Education.

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Introduction

Understanding marine ecosystems requires basic knowledge of the interrelated physical, biological and chemical processes taking place within and governing marine ecosystems. Training students in marine ecosystem studies thus requires an interdisciplinary approach. Students should not only be made familiar with the basics of physical transport, chemical transformations and biological entities, but also have an integrated system view in which the interactions among players and processes are analyzed and quantified.

My chair at Utrecht university has contributed to Utrecht's teaching programs by strengthening and further developing courses in marine reaction-transport modelling (together with Dr. Lubos Polerecky). This class deals mainly with biogeochemical models. The environmental modelling class in Ghent University (with Prof. Dries Bonte) focusses more on biological processes.

Construction of conceptual models followed by translating these concepts into mathematical relationships provides a systematic and instructive approach on many current environmental issues. Moreover, we also train our students how to use these models and how to evaluate their output.

Together with co-teachers Lubos Polerecky and Dries Bonte, I have created a reaction-transport / environmental modelling modelling course that is unique in terms of contents and teaching style.

Course content

Many modelling classes do not really focus on model development but rather on model applications. Often the contents of these courses is very diverse, and more patterned towards model application (stability and steady-state, model fitting, …) and mathematical treatment, rather than on model creation.

For both modelling classes that I teach, the focus is different in the sense that the mathematical aspects are less important, and most emphasis is on the *building* of a model from scratch up to its implementation as a computer program and model interpretation.

We are living in the Anthropocene where humans are a major force in shaping our environment. Our marine systems have to face many challenges: global warming, acidification, de-oxygenation, eutrophication, overfishing, biodiversity decline, etc. These stressors are acting together, implying that an integrated vision on these challenges should be using key knowledge of various disciplines. In line with this, our students make models on several of these environmental problems and they learn for instance, how to estimate human impacts on the environment, or what are the effects of certain mitigation strategies.

Examples that they work on in class are (1) models of the global carbon cycle and estimating the effects of e.g. large-scale deforestation, or carbon storage in deep waters on the earth's C-cycle, (2) ocean acidification, (3) eutrophication in agricultural systems, (4) the spread of infectious diseases (corona), (5) deoxygenation in river systems. Other topics taught at Utrecht are more fundamental of nature, such as the modelling of dissolution kinetics, early diagenetic process modeling.

In Utrecht, after the exams, the course ends with a group work, where 2-5 students work on one topic, in order to demonstrate their newly acquired skills and ability to apply the modelling to a real-world problem.

Teaching style: flipped classroom and blended learning

For teaching we adopted the blended learning and flipped classroom approach. I have used the flipped classroom concept successfully in my ecological modelling course in Ghent University for more than 20 years. Also, a few years before I accepted the chair in Utrecht, we had switched to blended learning in my Ghent course, so it was natural to also implement this for mu Utrecht course.

In a flipped classroom, the traditional learning environment, where the instructor teaches the theory of a course during the lectures and encourages the students to practice by themselves when at home, is reversed. This is, the students obtain the theoretical lectures in advance and prepare for class, where they put the learned concepts into practice. One of the advantages of a flipped classroom is that students can work more focused and obtain a more thorough understanding of the material. Typically the level of understanding of students in our class is highly diverse. In the traditional way of teaching, the brighter students often get bored as the material is being taught too slowly, while less bright students become frustrated as they cannot follow. In the flipped classroom concept, students can take the time they need to prepare the lessons. While in class, the topics can be explored in greater depth, where students directly interact with the tutors. This provides more room for tutoring “à la tête du client”.

The easiest way of flipping the classroom is by blended learning, i.e. combining traditional (on site) classes with online tools and activities.

In order to accommodate the large variety of student backgrounds, our teaching material now consists of a mixture of video material (to learn new concepts), quizzes (to check whether the students grasp these concepts), and exercises (to practice).

The entire reaction transport modelling course is available as an R-package from github (https://github.com/dynamic-R/RTM); the videos with the lectures can also be accessed from youtube (https://www.youtube.com/@lubospolerecky1930/videos). Other videos have a more artistic layout, e.g. (https://www.youtube.com/watch?v=eOsZzk_eN4I).

Quantitative problem solving

I believe that the modelling course is also a suitable didactic approach for teaching students' *quantitative* problem-solving skills. This is particularly important considering that such skills need to be improved among the student population in general, and the Earth Sciences and Biology students in particular.

Via our course, the students receive a training in integrated modelling and while doing so, improve their quantitative skills, as well as their computer programming skills. This not only prepares them for an academic career, but also e.g., for employment at applied research institutes, water governing bodies and other environmental agencies dealing with aquatic ecosystems.

Also, the blended learning concept, makes it simpler for students to refreshen their knowledge on a certain modelling topic. For instance, with a set of artistic-didactic videos, we show how students and researchers can make and implement computer models (see link above), and to which they can always refer to if they are working on a model.