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Experiences from online and classroom education in hydroinformatics

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Abstract

Universities and other higher education institutions involved in water-related engineering education are facing new challenges in offering life long learning services and online educational support. Both the curricula and the form of delivery are changing, as contemporary water problems require interdisciplinary approaches involving diverse and up to date expertise maintained via continuous professional development. Hydroinformatics education faces similar challenges in developing relevant curricula and finding appropriate combinations of course delivery to its target group. This article presents experiences from delivering two hydroinformatics courses in the fields of Flood Modelling for Management (FMM) and Decision Support Systems (DSS) in River basin Management that in recent years have been delivered both online and in classroom settings. Comparisons between the two modes of delivery are provided, with the conclusion that online education in this field although still faced with many challenges has a promising potential for meeting future educational needs.

1 Introduction

Contemporary water-related engineering projects are characterised by high complexity and clear necessity of interdisciplinary approaches, which in turn requires a broader academic education as well as continuous professional development of modern-day engineers. Consequently teaching demands are currently significantly different than they were only 5 or 10 yr ago. This is due to the needs in diversification of disciplines, the shortage of skills in key areas and the needs for employability of the graduates.

In order to overcome these needs, and to make the European Higher Education Area attractive to students from all over the world, twenty nine European countries in 1999 signed the Bologna agreement. Each signatory has been committed to reform the respective higher education systems in a consistent and common way.

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The Bologna declaration brought many changes in the universities' curricula, and one of the most important changes is the introduction of the European Credit Transfer System (ECTS), leveling education in Bachelor and Master, with 180 to 240 ECTS for bachelor and 60 to 120 ECTS for the Master level. The Bachelor level prepares engineering graduates for direct entry into employment, whereas the Master level is conceptualized as a specialization. The third level of specialization is the Doctoral study (PhD). Bachelor and Master degrees are formulated with clearly defined learning outcomes and associated competencies, which can also serve for comparison of higher education among different universities and countries. The Bologna declaration also recognised that further to the necessary changes in higher education there is a clear need for life-long learning and professional development, which is especially relevant for engineering education (Gonzalez, 2003).

Water problems usually cut across boundaries, both geographical and professional, and it is becoming more and more frequent to build alliances that link different professionals at many locations. Appropriate education for this new working modes becomes increasingly important for enhancing the capacity to manage water-related assets and the aquatic environment. UNESCO-IHE (Delft, The Netherlands) is an academic, water education institute providing MSc and PhD education, as well as a large number of short courses and online courses (UNESCO-IHP, 1999). Mid-career participants from all over the world come here to study in one of the four MSc programmes (which lead to 14 specialisations), while many others come either for short courses, or to follow online courses. Being located in Europe, the accredited programmes of UNESCO-IHE follow the structure and set-up introduced by the Bologna declaration. This opens the possibilities for harmonising the education (Including ECTS exchange) with other European Universities and higher education institutions. At the same time this introduces a common standard for similar harmonisation with an increasing number of global higher education partners of UNESCO-IHE engaged in water-related education (UNESCO-IHP, 1999).

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The institute is aware of the continuous tension between academic educational offering (embedded in larger degree programmes) and the requirements of professional competence development of those who work in a professional water sector environment (frequently for specialised, stand alone learning components). Although the institute delivers formal education, it recognises that much of professional competence development is also the result of informal learning, which also needs to be supported with adequate learning components. To better address the new demand students at UNESCO-IHE are increasingly being offered more flexibility in their future learning paths by taking the initiative to provide some key components of water-related education through online courses. The advantages of online courses are that they are relatively cheaper (smaller tuition fees for the students), they provide flexibility in the use of time, travel is not involved, families are not separated, etc. It also may be pointed out that education in general is gradually moving more towards asynchronous sharing of knowledge and reduction of direct contact with teachers (Price et al., 2007).

One of the fields where two online courses were developed at UNESCO-IHE is hydroinformatics. Two of the online courses developed in hydroinformatics field are Flood Modelling for Management (FMM) and Decision Support Systems (DSS) in River Basin Management (Jonoski and Popescu, 2012).

The development of online courses requires significant efforts in both developing the learning material and supporting the online learning process of diverse groups of learners. Therefore, the comparison of the experiences from face to face (classroom) education, as opposed to online courses is useful in improving the online education system.

The present article aims at presenting the above mentioned hydroinformatics courses in both face to face and online implementation and look at the advantages of using one system or the other.

After this first introductory part the second section of the article introduces briefly the hydroinformatics field and its education implementation at UNESCO-IHE. Two of the courses in the field are presented in their implementation in the face to face and online approach, followed by the comparison between the two systems.

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2 Hydroinformatics education

2.1 The field of hydroinformatics

The concepts of Hydroinformatics as a new and distinct academic discipline were conceived and implemented by Michael B. Abbott. Hydroinformatics has since been widely recognised internationally, attracted a successful series of biennial international conferences and a peer reviewed journal.

Broadly hydroinformatics can be defined as: "the study of the flow of information and the generation of knowledge related to the dynamics of water in the real world, through the integration of information and communication technologies for data acquisition, modelling and decision support, and to the consequences for the aquatic environment and society and for the management of water based systems" (Abbott, 1991).

This definition includes merging of traditional fields of computational hydraulics with newer developments in numerical analysis, computer science, and communications technology. It includes the integration of information obtained from diverse sources, from field and remotely sensed data to data from hydraulic and numerical models to data from non engineering fields like ecology, economy and social science. Hydroinformatics is new and rapidly developing field and integrates knowledge and understanding of both water quantity and quality (Price et al., 2006). In recent years hydroinformatics has been transforming from a purely technical, into a sociotechical discipline (Abbott and Jonoski, 1998).

Hydroinformatics education is provided by few institutes and as such following a course is expensive and not many professionals from the developing countries can secure funds to follow such a course, therefore hydroinformatics teaching nowadays considers new methods of transferring knowledge, like group learning via collaborative engineering as well as online courses, not previously found in the curricula.

Hydroinformatics integrates many different technologies, such as simulation models, latest advances in information systems (databases, GIS, etc.) and latest web-based communication and integration tools for purposes of engineering problem-solving as

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well as broader decision support in the fields of the aquatic environment and man-made water-related infrastructure. The diversity of the involved technologies requires structured and goal-oriented development of hydroinformatics applications, which requires similarly adequate educational approaches. At the same time these technologies are rapidly evolving and there is a clear need for introduction of educational components that supports continuous professional development in this field (Abbott, 2001).

2.2 The Master of Science in hydroinformatics

The Master of Science course in Hydroinformatics course enriches traditional engineering education by introducing innovative concepts and tools, primarily related to the usage of various Information and Communication Technologies (ICTs), which opens up new and broader perspectives for the students. The course starts from the classical approach of developing mathematical models, based on first principles as a means for solving real engineering problems, and continues by introducing methods from new modeling paradigms such as data-driven or agent-based modeling. These different modeling approaches, together with their advantages and disadvantages are demonstrated on different application areas.

The Hydroinformatics course at UNESCO-IHE is designed to achieve three main objectives: to provide understanding of the underlying principles of Hydroinformatics, to develop and reinforce students' modelling skills through investigation of real-world applications and to provide students with opportunities to develop projects and case studies for later use in their career.

The study programme has evolved from its initial form to a structured programme in such a way that several different and interrelated themes are being covered through the introduction, and the extensive use of various modelling, information technology and decision support tools. The objectives of the programme are achieved in a systematic order: first knowledge and theory; then methodology, techniques and tools; integration, analysis and techniques; and finally, research and experimentation (Fig. 1). In Fig. 1,

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the structure of the Master of Science in Hydroinformatics is shown, along with the application areas to which the techniques and tools are applied. The course length is of 18 months and leads to a Master of Science (MSc) degree.

Organisationally, Hydroinformatics is one of the five specializations in Water Science and Engineering programme(WSE). It consists of two parts: the taught part, which lasts for 12 months, and a MSc research part, which lasts for 6 months. The first 12 months of the programme is structured in fourteen "blocks", called modules – each with a duration of three weeks. During any particular module students are focusing on one group of thematically interrelated subjects. The Hydroinformatics course has in its curricula fieldtrips, during which students are exposed to a wide range of applications and problems involving Hydroinformatics. In addition to the regular academic staff of UNESCO-IHE, invited speakers and guest lecturers address issues relevant to a broad understanding of Hydroinformatics and its applications in society.

The entire WSE programme is evaluated and improved based on the feedback of students. Students are required to evaluate the course materials and teaching styles through written evaluation forms. The appreciation of students with respect to the balance between the theoretical and practical (hands-on) curriculum components is also monitored through these routine programme evaluations. Since 1991, in Hydroinformatics, there were 160 graduates awarded with an MSc degree and 60 with a Master of Engineering degree.

2.3 Need for a change in education system

The volume of information that hydroinformaticians are called upon to know is increasing far more rapidly than the ability of engineering curricula to "cover it". The nature of this filed is such that graduates are required to master a broad spectrum of subjects, such as concepts in physics, mathematics, ecology, geography and computer and software engineering. This spectrum is well beyond the range of traditional hydraulic engineering curricula. While modeling and information and communication systems are at the core of hydroinformatics (which are quite specialized), their adequate

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implementation for diverse application areas requires the coverage of broad range of topics. In fact these requirements are increasingly put forward to present day engineers. It has been recognized, however, that the growth of the field, primarily driven by the rapid development in ICT technologies, but also by increased demand for water- and environmental knowledge by many sectors in society, brings challenges to designing adequate hydroinformatics education.

For these reasons, structuring the curriculum that meets the needs of most hydroinformatics students appears to be an elusive goal. The solution is to institute multiple tracks for different areas of specialization. Due to this, the content of the course has three modules for which the participants can select the content depending on their interest. The courses that are subject in this article actually belong to these elective modules. For example in one of the modules they can choose among three topics, out of which one is "Flood modelling for management", or in another one, out of five topics they can select "Decision Support Systems in River basin management". These elective courses are offered as online courses as well, so that later on hydroinformaticians professionals can enroll in a course of his/her choice that was not followed previously and improve their competence in that particular area. Equally, alumni of the institute or professionals who were not participants in a Master programme, but they do want to acquire extra competencies can enroll in these online courses.

The two modules, that are analysed in this paper are the Flood modelling for management (FMM) and the Decision Support System in River Basins (DSS).

The purpose of the FMM course is to provide professionals with the necessary background to appreciate the role and application of models in flood management, whereas the purpose of the DSS course is to present the general aspects of water resource management on the scale of the whole river basin. (Jonoski and Popescu, 2012).

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3 The FMM and DSS face to face modules

The FMM and DSS modules, as a part of the regular taught part of the WSE MSc, specialization Hydroinformatics, but they are offered to the whole WSE programme students. Any student in WSE programme can choose to follow FMM or DSS as a part of their MSC. FMM and DSS modules are carried out for three weeks in module 8 and 11, respectively, and have a curricula as defined in Tables 1 and 2. Due to its learning objectives, the DSS module is taught at a later stage, than the FMM module, in the MSc taught part.

The learning objective of the FMM module are to:

- understand and explain the main flood management problems;
- understand and explain the governing processes of flood generation and propagation;
- identify the proper modelling methodology for a given problem;
- utilise hands-on experience in the step-by-step modelling procedure (geometry, bathymetry, boundary conditions, forcing) needed to carry out a practical study with river modelling software packages; and – know how a river flood model may be used for structural and non-structural measures for flood mitigation.

The FMM course is designed for current and future water professionals (engineers and scientists), decision-makers and others involved in flood modeling and flood management, particularly those who would like to be familiarised with the latest tools and techniques in flood modelling management.

The learning objective of the DSS module are to:

- understand the role of system analysis in water resources planning and management;
- formulate and solve water resources problems as optimisation problems;

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– distinguish and properly use different types of decision support methods for water problems;

– build simple software applications that integrate data and models, both as stand-alone and Internet-based; and

– understand the potential of newly available data sources (e.g. remote sensing, web resources, data generated from climate and meteorological models) in advanced integrated modelling and decision support.

The FMM course is not provided just as module within WSE MSc programmes, it is offered as short courses as well. A participant to a short course joins the regular MSc programme, just for 3 weeks during the period of the module. The module is designed as such that water professionals, flood managers, or professionals who would like to know more about a particular domain, can join the MSc programme, as a participant to a short course.

In case of the FMM short course the pre-requisites to enroll in these modules, as short course participants, are knowledge about hydrology and hydraulics. Some experience with flood modelling/management is desirable but not a must.

4 The FMM and DSS online modules

4.1 Course requirements and target audience

The online modules on FMM and DSS are at postgraduate level, and ideally suited for flood managers, flood modellers, and water managers, respectively.

When it comes to the field of FMM and DSS, the development and implementation of online courses becomes challenging, because these topics requires not only the introduction of concepts, but also their exemplification by various software tools and systems, such as simulation models, encapsulated optimisation techniques, or MCA

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tools in case of the DSS course (Calizaya et al., 2010). Therefore the usual requirements for development and deployment of online learning material, in an interactive approach, becomes difficult.

The advantage of the online courses is that participants in their convenient times can download lectures, lecture notes, etc. from an Internet-based platform and can communicate with fellow participants and teachers. Lectures are provided in the form of video, audio or slides with notes. A video lecture may contain slides with an audio of the teacher's commentary. Occasionally it can contain a video window as well for displaying explanatory material (such as a movie). Theoretical lectures usually contain slides with notes. Soundtracks of lectures are incorporated in the presentation slides.

Modelling tools are introduced with instructional movies. Recent technologies (e.g. Camtasia, version 2007) allow such movies to be created easily and cheaply. The instructor presents the modelling tool by running it on his/her computer in a similar manner as they would in a face to face classroom. Nowadays technologies can record the computer screen and add the instructor's voice to create the movie. Such movies can be edited easily. Participants can download these movies and become acquainted with the new tools. Because participants can run such a movie several times in order to master some specific features of a tool, experience shows that this is preferred to a classroom demonstration of a new tool. Nevertheless the inability to have live question and answer sessions (as in a classroom situation), frequently about concepts behind the introduced tools, often leads to overall smaller appreciation of online learning when it comes to modelling topics supported by tools. This is sometimes overcome by using educational tools for synchronous discussions (see below). Very often public domain modelling tools are used but if commercial packages are needed then arrangements for Internet-based simulation with the licensed software at UNESCO-IHE's server are made available.

The developments in ICT helps in arranging a synchronous discussion if that is needed. The Moodle platform allows for communication in a forum and software such as Breeze or Skype allows for arranging a virtual classroom. During a virtual classroom, many-to-many communications in the form of video, voice and text enable everyone to see, talk and write (chat) to each other. Others can see ones own computer screen, documents can be shared and a writable board can be used and shared by everybody. These virtual classrooms are arranged at preset times. However, the number of participants in such a meeting has to be limited.

Currently, the learning objectives of the online courses are similar to their face to face versions. In the face to face version the assessment consists of an oral examination, assignment reports on modelling exercises and classroom discussion. In an online version the oral examination cannot be conducted easily because it is difficult to organize a classroom for examination or to conduct an oral examination over the Internet. During initial runs of the course an oral discussion was arranged but that turn out to be expensive not easy to arrange. In such cases other institutions in the country of the participant to the course had to be involved and this turned out to be expensive. As a result the current assessment relies heavily on the evaluation of the assignment reports. This would necessitate re-adjusting the learning objectives, which currently the authors are contemplating.

The FMM and DSS course were implemented as from 2006 and 2009, respectively. The participants to both courses are always with a minimum of a BSc degree. They are commonly capable and used to search for information, and motivated to develop the respective expertise relevant for their professional occupation. In other respects they are a very heterogeneous group: participants come from all over the world, the number of years of experience in the profession differs as well as their experience with online learning.

The FMM and DSS courses are designed for young and mid-level professionals who are involved in flood modelling or flood management, or who want to develop competences in this field, it is a postgraduate study ideally suited for flood managers, water managers, flood modellers/engineers and scientists dealing with floods.

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4.2 Courses implementation

Access to the online modules is via an Internet-based platform known as Moodle (http://moodle.org/) accessible through the UNESCO-IHE's e-learning campus is done via a web-based interface, accessible at the address http://ecampus.unesco-ihe.org. Each participant to an online course receives a user name and password after being accepted to the course. Acceptance to the course is based on several criteria such as educational background, working experience and motivation expressed in the application. A minimum of a Bachelor's qualification is required from any applicant in fields such as: civil, environmental or agricultural engineering, earth sciences, computer science or systems engineering.

An online module is structured into units, where each unit addresses a lesson (Fig. 2). The advantage of using the Moodle platform is that the educational material is decomposed into its basic components and allows different people to use the same source material while developing individual units based on their own expertise and insight.

As already mentioned the lectures are provided in the form of videos, slide-shows with audio, or slide show with text explanations. Additionally reading materials are provided. The participants can follow the lectures at their own pace, time and venue, and can communicate with the lecturers and fellow participants using the functionalities of the platform.

The average time of running an online course is 10 weeks and the content of the course is the same as the content of the face to face course. The online courses are carrying a weight of 5 ECTS and they require the same amount of study hours as in a normal face to face course.

The online course can not, at this moment, be evaluated in an examination set-up, and therefore it is evaluated based on assignments. Both FMM and DSS course have a set of 5–7 assignments that participants to the course have to finish and for which they have to submit reports. The assignments are evaluated by the lecturers to the

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course and in case of good answers they are the basis for successful completion of the course.

5 Discussion on experiences of face to face versus online education

The main educational challenge regarding the two courses described herein was how to structure the content of the course in such a way that the learning objectives are achieved, in both face to face and online mode of delivery. Main topics related to hydrological and hydraulic processes need to be presented to the students in a clear sequence. This is normal in face to face delivery, however difficult to ensure in an online setting. In this case, once the learning material is deployed, students tend to jump in their learning activities from one topic to another, led by curiosity or confidence that some topics are already familiar to them. This can be controlled by introducing lectures and exercises gradually (hiding some topics for later introduction), but this is normally not appreciated by the students. In both modes of delivery exercises were introduced after each set of lectures to ensure that a particular topic is understood before a new topic was presented. Working with such exercises to some extent leads the students to follow a recommended sequence in mastering the topics.

In both the DSS and the FMM course, the approach to structure the content was done based on the concept of competence-based learning, which ensures that final learning outcomes are achieved (Cheetams and Chivers, 2005). It needs to be realized that even when using competence-based learning prerequisites are important and certain learning sequence is preferred for the kinds of hydroinformatics topics as these. In this setting a recommended approach is to include extensive self-evaluation tests for each competence, which was not done so far for the two courses introduced here and remains to be introduced in the future. The design and development of content of the DSS course into competencies, so that understanding is achieved in a short period of time, is described in detail in Jonoski and Popescu (2011). A similar description for the FMM course is available in Popescu et al. (2009).

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Structuring of the course content is especially important when it comes to modeling concepts, which represent major parts of both courses. They are first presented in a generic way so that the students can use them with any available software tool, no matter the graphical user interface implementation. In a face to face environment, because of the in-house licenses for commercial software for hydrological and hydrodynamical modeling (such as Mike SHE of DHI or Sobek of Deltares) students can have hands-on exercises and training on all types of tools. This, however, is difficult to be achieved in an online environment where students do not have local licenses for such tools. Therefore, in this case only open-source or freely available modeling tools were used. Experience shows that in both face to face and online courses the generic introduction of modeling concepts was adequate for their understanding and students can subsequently easily apply them when requested to solve problems in an exercise.

The key element that made a difference between the classroom education and the online education, in terms of guiding the students learning, is the online discussion forum, which due to its nature of exchanging information becomes, in a certain way, a study guide. Lecturers need to be very active and to follow closely what is posted on the forum because a non-reaction can be understood by the students as an approval. While other fellow students may provide the right guidance, for some questions the interventions from the lecturers are necessary. In a face to face environment this is not the case because students are following the key points emphasized by the lecturer and can ask immediate questions and clarifications.

Due to these differences the time involvement of the academic staff in the face to face and online courses is also different. While in face to face settings most of the time is spent in a concentrated period of lecturing and exercise sessions, in online courses a prolonged commitment is required because they need to verify on a regular basis if there are questions and if they need to write elaborate answers. From a lecturer's point of view it is not always clear to which extent certain notions are understood by the students, especially related to modeling concepts and their application.

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The time investment of the student in an online course is designed to be the same as for a face to face course. The advantage of the online course is that the participant to the course has a higher control on the time they spend for learning, while in a face to face course due to the fact that the course is carried out for three consecutive weeks the time for learning is clearly defined and stricter. A thorough evaluation of students' experiences with the two types of courses may provide further insights into actual student time spent on learning. Because same students commonly would not take same courses both online and face to face, a longer record with many more online participants is required for such analysis and remains a task for the future.

As mentioned earlier, topics such as hydraulics, hydrology and decision support systems are better assimilated by the students if analyzed and discussed in a group setting, through problem solving. This is done naturally in a face to face environment due to the fact that students share the same classroom, whereas the vehicle for such activities in an online environment is the earlier mentioned discussion forum, or similar tools. One of the major issues for an online course is therefore the level of attainment of the desired collaboration among participants.

In order to assess the collaboration level in the online courses, in the year 2009, participants to the online courses were asked to score six statements regarding collaboration on a five-point scale (1-Do not agree, 2-Partially agree, 3-Neutral, 4-Agree, 5-Completely agree). The statements and the result of the scoring are presented in Table 3. When counting specifically the (completely) agreeing percentages, it can be seen that almost half of the participants tend to agree on having had good collaboration.

Looking at the overall numbers presented in Table 3 for the FMM course the statement of "I had lively and stimulating discussions with other participants in the pilot" has relatively the lowest score, but still one third agree (completely). In the DSS course 45,2 % participants tend to agree (completely) with the same statement. The overall numbers for this course also give indication of high collaboration, except that in this case smaller portion of participants agree that they have themselves provided help to others and received feedback (last two rows in Table 3).

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Finally, both online and face to face approaches to learning are evaluated quite well by the participants to the courses.

6 Conclusions

There is still much to learn from the experiences with online education in hydroinformatics, such as how to produce interactive materials much more cheaply and effectively. UNESCO-IHE's experience is proving valuable in helping it to fulfill its international remit in education in hydroinformatics. The main challenging questions for the academic staff involved in conducting the online courses is how to measure "students' learning" and how to set up the online course in such a way that students' learning is facilitated.

The further development of the hydroinformatician depends upon adequate preparation, education and training. The latest technological developments that will determine the success or failure of major water-related projects are explicitly taken into consideration during the development of the Hydroinformatics programme, and they achievements are directly used in the educational process and in implementation of numerous research projects. Dozens of the trained specialists have experienced that this programme is a very challenging but rewarding undertaking that opens new horizons in the professional career.

It is clear that the involvement of UNESCO-IHE in developing online courses, in parallel to face to face approach, has raised interesting didactical, organisational and technical issues regarding the (future) support of life long learning for water professionals all over the world.

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Table 1. Content and contact hours for the FMM course.

Topic	Contact hours [hrs]			Study load [hrs]	Examination/ weight
	Lec ture	Exer cise	Work shop		
Application domains of Hydroinformatics: floods, urban systems and environment	4	2	2	14	Written exam
Climate change and its impact on hydrology	4		2		10 %
Intro to modelling with 1-D applications	4				Exercise
Introduction to 1D2D, 2-D modelling	2		2	14	report
Flood analysis, river flood modelling and 1-D flood routing		22	2	24	(50 %)
New data sources to support flood modelling	8	2	2	14	Oral
(total contact hours 62)				74	exam
Total study load hours				146	(40 %)

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Table 2. Content and contact hours for the DSS course.

Topic	Contact hours [hrs]			Study load [hrs]	Examination/ weight
	Lec ture	Exer cise	Work shop		
System analysis in water resources	8	6	6	42	Assign-
Decision support systems	6	4	4	30	ments
Software technologies for integration	4	8	8	36	(35 %)
Integration of weather prediction and water models	8	2	4	32	(30 %)
(total contact hours 68)					(20 %)
Total study load hours				140	(15 %)

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Table 3. Appreciation of Collaboration in online courses.

What is your opinion on collaborative aspects during the course?	FMM	DSS
	(Completely)	agree
* I had lively and stimulating discussions with other participants in the module.	33.4 %	45.2 %
* I learned a lot from other participants in the module.	43.2 %	52.4 %
* Other participants in the module were able to answer my questions.	48.6 %	61.9 %
* I provided useful help to other participants in the module.	45.9%	33.4%
* I had feedback that this help to other participants in the module was useful.	48.6 %	35.7 %

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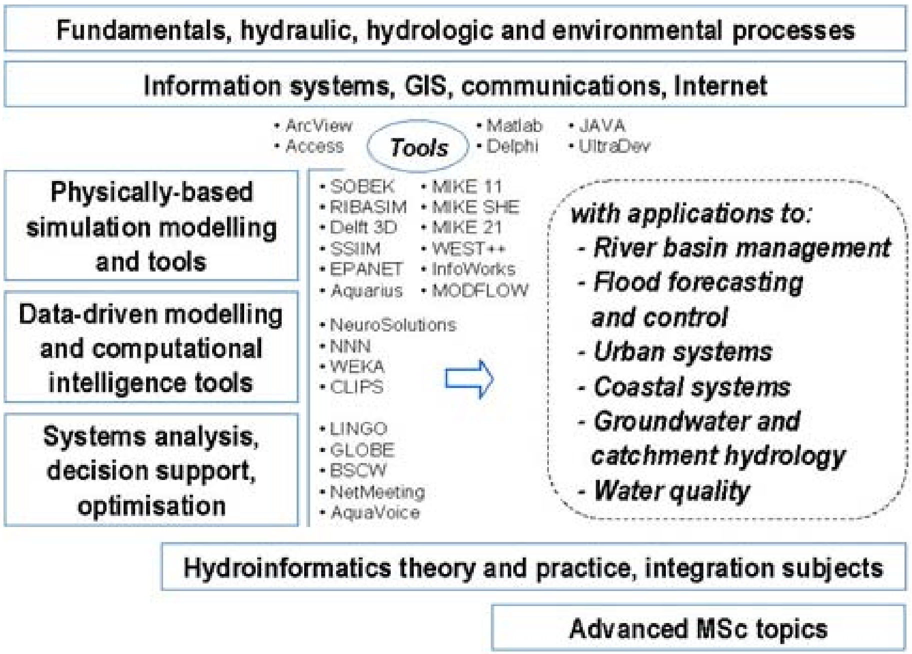

Fig. 1. The general thematic structure for Hydroinformatics for the first 12 months.

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Experiences from online and classroom education in hydroinformatics

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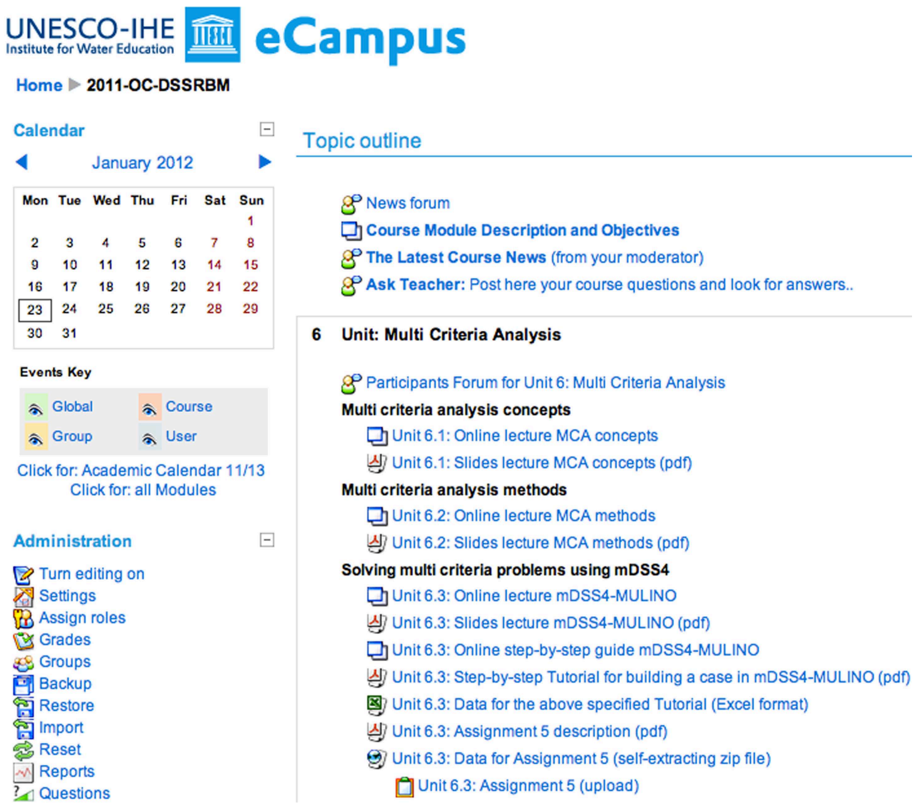

Fig. 2. Moodle implementation of the DSS course, unit 6 (units and lectures).

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