Education for the future

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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

Takeaway message. A successful research program cannot be disconnected from education and vice versa

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.

- **Nanotech and Materials**: quantum physical systems in nanotechnology; characteristics of new materials; semi-conductor devices and quantum computers
- **The smallest particles in nature**: subatomic physics at its smallest length scale
- **And the largest**: simulating galaxies and the evolution of the universe
- **Life science**: cancer treatment and how the brain works

- **Geosciences**: predicting climate changes and this week's weather, simulating natural disasters
- **Finance**: 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 *per se*.

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 research-based education? It is fully integrated with a direct participation in actual research and builds upon established knowledge and insights about scientific methods.

hpl 1: Think this is unclear...better to just phrase it orally?

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

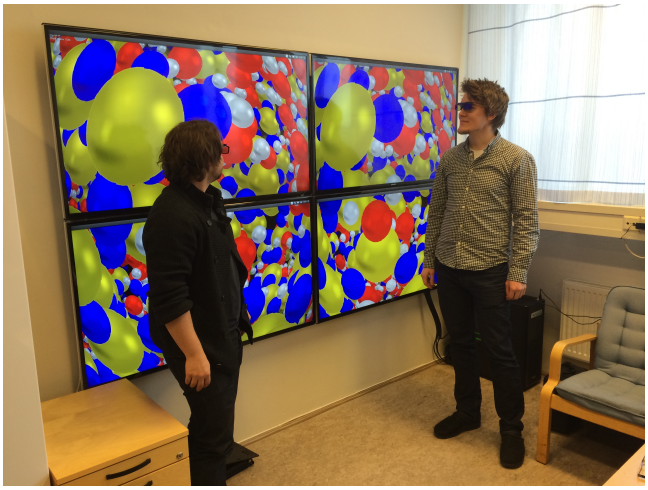
We develop a social and scientific learning environment

- 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

8/26/2015 Milliongave til fysikkstudenter - Forsiden

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

ÅRETS JULEGAVE: Supercomputeren *Titan* fyller selv store skap på Fysisk institutt. Studentene *Henrik Steinsson* og *Fredrik Pettersen*, professor *Morten Hjorth-Jensen*, og studentene *Anders Hafreager* og *Sigve Bøe Skattum* har store forventninger til gaven.

Foto: Grethe Tidemann

I september i år erstattet Universitetets senter for informasjonsteknologi (USIT)

http://www.uniforum.uio.no/nyheter/2012/12/supermaskin-til-jul.html 1/3

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

Undergraduate student publishes in PNAS

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 ekstra utfordringer. Allerede i sitt første år som student gjorde Henrik helt nye oppdagelser om friksjon som kan være nyttig for å forstå jordskjelv, sier Anders Malthe-Sørenssen, initiativtaker til Grand Challenge.

Henriks forskning ble publisert i det prestisjetunge tidsskriftet "Proceedings of the National Academy of Sciences" (PNAS) i juni 2014. Selv for etablerte forskere er dette en prestasjon. For en bachelorstudent er det oppsiktsvekkende.

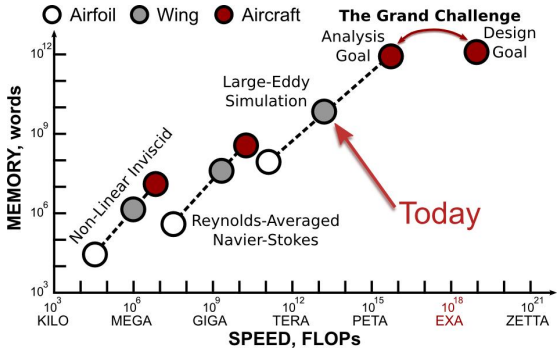
Using research funds for visualization tools.

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!

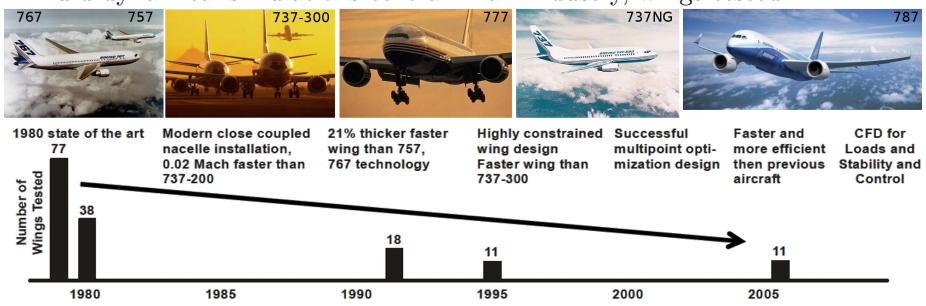
Examples of large scale simulations



Fluid dynamical simulations central in air industry.

Testing plane wings via massive numerical simulations

Fluid dynamical simulations central in air industry, wings tested.



The future: A new type of students

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

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

We need students that

- can handle large and demanding multi-disciplinary projects. This requires 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.

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 important examples from fields like *Energy research, Materials science and Life Science*.

hpl 2: Repetitions on this slide, lengthy text - better to just phrase this in the delivery

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.

hpl 3: True, but at this point time is needed for the new institute... Suggest to remove this slide.

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 takeaway messages

- Computing plays and will play an even more important role in future scientific and technological advances
- A successful research program cannot be disconnected from education and vice versa
- An educational and research program which focuses on these issues needs to be established as soon as possible
- Key goal: students must realize their own potentials and creative power

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
- **And: all our fantastisc students who keep giving us new insights!**

Thanks for the attention.