MSP EPC, KAN PARTY & MSP ALUMNI

EDUCATION FOR THE FUTURE

A PROPOSAL FOR MSP

FEBRUARY 2021

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CONTENTS

1 - PREAMBLE

Being a generation of students growing up in a world that is greatly affected by human-induced climate change and related challenges, it is crucial we receive sufficient education on how these topics impact our field of study.

Maastricht University wants to contribute to a more sustainable future with its education, research and operations. This vision is guided by the goal of stimulating the integration of sustainability into programmes and courses UM wide.

The Maastricht Science Programme (MSP), part of the Faculty of Science and Engineering, is therefore presented with the opportunity to be at the cutting edge of educating the scientists and researchers that our future demands.

As a group of MSP students, we became interested in the possibility of integrating sustainability in the MSP curriculum and organised a brainstorm with interested students, alumni and EPC members.

We discussed integrating various aspects of sustainability into existing courses, as well as the introduction of entirely new courses and practicals to enrich the current curriculum.

With a broad overview in mind, we then introduced this initiative to professors and course coordinators from different disciplines, which helped us refine the ideas we had. We also met with the Dean of MSP, Prof Dr. Leon Claessens, to pitch the ideas at this early stage.

The following report is therefore based on the discussions we have had over the last few months with the intention of creating a constructive approach to truly integrating sustainability in the MSP curriculum.

It is structured as follows:
First, the importance of a toolbox and the necessary stepping stones for its creation is presented. This can facilitate the integration of a strategy to incorporate sustainability into MSP's curriculum as a whole.

Second, topics that may be interesting to integrate into existing courses and skills, with concrete examples, are presented.

Lastly, an overview of new courses that might complement the current MSP curriculum are elaborated upon.

Education for Climate Coalition, European Commision
https://ec.europa.eu/education/education-in-the-eu/european-education-area/education-climate-coalition_en

Sustainability at UM
https://www.maastrichtuniversity.nl/about-um/sustainability

Sustainability Vision 2030
https://www.maastrichtuniversity.nl/file/visionandstrategysustainableum2030newversionfebr2020pdf

2 - TOOLBOX

In developing the sustainability offerings in the curriculum of MSP, an integrated approach is necessary. It has been shown that introducing a holistic view to curricula and establishing a link between societal challenges and the content of a course promotes scientific literacy and fosters co-responsibility. For this reason, it is not sufficient to simply add additional courses and skills.

A strategy is needed to assist course coordinators in developing links between the theory taught in their course and societal challenges (i.e. climate change, biodiversity loss, human impact), as well as developing relevant problem-based learning tasks and assignments. This led us to the idea that a 'toolbox' of sorts must be created, in which different approaches to reach this goal are available for course coordinators.

i Keeping track of sustainability at MSP

The first step in developing this toolbox is to create a complete curriculum assessment in relation to the existing courses and skills that tackle sustainability/climate change. This would make clear at an MSP wide level what topics are well covered and which ones are not. A dynamic overview, updated on a timely basis, should be created for this. Therefore, when course coordinators successfully implement and adapt courses, it can be reflected in the new overview. This could be kept up to date over time, with the help of a student assistant.

Sjöström et. al. (2017) Use of the concept of Bildung in the international science education literature, its potential, and implications for teaching and learning, Studies in Science Education, 53:2, 165-192, DOI: 10.1080/03057267.2017.1384649

Zuin, V.G., Kümmerer, K. Towards more sustainable curricula. Nat Rev Chem (2021). https://doi.org/10.1038/s41570-021-00253-w

ii A repository for course coordinators

In conjunction with the creation of a document which contains an overview of the sustainability courses at MSP, it would be ideal to create a repository of methods which allow the integration of sustainability into courses/skills/projects. Through this, course coordinators who have successfully integrated sustainability can share their examples and best practices. Ideally, this could be combined with a central MSP knowledge repository available for staff members, regarding not solely sustainability, but a broad range of subjects. A repository such as this could facilitate the development of intra-course/skill topics.

iii Communication to current and prospective students

Finally, an overview could be added to the MSP Canvas group so current students can be well advised on the different sustainability/climate change concepts that are covered within the curriculum. With this information available on the current state of sustainability/climate change education at MSP, there is also the opportunity to add to the MSP website, ensuring prospective students are aware of these educational possibilities at MSP.

3 - CONCRETE SUGGESTIONS

This section introduces specific suggestions for the fields of Biology and Chemistry, which could be integrated into the current curriculum.

All the proposed changes are intended as conversation starters aiming to highlight the potential at MSP for integrating sustainability, rather than concrete demands for the course/skills coordinators.

While some of the suggestions below could potentially be applied as (or in) projects and thesis research, we decided to focus on the integration of sustainability in courses and practicals specifically, as this is where the majority of students can be reached.

BIOLOGY

Concrete suggestions

Introduction to Biology (BIO1001): As environmental issues become increasingly common, having an introductory level lecture or tutorial task on biodiversity loss could help freshmen familiarise themselves with the challenges present in modern-day (macro)biology. Especially in the lecture about ecology, an introduction to the concept of conservation and biodiversity may trigger students to develop an interest in sustainability, and provide the basic tools to approach future sustainable related courses.

Botany practical (PRA2011): The application of a literature review assignment on endangered plant species in conjunction to the practical skills gained. The focus could be put on questions such as “what is the cause of plant biodiversity loss, what are its effects on specific ecosystems, etc.” could be answered in an interactive way (such as in BIO3007).

Botany course (BIO2003): A tutorial relating to plant conservation, the effects of pesticides etc., on modern-day crop systems (e.g. monocultures) and the changes required for a shift towards sustainable agriculture. Chemical Ecology’s (INT3009) final lecture is a good example of this and could be used as a reference point. Alternatively (or conjointly), these topics could be given as an assignment in the course.

Limburg landscape (PRA3011): Here, forestry management and urban planning could be incorporated, Limburg as an urbanised area with much agriculture and few patches of forest, is an ideal location for exploring these topics. Especially within the current format of the course, issues relating to nature conservation at a local level, forest management practices to increase biodiversity or the effects of agriculture on the landscape etc. could be discussed.

BIOLOGY

Concrete suggestions

In **Great Transformations in Vertebrate Evolution (BIO2008)** and **Evolutionary Biology (BIO2005)**: Although we are exposed to the concepts and characteristics of the 5 previous mass extinctions, the 6th one we have entered is barely touched upon. This would be a very interesting area to expand upon here (or elsewhere in the curriculum such as Ecology, Evolutionary biology or Introduction to Biology). An example of how to insert the topic of mass extinction or climate change within Evolutionary Biology courses can be found in the course Hominin Paleontology BIO3008. In this course, we observe how the extinction of other animals or changes in ecosystems due to climatic changes have affected the evolution of humans. Observing climate change and mass extinction events as driving factors of evolution and development if new adaptations may enrich Evolutionary Biology Courses.

CHEMISTRY

Concrete suggestions

Inorganic Chemistry (CHE2002): As this course introduces students to elements which are scarce, this should be highlighted in a tutorial through, for example, the use of the EuChemS periodic table of elements of element scarcity.

Physical Chemistry (CHE3002): The more advanced topic of ionic liquids is one gaining large interest in research due to the minimised solvent loss from the absence of vapour pressure, thus they are classified as green solvents. This concept and placing it in the context of sustainability could be introduced in one of the lectures.

Modern Catalytic Chemistry (CHE3004): Incorporating a tutorial exercise on catalysts based on main group elements to display the scarcity of TMs and the move towards more accessible elements is an important trend to discuss.

Chemical Synthesis (PRA2002) or **Advanced Organic Synthesis (PRA3001)**: Setting the task of determining sustainability metrics (i.e. atom economy and the E-factor) when preparing for an experiment will remind students of the impact of the reaction. A DOZN 2.0 tool has been developed for recognizing and assessing such risks for individual reactions.

Chemistry practicals (a general approach): Students with a focus in chemistry could be trained to critically assess the impact of laboratory work with regards to both environmental and health risks (Latimer & Wiebe, 2015). Constant reminders should be introduced throughout the chemistry labs regarding the impact of research practices, for example by placing posters by the sink regarding solvent waste. Clear guidelines and approaches to making chemistry practicals more sustainable have been well formulated in several sources.

https://www.euchems.eu/euchems-periodic-table/
https://www.sigmaaldrich.com/chemistry/greener-alternatives/matrix-scoring.html
https://pubs.acs.org/doi/10.1021/acs.jchemed.0c00134 (making chemistry practicals more sustainable)
Guide to Green Chemistry Experiments for Undergraduate Organic Chemistry Laboratories (developed by Beyond Benign, My Green Lab, and MilliporeSigma).
https://www.beyondbenign.org/curr-green-chemistry-organic-resource-guide/

4 - COURSES

Various courses which can be added to the current MSP curriculum are described in this section. The reasoning behind their addition, how these could be integrated, and some proposed content is discussed. From these courses we want to kickstart the inclusion of these crucial topics, and provide a starting point from which course coordinators can be inspired.

GREEN CHEMISTRY

Rationale

- Develop a thorough and complete understanding of the 12 principles of green chemistry. Each week, approximately, two principles can be introduced, discussed and deepened.

Integration into MSP Curriculum

- 2000 level course
- Prerequisite Organic Chemistry (CHE2001)
- Could be a recommended prerequisite course for Modern Catalytic Chemistry (CHE3004) and/or Biobased Materials and Technology

Proposed content

Prevention

- Measure of waste: E-factor and Process Mass Intensity

Atom Economy

- Concrete examples of calculating this metric for various reactions, focusing on the reactants

Less hazardous chemical syntheses

- Understanding hazard codes associated with chemicals (i.e. toxic, carcinogenic, irritative)
- Minimising the use of such hazardous chemicals in reactions through comparing two routes to a product

Designing Safer Chemicals

- An introduction to toxicology and its applications in for example molecular biology

Safer Solvents and Auxiliaries

- Use of solvents, separating agents etc. should be made unnecessary, calculating this with a green metric shows this
- Understanding the influence of solvents in a reaction by mass and energy consumption

https://www.acs.org/content/acs/en/greenchemistry/principles/12-principles-of-green-chemistry.html
https://pubs.acs.org/doi/10.1021/acs.jchemed.9b00354 : J. Chem. Educ. 2019, 96, 12, 2872–2880

GREEN CHEMISTRY

Proposed content (continued)

Design for Energy Efficiency
- Understanding the energy consumption of a reaction from the heating, cooling or pumping required
- Expressing this in terms of Gibbs Free Energy

Use of Renewable Feedstocks
- Discussing sustainable coal sources such as biomass and lignocellulose
- Introducing disciplines such as biotechnology and agronomy

Reduce Derivatives
- Reduce the use of derivatives and protecting groups through the use of enzymes
- E.g. production of semi-synthetic antibiotics ampicillin

Catalysis
- Introduction to catalysis and its definition
- A comparison of energy and resource demands for different catalytic processes (e.g. Haber Bosch) should be highlighted

Design for Degradation
- Understanding criteria for chemicals that are Persistent, Bioaccumulative and Toxic (PBT)
- Processes such as biodegradation, hydrolysis and photolysis can be introduced as methods

Real-time analysis for Pollution Prevention
- Understanding the crucial role of analytical chemistry in preventing pollution

Inherently Safer Chemistry for Accident Prevention
- All previous 11 principles give the logical outcome of enhanced safety.
- Giving a practical based example of how the laboratory worker benefits from green chemistry from an example practical in Advanced Organic Synthesis (PRA3001)

https://www.acs.org/content/acs/en/greenchemistry/principles/12-principles-of-green-chemistry.html
https://pubs.acs.org/doi/10.1021/acs.jchemed.9b00354 : J. Chem. Educ. 2019, 96, 12, 2872–2880

EARTH SYSTEMS

Rationale

- Understanding Earth's systems is crucial to seeing how the Anthropocene has emerged
- The Anthropocene can only be understood by first understanding its history
- The Earth's systems complexity and interconnections are crucial to sustainability
- Geology is an essential component of earth systems, and an understanding of our system's minerals can be very useful in understanding their importance and impact in modern day society and ecosystems.

Integration into MSP Curriculum

- 2000 level course
- Practical Integrated Assessment Modelling of Climate Change (potential as a complementary skill to this)
- Useful in courses such as Hominin & Vertebrae Evolution, Great Transformations in Vertebrae Evolution and also some other chemistry courses (e.g. Analytical Tools in the Art World)

Proposed Content

Earth's historical periods

- Hadean, Archean, Proterozoic, Phanerozoic, Holocene, Anthropocene

Understanding the four main spheres (Biosphere, Geosphere, Hydrosphere, Atmosphere)

- What they consist of
- Their role in the creation of a stable Earth System
- Humanities impact on each

Understanding the main natural cycles (Water, Carbon, Nitrogen, Nutrients)

- What they are
- Their respective time scales
- Anthropogenic impacts on these cycles

Creating Earth System models, and understanding the limitations and potential

- The use of Earth System models today
- IPCC predictions

EARTH SYSTEMS

Proposed content (continued)

Earth system minerals (a comprehensive look on which are the earth's most used material and what are their properties)

- How do these materials form
- What are their properties
- What is the impact of their extraction
- Main minerals (Lithium, Carbon, Iron, Bauxite and Phosphorus)

Dating techniques for Earth crusts' layers

- Use of isotope degradation
- Paleomagnetic polarity analysis
- Luminescence analysis
- Fossil biodiversity as a dating measure

Climate Change, from a geological perspective

- Factors that influence short term climate variability (Milankovitch cycles, sunspot cycles)
- Factors that influence long term climate variability:
  - chemical weathering of silicate minerals removes CO2 from the atmosphere
  - paleogeography: positioning of continents
  - large-scale volcanism from rift systems and the corresponding subduction zones

SOLAR CELL SCIENCE

Integration into MSP Curriculum

- 3000 level course
- Interdisciplinary Chemistry and Physics course

Proposed Content

Introduction to both organic and inorganic solar cells

- Intro to semiconductors
- Basic energy harvesting principles
- Discuss differences between crystalline cells, thin films, perovskites, etc.

Shockley-Queisser limit

Loss mechanisms

- Include efficiency, fill factor, Voc, different types of recombination, etc.
- Compare dominant loss sources for different solar cell types

Methods to increase efficiency (these can be introduced as student presentations)

- Concentrators
- Singlet fission
- Nanodots
- Multijunction

Modeling

- Efficiency limits.
- Mathematica or Python

'Solar Energy' is an example of coursebook that can be used:
https://courses.edx.org/c4x/DelftX/ET.3034TU/asset/solar_energy_v1.1.pdf

INTRODUCTION TO SUSTAINABLE ENERGY TECHNOLOGIES

Rationale

- To get an idea of the different sustainable ways of energy production and storage
- Encourage students to think critically about each technology and assess how sustainable they actually are
- With simple exercises make them aware of the energy production capacity of each method (e.g. how many wind turbines do you need to power this city?, Can we produce enough energy for households by covering all the roofs with solar panels? etc.)

Integration into MSP Curriculum

- 2000 level course
- Interdisciplinary Chemistry and Physics course

Proposed Content

Wind energy

Geothermal energy

Hydropower

Tidal wave energy

Solar energy

Biomass/biofuels

Nuclear energy

Fuel cells

Emergent Energy Technologies (these can be introduced as student presentations)

- Discuss novel sustainable energy production methods and their potential

Energy storage methods

Example syllabi:
https://www.e-education.psu.edu/eme802/syllabus
http://web.mit.edu/renewable-iap09/www/Course_Information.pdf
https://www.nuvhs.org/assets/resources/courseResources/Syllabus_Renewable_Technologies2.pdf

FLUID MECHANICS

Rationale

- Fluid Mechanics is an essential physics course, which is a prerequisite for many physics oriented masters. Examples include Masters programmes in Climate Physics (Utrecht University) and Water Management (TU Delft).
- There are also numerous applications of Fluid Mechanics in engineering.

Integration into MSP Curriculum

- 2000 level course
- Physics course
- Prerequisite Calculus & Classical Mechanics

Proposed Content

Fluid Statics

Bernoulli Equation

Fluid Kinematics

Integral control volume analysis

Differential analysis of fluid flow

Dimensional Analysis

Viscous Flow in Pipes

External Flow

Computational Fluid Dynamics

https://tbp.berkeley.edu/syllabi/565/download/
https://www.ntnu.edu/studies/courses/TEP4100#tab=omEmnet
TU Delft. (n.d.). MSc Track: Water Management - Admission, Application & Finance. Retrieved January 17, 2021, from https://www.tudelft.nl/onderwijs/opleidingen/masters/ce/msc-civil-engineering/msc-programme/track-water-management/admission-application-finance/
Utrecht University. (n.d.). MSc Climate Physics - Admission and Application. Retrieved January 17, 2021, from https://www.uu.nl/masters/en/climate-physics/admission-and-application/eu/ru#quicklinks

AQUATIC BIOLOGY

Rationale

- Understanding aquatic systems is essential for having a holistic view on (macro)biology. All organisms find their origin deep down in the ocean. The vast majority of the Earth's surface is aquatic, yet our knowledge on marine and freshwater biology is very limited. The course can be complemented practically with visits to aquatic ecosystems in the area. Maastricht is also the name of a geological era and a rock formation from the Cretaceous, in which the landscape was submerged underwater and the climate was tropical. Fossils are diverse and plentiful, and a visit to St. Pieters could complement the course for a more interactive, field-like approach to aquatic biology.
- Extremely relevant to the university, as the Maas is one of the main polluted rivers in Europe and given the strong relationship between prehistoric marine organisms and the Maastricht area. Through this course, further collaborations with the Natural Science Museum might develop
- Moreover, both within Belgium and the Netherlands, the Maas suffers from invasion of alien species, mainly quagga mussels and round gobies. A study of our aquatic ecosystems may provide the University of Maastricht with the tools to start building projects that are related to our river fauna and flora and their conservation.

Integration into MSP Curriculum

- 2000 level
- Great introduction to paleontology courses (e.g. Great Transformations in Vertebrate Paleontology) and possibly to Tropical Ecology
- Follow-up course to Evolutionary Biology, Zoology and Ecology

http://biology.kenyon.edu/courses/Biol352/SyllabusFall06_new.htm
http://academics.smcvt.edu/dfacey/AquaticBiology/Aq%20Bio%20Syllabus.htm
https://www.uttyler.edu/biology/course_syllabi/files/4305.pdf
https://canvas.harvard.edu/courses/4243/assignments/syllabus

AQUATIC BIOLOGY

Proposed content

Formation and maintenance of aquatic ecosystems

- Ocean and basin formation
- River formation
- The Maastrichtian Formation (intro to Paleo)
- Fossils: from Belemnites to Mosasaurs (visit St. Pieters)

Aquatic Ecosystems Overview

- Phytoplankton and zooplankton dynamics
- Aquatic organisms: from marine to freshwater (Zoology recap)
- Keystone species in the marine ecosystem and trophic webs, from the smallest plankton to the biggest whale
- Polar ecosystems, kelp forests, coral reefs, coastal ecosystems and deep ocean

Marine Ecosystems

- Water movements: oceanic currents, upwelling, tides (Ecology recap)
- Adaptations for living in marine ecosystems (osmoregulation)
- Introduction to marine invertebrates
- Introduction to marine fishes
- Introduction to marine reptiles and mammals

Marine Systems Disturbance

- Invasive species and marine extinctions
- Marine threats (pollution, overfishing and fish farms, acidification, coral bleaching, biodiversity loss, sea level rise)
- Conservation and sustainability
- Fish farming, its impact and implications.

http://biology.kenyon.edu/courses/Biol352/SyllabusFall06_new.htm
http://academics.smcvt.edu/dfacey/AquaticBiology/Aq%20Bio%20Syllabus.htm
https://www.uttyler.edu/biology/course_syllabi/files/4305.pdf
https://canvas.harvard.edu/courses/4243/assignments/syllabus

AQUATIC BIOLOGY

Proposed content (continued)

Estuaries (transition from marine to freshwater)

- General estuary ecology
- Water properties (buffer zones)
- Importance of estuaries
  - Biodiversity
  - Nursing areas
  - Bird migration stops
  - Mangroves as a carbon sink
  - Special animal adaptations to estuaries

Freshwater Ecosystems (abiotic factors)

- Hydrology and basic water chemistry
- Freshwater primary production
- Freshwater trophic webs and energy transfer
- Watershed overview:
  - Groundwater, glaciers, springs
  - Rivers and streams (e.g. Maas, Grensmaas)
  - Fluvial geomorphology
  - Lakes, ponds and wetlands

Disturbance of Freshwater Ecosystems

- Extreme landscape modification in the Netherlands
- River modification (industrialisation, dams, erosion)
- Aquaculture and Fisheries
- Current threats: invasive species, pollution, biodiversity loss, eutrophication, erosion and drought
- Sustainability, conservation and restoration (e.g. Grensmaas)

http://biology.kenyon.edu/courses/Biol352/SyllabusFall06_new.htm
http://academics.smcvt.edu/dfacey/AquaticBiology/Aq%20Bio%20Syllabus.htm
https://www.uttyler.edu/biology/course_syllabi/files/4305.pdf
https://canvas.harvard.edu/courses/4243/assignments/syllabus

STATUS OF BIODIVERSITY

Rationale

- Biodiversity is declining at rates unprecedented in human history, and we are only beginning to understand the impact of this decline on the ecosystems around the world that ultimately we all depend on.
- This topic is highly relevant for current times, as biodiversity may be one of the key factors in fighting climate change and ensuring a sustainable future. Indeed, it has been proven that biodiversity significantly increase the capture of CO2, increases an ecosystem's ability to create sinks in biogeochemical cycles, and enhances the ability of an ecosystem to produce services useful to humans, for example through the creation of a healthier soil, a more populated community and by strengthening the relationship between biotic and abiotic factors.
- However, biodiversity, its current state and effects on ecosystems and people are also highly complex topics in which many biotic and abiotic factors influence and interact with each other. This leads to debates both within and outside the scientific community on what the state of global and local biodiversity exactly is, how it is affected by people and what it's value exactly is. This course will provide an opportunity to MSP students to dive deeper into this material and use scientific publications to form an opinion about these topics.

Integration into MSP Curriculum

- Biology course

https://naturalscience.tcd.ie/postgraduate/msc-biodiversity/

STATUS OF BIODIVERSITY

Proposed Content

Biodiversity: what is it and how is it measured

- What is meant by biodiversity?
- Importance of biodiversity
- How do you measure biodiversity?
- How does biodiversity vary across the different biomes

Biodiversity loss: what are the causes?

- What factors affect (increase or decrease) biodiversity
- How are humans affecting biodiversity?
- What are the controversies around biodiversity loss?

Biodiversity (decline): what are the effects?

- On ecosystems
- On people

Conserving biodiversity

- What are different conservation practices?
- How can they be implemented (considering different interests)?
- How do you evaluate the effect of conservation?

5 - SUMMARY

The importance of climate education at MSP can be addressed by incorporating sustainability aspects in a number of existing courses and by introducing new ones with distinct core rationales.

As shown by our suggestions, each of the areas within the scientific field has an impact on this climate emergency, highlighting the urgency of instruction independently from the area of interest as well as the need for a holistic approach.

With this structured proposal, we hope to have inspired MSP to introduce new elements of sustainability in its curriculum and to appreciate the relevance of such action. As the MSP EPC, KAN Party and MSP alumni, we are enthusiastic and motivated to further contribute to the implementation of forms of improvement which will be considered most sensible.

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6 - Acknowledgments

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