Chapter 79
Water Europe: Hydroinformatics for Water Resources and Water Related Hazards Management in Europe

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Abstract European countries are facing serious challenges within the water sector despite regular investments over the last half century. The current challenges are reflecting a growing complexity and request an adaptation of the management approaches in order to develop a more holistic vision and strategy. In order to tackle part of these challenges, initiatives should be taken within the education field and especially for the water engineers training. The WaterEurope project (2018–2021) was developed within the Erasmus + framework as a Strategic Partnership action. In order to address some of the challenges on water identified at the European level, WaterEurope academic partners wish to innovate massively in a new pedagogic approach supported by a collaborative organization between six European MSc courses focused on hydroinformatics and water resources management. The experience already gathered has demonstrated that project oriented pedagogy can provide a relevant approach in water domain and contribute to bring competences

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and skills to the new engineers in charge of water issues. WaterEurope has developed resources to equip young engineers with the competences and skills related to hydrological analyst, flood modeling, damage assessment and engineering design with advanced simulation tools.

Keywords Collaborative engineering · Project based approach · WaterEurope · Hydroinformatics · Education and training · Numerical modeling · Study cases · Extreme hydrological conditions · Floods · Decision making · Erasmus

79.1 Introduction

As mentioned in the Horizon 2020 strategy (H2020 CS5) [1], "the world market for drinking and waste water reached € 250 billions in 2008, with corresponding investments of more than € 33 billions per annum. The market for technologies to adapt to climate change—like protecting from floods and droughts—is rapidly growing, considering that the cost of repairing damages is estimated to be about 6 times higher than the cost of adaptation. Moreover, there is significant potential to boost the competitiveness and growth of the European water sector, which includes 9000 active SMEs and provides 60,000 direct jobs in water utilities alone. A 1% increase of the rate of growth of the water industry in Europe may mean between 10,000 and 20,000 new jobs, while synergies with other sectors may generate even larger returns (some estimates indicate that the application of ICT in water management and monitoring could produce growth of 30% per year)."

The H2020 framework was planned to address innovative tools and methodologies, "such as advanced ICT and earth observation technologies, for risk assessment, mitigation and adaptation strategies". It also addresses eco-innovative, integrated and cross-sectoral solutions for water management such as: "wastewater and drinking water treatment technologies; water reuse systems; closed water cycles in industry; enhanced desalination technologies; improved materials; process, behaviour and technologies to enhance water and energy use efficiency; and appropriate management systems and strategies that incorporate water, wastewater, storm water and energy systems and duly consider changes in its availability due to climate change or other stressors."

Floods are natural phenomena that on the one hand are essential for the survival and health of the ecosystem while on the other hand can critically and permanently affect citizens, businesses and agriculture. According to the Centre for Research on the Epidemiology of Disasters' (CRED) [2], flooding is one of the most important natural hazards in Europe in terms of economic loss. In 2012, of the 905 natural catastrophes worldwide 36% were hydrological (floods), affecting millions of people's well-being and livelihood, especially in developing countries where poverty and food insecurity issues further aggravate the situation. According to the UN Office for Disaster Risk Reduction (UNISDR), floods are the single most widespread and increasing disaster risk to urban settlements of all sizes. In addition, urban flood risks are expected to increase significantly in the future as a result of climate change and demographic growth: the former is likely to increase the magnitude and frequency of extreme storm events, while the latter will increase exposure and vulnerability of humans as well as urban settlements.

Against this serious backdrop, nowadays European and worldwide urban environments are confronted with increasingly complex issues in terms of flood risk management and resilience. Specialists and experts in the field of water resources management and disaster risk response as well as urban planners, decision makers and industrial professionals are called upon the important task to reconsider traditional methodologies in favor of innovative and sustainable approaches which improve safety of exposed populations and reduce impact on natural environment. It is clear that the risk of flooding cannot be eliminated, but the reduction of vulnerability in flood-prone are can be achieved through a combination of elements organized around the concept of resilience.

Drawing from a definition proposed by the United Nations' International Strategy for Disaster Reduction (UNISDR) [3], in the context of urban flooding "resilience is the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase this capacity for learning from past disasters for better future protection and to improve risk reduction measures". In the near future, communities will have to adapt even more to increasing stressful environmental conditions, through disaster risk reduction and resilience building measures.

Since the year 2000, the European Commission has adopted eight Directives as legislative framework aimed at better manage water resources as well as reduce, through the right measures, the risks and impacts of floods to human well-being and the environment. Experience has shown that the most effective way is through the adoption of an integrated approach to flood management—one that recognizes both the opportunities provided by floodplains for socio-economic activities and that manages the associated risks—which is essential for the sustainable exploitation of water resources. The success of an urban planning project is thus based on adopting an across-sector approach and know-how based on:

- Sound knowledge of legislative frameworks (Water Law and European Directives) and economics (micro-economics, public finance and government procurement);
- Fundamental knowledge of earth science (e.g. hydrosphere and atmosphere)
- Strong skills in numerical modeling and data processing;
- Experience of using analysis and synthesis tools and associated methodologies;
- Familiarity with decision support system (DSS) and communication techniques.

79.2 The WaterEurope Project

In order to promote and stimulate students mobility, the European Union has setup in 1987 the Erasmus Programme ("EuRopean Community Action Scheme for the Mobility of University Students"). From January 2014, the Erasmus+ has been initiated as a new programme and combines all the EU's current schemes for education, training, youth and sport. Within the Erasmus+ framework and to tackle the societal challenges of the European Union, several actions have been created in order to promote education innovation and collaboration among higher education institutions.

From 2018 to 2021, WaterEurope was developed under the Strategic Partnership framework of Erasmus + and was implemented in the curricula of six European master degrees specialized in water management [4]. It was coordinated by the University of Nice—Sophia Antipolis (France) with 5 partners:

- Brandenburgische Technische Universität Cottbus—BTUC (Germany);
- Universitat Politècnica de Catalunya—UPC (Spain);
- Newcastle University—NU (United Kingdom);
- Warsaw University of Technology (Poland);
- Vrije Universiteit Brussel—VUB (Belgium).

WaterEurope developed an approach based on collaboration among various universities, research institutes and companies that are specialized in water management. Within this environment, the key principles of collaborative engineering are fostered among the participants through the ICT platforms and computation models. The participants learn through collaborative engineering in flood management on the real case of the Var river (France). The participants use a collaborative engineering environment (CEE) which can be considered as a prototype for the hydroinformatics community and professional involved in that field.

79.2.1 The Objectives of WaterEurope

The main objective of the WaterEurope project is to develop a unique set of pedagogic resources dedicated to the implementation of hydroinformatic solutions (numerical modelling tools) for water resources and water related hazards management at the European scale. This set of resources (course material, exercises, data sets, modelling environment integrating numerical models and communication services) is jointly elaborated by the project partners. The partners integrate these new resources in specific training modules integrated within their master course and intensively use an innovative project oriented pedagogic approach towards the participants. The development of the resources and their innovative use allow promoting to young professionals the new approaches for water resources and water related hazard management. Most important, the practice gained through these training modules contributes to increase competences and professional skills of young engineers in charge water resources at the international scale.

The WaterEurope project meets the objectives set for the Europe 2020 Strategy by addressing many aspects of all the identified societal challenges:

- Health, demographic change and wellbeing;
- Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the Bioeconomy;
- Secure, clean and efficient energy;
- Smart, green and integrated transport;
- Climate action, environment, resource efficiency and raw materials;
- Europe in a changing world—inclusive, innovative and reflective societies;
- Secure societies—protecting freedom and security of Europe and its citizens.

Water—and its management—is a component that is explicit or implicit a component of each identified theme. The concepts developed WaterEurope project address explicitly those aspects within the Erasmus + framework.

79.2.2 The Innovative Pedagogic Approach

Water challenges are some of the most complex issues that have to be addressed by modern societies for their sustainability. The competition among uses in one hand and the necessity of preserve water resources and environment in the other than request to develop a holistic vision for a proper water management. Up to now, the classical education and training activities for water engineering were very much driven by a "mechanical inspired approach" where technical solutions are defined, designed and implemented. The gradual integration of uses and competition among them is requesting an evolution within the water engineering education curricula. Most of the education professionals are regularly updating the contents of the courses but the requested current change implies to review the full teaching methods.

In order to tackle this education challenge, the WaterEurope partners wished to innovate massively in the pedagogic approach and to promote a completely new approach that is based on the concept of "problem oriented project based learning" (POPBL). The experience already gathered has demonstrated that POPBL can provide a relevant approach in water domain. The introduction of a multidisciplinary course within which almost all generic competencies required for employability and sustainability can only be delivered through a complex curriculum and innovative teaching and learning as oppose to traditional teaching method [4–6]. The basic principles of POPBL can be summarized as:

- Student-centred and able to motivate and gain commitment among students;
- Problem-oriented and not subject-oriented;
- Focus is more on learning process in finding solution rather than recall knowledge Project-Based which has goal and action for change;

- Exemplarity instead of generality;
- Promote group work/team work, social and communication skills.

The implementation of the approach requests a complete adaptation of the course materials and resources currently used in most of the M.Sc. degrees.

Differently from other theory-based Masters programmes, WaterEurope proposes a collaborative and innovative educational approach equipping participants with a combination of the necessary in-depth academic theoretical concepts and with an intensive practice approach and operational analysis of concrete case studies of various European catchments located in the project partner countries. The project oriented pedagogic approach is based on the teamwork with an international distribution of the teammates within the different participating institutions.

79.2.3 Collaborative Engineering and Collaborative Engineering Platform

The collaborative approach induces a complete reorganisation of the engineering work. This strategy is based on the project methodology. This choice induces an integration of the different tools used in the project as for the scientific and technical aspects or for the team and budget management in a common environment that is defined as the Collaborative Engineering Environment (CEE) [6, 7]. The collaboration portal can be defined as a single web based entry point that is able to integrate all the dimensions of the project. This website must be multi-project and multi user oriented. The environment must be flexible and open for the integration of CEE elements as engineering or communication tools. This concept and operational approach are fitting both with water issues management and associated hydroinformatics projects. In order to promote these methods and the tools of the collaborative engineering in the hydroinformatics field, it is essential to implement this approach in the educational and training processes [7].

The consortium involved within WaterEurope has chosen to create this specific environment for the project. This tool is a unique web-based platform that was developed and benefited from the knowledge and experience of the consortium members already applied in similar approaches during the last ten years. This unique environment host currently the most advanced technologies and the most advanced modelling tools provided by research and industrial partners. The objective is to set up a unique numerical environment that gathers the most advanced modelling tools and allows all participants to be exposed to such technologies. The platform is dedicated to serve as main work tool for all course participants throughout the three-month duration of the training module: during the first 3, 5 months participants are based at their host university and work remotely collaborating with their peers through the platform. A final and intensive two-week phase reunites all participants at one location where they finally conclude their work project. This unique collaborative working platform groups all modelling tools developed by world leading enterprises and research institutes allowing participants to put their skills and competences into practice. The Collaborative Engineering education methodology was invented by the consortium and obtained numerous international rewards and nowadays is used by more than 3000 engineers worldwide as part of their education programme as well as within the framework of intensive programmes in Asia and in South America.

79.3 The Var Catchment

In order to develop the WaterEurope project, real data on a catchment and on the associated hydrological processes were needed. To be relevant, the chosen example should be representative and offers the possibility to address various topics and the chance to implement different modelling approaches and tools. Due to the magnitude of the observed hydrological processes, the long history of hydraulic structures development and the tremendous competition among the water uses, the Var catchment on the French Riviera was selected. This choice was also motivated by the availability of high quality data and the willingness of the local authorities to engage collaboration with the programs.

The Var catchment is the largest catchment in the French Riviera, which has around 2800 km^2. The river gains water from the Alps mountainous area and flows to the Mediterranean sea. Due to the conspicuous variation of surface elevation (from sea level up to 3000 m), 90% streams in the catchment are identified as mountainous streams characterized with steep drainage slope and narrow crosssections. Only the last 22 km of the Var river shows more gentle terrain variation (surface slope: 19.9°) and wider river width (from 100 to 300 m). The Var river, which is the longest river in the catchment, begins at the spring in the village of Estenc to the south of the mountain pass of Cayolle, flows over a distance of 114 km and into the Mediterranean sea between Nice and Saint-Laurent-du-Var. Close to the outlet of this catchment, the growing urbanization of Nice city (5th largest French city) is currently taking place within the Var floodplain replacing gradually a long history of agricultural development associated with major hydraulic infrastructures. Today, the challenges of water management at this area show higher complexity, which covers many aspects such as groundwater supply, inundation risk and climate change impacts [8, 9] (Fig. 79.1).

The Var catchment concentrates a wide range of hydrological processes including extreme flood events generated by intense rainfall events that are frequently observed in the Mediterranean region and that have similar characteristics—intensity and total volume—with the most extreme rainfall events observed during tropical cyclones and typhoons. At the same time, the numerous challenges related to water management within the context of intense urban development make the catchment an ideal study case for future water engineers who will have to handle similar situations in their professional life.

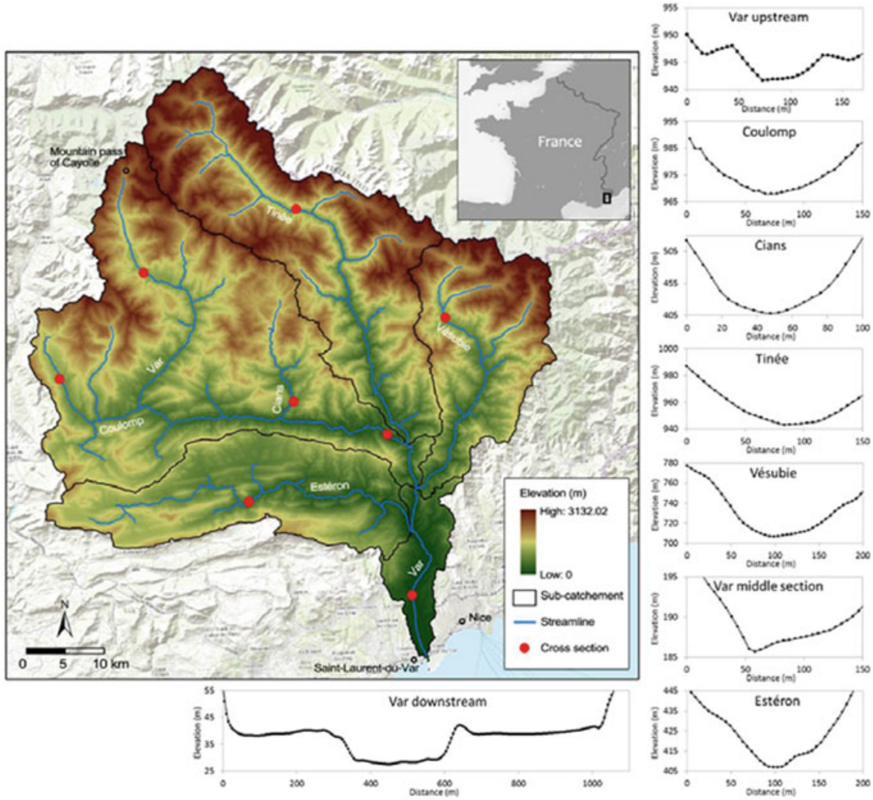

Fig. 79.1 Var catchment morphology from 5 m DEM. *Data Source* MNCA [11]

Constructions and massive urban development within the lower Var flood plain have been going on constantly since 1960s. Moreover, in recent years, the urbanization of downstream cities significantly changed the landuse in the lower Var valley. Consequently, the damage of natural disasters has been obviously increased. Since 1990s, there are several serious flood disasters caused by extreme rainfall events observed in the Var catchment: November 1994, November 2011, October 2015, November 2019 and November 2020. Those events represent reference situations that are used as study cases for the collaborative exercise and are reflecting what are the tasks given to engineers who have to analysis consequences of extreme situations and formulate mitigation strategies (Fig. 79.2).

The flood events are the core components of the collaborative exercise. The participants, with their teams have to analyze those events, understand the physical processes, identify the challenges, formulate modelling strategies, develop models and define mitigation strategies that could offer an efficient answer to those extreme situations. Obviously, structural measures like embankments or dikes cannot cope with the magnitude of the events and an alternative approach must be elaborated. The

Fig. 79.2 Damages of 1994 flood event in Var low valley. *Source* Nice Matin [11]

selected approach is based on the resilience evaluation through the Flood Resilience Index (FRI) methodology [10–12].

79.4 The Collaborative Engineering Environment

79.4.1 The Operational Architecture

In WaterEurope, the coordination is the core element required in order to ensure efficiency among participants and delivery of results. It's also a central issue for the pedagogic teams who have to produce supports and manage the activities of participants. Various strategies can be defined and of course should be based on a Web based environment. The WaterEurope web portal (https://watereurope.aquacloud.net) is currently based on Google solutions and in particular on the Google Web Toolkit that is allowing to produce a general orchestration of the various services. General information about the project can be found on the portal. In addition, it serves as the gateway to online courses and classrooms for the participants as well as data source for resources regarding the research case study (Fig. 79.3).

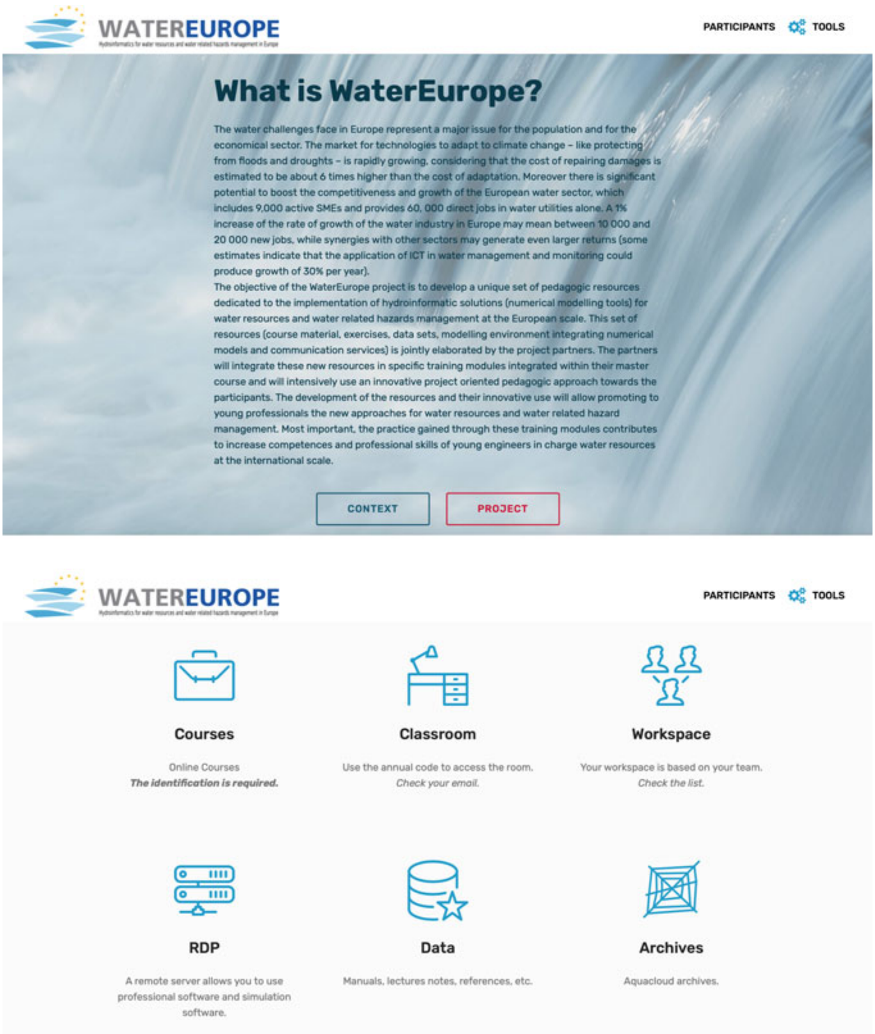

Fig. 79.3 Snapshot of the WaterEurope portal (left) and gateway to services (right) provided to participants and pedagogic teams (https://watereurope.aquacloud.net)

79.4.2 *The Online Courses*

For the implementation of online courses, Google Sites is used for the creation of the online lectures and tutorials. Google Sites is a structured wiki and Web page-creation tool offered by Google as part of the G Suite productivity suite. One of the advantages is that Google Sites enables WaterEurope to create a team-oriented site where multiple supervisors and professors from different geographical locations can easily collaborate on the creation of the content of the lectures and tutorials. In addition, Google Drive, Google Docs, Sheets, Slides and Forms are integrated within the Google Sites. This allows seamless blend of lectures notes in various formats (PDFs, PowerPoint presentations, Word documents, Excel sheets and videos) to be integrated within the online lectures' page itself. Tutorials are created using Google Forms which validate the participants learning after finishing each of the online courses. Similarly, Google Forms are also used to create feedback forms for each lecture course, in order to further improve and refine the lectures (Fig. 79.4).

Over the 3 years of the project, the pedagogic teams have produced 15 training modules that are addressing the following topics.

- Pre-processing: DEM data management with GIS, QGIS and ARC GIS Pro applications;
- Hydrological modelling: statistical hydrology for floods and droughts, hydrological modelling, Rainfall generator, MIKE SHE and SHE TRAN tutorials, HEC HMS and SWAT tutorial;
- Hydraulic modelling: 1D modelling with MIKE 11 and HEC RAS, 2D modelling with MIKE 21, MIKE URBAN, Flood Modeller, IBER, CITYCAT and TELEMAC;
- Groundwater modelling: FEFLOW tutorial;
- Resilience assessment: Flood Resilience Index methodology tutorial.

Fig. 79.4 Online courses offered to participants for the collaborative work

Remote Desktop solution is made available to all the participants for accessing modelling tools and GIS solutions. The participants can perform their modelling analysis at any location as long as the participant has access to internet connection. The Remote Desktop also reduce the computer requirements and lighten the workload of the participants' computers as all the heavy computations workload is conducted on the Remote Desktop servers.

Google classroom is used for the implementation of the online classrooms and forums for WaterEurope. The system has been highly appreciated by both participants and pedagogic teams over the 4 years of the project.

79.5 The Collaborative Experience

The online collaboration is conducted from December to February each year. During this phase, the participants are grouped into teams of eight to ten students with one to two supervisors assigned to each team. During this phase, the participants will work collectively using the web-base platform on hydrological analysis of a specific flood event developed by one of the consortium partners such as the 1994 Var flood event. Online courses on geographical analysis, hydrology hydraulics analysis are provided to the participants via the web-base platform (Google Sites and Google Classroom). The lectures (PowerPoint presentations and videos) and step-by-step tutorials and the necessary data to do the exercises are provided on the Google Sites. Each team should hand in one technical report in Google Classroom after each lesson. The reports and exercises results will be evaluated with a mark which is a part of the final score of the programme for the participants. The aim of these online courses is to ensure that each participant acquires a basic knowledge of hydrological modelling and hydraulic modelling. Five steps are included in the courses list, which covers the most of practical work in water engineering domain:

- Preprocessing with catchment and sub catchment delimitation with GIS tools;
- Hydrological modelling to estimate discharges by using physical based and lumped rainfall-runoff models;
- Hydraulic modelling to produce floodmap by using shallow water equation model implemented in different modelling environments;
- Groundwater modelling to perform groundwater flow simulations;
- Flood damage and resilience estimation with the local landuse information and floodmaps.

During the face-to-face meeting, the teams work on the Var catchment case study for two weeks. The supervisors give one technical question about processes analysis and modelling to each team at the start of each week. The tasks for each team during face to face meeting include:

- Hydrological and hydraulic modeling and analysis;
- Solving of the technical question given to the teams;

- Update technical results and other details on the team website where all activities are reported.

By the end of the second week, a complete technical report and a team management report are produced and uploaded on each team website. During the face-to-face phase, several international experts are joining activities and provide technical advices and field feedback to the various teams. This close synergy is highly beneficial to the teams. In addition, all participants go on a field trip on the Var Catchment case study area to have a firsthand view of the conditions on the catchment. During the field trip, various experts provide explanations and hydrological details about the observed extreme events. In addition, the participants have the chance to visit existing water facilities and structures to learn more about their operations.

79.6 Conclusions

The WaterEurope project has allowed to deliver several key results:

- Set of pedagogic resources. The project has produced a large set of project oriented pedagogic resources dedicated to water resources and water related hazards management strategies;
- Innovative project oriented pedagogic approach based on the collaborative engineering concept. The WaterEurope project is developed on the close partnership between the academia and the professional sector (businesses and public services). Differently from other theory-based Masters programmes, WaterEurope has developed a collaborative and innovative educational approach equipping participants with a combination of the necessary in-depth academic theoretical concepts and with an intensive practice approach and operational analysis of concrete case studies;
- Development and use of a Collaborative Engineering Platform. This web-based platform has been intensively applied and has strongly contributed to improve the efficiency of the collaboration among participants and pedagogic teams.
- Validation of study credits. The new pedagogic resources and the collaborative platform are now used and implemented as a compulsory part within the master curricula of each participating institution and the relevant ECTS study credits will be validated by partner institutions.
- Emphasis towards employability. WaterEurope was aiming to strengthen the capacities of young and skillful engineers equipping them with hands-on modelling competences of real case-studies. The professional associated to the project have underlined the interest of the approach for growing competences and requested skills for the young engineers.

The WaterEuope participants have gained scientific and technical competences associated to specific skills that allow them now to enter their professional life and at the same time to be ready to use and promote a more holistic view for the management of water related issues. The introduction of the new pedagogic approach has contributed to improve curricula and to increase synergy with professional sector [5, 6]. Even if the development of communication solutions has quickly populated the digital environment that commonly used today, the experience has also demonstrated that the collaborative practice requests a specific and careful training. Hydroinformatics is a field where this collaborative approach is an added value that contributes enriching the developed modelling solutions and enlarge vision on water management.

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