Education for the future

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How we perceive the role of education, present and future

The main topics of this talk are:

- **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 finite set of unambiguous instructions that, given some set of initial conditions, can be performed in a prescribed sequence to achieve a certain goal.

Algorithmic thinking as a way to

- Enhance instruction based teaching
- Introduce research-based teaching from day one
- Trigger further insights in math and other disciplines
- Validation and verification of scientific results, with the possibility to emphasize ethical aspects as well. Version control is central.
- Good working practices from day one.

What do we mean with computing and computational science and physics?

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.
And this 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

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?

The standard situation we meet at an almost daily basis:

- Theory+experiment+simulation is almost the norm in research and industry
- To be able to model complex systems with no simple answers. Solve real problems.
- Emphasis on insight and understanding of fundamental principles and laws in the Sciences.
- Be able to visualize, present, discuss, interpret and come with a critical analysis of the results, and develop a sound ethical attitude to own and other's work.
- Enhance reasoning about the scientific method

Our education should reflect this. An example where this takes place is the Computational Physics group at UiO. How can we implement in a systematic was a research-based education?

Computational Physics group at UiO; implementing 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.

Develop a social, scientific and 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 is to foster students which are better than their supervisors. This is how we define progress
  - This creates an atmosphere for learning and sharing knowledge
  - The emphasis is on learning and getting new insights. Students and teachers help each other
  - This creates an enviroment where students with different backgrounds and needs can thrive socially and scientifically
  - No competing environment but a drive and enthusiam in sharing and developing new knowledge

Develop a social, scientific and learning environment

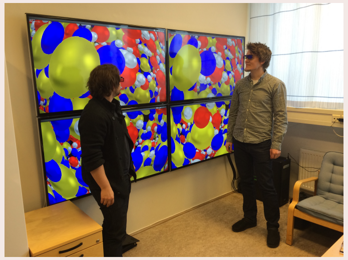
- The computational physics group includes bachelor, master of science and doctoral students
- Project oriented work where students develop and mature their own ideas, with an individually tailored approach to each students
- Office space with desktops to every student and large common room for recreational activities (meals, common lunches, gaming, watching movies etc etc)
- Many students collaborate on similar thesis topics and publish in top scientific articles

Developing a good learning environment

- 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
- The students keep shaping and developing the scientific, social and pedagogical activities of the group
- A group of PhD students is now developing new textbooks for Computational Life Science
- During the last ten years more than 60 students have finalized their master theses in computational physics and almost 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)


8/16/2015 Milliongave til fysikkstudenter - Forsiden

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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


8/27/2015 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

The future: Multiscale modeling is the big open research question

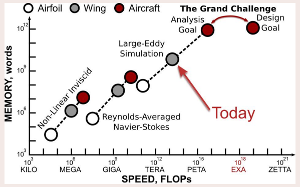
Present and future problems, unlike traditional science and engineering, involve complex systems with many distinct physical processes.

- 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 and therefore the need for multi-disciplinary educational and research programs.

We need to foster candidates with the right multi-disciplinary background and computational thinking for understanding present and future simulation technologies and their challenges.

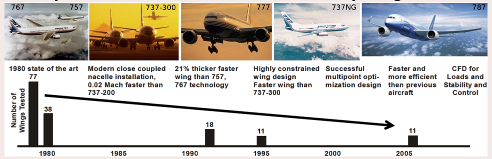
Examples of large scale simulations

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

What we should do: create the Department for Computational Science

What we have and where we can arrive

- UiO's strength in computational science (education and research) will play an important role in determining new research and educational directions
- Exploiting this strength has the potential to make UiO a center of excellence for scientific innovation

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 (or more) young professors (age < 40) dedicated to innovative research and education where computations play a central role
- Establish another ten professorships (or more) with shared

The Computing in Science Education project, UiO educational prize in 2011

The insights, ideas and thoughts presented here, would have been impossible or difficult to gain without discussions, exchange of ideas and much more over many years with colleagues involved in the Computing in Science Education project at UiO. These dear friends and colleagues are

- 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