

# Education for the future

Morten Hjorth-Jensen<sup>1,2</sup>

Anders Malthe-Sørensen<sup>1</sup>

*<sup>1</sup>Department of Physics, University of Oslo*

*<sup>2</sup>Department of Physics and Astronomy,  
Michigan State University, USA*

# Present and future education

Research-based education, from undergraduate studies to a PhD: [The Computational Physics group at the University of Oslo](#) as an example

Future challenges and directions

**Takeaway message:**

Excellent research depends on excellent education – and vice versa!

# The role of computations, from education to society

Computations are central to our understanding of nature and to technological advances

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

## 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:** climate change and weather, natural disasters
- **Finance:** assessing risk in the insurance and financial industry
- and many many more

# Modeling and computations as a way to enhance algorithmic thinking

**Algorithm** : A set of instructions to solve a problem

**Algorithmic thinking applies to all disciplines. It**

- Enhances instruction-based teaching
- Introduces research-based teaching from day one
- Triggers further insights in scientific problems
- Emphasizes validation and verification of scientific results, and integrates science ethics in a natural way
- Ensures good working practices from day one!

# What does computing mean?

**Computing means solving scientific problems using computers.**

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 deeper insights into science

All these elements help students mature scientifically

# Computing and research-based education

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

## 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 sound ethical attitude to own and other's work
- Enhanced reasoning about the scientific method
- Individually tailored education for students to realize their full potentials

This is what we do in the [Computational Physics group](#) at UiO!

# Computational Physics group – our visions

- Students **pose** and **solve** problems that combine **physical insights** with **mathematical tools** and **computational skills**
- Essential for multi-disciplinary educational and research programs







# A social and scientific learning environment

**Goal:** Students should realize their full potential and discover their creative powers!

- Students come with different dreams, ambitions, and topics – we tailor an education
- Foster students that are better than ourselves!
- Emphasis on learning and new insights
- Students and teacher help each other
- Non-competitive and generous environment

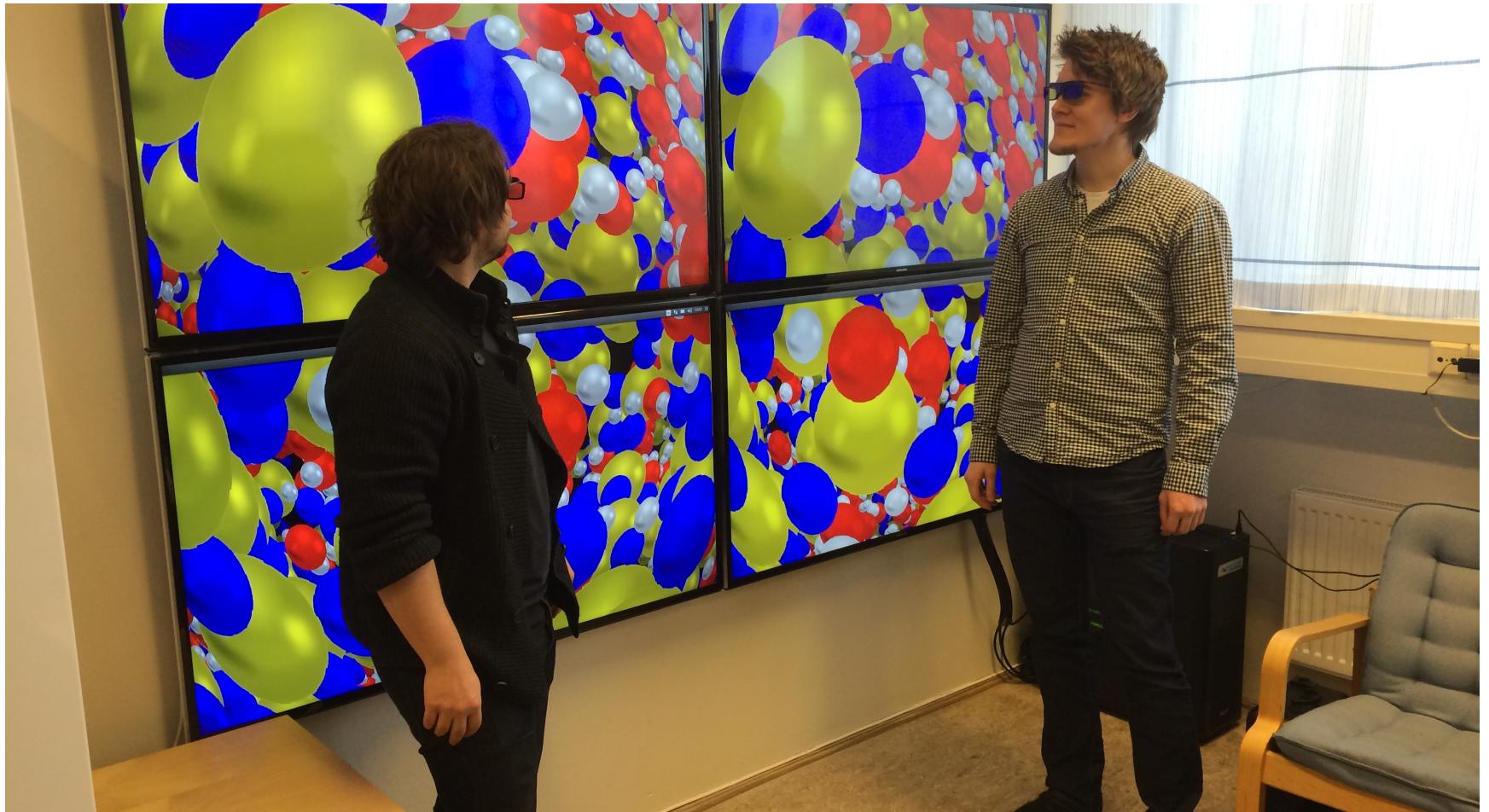
# We develop a social and scientific learning environment

- Target BSc, MSc, and PhD students
- Project-oriented work – students develop their own ideas
- Office space with desktops for every student
- Common room for scientific and social activities
- Collaborative thesis projects

# Features of the Computational Physics group

- Students contribute to the Computing in Science Education project (UiO educational prize 2011)
- Our students develop educational tools to improve student insights
- A group of PhD students now develop new textbooks for Computational Life Science
- 2005-2015: >60 MSc students and 60% have continued with PhD studies
- Many students do not want to leave the group after finishing their studies

# Investing in equipment for research and education





## Milliongave til fysikkstuderter

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 Sveinsson* og *Fredrik Pettersen*, professor *Morten Hjorth-Jensen*, og studentene *Anders Hafrenger* og *Sigve Bøe Skattum* har store forventninger til gaven.

Foto: Grethe Tidemann

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

# Undergraduate student publishes in PNAS

Participating in research from day one!

Bachelor and master students publish in scientific journals

Students are exposed to all stages of the scientific process

## 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 Steinsson. 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 problemstiller. Studentene får mulighet til å være med i toppforskning gjennom et prosjekt som kalles "Grand Challenge".

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

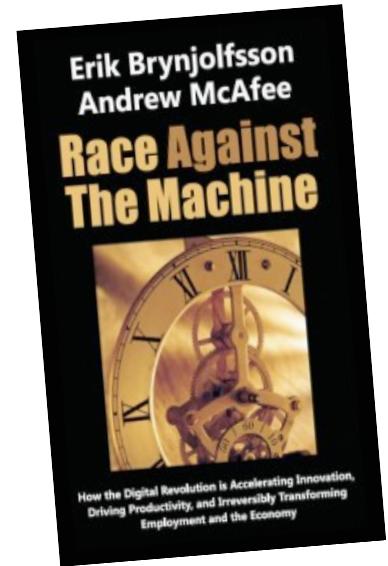
### Forstå jordskjelv

—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-Sørensen, 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.

# The computational revolution in science and society

- Computing will affect all aspects of society - and should also play a key role in research and education in our society
- Possible large shifts with the advent of automation
- Present and future problems involve complex systems
- Require a multi-disciplinary approach
- Collaboration and team work using computational tools
- To stay competitive as a society we need computing competence integrated in all fields – for both research and education!
- We need candidates with the right multi-disciplinary background and skills in computational thinking



# UiO has a unique chance to become a Leading European University

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

- We must educate the competence needed
- We are in a unique position to do so – across all fields!

## **How to achieve this:**

- Establish a new cross-disciplinary center/department with focus on computational science and its applications to a wide range of fields (science, medicine, humanities, social science, etc)
- Hire ten young professors (age < 40) dedicated to innovative computational research and education
- Establish another ten cross-departmental professorships
- Establish best practice for computational and educational innovations, with particular focus on new learning material – and real incentives

# Summary

- Computing plays and will play an even more important role in society – and this must be reflected in research and education
- Our program builds on this and allows students to realize their potential and unleash their creativity
- Social and scientific activities in harmony
- UiO is in a unique position to develop a leading research and educational activity – if we act now

# Computational Physics and the Computing in Science Education project

The results, ideas and thoughts presented here would have been impossible without the infinitely many interactions with colleagues in the [Computing in Science Education](#) project and all our fantastic students! Thank you!

- Hans Petter Langtangen
- Knut Mørken
- Arnt Inge Vistnes
- Øyvind Ryan
- Solveig Kristensen and Annik Myhre
- Hanne Sølna

