Grand Challenge-prosjektet.

Forstå jordskjelv

—Henrik viste tidlig både talent og interesse for forskning. Derfor mente jeg det var viktig å gi ham

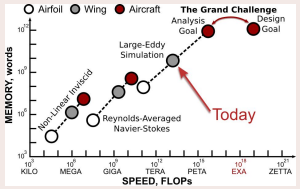
Multiscale modeling is the big open research question in the 21st century

- Present and future problems, unlike traditional science and engineering, involve complex systems with many distinct physical processes
- The wide open research topic of this century, both in industry and at universities, is how to effectively couple processes across different length and energy scales
- Progress will rely on a *multi-disciplinary* approach

We need to foster candidates with the right multi-disciplinary background and computational thinking!

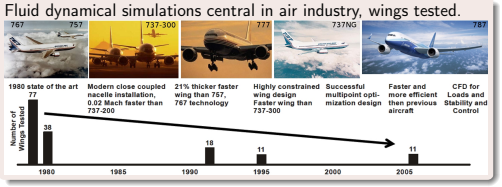
Examples of large scale simulations

Fluid dynamical simulations central in air industry. Typical university courses which are taught address the physics of the lower left corner.



Testing plane wings via massive numerical simulations

Fluid dynamical simulations central in air industry, wings tested.



The challenges for the future

We need to educate the next generation of science students with the knowledge, skills, and values needed to pose and solve current and new scientific, technological and societal challenges.

This will lay the foundation for cross-disciplinary educational, research and innovation activities. It will contribute to building a common cross-disciplinary approach to key strategic initiatives, with examples like *Energy, Materials, Life Science, and Enabling Technologies.*

A new type of students

Candidates who are capable of modeling and understanding complicated systems, are in short supply in society.

The computational methods and approaches to scientific problems students learn when working on their thesis projects are very similar to the methods they will use in later stages of their careers.

- To handle large numerical projects demands structured thinking and good analytical skills and a thorough understanding of the problems to be solved.
- This knowledge makes the students unique on the labor market, a labor market which in the years to come will experience heavy automatization and massive loss of jobs.

Computations (mastering and developing) will play a central role in almost all aspects of scientific investigations and technological innovation

Create the Department for Computational Science!

UiO's strength in computational science (education and research) has the potential to make UiO a top European university

How to achieve it

- Establish a new center/department with focus on computational science and its applications to a wide range of fields (natural science, medicine, social sciences, humanities, applied research etc)
- Hire ten young professors (age < 40) dedicated to innovative *computational* research and education
- Establish another ten professorships with shared positions between the new department and the discipline-specificdepartment (physics, chemistry, ...)

The process must start now in order not to lose momentum.

Our success builds on the Computing in Science Education project (UiO educational prize in 2011)

The results, insights, ideas and thoughts presented here, would have been impossible without the continuous interaction with colleagues in the Computing in Science Education project.

- Hans Petter Langtangen, Informatics and Simula Research Laboratory
- Knut Mørken, Mathematics
- Arnt Inge Vistnes, Physics
- Oyvind Ryan, Mathematics
- Solveig Kristensen and Annik Myhre, Deans of Education, MN faculty
- Hanne Sølna, Director of studies MN faculty