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Volume IV – Technology-enhanced Learning

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CONTENTS

Introduction

Patrick Parrish

When many people think about education and training innovations, technological innovations are the first that come to mind. While solid learning theory and genuine needs should in principle drive innovation, it is often new technologies that inspire us to try new things and even change our minds about how learning can occur. The technologies that have become available to us in the past two decades, and which continue to evolve at a growing pace, have led to a revolution in ideas about how to teach and learn. The papers here reflect a good sample of technologies impacting WMO-related disciplines.

1. Umnov et al. provide a detailed description of a multi-faceted technology and its pedagogical implementation through software and hardware systems to develop personal learning environments, and an account of designing Internet of Things applications, particularly in weather-related information for decision- making.

2. ter Pelkwijk et al. tell the story of international collaboration in the development of tools for creating and running instructional simulations for weather forecasters, the ultimate in learning-by-doing applications for this group.

3. Kung and Lam describe how the Hong Kong Observatory uses weather simulations for practical training, for self-assessment of competencies, and for creating a library of severe weather cases as a knowledge management repository.

4. Ross-Lazarov and Mancus add another level of complexity to instructional simulations by building branching simulations, with incremental feedback to guide, but not constrain learners to one path, so they can also experience the natural consequences of their decisions (and learn from their mistakes).

5. Quintana describes the AEMET approach to delivering a complete, blended-learning BIP-M package, using distance -learning tools for a 12-month, active online learning experience that precedes a two-month practical experience on site in Madrid.

6. Hung and Lam share their innovative tool for game-based learning and knowledge management on cloud and visibility identification, engaging the entire organization in developing a databank to serve these purposes.

7. Boyce and Cox describe the implementation of smart classroom technologies that can enhance the learning experience for both classroom and online students simultaneously and facilitate the transition to online teaching.

8. Kelsch and Page describe their work with WMO to deliver online hydrology training using well-designed, self-directed online resources in a structured, teacher-facilitated event that takes place over multiple weeks.

For a general introduction to the entire publication and to innovation processes, please refer to Volume I.

1. ECOIMPACT Personal Learning Environment: A new educational tool to facilitate the application of the Internet of Things and personal learning technologies in meteorology

Aleksei Umnov, Lobachevsky State University of Nizhny Novgorod, Russian Federation; Svyatoslav Tyuryakov, University of Helsinki and Finnish Meteorological Institute, Helsinki, Finland; Sergiy Snizhko, Taras Shevchenko National University of Kyiv, Ukraine; Sergiy Stepanenko, Odessa State Environmental University, Ukraine; Anna Timofeeva, Roshydromet Advanced Training Institute, Moscow, Russian Federation; Tetiana Nezhlukchenko, Kherson State Agricultural University, Ukraine; Denis Bespalov, Lobachevsky State University of Nizhny Novgorod, Russian Federation; Aleksei Kiryushin, Lobachevsky State University of Nizhny Novgorod, Russian Federation; Eduard Podgaiskii, Russian State Hydrometeorological University, Saint Petersburg, Russian Federation; Kalinka Kuzmova, Agricultural University – Plovdiv, Bulgaria, and Sergej Zilitinkevich, University of Helsinki and Finnish Meteorological Institute, Helsinki, Finland.

Abstract

This chapter describes the implementation of the concept of personal learning environment (PLE) within the framework of the ERASMUS+ capacity-building project in the field of higher education (ECOIMPACT project, http://e-impact.net/). The purpose of the ECOIMPACT PLE is to enhance the competence of several target groups in weather-related information for decision-making regarding the socioeconomic impacts of local weather, air quality and climate, and to develop their skills in the use of the Internet of Things (IoT) technologies for organizing and managing weather-sensitive activities. It focuses learners' attention on the creation of their own constantly evolving information collection – knowledge base – as well as on implementation of IoT-based projects aimed at developing prototypes of marketable products (weather stations, low-cost air quality monitoring instruments, smart greenhouse systems, etc.). The ECOIMPACT project has been designed in such a way that universities implementing the project could use the developed PLE in their educational processes. To enhance its universal applicability, the ECOIMPACT universities, which are presently Russian and Ukrainian, plan to conduct further testing of the developed PLE and gradually increase the number of PLE-based courses. Special attention will be paid to expanding the set of PLE-integrated laboratory works and training projects. It is expected that PLE could be used by start-ups working in such weather-dependent areas as agriculture, urban management, transport, energy sector, retail, environmental protection and healthcare.

1.1 Introduction

ECOIMPACT universities are a group of institutions working together towards modernization of meteorological education and training through application of the Internet of Things (IoT) technologies to improve efficiency of weather-sensitive economic activities. Their interest in personal learning environments (PLE) stems from the knowledge that human interaction with the environment over the past decades has become so intense and complex that it has led to rapid emergence of new hybrid systems, involving both natural and human-made objects, as well as individuals, social, business and government structures interacting with these objects. The development of such systems is decisively affected by the widespread introduction of digital technologies. If previously one could regard such systems only as local phenomena associated with large advanced technological enterprises, nowadays, the IoT expansion leads to such systems becoming the rule rather than the exception.

Examples of massively emerging hybrid systems include such "smart" objects as homes, offices, roads, vehicles, agricultural farms and green energy facilities. Their smart elements are integrated by local information systems, which in turn are connected to cloud services providing remote monitoring and control. In the near future, few industrial facilities, offices and households will remain unconnected to the IoT. Essentially, this entails full integration of the real and digital worlds in the future. Such integration in its extreme form is presented, for example, in the augmented reality concept of the Magic Leap (https://www.magicleap.com) start-up, which plans to complement the real world with digital layers.

Such hybrid systems are exposed to both direct and indirect environmental impacts, since their outputs (e.g., harvests in the case of an agricultural farm) and their external resources (e.g., prices of energy, water and fertilizers) depend on the state of the environment. The IoT technologies allow the collection of real-time data on elements of both the state of the environment and the state of the systems, as well as on conditions and actions of individuals engaged in production activities (e.g., irrigation, harvesting). Management decisions (taken by people and algorithms) in such systems can and should be based on real-time data coming from numerous spatially distributed sensors and should be executed by actuators (mechanisms that receive control signals and convert them into mechanical motion, e.g., water or fertilizer dosing units).

The new IoT reality, with its new opportunities and problems, is unfamiliar to many people: businessmen who run weather-sensitive companies; government employees who plan and manage urban infrastructures for weather and climate; personnel of companies developing and operating weather-sensitive systems; and the young generation – students and pupils, who will join the ranks of these professionals tomorrow. The challenge is to raise the skills in developing and using the IoT technologies for all the above-mentioned categories of people.

Traditional educational institutions do not keep pace with the rapid technological development and may not provide the economy and society with a sufficient number of specialists able to create and exploit the IoT solutions and understand the specifics of economic activities in weather-sensitive areas. Such specialists are needed among professional meteorologists and students in atmospheric sciences, as well as among businessmen and government officials. The lack of such specialists hinders the use of new technologies.

Classical forms of education prioritizing classroom lectures, practical training and seminars, as well as massive open online courses (MOOCs), imply a "top-down" approach to learning, when the selection of educational content, sequence of its mastering and educational goals are determined by an educational institution and updated very slowly. Slow upgrade of educational materials does not allow for timely introduction of modern technologies into training, which in turn does not provide the training of specialists demanded by the market. In addition, the traditional approach to learning may be poorly adapted to a particular student's level of knowledge, learning style and life circumstances, which may prevent a person from participating in formal full-time resident programmes or strictly regulated distance-learning processes.

As an alternative to traditional approaches, the ECOIMPACT universities of Russia and Ukraine have chosen to pilot the concept of a personal learning environment (PLE). The concept was developed methodically and implemented as a hardware and software system allowing learners to form their personal information and education space, increase collaboration with peers and interaction with teachers, and provide the ability to interface with Internet of Things systems. The purpose of the developed ECOIMPACT-PLE is twofold:

1. To enhance the competence of several target groups in the use of weather-related information for decision-making regarding the economic and societal impacts of local weather, air quality and climate; and

2. To develop their skills in using IoT technologies for organizing and managing weather-sensitive activities based on objective detailed data on environmental parameters.

In Section 1.2, we provide an overview of the PLE concept; Section 1.3 describes technical implementation of PLE; Section 1.4 summarizes methodological recommendations on developing PLE educational content and using PLE. Finally, in Section 1.5, we summarize the results of testing PLE in the ECOIMPACT universities and outline future prospects.

1.2 The concept of personal learning environments

The concept of personal learning environment (PLE) appeared more than a decade ago but is still evolving. Although heated exchanges on what constitutes a PLE are over, the discussion is not closed. In this chapter, we will follow the viewpoint of Attwell (2007), Attwell et.al. (2008), Nelkner et.al. (2008), Barrett and Garrett (2009), and Elfeky (2018), which considers PLE as a set of tools that allows learners to independently manage their learning process, collect information from various sources, structure and analyse it, and create new informational materials. In addition to the tools for working with information, PLE includes the information materials (both raw and processed by learners), methodological recommendations for using the materials (including interpretation of the information), as well as mechanisms for information exchange and its public presentation.

The range of tools for working with information largely determines the PLE's character and affects the way of learning. There are two opposite approaches: learners can use either a plethora of tools available in the modern information space, or specialized software and hardware systems (Torres Kompen et. al., 2019).

The advantage of the first approach is that among the existing tools one can always find the most convenient and user-friendly option, which is at the same time well-developed and stable (supported by a large commercial company or an open-source community). Its main disadvantages are relying on poorly adapted tools for educational needs; mass commercial products (typically designed for entertainment and informal communication); and the lack of integration of services into a single system, which obliges a user to memorize a lot of unnecessary information, making it difficult to focus on essential tasks.

Advantages of the second approach are the native adaptation of tools to the learning process and a high degree of integration, allowing minimal information transfer time between tools and enabling the users to develop efficient work scenarios. Where relevant, this approach can be extended to integration of external services that are not included in the basic solution. Its disadvantage is the complexity of implementation, requiring a high-quality replication of many functions that otherwise might be implemented in separate commercial products.

Currently, most PLE development projects are focused on exploitation of existing Web 2.0 services complemented by certain integrating components for navigating the Internet. Among the significant past initiatives are the EU projects Responsive Open Learning Environments (ROLE, http://www.role-project.eu) and Language Technology for Lifelong Learning (LTfLL, https://cordis.europa.eu/project/rcn/85779), the UK PLEX Personal Learning Environment (http://www.reload.ac.uk/plex/) and the German Personal Learning Environment Framework (PLEF) (Chatti et. al., 2009). Particularly noteworthy is the actively developed web-mixing Symbaloo platform (https://www.symbaloo.com) reviewed by Fociños (2017), used for organizing personal bookmarks.

The ECOIMPACT-PLE concept was created using the second approach, which influenced both the technical implementation of the PLE concept and (albeit to a lesser extent) the principles of designing the educational process. It is based on a structured information space. Various information objects are then placed in this space with tools that allow a user to work with those objects, as well as with their internal content. Within the information space there is also a set of recommended methods for effective organization of work and communication channels that allow for multi-user collaboration.

Our implementation of the concept relies on the following basic principles:

Principle	*Its implementation in ECOIMPACT-PLE*
The learner sets up a custom information space (as part of the common information space) and organizes it by creating a hierarchical system of thematic categories with which to structure knowledge bases (for example, glossaries, reference material, datasets, examples and cases, contacts). The categories and knowledge bases play the role of a system of semantic coordinates in the information space.	The learner registers a unique account on https://ecoimpact-ple.com and logs in (the same username and password are valid for the desktop application). Using the mash-up editor (see subsection 1.3.2, Mashup editor), the learner then creates a system of categories according to which the content will be structured later. For example, titles of university disciplines may be used as the basic thematic categories, while a full list of categories may include both the university disciplines and those studied independently (for example, Meteorological observations, Meteorological forecasts, Economic meteorology, IT in Meteorology, Biometeorology)
The created information space hosts both purely virtual information objects (e.g. multimedia documents, hyperlinks, tests) and interfaces to real "smart" things (e.g. IoT weather stations or air quality instruments which have built-in computational capabilities and internet connectivity).	Multimedia documents are, for example, course materials that learners upload to their accounts from the PLE cloud repository, as well as analytical materials, personal portfolio documents, materials of current training projects created by learners. The project materials may contain graphical interfaces to IoT devices (there is a dedicated interactive document type for that) allowing the system to both display the readings from environmental sensors and automatically operate the devices controlling the environmental parameters (see subsection 1.3.4, IoT component).
To facilitate searching and establish links between objects of any type in the personal information space, all the objects contain meta-information (e.g., keywords, geographic coordinates, time stamps), which can be added and edited at any time.	For example, a meteorological sensor linked to a geographic coordinate can be found on an interactive map, readings from sensors located in a smart greenhouse or at the airport - identified by the names of these locations.
Learners must have greater autonomy in the choice of educational materials (their sources, forms of presentation, etc.). Therefore, the PLE system must be open, allowing easily integrated content from a variety of sources (primarily online sources) into the learner's personal educational space.	Users have several options to integrate third-party content into their own documents, for instance, (1) embedding as iframe, for example, in the form of YouTube video, Wikipedia pages, readings from sensors of third-party services; (2) inserting as hyperlinks to third-party sites and individual files.
PLE should provide each learner with a large set of tools for working with information—collecting it from the Internet and other sources; saving, classifying and describing it with meta-information; combining and organizing it into useful structures.	The mashup editor allows for manually selecting blocks of information according to specific criteria (significance, scope, etc.) and automatically grouping these blocks in new documents. For example, while reading this chapter, one can save in two separate documents everything related to working with traditional educational content and everything related to working with IoT devices, as well as supplement this information with comments and links to relevant third-party sources.
Learners must have access to both educational materials and methodological guidelines, as well as to educational materials on the soft skills necessary for collaborating.	For each training course, methodological materials are placed in the cloud repository. These may include tips for studying the course and using automatic tests for self-assessment, as well as assignment templates allowing learners

Principle	*Its implementation in ECOIMPACT-PLE*
	to follow the correct algorithms, for example, when doing laboratory work.
Learners’ results should be saved for life-long use.	All content created by the learner is stored on PLE servers (in the cloud) and locally on the learner's computer, and can be deleted or modified only by the learner.
The learning environment should stimulate both active independent work and collaborative project work.	Active independent work is achieved through the inclusion in educational materials of a large number of tests and practical assignments in the form of laboratory tasks and training projects. Collaborative project work is facilitated by dialogue boxes that can be embedded in any document, enabling online content-related discussions, which are the basis for collaborative project activities.
Teachers and learners should have good communication channels linked to performed learning activities.	Such communication is established by embedding the above-mentioned dialogue boxes in assignment documents prepared by teachers.
It is the learner who decides on the duration of the learning process, chooses a convenient time and, if possible, the form of learning.	The learner has tools for both online and offline work, can access all materials anytime anywhere, and can maintain content-related communication with teachers and other PLE users both in real time and offline (via saved messages).

1.3 The PLE hardware and software system

The PLE system is based on a proprietary, well-integrated infrastructure, which includes a large number of software and hardware components supporting both online and offline modes. The ECOIMPACT-PLE focuses the learner’s attention on the creation of customized, constantly evolving information collections (knowledge bases) as well as on implementation of IoT-based projects aimed at developing prototypes of marketable products (for example, weather stations, low-cost air quality monitoring instruments, smart greenhouse systems).

The PLE user can create content directly in HTML format, which allows for its immediate publication on the Internet. The PLE interfaces in many ways resemble content management system (CMS) sites, but do not require knowledge of HTML and programming skills. The main information objects in PLE are:

1. Multimedia HTML documents;
2. Online bookmarks;
3. Documents containing questions and tests with automatic verification;
4. Documents containing mathematical data organized in the form of tables and plots;
5. Navigational documents, allowing the creation of indexes of categories and knowledge bases;
6. Homepages of users;
7. Dashboards providing interfaces to the IoT systems (consisting of a number of interacting smart things).

The ECOIMPACT-PLE system consists of the following elements:

1. Central knowledge base servers (storing, searching and delivering the multimedia documents and other similar information objects structured in knowledge bases, as well as generating user web interfaces);
2. Central IoT servers (collecting, storing, analysing, searching and delivering via web interfaces the data coming from multiple local IoT systems of PLE users);
3. Local IoT servers (collecting the information from multiple local IoT systems of PLE users, storing, processing and publishing it via web interfaces);
4. Desktop applications (allowing users to work offline, with periodic synchronization of content between servers and application);
5. Mobile applications (under development) should provide "on-the-go" access to full functionality of the PLE service, including interaction with smart things.
6. "Smart" things.

1.3.1 PLE interfaces

There are two possibilities for handling the ECOIMPACT-PLE: via the web application (launched in a standard web browser) and via the desktop application (installed on a personal computer). Each of the applications has its own graphic user interface and functionality.

However, the user interfaces and functionality of desktop and web applications are fully identical for both learners and teachers. Thus, users can take different roles at the same time and form groups with dynamically changing roles.

All the PLE content is divided into public (open to all users) and private (accessible only to a single user). The public interface of the ECOIMPACT-PLE web application, along with open-access user materials, contains lectures and laboratory work specially prepared by teachers (Figure 1.1).

A registered user can save any publicly posted material in a personal account with one click. It is important that the saved materials contain detailed step-by-step instructions (assignments) for a learner, who can respond using texts, images, video and audio fragments, and others, in the same document.

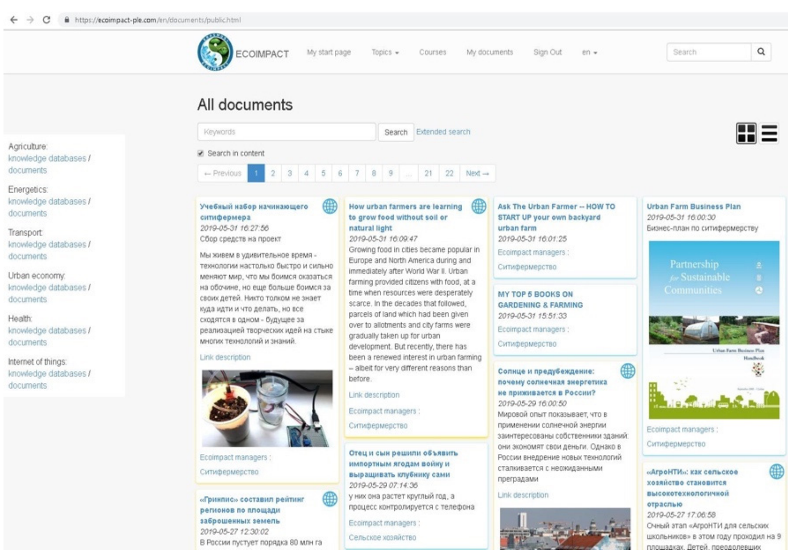

Figure 1.1. Public user interface of the ECOIMPACT-PLE web application

1.3.2 Mashup editor

The basic tools used by a learner to create and modify the PLE content are mashup editors, which allow users to create and edit multimedia HTML documents. A mashup editor is available both in the web and desktop applications (the functionality and graphical interface of the editors are not identical). The interface of the web version of the mashup editor is shown in Figure 1.2.

Mashup editors allow users to easily integrate their own and third-party content, combining in one document texts, images, video and audio clips, interactive geographical maps, plots (displaying data from the IoT objects), QR codes, iframes (allowing to add third-party webpages to display within the document, for example, Wikipedia pages), and more.

In the web and desktop versions of ECOIMPACT-PLE user interfaces, mashup editors are integrated with a content management system geared to create categories and knowledge bases, publish and search documents and other information objects. When creating a new category or a new document, a user must describe it with metadata by filling in a special form. This allows any information object to be simultaneously present in several categories. This also provides high flexibility in organizing the content.

Learners can embed one or more dialogue windows (chats) in a private document and authorize selected ECOIMPACT-PLE users to view and discuss the contents of the document in real time using the dialogue window. All comments are saved. This communication tool facilitates learner-teacher discussions on accomplishing the assignments given by the teacher, for example, instructions integrated into lecture documents.

Another way of using the mashup editor is to create questions and tests with automatic verification. For example, users can design tests in their knowledge bases for quick self-assessment while preparing for a conversation with a teacher.

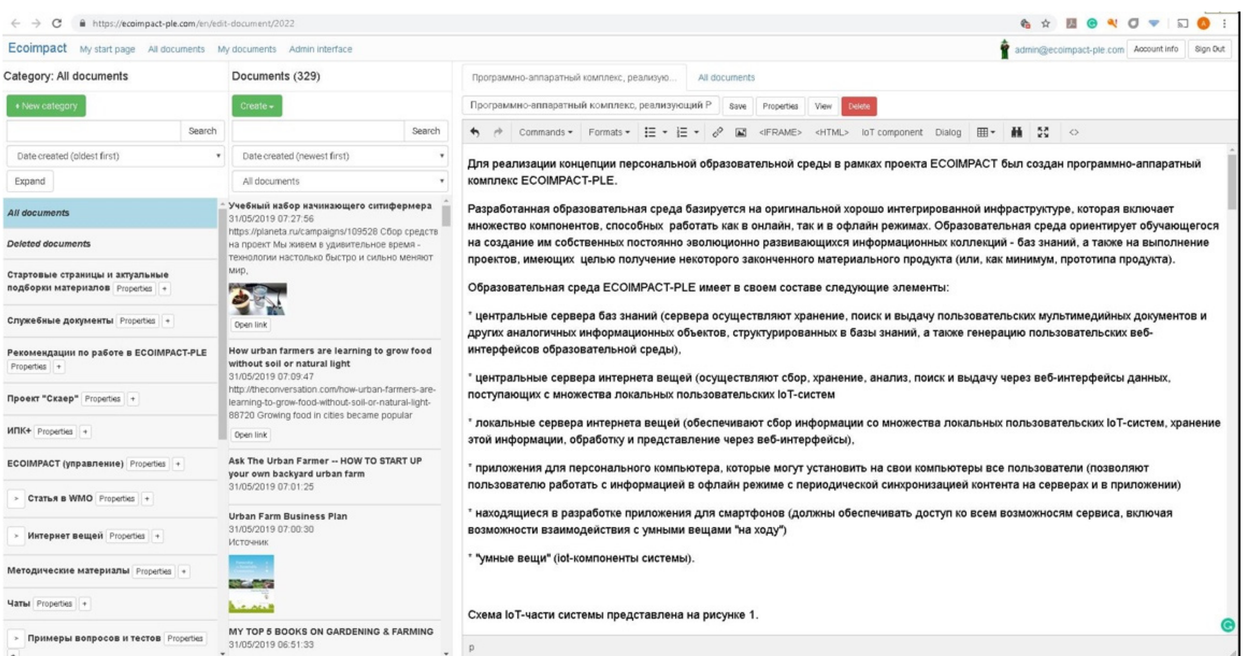

Figure 1.2. Mashup editor: user interface of web version

To summarize, the above features of mashup editors, the ability to store and quickly find content, as well as to discuss it with a teacher or in groups, allow learners to implement many forms of active work with information, namely:

1. Study educational materials while commenting on them, modifying and expanding them with external resources and new own content (authors of educational materials can additionally provide templates, for example, a Cornell method template, to help learners create new content;

2. Create personal knowledge bases (organized information collections) containing both modified educational materials and original user documents, as well as links to external reference and information;

3. Organize project work in small teams, using the PLE communication functionality;

4. Organize individual work in student-teacher pairs, with the possibility to save the results of this work in the personal knowledge bases of both student and teacher;

5. Use instruments of programmed learning (Skinner, 1968; Emurian et al., 2008) allowing different learning tracks depending on the results of testing.

1.3.3 Additional features

In addition to mashup editors, the PLE system includes tools for placing information objects on a geographical map; calendars for handling objects with reference to date; a quotation management system for conveniently collecting items from different sources and combining them into a single document; and a number of other useful tools for working with information.

Content navigation in the PLE is implemented in several ways, such as using the category tree, searching the metadata, using special navigational documents containing the tables of contents of knowledge bases, and by means of personal home pages where a user can collect links to favourite documents for quick access, or place a to-do list and dialogue windows with currently important chats.

1.3.4 IoT component

The IoT component of the PLE offers unique opportunities to students and teachers. Its scheme is presented in Figure 1.3. Users have access to their own local servers with connected sensors and actuators, as well as to central servers receiving data either through a network of local servers or directly from smart things. Local servers allow for building multi-element local IoT systems and can locally (without internet delays) process data to automatically control all the elements of the systems.

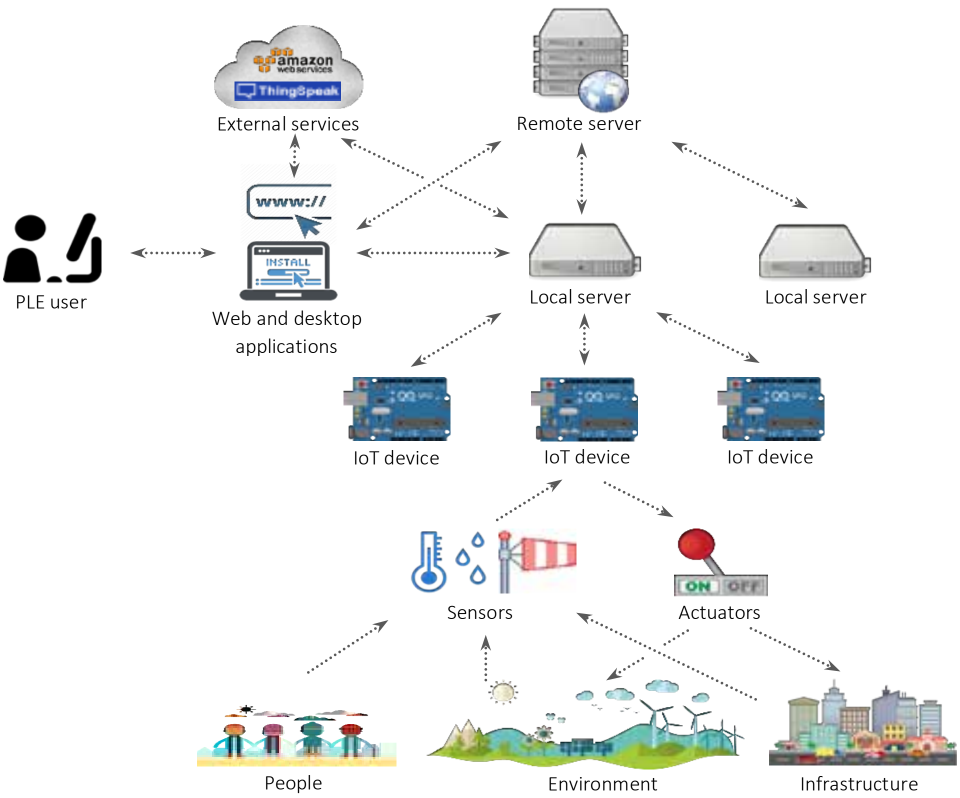

Figure 1.3. Schematic representation of the IoT component of the PLE

The PLE user is provided with ample opportunities to create local spatially distributed IoT systems. Operating these systems (for example, obtaining the monitoring data) is possible via both the desktop and web applications. It is also possible to configure the interaction of IoT systems developed by users with external IoT clouds created by ThingSpeak, Amazon and Google.

Examples of IoT systems that can be built within the PLE, include:

1. Wireless sensor networks of various spatial scales for meteorological monitoring;

2. Sensor networks for air quality monitoring;

3. Smart home systems (to control appliances and energy usage);

4. Smart farm systems (to control the condition of the soil, crops and equipment in the fields, among others).

Figure 1.4 shows the dashboard of a smart office system (linked to the floor plan), allowing it to:

1. Monitor the microclimate in separate office rooms (temperature, humidity, air pressure, carbon dioxide and oxygen concentrations);

2. Control air conditioners and humidifiers, as well as open and close windows for ventilation;

3. Control the lighting in the rooms by zones;

4. Control household appliances in these rooms (including a wall of living plants).

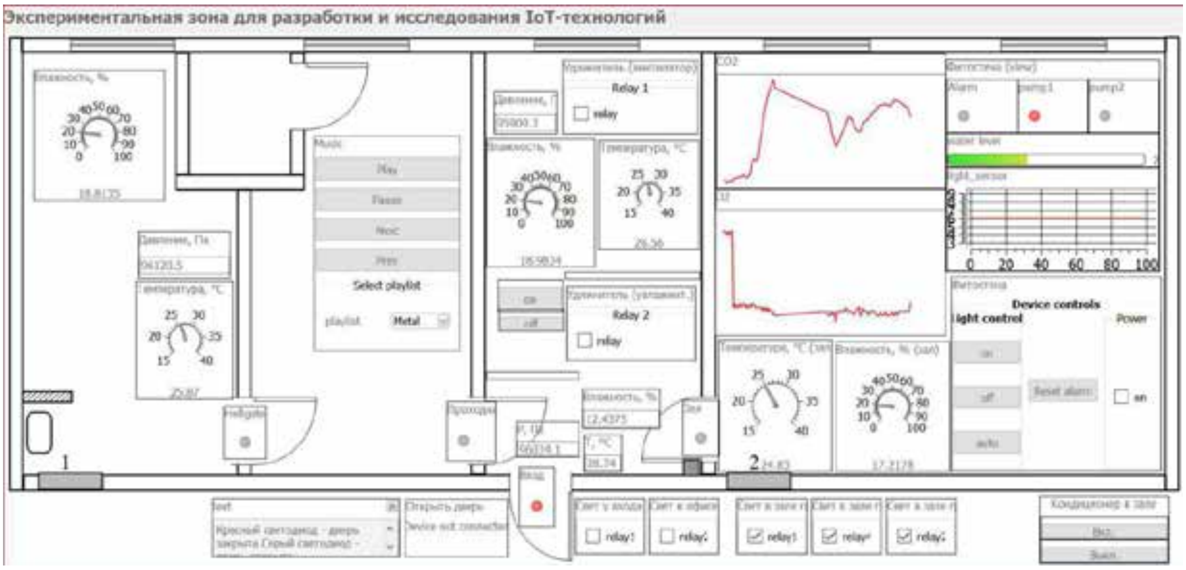

Figure 1.4. Dashboard of a smart office system (linked to the floor plan), for monitoring and controlling air temperature, humidity, CO_2 and oxygen concentrations in the office space

This monitoring and control system was developed in the ECOIMPACT-PLE by one student (advised by a teacher) within a few days. Installing the devices, connecting them to a local server and creating a dashboard do not require programming skills. Complex scenarios of interaction between devices through a local server are currently implemented using JavaScript, which may be substituted by a simple visual language.

The local server software enables the development of such independent IoT systems, belonging to different users, in a single network. This feature allows, for example, the organization of simultaneous projects with groups of students in one laboratory or one experimental zone, where students can still do their own laboratory work or training projects.

The creation of a network that records environmental parameters is an example of a training project, which can be implemented by students working in parallel and independently of each other.

In this training project, students could assemble devices containing a set of sensors and actuators and connect these devices to a desktop application, local server and remote server. The battery-powered devices must be assembled in portable housings that allow them to be moved freely around the room and must include:

1. A NodeMCU development board with a WiFi module (platform for assembly of IoT devices);

2. Air temperature, humidity, pressure and light sensors;

3. A set of LEDs and a sound generator to indicate various states.

The devices must transfer environmental data to a local server. In the desktop application, each user must create a dashboard for receiving the data from the local server and controlling each device (turning on a sound signal for locating the device among similar ones and remotely setting the levels of the environmental parameters triggering LEDs.)

The microclimate and lighting in the room can be changed by a wireless power terminal that switches on/off a humidifier, air blower, additional lighting and fan heater, for example. Each user, in turn, can program the local server so that when a particular user's device registers certain values of environmental parameters, equipment that changes the environmental conditions in the room turn on/off.

1.4 Recommendations for teachers and learners on preparing and using the educational materials in PLE

The ECOIMPACT project has been designed so that Russian and Ukrainian universities implementing the project could use the new PLE in their existing educational process, although the PLE changes at least some parts of this process (in respect of teacher-student communication, pace of learning, etc.). Thus, to make the most of the university educational materials, they were adapted to the PLE functionality already at the design stage. A model scenario of interaction between teachers and students was also developed. To enrich the PLE educational content and enhance the PLE use in the university context, several methodological recommendations should be considered.

Educational materials should be arranged as courses of lectures. A course is designed as a knowledge base, divided into categories presented as lectures. Educational materials are prepared mainly by teachers, who might need to involve assistants. As a rule, the latter are appointed from among the students and postgraduate students who have previously successfully completed the course.

The materials should be structured in such a way as to encourage a learner to take the following actions:

1. Read, comment and complement with new content the provided educational materials;
2. Take tests for self-assessment;
3. Accomplish the assignments prepared by teachers in the form of instruction templates;
4. Search various sources of information required to perform the assignments;
5. Discuss the results of assignments with teachers and assistants;
6. Implement laboratory tasks and training projects.

The lectures consist of the following key elements:

1. Standard instructions describing the sequence of actions expected of a student;
2. Text of the lecture (containing basic information for a student to master);
3. Presentation (reference notes of the lecture);
4. Set of tests with automatic verification for all contextually related parts of the lecture and for the entire lecture (meant for both self-assessment of learners and organization of programmed learning);
5. Templates for independent work (designed to master the material according to a taxonomy of learning outcomes and to check the progress with the participation of teachers and assistants. The recommended taxonomies are Anderson's and Bloom's.);
6. Descriptions of laboratory work and training projects on the lecture topic;
7. Templates for presenting the results of laboratory work and training projects (can be combined with the descriptions);

8. Glossary for the lecture.

Lectures may also contain additional materials, including the reference documents needed for accomplishing the assignments, journal articles on the lecture topic and news feeds helping to track the topic’s development.

All the products of a student are saved to a personal account and can be used at any time during the studies and in future professional activities. The saved materials may be modified and supplemented with any other document as needed without affecting the source materials. This feature supports lifelong learning, as PLE users can easily review and update the materials on a given topic during their entire professional life.

The PLE allows a student to learn most of the provided educational material independently at his or her own pace and convenience. Teachers and assistants evaluate the outcomes using a dialogue box in the student’s document. A discussion can take place both in real time and in delayed question/answer mode, and the entire dialogue is saved. Part of the material (for example, an overview lecture, a lecture covering the latest achievements in the field of study, as well as key lectures for guiding the learning process) can be given as face-to-face lectures, seminars, consultations, or webinars. For taking notes during face-to-face lectures, students are provided with a note-taking template based on the Cornell method (Pauk and Owens, 2010).

To assess students’ progress, teachers prepare templates for their independent work on the basis of Anderson’s or Bloom’s taxonomies of learning outcomes (Anderson and Krathwohl, 2001*).* Students have to copy the template to their own account, complete the required assignments, insert a dialogue box into the template, grant access to the completed document to the teacher or assistant and send them a link. After that, following the comments left by teachers in the dialogue box, a student by iterations improves the answers and reports provided initially. The work on the assignments continues until the teacher considers that learning outcomes have been achieved.

During the ECOIMPACT project, the above recommendations have been elaborated and used for developing and testing educational materials in the following areas:

1. Management of municipal services for local weather and microclimate;

2. Impact of local weather and microclimate on agricultural activities;

3. Impact of local weather on energy;

4. Biometeorology;

5. Impact of local weather on transport;

6. Use of IoT solutions for development and exploitation of local weather monitoring systems.

This selection responds to both the high demand for specialists in these areas capable of using modern technologies, and the specific competencies of ECOIMPACT universities. In Russia, these were Lobachevsky State University of Nizhny Novgorod, Roshydromet Advanced Training Institute and Russian State Hydrometeorological University; in Ukraine, Kherson State Agricultural University, Odessa State Environmental University and Taras Shevchenko National University of Kyiv.

Courses were prepared for the following groups of learners:

1. Businessmen and civil servants engaged in weather-sensitive activities;

2. University students of hydrometeorology;

3. Professionals in hydrometeorology (an advanced training course).

During the preparation of all the educational materials, particular attention was paid to sections on modern IoT-based instrumentation for monitoring the local weather and microclimate, as well as to development of business processes taking into account local weather monitoring and nowcasting data.

During the PLE testing, individual students and groups were engaged in the implementation of complex innovative projects aimed at creating effective weather-sensitive businesses and elements thereof.

Examples of the prepared educational materials in Russian and Ukrainian can be found at https://ecoimpact-ple.com/.

1.5 Discussion and conclusions

Tests of PLE in the ECOIMPACT universities have allowed us to conclude the following:

1. To effectively start working with the PLE, one or two face-to-face seminars are needed (with a total duration of 3–4 hours) for potential users to get a general idea of the PLE concept, become familiar with its scope and functionality, and gain initial working skills. This is typically sufficient for teachers to start working on development of PLE-tailored lecture materials. At the same time, it should be noted that the use of PLE in regular educational process of universities often encounters difficulties of organizational and cultural nature, since it is unusual for both university administration and students.

2. Students and other users easily learn to use the PLE if they have previously been involved in implementation of individual or group projects that require collecting information from various sources, analysing and applying it to make decisions or solve problems. Project work should be performed with the participation of teachers and assistants who interact with students both personally and (to a greater extent) through communication channels built into the PLE. This conclusion is based on more than thirty student miniprojects at the University of Nizhny Novgorod within the course "Using Information Technologies in Science and Education," as well as seven courses and graduation projects at the same university.

3. Seminars and project work can be organized within the regular educational process, but it proved to be more efficient to use specialized intensive schools for that purpose. In the ECOIMPACT project, several summer and winter schools were organized with the participation of both students and teachers as learners in mixed teams. The schools' duration ranged from five days to three weeks during student holidays. During a school, participants had to attend several introductory lectures, master the educational materials required for their project, perform a number of laboratory tasks to familiarize themselves with the PLE, and build a prototype system for monitoring and controlling the environmental parameters in a limited space (in a greenhouse, residential premises, or local territory) using the PLE's IoT component. After attending the schools, some teams continued developing their projects in order to create start-ups. Examples included city farming and environmental monitoring, as well as developing courses to teach schoolchildren the basics of meteorology using DIY weather stations. One of the student teams went as far as building a commercial version of a mini greenhouse controlled by PLE.

4. Students who have used PLE for studies often try to use it for organizing their personal activities not directly related to the educational process (to keep a personal blog, to develop a personal webpage, to communicate and discuss personal issues via dialogues created for each topic).

A further development of the ECOIMPACT-PLE will be aimed at collecting and analysing big data on patterns of students' work with PLE to better adapt it to the personal characteristics of each student.

The ECOIMPACT universities plan to conduct further testing of the developed PLE and gradually increase the number of PLE-based courses. Special attention will be paid to expanding the set of PLE-integrated laboratory tasks and training projects. Other plans include using PLE to build a crowdsourced network for weather monitoring consisting of DIY weather stations and other IoT-enabled environmental monitoring instruments. Over time, it is foreseen that PLE could be used by start-ups working in such weather-dependent areas as agriculture, urban management, transportation, energy, retail, environmental protection and healthcare. This broad potential highlights the value of introducing PLE in the education process.

Acknowledgements

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2. Simulations for meteorological training and assessment

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Abstract

Preparing forecasters to respond to extreme weather situations is a difficult task due to their limited occurrence. However, simulations offer a way to involve forecasters in practicing decision-making for even the most complex situations. This chapter describes the evolution of tools and processes for using simulators in forecaster training and assessment within an international collaborative community. This has resulted in tools that anyone can easily use to create weather forecasting simulations, as well as many different applications for their use. Results and feedback have shown that simulations greatly enhance the practical side of courses and allow increased work on developing skills

2.1 The need for simulators in meteorological training

Preparing forecasters of the Royal Netherlands Meteorological Institute (KNMI) to act in the best possible way during extreme weather situations is a particularly difficult task for trainers because extreme weather situations don't occur very often. The Royal Netherlands Meteorological Institute joint simulation training programme began in the 1980s with a group of new forecasters at the Dutch Storm Surge Warning Center who had never faced a serious storm surge but had to be able to forecast the extreme storm surges in the North Sea. Originally, simulation sessions were run in a role play setting with an ordinary clock and a pile of weather maps which the forecasters used to create their forecast. People from the Dutch Storm Surge and Warning Service and trainers in an adjacent office took the role of the outside partners during these simulation sessions. Over time, the pile of paper weather maps became a website, then a Flash-based simulator (Figure 2.1) and later a PHP/HTML-based simulator. Seeing the benefit of simulations, the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the UK Met Office and the COMET programme developed their own simulation tools and uses of simulations for meteorological applications.

The use of the simulator has changed over the years. At first, KNMI used this tool primarily for training sessions, but after the Australian Bureau of Meteorology shared its competency assessment plan for Queensland, KNMI developed simulator sessions to assess aeronautical forecasters (Figure 2.2). Today simulators are used in many countries and in many different capacities. Simulations are not only used to prepare and assess forecasters, observers and their customers for extreme situations, but also in training sessions on the use of new data types and the application of new theories and techniques. Trainers also use simulations to provide learners with realistic events to work through and develop soft skills like communication with users and decision-making support.

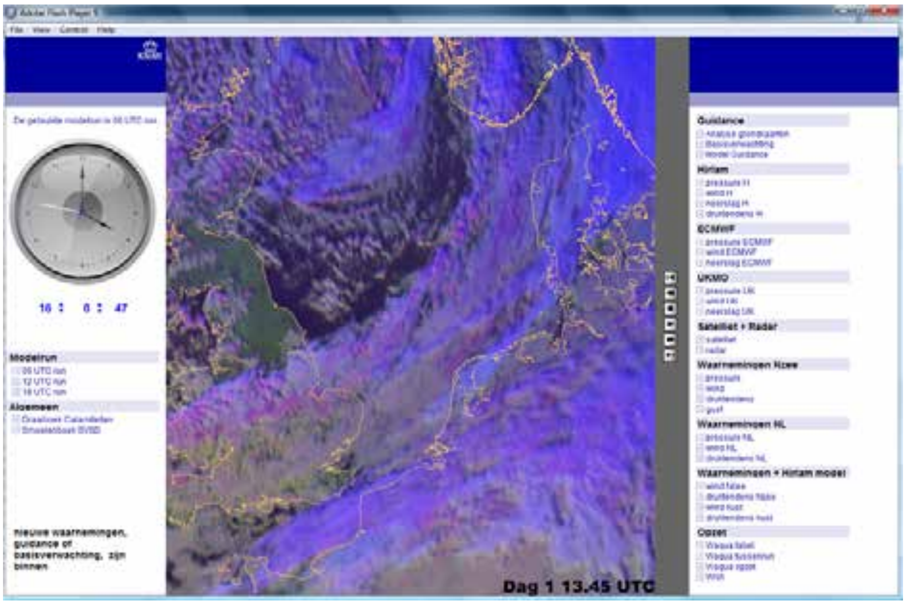

Figure 2.1. The first Flash simulator interface for an extreme high-tide event
Source: KNMI

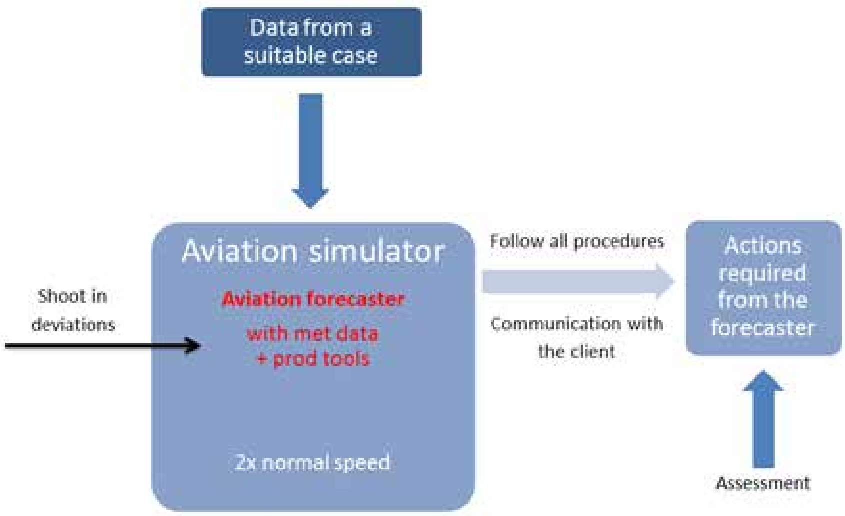

Figure 2.2. Schematic approach of a simulation exercise at KNMI
Source: KNMI

2.2 Learning with simulations

Daily life gives little opportunity to gain relevant experience in dealing with low-probability, high-risk events. This makes it difficult to anticipate risks and develop competencies that lead to an effective team.

Gaining experience is learning! When participating in simulation exercises you experience processes and gain insights into:

1. Using procedures and processes appropriately;

2. Collaborating and communicating with internal and external partners;

3. Making decisions in a team setting in highly stressful situations.

Learning must occur through both study and practice to prepare professionals to be fully competent to perform their job. During the study phase background knowledge is gained; during the practice phase the learner transfers knowledge into skills for the appropriate application of both theoretical knowledge and practical skills. During practice such as that provided by simulations, learners become aware of the risks inherent in the situations they will encounter by observing the consequences of their decisions and actions. They also become aware of the things they don't know and need to learn.

Simulations* can be used as a tool to support the study and practice phases of learning. Simulations are an excellent tool to:

1. Find the gaps in learners' performance and see where they get things wrong. Problems might be found in meteorological background knowledge, the way procedures are followed or how they communicate with customers;

2. Prepare learners for both normal and extreme situations. It is important to realize that in extreme situations people act differently than in normal situations. When a dramatic situation happens, for instance a child drowning in a pool, one or two people may jump into the pool but many more will be watching and not doing anything. That can happen in your Weather Service too, if people are not trained to perform under the stress of extreme situations;

3. Help assess whether your people are competent to perform their job.

With simulators, you can create a safe environment for your learners where they can gain experience, be trained and be assessed.

2.3 Uses of simulations

The weather forecasting training community has now used simulations in many new and innovative ways that the creator of the original KNMI simulator could never have dreamt of. We continue learning a lot from each other as new ones are made!

Simulators allow data products to be connected to real-life applications, so that the use of meteorological data is taught in the context of performing a task (Figures 2.3 and 2.4). This has been a welcome shift for training on satellite applications, for example, in which teaching the production and capabilities of data products was frequently abstracted from the use of the products. This shift makes the training much more effective for continuing professional development and performance improvement.

* We use the term simulation to refer to the learning activity. The term simulator refers to the tools that make simulations possible.

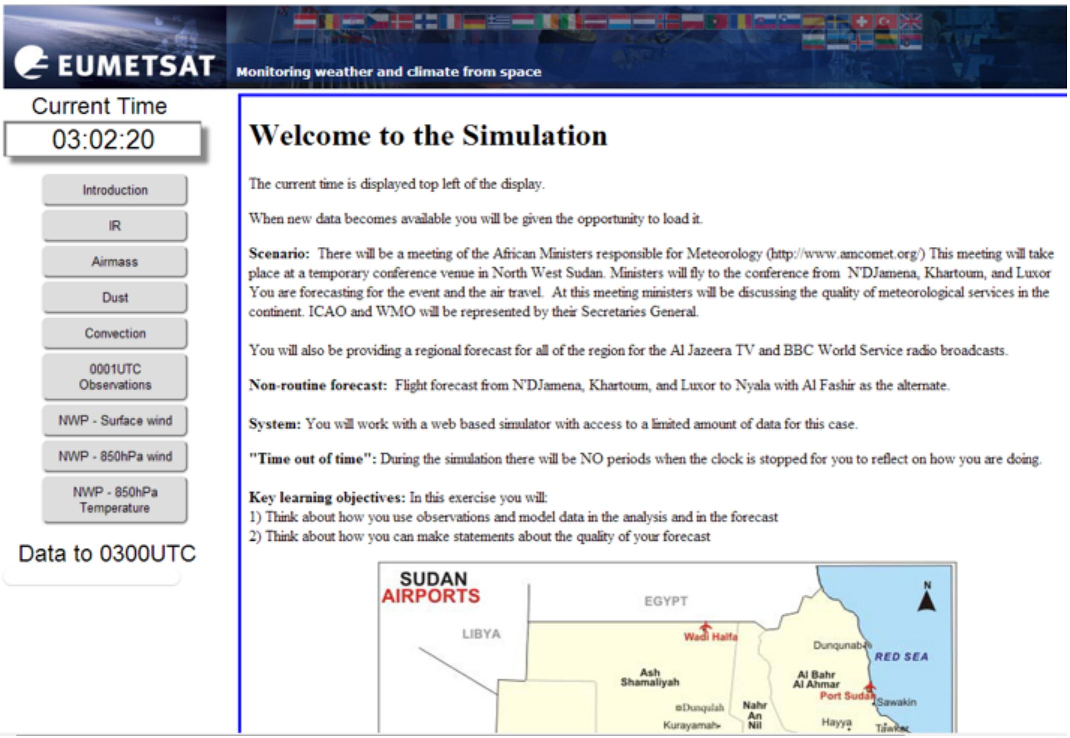

Figure 2.3. One of the first training simulators with a simulation on how to use satellite images for forecasting dust
Source: EUMETSAT

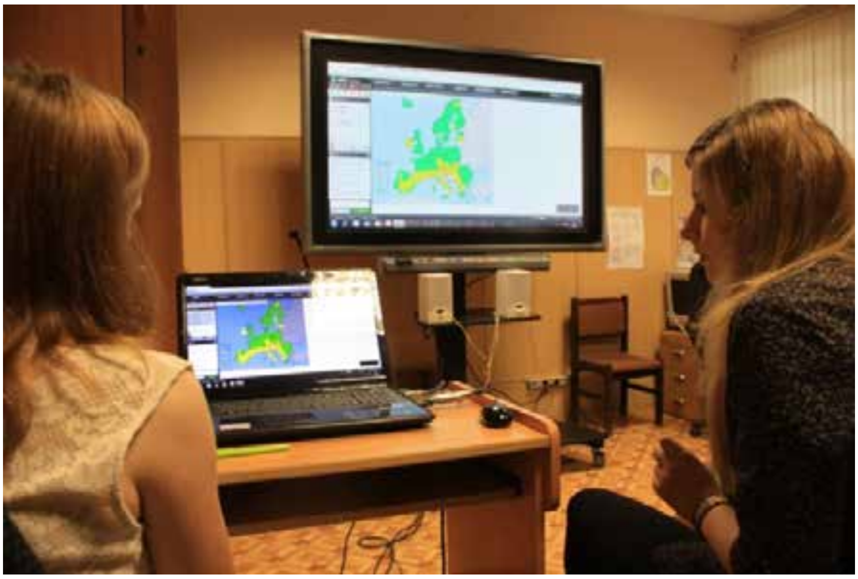

Figure 2.4. Trainees using a training simulator
Source: EUMETSAT

A simulation is also an excellent assessment tool for forecasters and observers working in aviation and other service areas because it allows trainers to create similar assessment circumstances for all individuals who are tested—which meets the need for fair and consistent assessment practices. By observing the participants in a simulation and evaluating the products they make, the trainer is able to collect evidence that the professionals are competent to do their job and ensure that all the required competences are assessed in an authentic context. This is different from the less authentic written test. The trainer is also able to see whether learners are competent to do their job under the circumstances that really matter—extreme weather situations.

A word of caution: when using recent cases for simulations, it is possible that some people will remember what actually happened during that case, and that will enable them to produce an excellent performance in the assessment. Yet in the community's experience so far it has never been a complicating factor in the assessment process.

Anecdotal evidence gathered during KNMI simulations has shown that if authentic assessments are implemented in the right environment and atmosphere, and participants have been given the time to adapt to the possible new circumstances, most people will be absorbed by the tasks in the work environment and will forget that they are engaged in a simulation.

Figure 2.5. Forecaster in action in a simulation session.
Source: KNMI

2.4 Collaborative evolution of meteorological simulators

Simulations used to be very costly and time-consuming to produce. The original simulation concept and simulator developed by KNMI was shared within the global meteorological education training community for free use, with the condition that new experiences and improvements of the tool should be shared within the same community. It turned out to be a great approach as it has resulted in a growing community using simulator tools for training. The European Organization for the Exploitation of Meteorological Satellites developed the tool for its own needs and created an easy-to-use JavaScript-driven simulator. Based on this version, a Moodle plug-in was developed in a joint effort by the UK Met Office, EUMETSAT and the South Africa Weather Service (SAWS) and was offered back to the community. Finally, the COMET Program, using its own HTML-based development system, created a branching simulation tool for training forecasters in online lessons.

The core innovation that made this evolution possible has been the use of simple simulators to support training and assessment for forecasters and observers (Figure 2.5). This approach avoids the problem of building a custom system on an institutional display that is powerful, but unusable outside of the National Meteorological and Hydrological Service (NMHS) that created it. Most of these simpler simulators are basically image viewers plus a built-in clock that can be set to run by the trainer at a desired speed to control when data products are available and when decisions must be made by users. Some simulators can ask learners to perform tasks while others are able to give personalized feedback based on the actions taken by the learners during the simulation session. Examples of simulators demonstrating the variety of implementations in our community are:

1. The UK Met Office, EUMETSAT and SAWS Moodle plug-in for creating custom simulations is currently available through info@eumetcal.eu. Many simulations made with this tool are available to the public at https://training.tools.eumetsat.int/sims/index.htm;

2. "Baltic+ 2019" course simulation using Google Forms: https://training.tools.eumetsat.int/sims/live/baltic+_2019fastloop/sim.html#;

3. The Argentinian National Meteorological Service (SMN) uses simulations to train and assess forecasters and observers. Some of the examples available at https://crf.smn.gob.ar/course/view.php?id=29 are simulations for training and assessing volcanic ash forecasters and for training on the Zonda (Foehn) conceptual model. The examples include a 3-D image of an observation site used for practice in meteorological observations;

4. The COMET Program's simulation on communicating risks: The impact-based forecast and warning service approach: https://www.meted.ucar.edu/wrn_sims/navmenu.php?tab=1&page=2-0-0&type=flash (account creation is required);

5. COMET's simulation that leverages social science to improve risk communication: https://www.meted.ucar.edu/social_science/ss_201/navmenu.php?tab=1&page=2-0-0&type=flash (account creation is required).

2.5 Challenges faced in implementing simulations

One challenge for the worldwide training community in implementing simulations was the fact that not all trainers have programming skills. The first simulator tool with a built-in clock used by KNMI was able to show data at specific times and was built in Flash, using the programming language ActionScript. ActionScript required a very steep learning curve for many institutions, and ten years later it became clear that Flash would disappear from use. The new EUMETSAT simulator tool was build using HTML and JAVA script, but even that turned out to be difficult to use for many.

As mentioned above, eventually the UK Met Office, with help from several partners, invested in a Moodle plug-in designed to build simulators using drag-and-drop techniques, which nearly anyone can master (Figures 2.6 and 2.7). However, having this Moodle plug-in available for the community did not mean that it could be implemented in every Moodle system. Because this plug-in was created by a private company and was not part of the official Moodle.org plug-in directory, other Moodle providers needed to determine whether they could install it on their systems at a reasonable cost. This procedure would have had to be repeated every time an update of the plug-in was created to make it compatible with updates to Moodle. To mitigate this limitation, both the UK Met Office and EUMETSAT have set up a Moodle server with the SIMS plug-in installed and have made it available to the community for creating a simulation (SIM). Once developed, the SIM can be exported to and used from another Moodle or internet site.

Figure 2.6. Moodle plug-in with drag-and-drop menu to create a SIM interface

Source: EUMETSAT

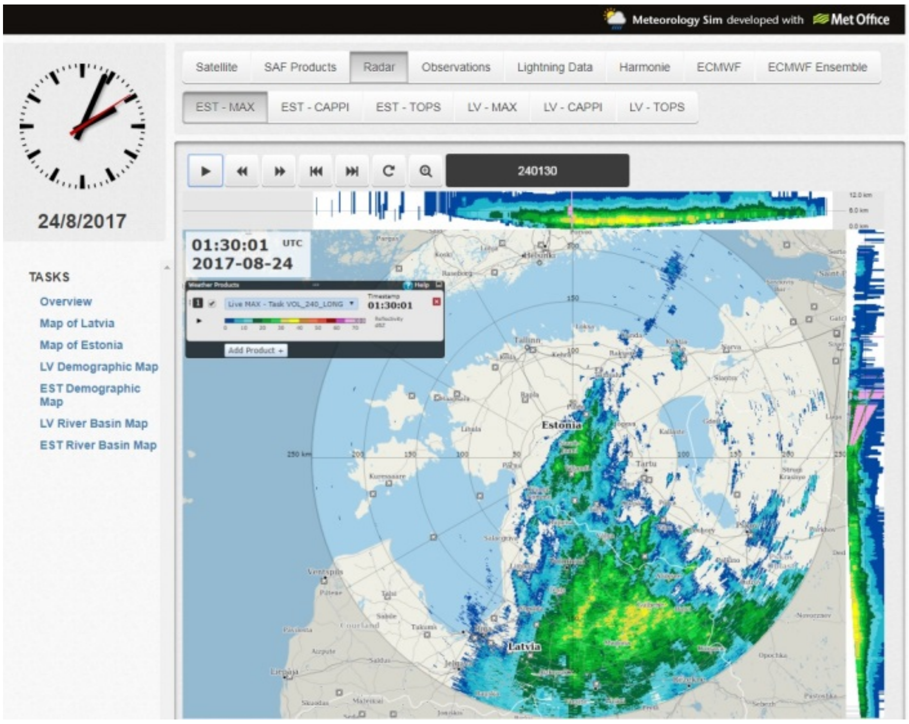

Figure 2.7. A simulator interface for a simulation over the Balkan region

Source: EUMETSAT

Another challenge related to the use of simulations is that it calls for pedagogical innovations. In recent years, we have noticed that too many trainers tend to focus on the technical requirements of building SIMs, while not enough time is devoted to defining the needs, goals and outcomes of the training. The result is that creating a simulation often takes more work than expected, and not all the simulation sessions are as effective as hoped. The training goals and needs determine the tools appropriate for the training, and not the other way around. In the past couple of years, in cooperation with EUMETSAT, some train-the-trainer events have been organized. The goals of these events were to help participants learn how a simulator can be used in training and assessment and how to use the simulator building tool in the optimal way. During training, participants inspire each other and begin collaborative projects. The participants go home with a training plan for a simulation training activity that includes a timed script for the training itself, and an early development of the simulation to be used for the training session.

Another challenge that KNMI has experienced is that at the start of each simulator session the differences between the working environment within the simulator tool and the normal forecast production tools can create some unease with learners. It is preferable to have either a simulator that is exactly the same as the tools used at work or a simulator tool that is completely different. If you allow time for the learners to adapt to a new simulator interface at the start of your simulation session, they will get used to it and use it well. Simulators that are similar to the normal forecast production tools but have subtle differences in the way they are operated, tend to irritate learners during the exercise because they have to behave differently from their normal conditions. This may adversely affect the learner’s performance in the simulation.

2.6 Results

During training courses, participants have said that the simulations greatly enhance the practical side of the courses and allow them to develop their skills. An important element of simulation training is the debriefing after the simulation exercise. It enables participants to reflect on their meteorological and decision-making skills used during the simulation. In this context, standard meteorological competency frameworks such as those offered by the *Compendium of WMO Competency Frameworks* (WMO-No. 1209) are useful in designing simulation experiences for either training or assessment. For example, the regional satellite training course Baltic+ 2019 used Google forms as the place where students entered their answers to specific tasks during a simulation. This allowed the facilitators to gather data and follow the progress of more than 20 participants in real time. The data were used during the debriefing to show the choices that the students had made and provide feedback on the best approaches in communication with customers. Debriefing can be aimed at increasing a student’s critical skills.

Another aspect that has been discovered is that learning times can be shortened when including simulations in training programmes. Each simulation session can cover many different aspects of the job and, last but not least, online simulations can be used day or night, regardless of the weather conditions outside the window! The Italian Civil Aviation provider (ENAV) has revised its training procedures for the initial training of meteorological technicians (MTs) and has included simulations at three different levels: basic, advanced and operational (Figure 2.8). The simulators used in all these simulations reproduced ENAV’s operational suite (Figure 2.9) for MTs. Different weather conditions were designed to prepare the MTs to face every possible weather scenario. After the first course, results were well above expectations, not only because students were fully competent and ready to work under supervision in a short time (4 weeks), but also because all of them showed motivation and engagement during the entire course.

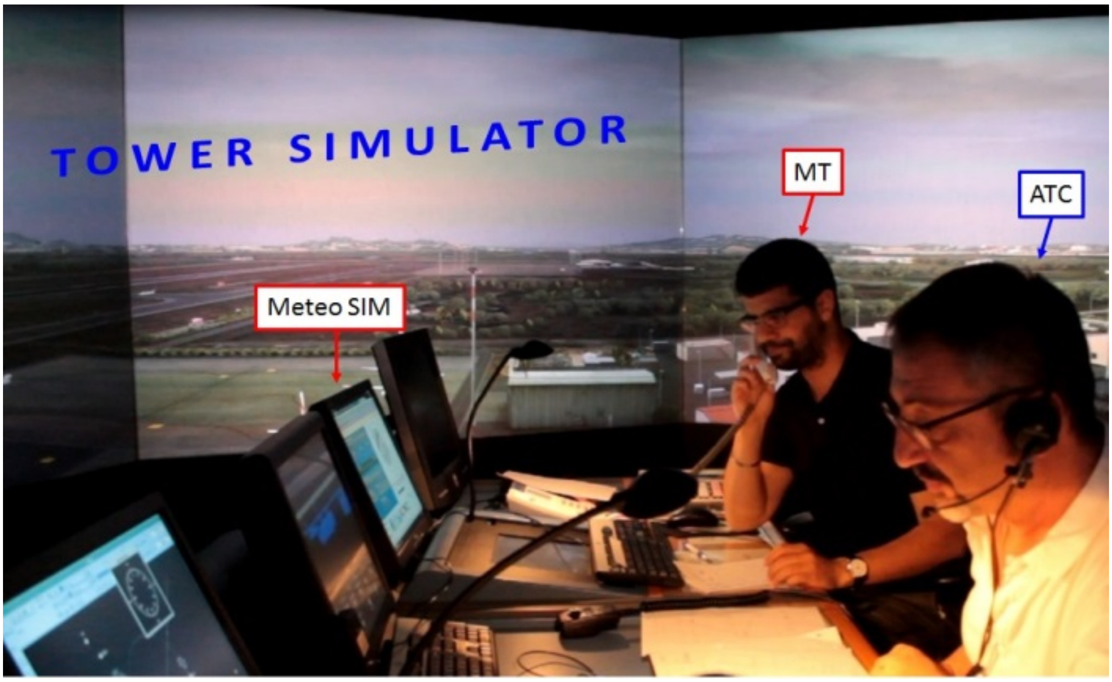

Figure 2.8. Integrated MT-ATC simulation for practice in an operational environment
Source: ENAV spa

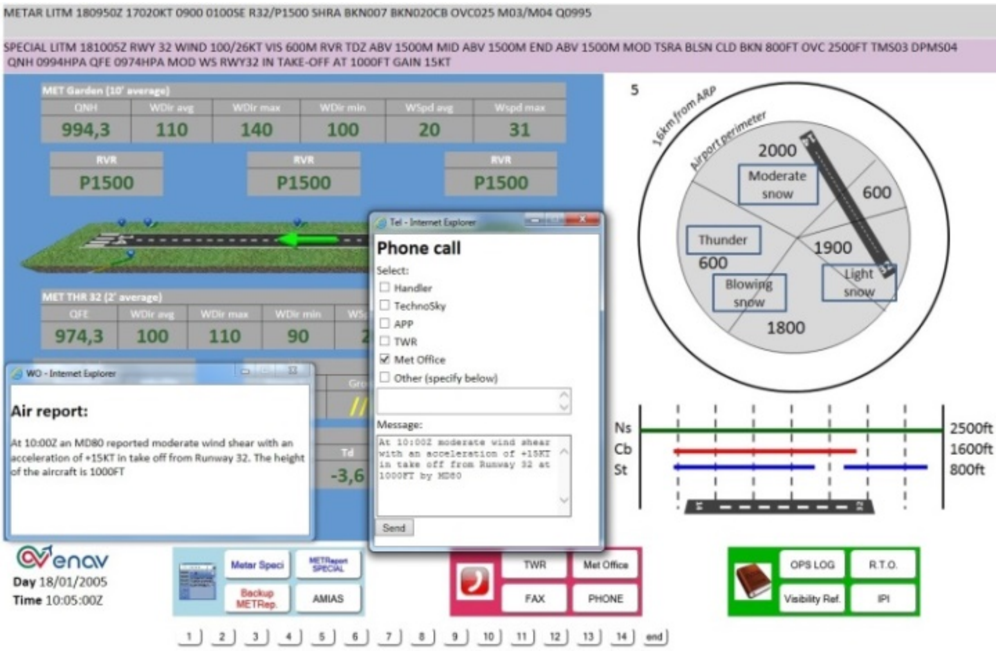

Figure 2.9. ENAV's SIM interface for practice on coding and coordination procedures using popups
Source: ENAV spa

When the Argentinian National Meteorological Service (SMN) started to use simulations in its training, it was found that they provided better learning experiences. The idea of developing a simulation is challenging and motivating, and building simulations requires teamwork. The major asset for SMN is that building these simulations encourages personnel from different departments to work together and to collaborate in the development of the training programme. Using simulators during training is catchy and gives a new perspective on training (for example, active learning, student centred, competency based) within institutions. Others wanted to try it and now it is spreading on its own. In addition, the use of simulations has given training a higher status within SMN.

2.7 Recommendations for further implementation

One area for future development of simulations is the inclusion in the simulation feedback of realistic consequences of learners' decisions . Realistic consequences may include an angry customer or even a serious accident or significant loss. With realistic consequences, learners will see the impact of their actions and will have to reflect on different strategies and approaches to use in the future. Learners can repeat simulations, they can experiment with different strategies until they find the one that works best. This engages the natural learning process of making mistakes, reflecting and trying something different that may be of use even in situations beyond those the learners worked on in the simulations.

Luckily there is still a lot to invent in the development of new simulations. Integrating virtual reality and 360 images generates a new feeling of being immersed in the simulations. This is SMN's challenge for the 2019 Meteorological Observations course (for WMO Regional Associations III and IV). The plan is to continue developing modules in collaboration with training partners to stimulate innovation and to increase the use and reach of simulations.

As more people get involved in developing simulations, there will be a wider variety of approaches, showing how people tackle problems in different ways. Many services are thinking of ways to engage trainees by creating new simulations. This can be done by encouraging learners to bring their own cases to training sessions on building simulations, thus co-creating the learning artefacts in cooperation with their trainers. The Argentinian National Meteorological Service is now considering running a simulator competition in which participants will work in teams to produce the best simulator for a specific training purpose in one week. The Royal Netherlands Meteorological Institute has good experience with a rotating team of assessors from the operational work floor who prepares and assesses the simulations.

Additional resources

A brief summary about creating simulations, prepared by Tsvet Ross-Lazarov, Bruce Muller and Patrick Parrish, is available at https://docs.google.com/document/d/1fWJsJdVPP-G7FtDhw8ebP_y17tEtREpj4xQTPfH2jUw/edit?usp=sharing.

3. Use of a weather event simulator in practical training and assessment of forecasters

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Abstract

This chapter introduces the use of a weather event simulation platform at the Hong Kong Observatory (HKO) for the practical training of forecasters to test their meteorological knowledge and their skills in using operational analysis and forecasting tools before on-the-job training in the forecasting office. The platform also serves as a self-assessment tool for operational forecasters. By gathering more and more past high-impact or special weather events, a weather event library can be built up in the platform, which could also be useful as a knowledge management tool. In this chapter, we discuss the design thinking and implementation process of the weather event simulation platform as well as the challenges we have overcome.

Keywords: simulator, simulation, training, weather forecaster, competency, knowledge management

3.1 Introduction

To satisfy the requirements of the WMO Basic Instruction Package for Meteorologists (BIP-M), it is necessary for trainees to demonstrate learning outcomes, including the understanding of physical principles of weather phenomena, atmospheric interactions and evolution of weather systems and parameters and, most importantly, the ability to apply knowledge in weather analysis and forecasting and the ability to communicate the impact of weather and climate on people and the environment. Practical forecasting sessions based on the current weather are one of the key learning methods in the induction training on operational forecasting for forecasters. These sessions provide the trainees with the opportunity to apply conceptual models, weather diagnosis and prognosis tools and interpretation skills of numerical weather prediction outputs, which they have learned in lectures. However, high-impact/special weather events may not occur during the current training session. Therefore, simulations of different types of high-impact/special weather event are useful for the practical training of forecasters. A weather event simulator can be used not only as a training tool for trainee forecasters during induction courses, but also as a refresher tool for young forecasters and a competency assessment tool for on-the-bench forecasters.

3.2 Meeting the qualification requirements for a meteorologist

New recruits to the positions of Scientific Officer (SO) and Experimental Officer (EO) at the Hong Kong Observatory (HKO) are normally required to attend professional meteorological induction training to meet the WMO qualification requirements for a meteorologist before they can work independently as forecasters or assistant forecasters at the Central Forecasting Office (CFO). This induction training, namely the Applied Meteorology Course for Forecasters (AMCF), consists of two parts. Part I equips the trainees with the theoretical and practical knowledge of different topics in atmospheric sciences, including the key elements of synoptic, dynamic and physical meteorology. This basic meteorological training is normally commissioned to the training centre of the National Meteorological and Hydrological Services (NMHSs) or the WMO Regional Training Centres (RTC). Part II, which focuses on local weather and forecast operations with respect to public weather service, marine weather service and aviation weather service, is conducted by in-house experienced staff. Management, communication and IT courses, which are conducted by commissioned market or domain experts, are also covered in Part II of AMCF.

The trainees are required to take written, practical and oral assessments to demonstrate the learning outcomes. Successful completion of the AMCF with all the assessments is needed for trainees to satisfy the requirements of the WMO BIP-M and the competency requirements as forecasters for the public weather service and the marine weather service.

Practical forecasting sessions based on the current weather are one of the key learning components of AMCF Part II. Through these practical sessions, instructors can check whether trainees know how to apply conceptual models and logical thinking in analysing, diagnosing and forecasting weather systems and phenomena; whether they can assimilate available observational data and make appropriate use of various monitoring and forecasting tools, including radar and satellite as well as numerical weather prediction (NWP) outputs; and finally whether they can formulate weather forecasts with sound reasoning. The current-weather sessions normally last around two weeks.

3.3 Meeting competency requirements for a weather forecaster

After fulfilling the BIP-M requirements to qualify as a meteorologist, the SO/EO new recruits need to undergo a 2–3 month doubling-up session at the CFO to work side by side with the duty forecaster/assistant forecaster. This session allows them to demonstrate their competency in performing operational tasks. They will undergo a competency assessment at the end of the doubling-up session and before they are allowed to work independently.

Scientific and Experimental Officers working in other divisions are required to perform occasional forecasting shift duty, normally once every three to four months, in order to maintain their professional competency in weather forecasting. Every year, a number of new forecasting tools and products are developed, and new operational procedures are implemented. These occasional forecasters need a platform for practising and familiarizing themselves with the latest operational procedures and forecasting tools/products. The weather event simulator fulfils this need.

At present, all forecasters in CFO and the Airport Meteorological Office (AMO) are required to complete a self-audit form on competency in weather forecasting on an annual basis. At AMO, the competency assessment system under the framework of the Quality Management System (QMS) requires aeronautical meteorological forecasters to pass a competency assessment every two years to ensure their competency in aviation forecasting. The Hong Kong Observatory has deployed event simulation as one of the competency assessment tools for aeronautical meteorological forecasters.

3.4 Design and implementation of the simulator

The objectives of the weather event simulator are:

(a) To enhance the participants’ forecasting/nowcasting skills in rainstorm and/or tropical cyclone (TC) situations;

(b) To familiarize the participants with the procedures for the issuance/cancellation of rainstorm- and TC-related warnings;

(c) To guide the participants through decision-making processes.

3.4.1 Considerations

We have designed the simulator with the following objectives:

1. To provide a guided and focused training platform;

2. To create a simulated environment that resembles the operational forecasting environment and to guide the participants through the monitoring, analysis, diagnosis, prognoses and decision-making processes;

3. To enhance the participants’ learning experience by selecting past weather events with various meteorological conditions, including TCs and rainstorms;

4. To serve as an assessment tool or a self-evaluation mechanism.

3.4.2 Features

The unique features of the simulator include:

1. Simulated real-time data update following the system clock;

2. The operational equipment and graphic display programs are used whenever possible, while other forecasting tools/products (e.g. NWP) are simulated on web-based displays;

3. Guidance mode - Pop-up messages/questions/hints to remind/test/alert the participants of the completion of tasks or grasp of the weather situation or issuance of forecasts and warnings;

4. Change time mode - To accelerate the progress of the event and enable participants to complete the exercise within a shorter time frame, say a couple of hours.

The weather event simulator is a portable Python web framework which simulates past severe weather scenarios. The simulator is able to reproduce much of the essential meteorological information that is available in the HKO Intranet, to link to the HKO chart archives and to provide an interactive interface for various tasks. Some Python modules are used to build the web framework, database support and time synchronization.

3.4.3 Implementation process

The process of creating a weather event for the simulator can be roughly divided into three steps. First, we select a high-impact/special weather event of interest (for example, a rapidly developing rainstorm over Hong Kong or a direct/near-direct hit of a TC likely to have a considerable impact on society) and collect observational data during the event.

Second, we formulate a range of tasks (assessing the potential of severe gusts, determining the TC position, estimating the TC intensity, etc.) that resembles the tasks performed by the operational forecaster (see Figure 3.1).

Third, we make available the weather monitoring, diagnosis and prognosis tools used by operational forecasters during these events on the weather simulation platform as far as is practicable. These tools include the display of different types of surface and upper-air weather observation (for example, the GIS-based meteorological display in Figure 3.2), remote sensing data (for example, the radar display in Figure 3.3), as well as nowcasting and forecasting tools (for example, the integrated panel of rainstorm nowcasting products in Figure 3.4 and tropical cyclone information processing system in Figure 3.5). The users can access these data and tools handily by clicking on the icons on the user interface (Figure 3.1). The final product is an integrated, interactive exercise on rainstorm and TC situations to assess/reinforce the participants' capability to execute the various responsibilities of an operational forecaster.

Figure 3.1. User interface of the weather event simulator

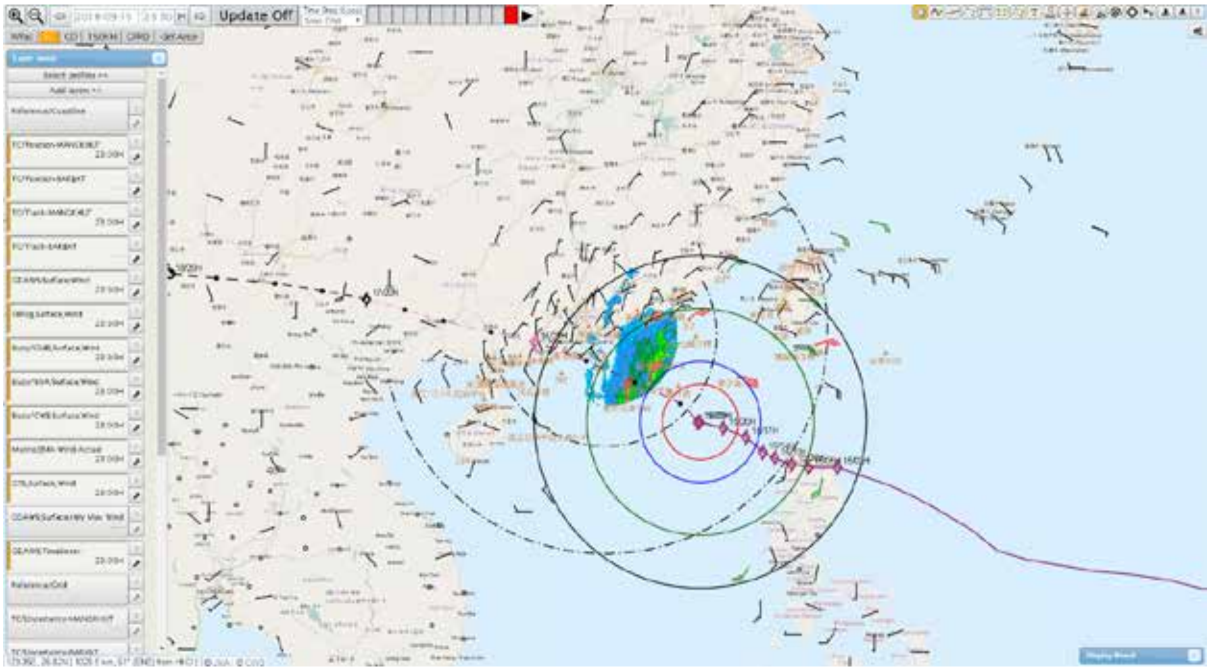

Figure 3.2. GIS-based meteorological display

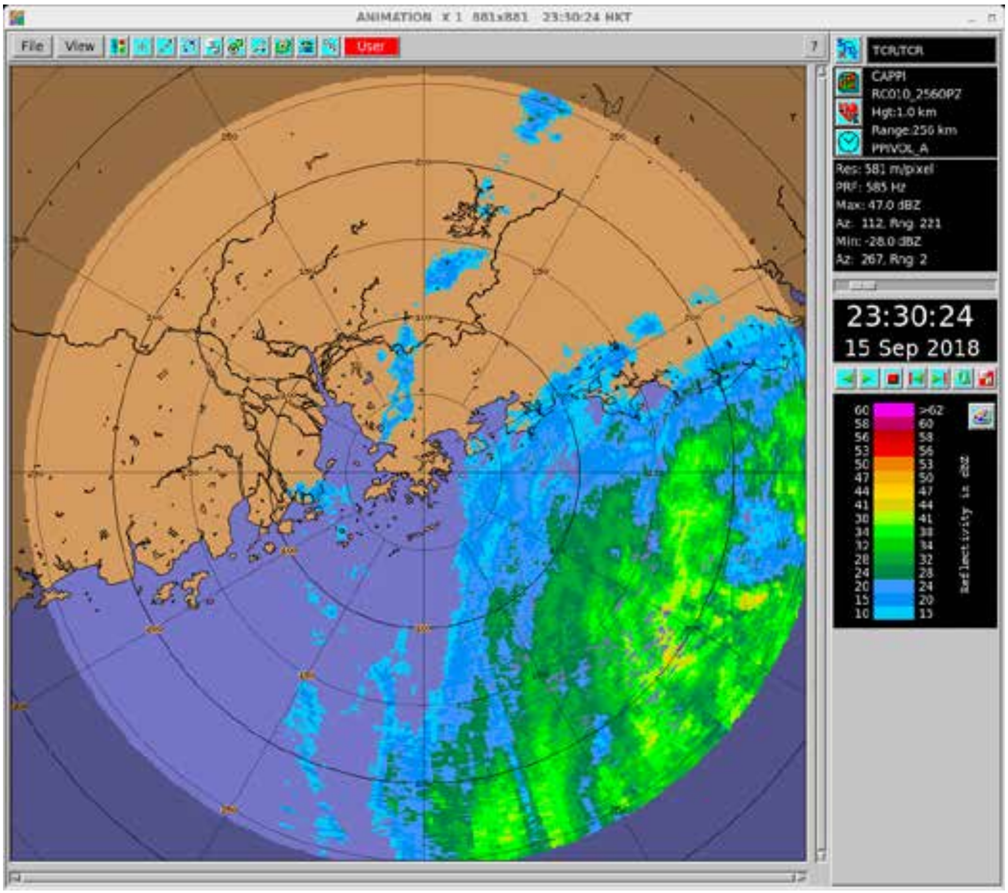

Figure 3.3. Radar display

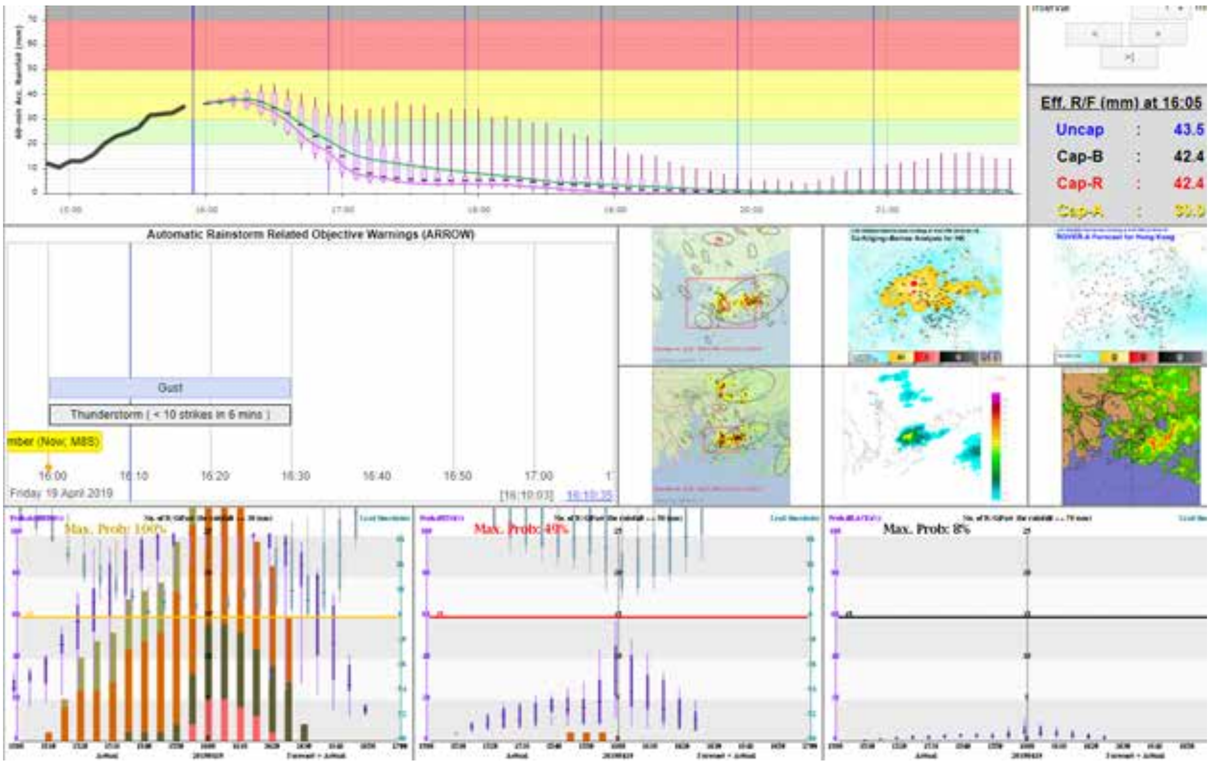

Figure 3.4. Integrated panel on rainstorm nowcasting products

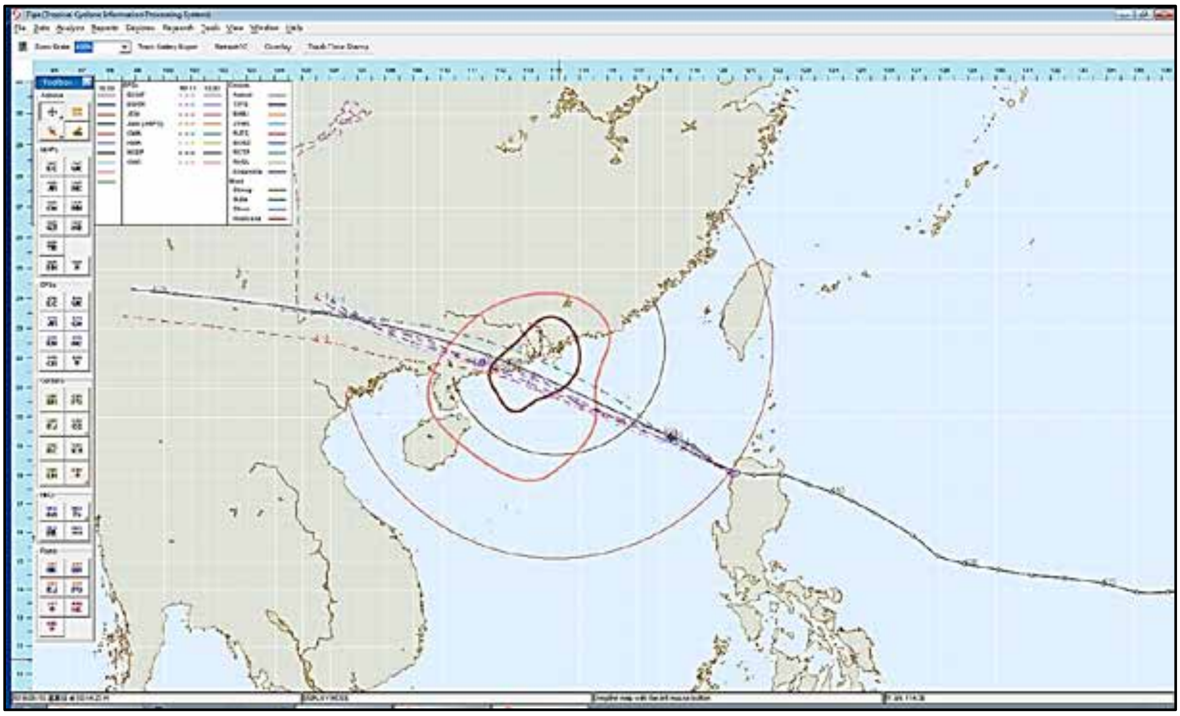

Figure 3.5. Tropical cyclone information processing system

3.4.4 Challenges overcome

There have been many challenges in the design and implementation of the weather event simulator. Detailed planning of the framework design, objectives to be fulfilled, criteria for the selection of weather events and resource requirements, as well as effective liaison and communication with internal owners of the meteorological data and operational systems, are key success factors in the implementation of the simulation platform.

We carefully selected the weather events for the simulator and prudently designed the tasks to test a broad spectrum of forecasting skills, logical thinking and decision-making ability of the participants in an exercise lasting a couple hours. The development team effectively liaised with the divisions responsible for the maintenance and development of the observational and forecast data and tools. As some of the forecasting tools are developed for operational use only and do not have a 'training' mode of operation, we developed a dedicated web interface to display the past data, and implemented the simulator in such a way that the 'answers' in the future are masked. The synchronization of animation in different workstations required substantial computer programming effort. Since different software applications run on different computer operation systems, integration of the systems into a single platform has been a challenge. In addition, some applications demand high computational power to run smoothly. With concerted effort, we have largely overcome the issue of time synchronization across different systems, including some stand-alone systems in the simulated environment.

3.5 Results and future plans

We make the weather event simulator available in the Training Lab (Figure 3.6) to trainee forecasters during AMCF Part II, and to forecasters who have to perform shift duty at CFO/AMO, especially before the commencement of the rain and TC season. Facilities such as multiple-monitor workstations, printer, microphone, telephone and reference materials, including the operation and procedure manuals as well as user guides of various systems, are ready for use. Relevant colleagues can enrol in the drill/exercise via an online registration system to reserve a time slot for using the weather event simulator. Participants in the drill/ exercise are required to complete a self-assessment form for each task performed in the exercise (for an example, see the table below). The questions in this self-assessment form are scenario-dependent. Should the participants notice any need to enhance their competency in forecasting, they would need to list the follow-up actions in the form. If the simulator is used as an assessment tool, the user needs to fill in an assessment paper and submit it to the assessor upon completion.

Through the drill/exercise, trainees can learn how to handle high-impact weather events such as rainstorms and TCs. Forecasters who already have forecasting experience can also familiarize themselves with the newly developed monitoring and forecasting tools as well as the latest operational procedures, thereby gaining more confidence in performing their occasional forecasting shift duties. The existing framework of the simulator has been deployed since 2014 and has been gradually evolving to suit our training needs. We have collected the participants' feedback over the years and the results have been positive. The participants mostly said that the drill exercise could enhance their skills for handling rainstorm and TC situations, and that the mode of individual practice could also serve as refresher training. Some participants suggested making available more special weather events ;n the simulation platform. Every year we review the simulation platform, taking into account participants' feedback; we incorporate new weather cases and enhance the simulator with updated tools.

Figure 3.6. Training Lab at HKO

In the long run, we will enrich the weather event simulator with a wide range of significant and special weather events such as hail, fog, extreme cold and hot weather, and even multi-hazard events, with the goal of setting up a weather event library. We will streamline the process of collecting and archiving data. We will also enhance communication and synchronization between different systems as far as is practicable. The development team will work closely with the forecasting team to identify suitable weather events as training/assessment material. The team will also liaise closely with other relevant divisions to include the latest monitoring and forecasting tools/products and to develop a 'training' mode of the operational systems as far as possible.

The weather event simulation platform can be deployed as a competency assessment mechanism for assessing the trainees' skills in using monitoring and forecasting tools, analysing the situation, making decisions and responding in a timely manner. During the evolution of the weather event, simulations of weather briefings to various stakeholders, handling of telephone enquiries, dissemination of information and handling of comments in the social media can also be incorporated to test the communication skills of the forecaster. Case simulation is in fact one of the assessment methods adopted in the competency assessment for aeronautical meteorological forecasters of the Observatory.

The weather event simulator has proved to be a useful training tool and a reliable assessment tool for weather forecasters in HKO. Furthermore, all the training materials and the noteworthy points of the drill exercises can be consolidated in the weather case library of the simulator, which thus becomes a useful knowledge management tool.

Self-assessment form for TC drill (duty forecaster)

Please circle your selection

1. Self-assessment for each task in the TC drill

	Task description	**Completed satisfactorily**		**Remarks**
1.	Prepare the NWP ensemble track	Y	N	
2.	Perform TC analysis and fix the warning position	Y	N	
3.	Prepare the TC working track	Y	N	
4.	Edit TC data sheet	Y	N	
5.	Calculate key parameters and perform TC assessment	Y	N	
6.	Issue precursor and pre-No. 8 signal	Y	N	
7.	Issue TC signal No. 8 and special announcement	Y	N	
8.	Complete TC bulletin part 1	Y	N	
9.	Determine satfix, perform Dvorak analysis and issue SAREP	Y	N	
10.	Issue/update local weather forecast and cartoon as necessary	Y	N	

2. Do you need follow-up to enhance your forecast competency? Yes/No

If yes, what follow-up actions will you take?

____

____

____

Name: ____________________ **Post:** ____________________

4. Use of branching simulations to improve learner engagement in online lessons on weather impact communications

Tsvetomir Ross-Lazarov and Tony Mancus (The COMET Program)

Abstract

This chapter describes the application of e-learning, branching simulations to train meteorologists in the communication skills required for providing impact-based forecasts and decision support. Carefully designed simulations can provide the contextual cues found in interpersonal communication of forecasts and warnings. Moreover, branching e-learning simulations are particularly effective in increasing learners' skills in preparing and selecting an effective forecast message.

E-learning simulations are convenient, limit disruption to work and can be used at any time and repeatedly, which heightens the return on investment. Simulations allow learners to learn from mistakes without real-life consequences. Simulations have been used to enhance learning outcomes in fields where failure is costly.

COMET has implemented this approach in several online lessons. Comments from the learners and experts indicate that the branching simulation exercises are very successful in engaging learners.

Keywords: impact-based forecast and warning services, communication, simulations, branching simulations, mistakes, effective learning, practice

4.1 Introduction

Many national hydrometeorological services around the world are training their staff in providing impact-based forecasts and decision support. A major component of that support is clear communication of the expected weather and potential impacts. With carefully designed use of video, audio and still images, e-learning can provide much of the contextual cues of interpersonal communication. It is possible and sometimes preferable to use branching e-learning simulations to increase learners' skills in preparing and selecting an effective forecast message.

E-learning simulations are convenient and cost-effective. For example, to carry out an in-person communication training simulation, one needs to bring together the learners and communication partners from various agencies, incurring costs for travel and work loss since everyone at the training session will be unable to perform their regular work duties while attending the session. Additionally, the partners who are playing a role in the simulation need to learn how to respond to specific learner actions and to intervene at appropriate times. Once those preparations are complete, an in-person simulation event can begin.

With branched e-Learning simulations, the cost and effort are tied solely to design and development of the product. E-learning simulations are also available at any time and can be taken repeatedly, which heightens the return on investment. These simulations allow learners to make mistakes and learn from them without experiencing the real-life consequences of miscommunication, or other types of mistake that could have larger impacts. Simulations have been used to enhance learning outcomes in fields where failure is very costly. For example, when training nuclear power plant operators "for obvious safety reasons, it is not appropriate to use a real nuclear power plant as the learning environment in which to teach novices about the complexities of operation. If the trainee were to make a mistake, the results could be catastrophic" (Alessi and Trollip 2001, p.227).

Well-designed branching simulations engage learners in effortful information processing and decision-making. "To learn is an action taken by and occurring within the learner. Instructors cannot learn for their learners, and neither can e-learning technology even with all its graphics, animations, effects, audio, interactivity, and so on. Learners must be active participants and, in the end, do the learning." (Allen, 2016, p.122). Learners need to engage with the information and take actions with it in order to learn. Branching simulations allow the learners to engage in a natural learning cycle. They encounter a problem, devise a solution, take action, observe the consequences, reflect and then devise a different course of action based on the responses they receive within the scenario. We engage in this natural learning cycle throughout our lives and branching simulations allow for it to occur in a space that is free from serious detrimental outcomes.

Peoples' reactions to communication are less predictable than physical processes. Branching simulations are a great way for learners to encounter and comprehend that unpredictability. Well-designed branching simulations offer learners choices and actions that reflect common misconceptions and pitfalls that should be avoided. With communication simulations, the learners see the results of their communication approach in the form of reactions from the partners with whom they are trying to communicate. The learners can act on the basis of their current level of understanding and, through the outcomes of their choices, experience the natural feedback of appropriate and inappropriate communication approaches.

In Figure 4.1 below, we see the reaction of an emergency manager after the learner described an oncoming event as a "prime example of bomb cyclogenesis."

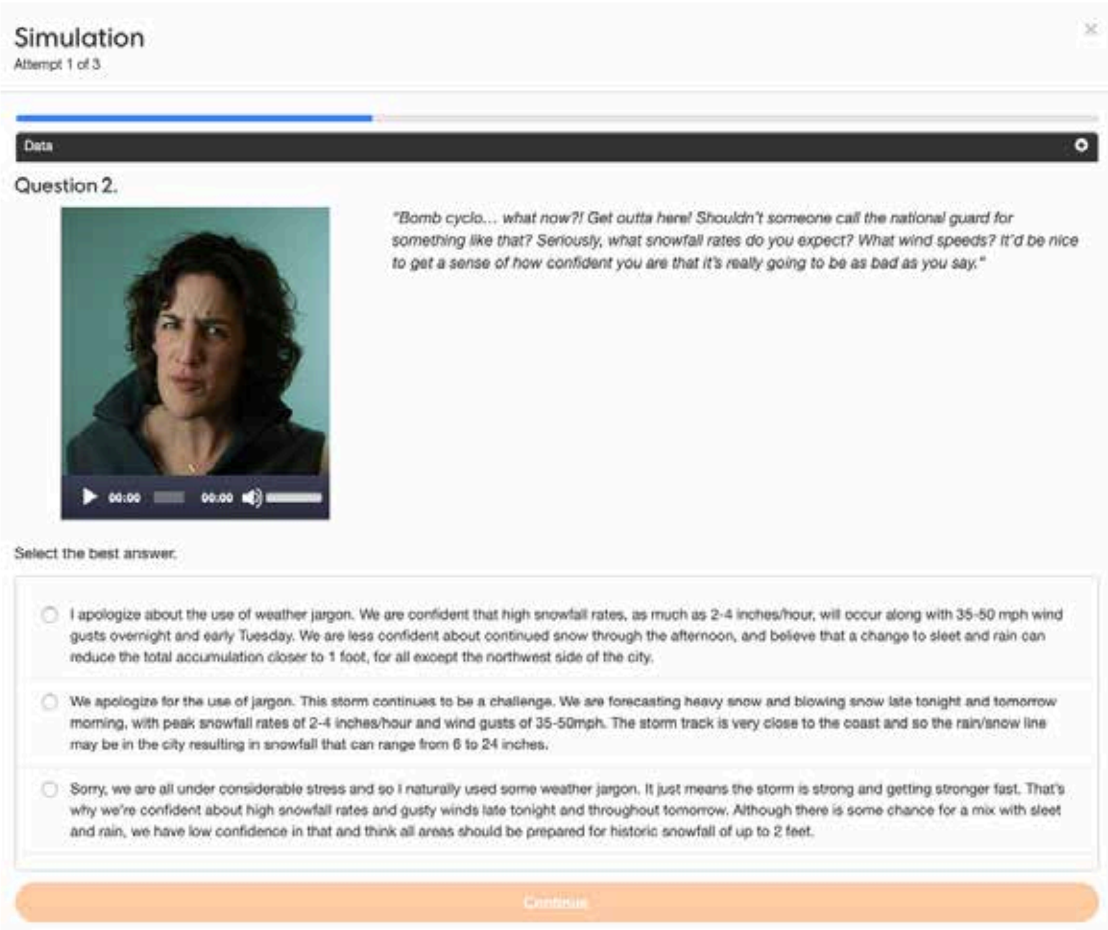

Figure 4.1. A branching simulation feedback screen

The manager's reaction (in this case, physical, textual and auditory) indicates the confusion that can be caused by using meteorological jargon during briefings in highly stressful situations.

This natural feedback indicates a problem without offering a solution. The possible answers to the emergency manager's questions offer a way for learners to adjust their response according to the manager's reaction, but learners have to think carefully about their solution to the situation.

In the context of branching simulations, natural feedback works like real life by indicating a problem without giving a solution. Learners encounter a problem in the scenario and must think through possible solutions. They may make choices that fail repeatedly until they figure out a viable solution. In the real world, when we issue a 2-day forecast there is nothing to tell us that our forecast is incorrect. The natural feedback arrives two days after issuing the forecast, when we observe how well our forecast matched the real weather impacts, as they occurred.

Challenging the learners through natural feedback enhances motivation and transfer of knowledge because they need to recall relevant prior knowledge, apply it to the situation before them, and figure out which action is best to take. Educational psychology research indicates that this approach of presenting a problem before teaching a solution results in better long-term retention of information, even when mistakes are made in the process. "Unsuccessful attempts to solve a problem encourage deep processing of the answer when it is supplied, creating fertile ground for its encoding, in a way that simply reading the answer cannot. It's better to solve a problem than to memorize a solution. It's better to attempt a solution and supply the incorrect answer than not to make the attempt." (Brown, Roediger and McDaniel, 2014, p. 87)

The simulations offer natural feedback the first two times a learner takes an incorrect path (see Figure 4.2).

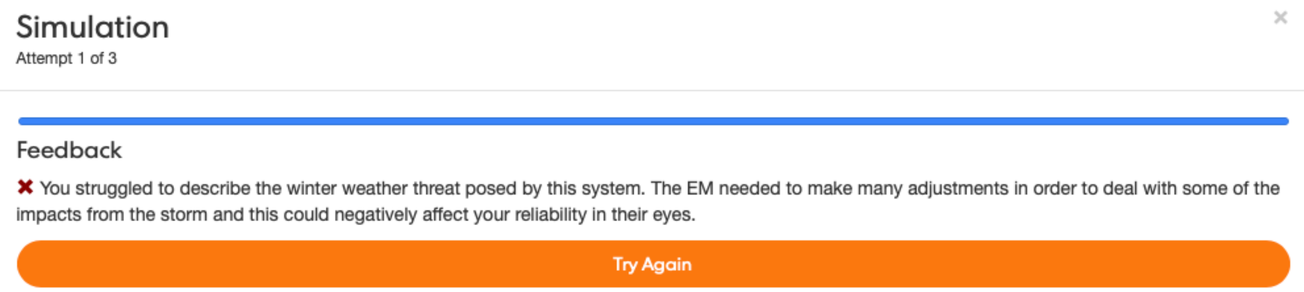

Figure 4.2. Natural feedback provided to an incorrect path

In this way, learners have a chance to correct issues on their own through three attempts to correctly navigate the scenario. Since the simulation questions have only three options, it is likely that by their third attempt the learners have selected all question options. If they continue to struggle on their third attempt, the simulation offers artificial, or corrective feedback, in other words, "this is correct or incorrect," with specific details tailored to the learner's choices. Returning to our 2-day forecast example above, the difference between natural and artificial feedback is that artificial feedback would tell us that our forecast is correct or incorrect as soon as we issue it. Whether to use natural or artificial feedback depends on the learning outcomes, the characteristics of the learners, and the simulation model.

Figure 4.3. shows the feedback that learners receive after their third failed attempt. This feedback describes the consequences of the communication failure and points out why the choices the learner made were suboptimal.

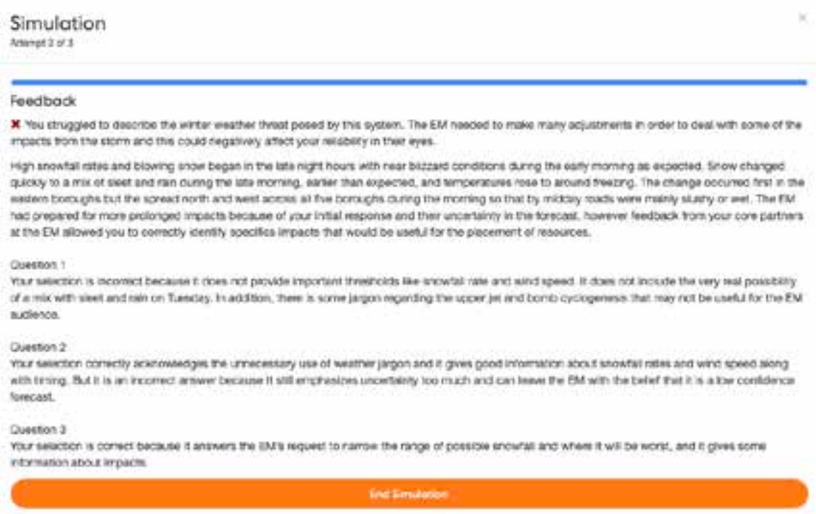

Figure 4.3. Feedback for a third failed response

4.2 Designing branching simulations

The most important step early in the design of communication simulations is the selection of the correct communication model that the users need to learn. With input from communication experts and people with experience in the particular communication situation, the design team creates the model's ideal path. This path contains the correct options and reflects the optimal communication approach that meteorologists from a National Hydrological and Meteorological Service (NMHS) should use.

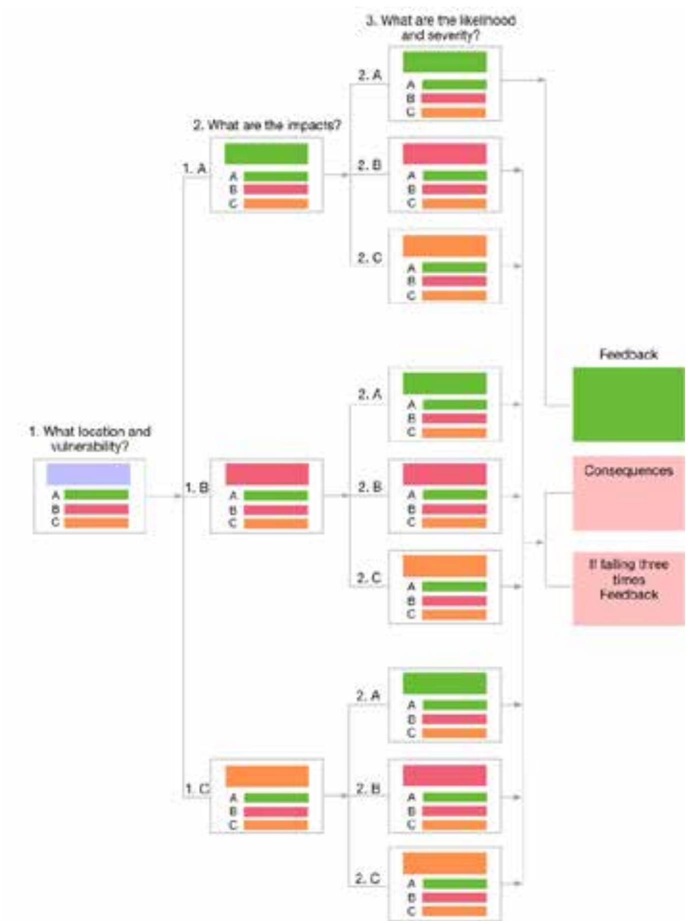

Figure 4.4. The simulation model path

In Figure 4.4 above, the green colour indicates the correct path, with red and orange indicating the two incorrect paths.

The next step is to create a range of suboptimal communication paths. The suboptimal paths reflect commonly observed problems or misconceptions. With the help of experts, the team creates options that reflect real-world situations and reactions. Next, the team carefully selects the natural consequences.

Designers need to select consequences that have some weight in order to create a sense of risk in the learner so as to "focus learners on primary points and on performance." (Allen, 2016, p. 144) Without this, learners may fail to truly consider the implications of their choices and the sense of risk will disappear, leading to diminished engagement and possibly boredom. At the same time, design teams should carefully avoid implying that loss of life resulted from miscommunication in order to "avoid causing anxiety that inhibits learning and performance." (Allen, 2016, p. 144) Selecting consequences is a balancing act, as the potential problems that could result from a communication failure should be significant, but not catastrophic and discouraging to the learners. It can be a challenge to find the right consequence level.

Alongside finding the proper consequences, a major change COMET teams faced when adopting simulations was a new approach to the creation of content. With branching simulations, our teams had to become comfortable with allowing learners to make mistakes based on their preconceived notions and misconceptions. This was a dramatic departure from the way COMET staff and other designers had created lessons in the past. The standard tutorial approach used in most lessons offers information about a subject followed by a brief interaction with the content and then immediate artificial feedback about why a selection was correct or incorrect. Scientific accuracy is an important value at COMET, and creating lessons that allow learners to follow their misconceptions and experience the natural consequences of their actions is a major shift for every team that attempts a simulation.

In part, this discomfort is fuelled by the notion that if learners come into the learning exercise with misconceptions, the branching simulations will simply allow them to express and consolidate those misconceptions. This is why creating effective natural and artificial feedback for learners is so important. The following paradigm shift was a useful guide: "Failure underlies the scientific method, which has advanced our understanding of the world we inhabit. The qualities of persistence and resiliency, where failure is seen as useful information, underlie successful innovation in every sphere and lie at the core of nearly all successful learning" (Brown, Roediger and McDaniel, 2014, p. 92).

4.3 Iterative testing and improvement

As part of the new process, when the simulation draft draws closer to completion, COMET teams invite users to work through it. We gather their input on the realism of the interactions, refinements in the information provided to the user to solve the problem, and any necessary changes to the feedback in order to increase its instructional usefulness. In a recent user test of two simulations of "Communicating Risk: The Impact-based Forecast Approach," users from South Africa, Barbados, El Salvador, Indonesia and Laos offered their suggestions for improvement. Their overall impressions of the simulation were positive, indicating that simulations have an appeal across cultures.

4.4 Technical challenges

The technical considerations surrounding the complexity of the branching paths are significant as well. The communication branching simulations made by COMET have three major decision points and offer three possible communication options. If our learners don't make all the right choices, they can see two potential paths demonstrating how their suboptimal communication choices might play out. On the learner's third try, our teams provide specific feedback about the incorrect choices that were made. We selected this configuration because it limits the branching paths that need to receive feedback to twenty-seven.

COMET programmers needed to develop different sets of scripts to keep track of the user selections in the simulations in order to provide specific feedback based on the user choices. The content creators then provided the appropriate feedback for each path through the content. Since there were twenty-seven possible paths, the teams created twenty-seven individual feedbacks. The inclusion of four decision points with four possible options would increase the feedback requirements exponentially.

Creating branching simulations that allow learners to make various choices and mistakes required not only a new mindset and process but also the development of new storyboard templates, programming tools and online interfaces. Our team used a mixture of Google Docs, Articulate Storyline, custom software and Adobe Creative Suite to develop the simulations. The new storyboard template allows us to keep track of each path through the simulation. Over the last two years, we have added Articulate Storyline as a rapid prototyping tool that enables us to quickly generate a testable version of the paths based on content provided by our clients. In this way, our teams and expert reviewers can easily see the correct route and all the incorrect options and make corrections to the content.

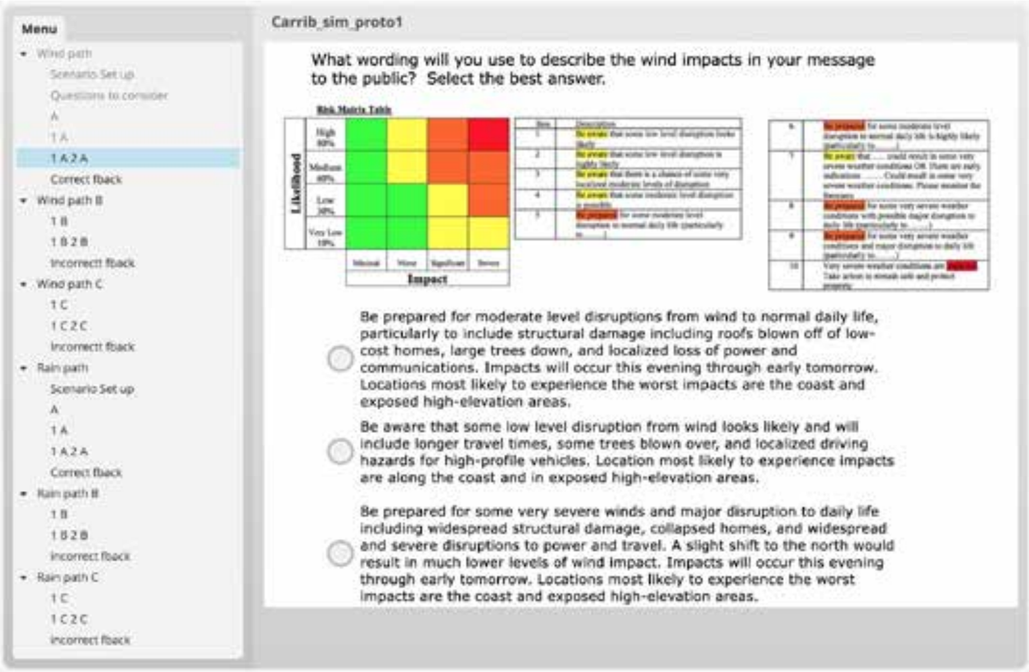

Figure 4.5. A simulation prototype developed in Articulate Storyline

Figure 4.5 shows an early prototype of a simulation. On the left, reviewers can see where in the simulation paths they are located, on the right, they see the decision that they need to make.

In addition to changing the storyboard process, a team of instructional designers and interface designers prototyped many different interfaces. The first simulation was very text-based and relied on the written word to convey emotions and responses. As our experience and confidence increased, we transitioned to using images of our partners that reflected different emotional responses tied to different communication choices in the scenario. Soon after, we also added audio so that our learners could both see and hear the emotional response that resulted from their communication choices. Facial expressions and audio add the emotional impact that was missing from the early text-only interface. In some of our user tests, we have observed users returning to the simulation many times in order to follow the different paths, simply to see the reactions tied to different communication approaches.

Overall, this emotional engagement, the risk associated with natural consequence feedback, and the challenge of finding the right path through the simulation have increased learner motivation and engagement.

4.5 Learning effectiveness

COMET has successfully implemented this approach in several online lessons. Comments from the learners and experts indicate that the branching simulation exercises are effectively engaging learners. The mean pre- and post-test scores in one lesson showed an improvement of 25 percentage points, to a mean post-test score of 85 (n=109). A second lesson showed 13 percentage points improvement, to a mean post-test score of 89 (n=202). COMET has also implemented branching simulations in topics such as maintaining situational awareness during the forecast process and impact-based forecasting and warning services.

When designed well, a branching simulation can provide real-life context, challenge, activity and feedback that can make learning engaging, meaningful and memorable.

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5. The Basic Instruction Package for Meteorologists: The blended-learning experience of the Spanish State Meteorological Agency

Francisco Jesús García Quintina, Spanish State Meteorological Agency (AEMET)

Abstract

The Spanish State Meteorological Agency (AEMET), in collaboration with WMO, organizes a course on the Basic Instruction Package for Meteorologists (BIP-M). This is a blended training course (distance and face-to-face) for meteorologists from Ibero-American countries, designed in accordance with the *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083) and *Technical Regulations* (WMO-No. 49)*, Volume I: General Meteorological Standards and Recommended Practices.* The course, designed for a maximum of 25 students, lasts approximately 18 months and is in two phases:

1. An online phase of 650 hours, tutored by AEMET staff, which tackles 110 topics related to atmospheric sciences. To participate in the face-to-face phase, students must pass the compulsory exams of this online phase;
2. A face-to-face phase of 200 hours (approximately eight weeks), held at the AEMET Regional Training Centre (RTC) in Madrid and funded by WMO.

The first course was held between June 2015 and October 2016, the second between June 2017 and October 2018, and the third is ongoing (2019–2020).

Keywords: Operational meteorology professional training, BIP-M, blended training, online training instructional design, online assessment design

5.1 Introduction

The Spanish State Meteorological Agency (AEMET) has been cooperating with the Ibero-American National Meteorological and Hydrological Services (IA-NMHSs) for over forty years. This relationship was formalized in 2003 with the creation of the Ibero-American Meteorological Cooperation Programme and its management authority, the Conference of Directors of the Ibero-American NMHSs (CIMHET) which, together with the WMO Secretariat, established multi-annual action plans on three strategic lines:

1. Institutional strengthening and resources mobilization;
2. Provision of weather and climate services:
3. Education and training.

In the strategic lines of AEMET's international cooperation, training has always been especially relevant.

Since 1969, when the National Meteorological Service of Spain (now AEMET) began to teach an international meteorology course for foreign students, numerous training courses have been carried out with different formats, face-to-face and online, and more than 2 000 meteorological service professionals from different countries, mainly Ibero-American, have been trained.

In recognition of this important training task, the seventieth WMO Executive Council, designated AEMET as a WMO RTC in Spain.

One of the most important AEMET courses is the Basic Instruction Package for Meteorologists (BIP-M).

5.2 Basic characteristics of the current AEMET BIP-M course

The current BIP-M course run by AEMET focuses on the atmospheric sciences content specified by the *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083). The course does not address the disciplines of mathematics, physics and complementary subjects. Thus, the AEMET study programme satisfies the requirements of BIP-M only in atmospheric sciences, not conferring an official degree, even though it is taught rigorously.

The course is designed to accommodate 25 students per session. The intended audience for the AEMET BIP-M course are professionals in Ibero-American meteorological services, specifically those who work in the field of aeronautical forecasting. Participants are selected from among candidates proposed by each country of the CIMHET. In addition, the NMHS director must certify that the participant has achieved an adequate academic level in mathematics, physics and complementary subjects, in order for him/her to be able to attend this AEMET course. The objective is that at the end of the course, the students meet the requirements of the BIP-M.

5.2.1 Online phase (650 hours: 1 year)

The training platform of the AEMET virtual campus (https://campusb.aemet.es/moodle/login/index.php, Course: Basic Instruction Package for Meteorologists - online phase) contains all the course material. Students log in to access the material, take tests, view the work plan and use forums and other Moodle applications (Figure 5.1).

The online phase lasts about 650 hours. The non-teaching periods can be used by the students for revision.

Four AEMET meteorologists tutor the course. During the online phase, each tutor is responsible for one of the four thematic blocks into which the programme has been divided. The tutors supervise the development of the course, monitor students' progress, solve students' technical and didactic doubts, and evaluate student performance.

Figure 5.1. Partial view of the BIP-M course in the AEMET's Moodle system

Because there are 110 topics in the Atmospheric Sciences module, the normal rate of progress is three topics per week. Participants dedicate about 17.5 hours per week to course work, distributed approximately as follows:

1. 15 hours per week (3 hours per day from Monday to Friday) for the study of the given topics;

2. 2.5 hours per week for tests and proposed exercises, review of questions, and other tasks

SEMANA	DEL	AL	TEMA INICIAL	TEMA FINAL	
1	10-abr-17	16-abr-17	Presentaciones	Presentaciones	
2	17-abr-17	23-abr-17	1	3	
3	24-abr-17	30-abr-17	4	6	
4	01-may-17	07-may-17	7	9	
5	08-may-17	14-may-17	10	12	
6	15-may-17	21-may-17	13	15	
7	22-may-17	28-may-17	16	18	
8	29-may-17	04-jun-17	19	21	
9	05-jun-17	11-jun-17	22	24	
10	12-jun-17	18-jun-17	25	27	
11	19-jun-17	25-jun-17	28	30	
12	26-jun-17	02-jul-17	31	32	
13	03-jul-17	09-jul-17	REPASO		
14	10-jul-17	16-jul-17			
15	17-jul-17	23-jul-17	1 EXAMEN PARCIAL		

Figure 5.2. Calendar of the first BIP-M block (online phase)

Although students may work at their own pace, it is important that they try to follow the proposed study schedule (Figure 5.2).

On the training platform there are three forums available:

1. Initial presentations forum. In this forum, in the course of the first week, each student and tutor will make a presentation introducing themselves to the rest of the group (better if in video format), commenting on their biographical data, job and experience, availability and expectations of the course and any particular feature they want to mention;

2. News forum: Used by tutors to comment on key ways to move forward during the course;

3. Follow-up and doubts forum: Used to comment on technical aspects of the programme, consult about certain specific topics, ask questions, etc. It will be used by tutors and students for answering questions, exchanging opinions and presenting different points of view. It is, therefore, very important that students ask questions and discuss them using this forum, since the recommendations and insights shared there will benefit all course participants—teachers as well as students.

At the beginning of each week, the tutor indicates in the forum which are the proposed topics for that week.

For each topic, and before moving on to the next, each student will have to carry out the following activities:

1. Access the main document (and appendices) on the topic and study it;

2. Carry out any exercises proposed by the tutor;

3. Complete the self-evaluation test on the topic;

4. Be attentive and participate in follow-up and doubts forums;

5. If necessary, send the corresponding questions to the tutor.

If the result of any self-assessment test is not satisfactory, it is important for the student to review the concepts related to the mistakes made and to ask the tutor any questions that have arisen.

The tutors will be attentive to the development and performance of the students, answering the questions raised, mainly through e-mail and the forum of doubts, and responding to student inquiries within 48 hours. The answers to many types of question can be of general interest and should, therefore, be answered in a global way in the corresponding forum. However, questions may arise that will be dealt with by the tutors in a personalized and discretionary manner by e-mail.

After a participant has completed a test, the training platform will show the test score. Students' gradual study of each subject and completion of the associated self-assessments will allow both students and teachers to systematically evaluate the students' progress in the course. Students can also use the self-assessments to review and consolidate concepts.

We recommend that participants achieve a score of at least 70% to ensure that they have correctly assimilated the topic. To obtain this score, a maximum of two attempts are allowed, with no time limits for completion. It is highly recommended that students complete all self-assessment tests according to the rhythm recommended by the tutors.

There are four obligatory partial tests after each thematic block, which count towards the final qualification and also serve as practice and revision for the decisive final exam. Each tutor makes a brief report at the end of each of the four thematic blocks, assessing the students' performance during that phase.

Students take the partial tests during a fixed week, although they can choose the time that is most convenient for them within that week. For these partial tests, a single attempt is allowed, and each tutor sets a maximum time for completion.

At the end of each of the four thematic blocks, the students anonymously complete a satisfaction survey on the progress of the course.

At the end of the online lecture phase, all the students complete a final simultaneous examination, in a limited period of time without being allowed to consult the course documentation, notes or any electronic device. This examination consists of a multiple-choice questionnaire with questions of a similar level of difficulty to the self-assessment and partial tests. Points are not subtracted for incorrect answers. The exams are carried out in person at the Spanish Embassy in each of the countries. To this end, when the time comes, students are instructed to contact the Embassy about the supervision of the exam. At the end of the online phase of the course, there is a non-teaching period that allows students to revise and prepare for the final exam.

The final mark for the online phase is calculated as follows:

1. 20% is given by the score obtained in the self-assessment tests and especially in the obligatory partial tests;

2. 80% corresponds to the result of the final examination.

Each student's pace of study, course participation and self-evaluation tests will also influence their final mark, because these are activities that allow the tutors to assess the student's progress.

To participate in the face-to-face phase of the course, students must pass the online phase with a score of 70%. However, all scores higher than 60% but not reaching 70% are reviewed and may be increased if the student has completed the course at the established pace and has demonstrated commitment.

The success rate for completing the online course to date has been approximately 50%. Two factors could explain this modest success rate. First, the students take this course while working at their NMHSs, so it is difficult for them to find time to study due to their professional responsibilities. Secondly, knowledge of physics and mathematics is a prerequisite to attend this kind of course. However, students have a heterogeneous level of knowledge of these subjects, and some of them need more time to learn topics where the physical or mathematical formulation are more complex. To achieve greater success in the online phase, it would be useful for candidates to demonstrate their knowledge of physics and mathematics by taking an exam before being selected. In addition, AEMET must be sure that students are going to have enough time to study, so a commitment signed by the institution and the student is necessary.

Those that do complete the online phase and move to the face-to-face phase have a 100% success rate.

5.2.2 Face-to-face phase (200 hours: 2 months at AEMET headquarters)

The face-to-face phase at the AEMET RTC in Madrid lasts approximately eight weeks. Scholarships funded by WMO cover students' travel and full-board accommodation in a university residence near AEMET.

The first week is devoted to the review of important characteristics, functioning and services of a modern meteorological service such as AEMET. The focus of the fundamental block of the course, which takes seven additional weeks, is practical, with weekly monographic subjects and guided exercises that students carry out individually or in groups.

Each week the teacher introduces the exercises and supervises students closely. The topics to be dealt with during the seven weeks (apart from the initial week) are the following:

1. Climate statistics (practical cases with R);

2. General forecasting at AEMET. Problems of dynamics and thermodynamics applied in operational forecasting;

3. Practical interpretation of remote-sensing images (satellite, radar and lightning);

4. Practical activities and tools for the interpretation of numerical model output products at both middle latitudes and tropical latitudes;

5. Production and presentation of meteorological reports (teamwork);

6. Practical aeronautical forecasting;

7. Geographic information systems in meteorology and climatology. Use of SAGA GIS.

The course ends with a closing ceremony and the awarding of diplomas to students who have definitively passed this face-to-face phase.

5.3 Proposals for improvement of the future BIP-M course

The BIP-M course, being the most general and basic, must be practical and focused on the contents that are considered fundamental. It should feature only the minimum knowledge necessary to perform specialized jobs in meteorology and climatology. Then, depending on the job, each professional should take specialized courses to acquire the necessary associated skills.

One possibility is for the BIP-M course design to focus on the Atmospheric Sciences programme, excluding physics and mathematics and current complementary subjects, the knowledge of which could be prerequisites. The *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083) suggests this pattern, which corresponds to the design of the AEMET BIP-M course for Ibero-American professionals.

It might be convenient to organize the BIP-M course in several basic modules (nuclei) and diverse optional blocks or units. For example, the thematic content of the BIP-M can be grouped into three modules: Essential Meteorology, Operational Fundamentals and Essential Research and Development.

For other more specialized types of basic instruction package (aeronautical, marine, climate services, etc.), accreditation should be required for some or all of the competences included in the BIP-M and, in addition, those specific to each service area.

The tutors of a blended BIP-M course play an important role. They must monitor the development of students, resolve their doubts and motivate them to continue in the course. The tutors must also encourage the students and carefully monitor their pace of progress. Furthermore, a BIP-M course should include both theoretical learning components and practical exercises.

In general, the learning objectives of the BIP-M course should be more developed and detailed. Additionally, some of the 110 themes in the Atmospheric Sciences programme could be grouped together, thus reducing the number of themes.

5.4 Conclusions

The training course we design must respond to the needs of the institutions receiving it, and must take into account the capabilities of AEMET itself. Thus, we designed the AEMET BIP-M course so that participation by Ibero-American NMHS staff would not significantly interrupt NMHS operations. For this reason, the course has a long online tutored phase (650 hours over 14 months), and a shorter face-to-face phase (200 hours over 2 months in Madrid).

The development and delivery of this course has been a challenge for AEMET. We are now in the third edition of the course and our experience is helping us to improve certain aspects. By the end of 2018, 25 Ibero-American meteorologists were certified, helping Ibero-American NMHSs substantially improve their services.

6. A new approach to training weather observers, from making cloud and visibility observations to managing observations

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Abstract

This chapter discusses the methodology for training newly recruited Student Scientific Assistants (Student SAs) of the Hong Kong Observatory in weather observation on the basis of the requirements of the WMO Basic Instructions Package for Meteorological Technicians (BIP-MT). The purpose is to enhance the capacity of Student SAs in weather observation effectively and efficiently. Information technology was used to build a databank of cloud and weather photos with which the trainees can learn and experience a wide range of cloud types and weather phenomena within a relatively short period of time. The databank consists of a cloud observation training tool which provides an effective way to learn and gain experience in weather observation. Online self-learning via the databank was used to facilitate the trainees' exploration of a topic and encourage further independent study to gain a deeper understanding. The success of the training method indicates that the tool can be further refined to be used for additional training of weather observers in general.

Keywords: weather observer, cloud observation, weather photo, databank, knowledge management

6.1 Introduction

In the past, a weather observer was required to take weather observations directly from thermometers, barometers and wind recorders, and make manual observations of clouds, visibility and weather phenomena. Today, automatic weather instruments can provide meteorological data including temperature, pressure, wind direction and speed to weather observers automatically. Visibility assessment is basically a combination of human and instrumented observations.

Despite advances, it is still difficult to use automated recognition methods and computer algorithms to generate cloud observations in the Hong Kong region. Thus, it is important to maintain the professional skills of weather observers in making weather observations, such as identifying cloud types and assessing cloud heights, as well as recognizing various weather and optical phenomena, in order to maintain the competency of weather observers and ensure the quality of meteorological information and services.

The occurrence of some special weather phenomena and specific cloud types, in particular, is highly dependent on location (for example, with or without terrain) and season. Even though there are routine practical sessions on weather observation during the induction training course (ITC), the trainees may only encounter a limited number of cloud types and weather phenomena during the training period. Hence, there is a need to use information technology to build a knowledge database of various cloud types, local weather and optical phenomena, through which the trainees can learn and experience a wide range of cloud types and phenomena within a relatively short period of time.

This chapter describes the weather observation tool of the ITC designed by the Hong Kong Observatory (HKO) to train newly recruited Student SAs, before they take up duty as weather observers. The contents of the ITC are, in general, based on the requirements of the WMO Basic Instruction Package for Meteorological Technicians (BIP-MT). The ITC is organized in-house and conducted by experienced staff of HKO.

The ITC consists of lectures and practical training. After successful completion of written and practical assessments, Student SAs are expected to proceed to prolonged on-the-job training at the Central Forecasting Office (CFO) and the Airport Meteorological Office (AMO) to gain practical work experience and to become competent weather observers.

A Cloud and Weather Photos Databank, hereafter referred to as the Databank, has been developed to facilitate sharing and learning of cloud types, local weather and optical phenomena. It adopts a crowdsourcing strategy in data collection as well as a blended-learning approach that includes classroom teaching and the development of online self-learning materials.

6.2 Design and implementation

Weather photos, including clouds and optical phenomena, are routinely taken by the operational weather observers at CFO and AMO (Figure 6.1). A user-friendly interface was developed for weather observers to upload the photos and their metadata, such as information on the cloud type, cloud amount and cloud height, type of weather or optical phenomenon, and date, time, location and viewing direction of the photo, which will be stored in the Databank.

Key tags are used to facilitate search of the specific types of clouds, optical or weather phenomena by trainees during the learning process. The training materials in the Databank are designed to include many videos/images with a minimal amount of text. These materials can be easily understood by the young trainees.

Figure 6.1. Photos of clouds taken by weather observers

The Databank consists of a cloud observation training tool that provides an effective way to learn and gain experience in weather observation. Trainees can learn and practise, using the tool anywhere and anytime. The tool has graphical interface for enhancing user experience and motivation of trainees. The Databank is also designed to be a platform for experienced staff to share experience and knowledge.

The cloud observation training tool emphasizes the cloud features and codes. Its main purpose is to train new recruits on the coding of different cloud types in meteorological reports. It includes a training module (Figure 6.2) with randomly picked photos of clouds for the trainees to practise identifying the correct codes.

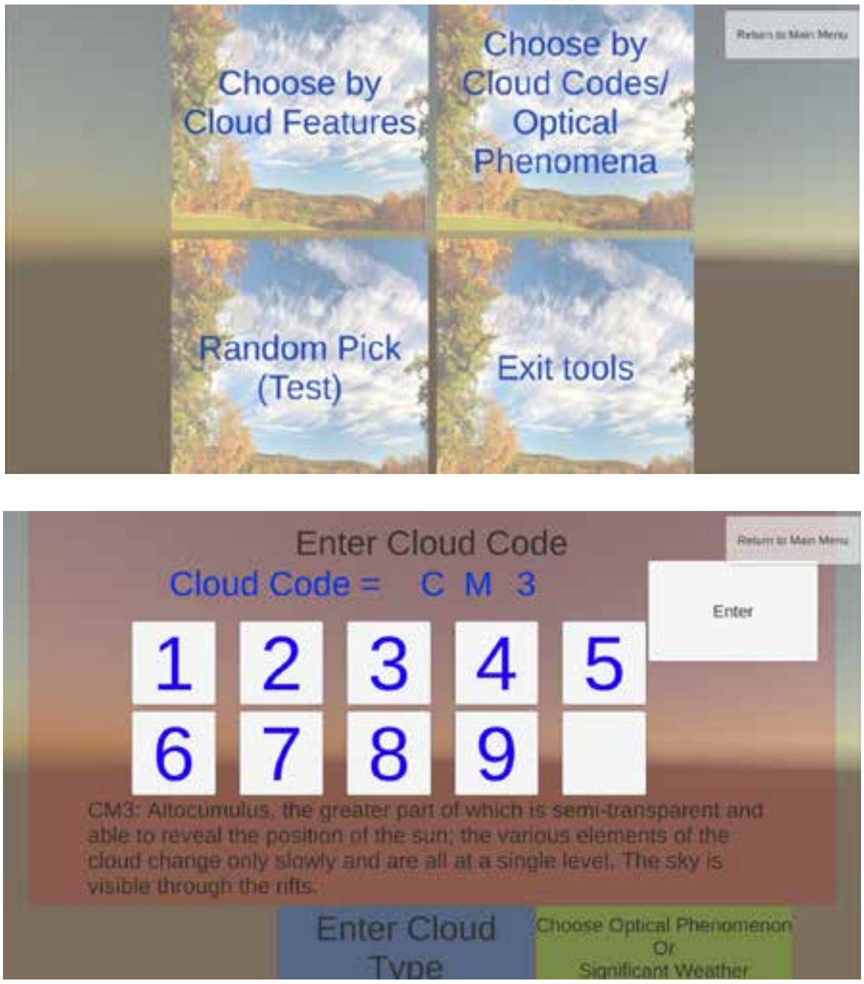

Figure 6.2. Training module in the cloud observation tool

To make the learning process more interactive and interesting, a game approach is adopted. Online quizzes related to clouds, various optical and special weather phenomena are incorporated in the Databank to help assess the trainees' knowledge and ability in identifying cloud type and understanding the formation mechanisms. The quizzes are also conducted in the form of group competitions in classroom during the ITC.

A blended-learning approach with a combination of online learning and classroom training is adopted at HKO. Online individual learning via the Databank can facilitate the trainees' exploration of a topic and encourage further study to gain a deeper understanding.

6.3 Discussion

The Cloud and Weather Photos Databank is a useful training tool in the ITC for weather observers. It was also adapted for the training of Student SAs at the HKO. Working tips and knowledge from experienced weather observers are shared with the trainees via the Databank, making it also a knowledge management tool. Within a short period of time, trainees are able to gain knowledge of cloud types and coding as well as weather and optical phenomena, more than in classroom training alone.

Following the deployment of the Databank for induction training in 2018 and the subsequent development of the cloud training tool, most trainees found the Databank a very useful information source and effective learning tool. The trainees generally opined that the platform facilitated their learning and self-assessment during the induction training. Active engagement of trainees using the tool increased the effectiveness of training.

A challenge in the use of the training tool in the Databank is the difficulty of judging the cloud height merely from the photo, especially if there are no low-level clouds and no landmarks in the photo to refer to. Moreover, photos with insufficient metadata are less useful in teaching and learning.

An increasing number of cloud, optical and weather phenomena photos taken locally will be uploaded to the Databank by operational weather observers, thus generating big data for computer analysis using machine learning techniques. There has been an ongoing effort to develop the automation of cloud and visibility observations around the world. Noting recent technological advances, the HKO is moving towards using artificial intelligence and machine learning techniques, such as deep-learning methods, to develop an automation process for generating weather reports, in collaboration with data science experts in universities.

In view of these developments, the training programme will be refined and enhanced to take into account the possible transformation of the roles of weather observers, which might include tasks such as quality management of meteorological observations and data, meteorological instrumentation, communication of weather and climate information to stakeholders and the public, and assisting weather forecasters in severe weather nowcasting, to prepare them for future challenges and opportunities.

7. Smart classrooms and online learning

Shawn Boyce and Megan Cox, Caribbean Institute for Meteorology and Hydrology

Abstract

The Caribbean Institute for Meteorology and Hydrology (CIMH) is a World Meteorological Organization (WMO) Regional Training Centre (RTC) proficient in the delivery of training to (a) meteorological and hydrological personnel at various levels, ranging from observer to forecaster, and (b) climate service personnel. In 2017, the Institute completed the implementation of Building Regional Climate Capacity in the Caribbean (BRCCC), a programme sponsored by the United States Agency for International Development (USAID) and delivered through WMO, which facilitated infrastructure upgrades to the CIMH campus. These upgrades included the transformation of all classrooms and the computer training laboratory into smart classrooms through the introduction of smart-boards, high-speed internet connectivity and online collaboration and training software. This transition is supporting improvements to course delivery, access to course content and the expansion of online and blended-learning options offered by the CIMH both regionally and internationally. The availability of such options is addressing the often prohibitive cost of face-to-face learning in the Caribbean and supports synchronous delivery of training across international jurisdictions. This chapter outlines the improvements made to the CIMH training programme and highlights innovative approaches to learning.

7.1 Transitioning to innovative technologies and e-learning

The Caribbean Institute for Meteorology and Hydrology is (a) a specialized institution of the Caribbean Community (CARICOM), (b) the technical organ of the Caribbean Meteorological Organization (CMO) and (c) an affiliate of the University of the West Indies (UWI). The mandate of CIMH is "to improve the meteorological and hydrological services in the CMO Member States and to assist in promoting the awareness of the benefits of these services for the economic well-being of Member States" (Figure 7.1). This is achieved through training, research and development and the provision of specialized services. The Caribbean Institute for Meteorology and Hydrology is recognized as a World Meteorological Organization (WMO) Regional Training Centre (RTC), providing the full suite of training to meteorological, climatological and hydrological personnel, many of whom support Disaster Risk Reduction (DRR).

Figure 7.1. Member countries of the Caribbean Meteorological Organization

In 2011, CIMH was invited to attend a Training of Trainers (ToT) workshop focussed on the online delivery of hydrology courses sponsored by the World Meteorological Organization (WMO) and hosted by the COMET Program. The aim of the workshop was to train interested personnel from academic institutions on the planning, development and delivery of distance-learning courses in hydrology. The course provided CIMH staff with an introduction to Moodle—a free, open-source, customizable learning platform for educators.

On completion of the workshop, it was clear that making use of such applications would facilitate the modernization of the hydrology training programme at CIMH, potentially reducing future training costs associated with capacity-building initiatives. By the end of 2012, CIMH was hosting a fully operational Moodle server and, in 2014, it offered a flood hazard mapping online course—CIMH's first hydrology-related online course—through the myCIMH eLearning portal based on Moodle. Subsequently, the injection of substantive resources through the United States Agency for International Development (USAID) and delivery support by WMO led to the Building Regional Climate Capacity in the Caribbean (BRCCC) programme. This programme, concluded in 2017, led to the modernization of CIMH in part through the procurement and installation of audiovisual tools such as smart-boards, televisions, communication software and the improvement of conference facilities.

Substantive training for hydrological technicians at CIMH is delivered through two courses: (a) the Hydrological Technician (HT) Course and (b) the Diploma in Hydrology (DipH). The former (HT) is an eight-month course that focuses on aspects of operational hydrology and prepares the technician to assist with hydrology-related tasks. The latter (DipH) is an 18-month course that introduces theoretical aspects of hydrology and expands on the practical aspects of hydrology. More information on these courses can be found at http://www.cimh.edu.bb/?p=training&c=hydrology. These face-to-face courses at CIMH have been undersubscribed in the recent past. The latest offering of the HT course (2018–2019) had no enrolments, while the ongoing DipH has only one (1) student enrolled. This pales in comparison to the size of classes in the recent past and is a concern given the current and expected stresses on the water cycle in the Caribbean due to climate change, increasing climate variability and increasing water demand resulting from increased urbanization and industrial development. These low enrolment numbers are thought to be due to the increased cost of travel to Barbados and the associated living expenses, coupled with the inability of hydrological services to attract appropriate funding.

The demand for such training opportunities in hydrology and hydrology-related applications is evident from the response to the calls for participation in the online professional development courses managed by the Hydrology Section and hosted through the myCIMH eLearning portal. These courses continue to attract participants from around the Caribbean annually and have also been successful when offered outside the region. To build on these successes while addressing low enrolment for face-to-face courses, the Hydrology Section is considering transitioning the face-to-face hydrology training programme to a blended alternative, combining both online and face-to-face learning. The blended alternative would effectively utilize the innovative smart classroom technologies and content management systems, including the Moodle virtual learning environment previously implemented, that are now available at CIMH for both synchronous and asynchronous online delivery. In order to investigate the feasibility of transitioning to a blended-learning solution, instructors have started to incorporate innovative learning tools and techniques first within the classroom. The ongoing DipH course has provided instructors with an ideal opportunity to utilize and assess aspects of the technology and innovative approaches to training within a classroom environment without causing too much disruption during class time considering that there is only one (1) student enrolled.

The following sections will first describe the implementation of smart classroom technology at CIMH, and then close with a description of our myCIMH eLearning portal, currently being used to manage course content and delivery of the hydrological training programme.

7.2 Smart classrooms

Each classroom at CIMH, the Library Reading Room (LRR) and the computer lab are equipped with an Epson BrightLink® interactive projector and a PC. A dedicated PC application is used to manage connections to the projector. The projector does not require a dedicated electronic whiteboard as it can be used with existing whiteboards onto which a fully integrated virtual whiteboard is projected (Figure 7.2). The ability to write, copy, cut, paste, highlight, rotate and share whiteboard content during class through the use of the projector pen has greatly enhanced the delivery of course material. It has eliminated the need for several differently coloured whiteboard markers, board erasers and cleaning solutions allowing for more time to be spent on interaction with students. Notwithstanding, one of the key benefits is the integration of the interactive projectors into the Local Area Network (LAN) at CIMH. LAN integration facilitates cabled and remote connections to the projector via personal computers, laptops, tablets and smartphone applications. These capabilities are currently being tested and assessed by instructors on the DipH course.

During classes the student is provided with a code for controlled access to the virtual whiteboard via an internal URL. The URL is accessed through any device used by the student. Once accessed, a share of the virtual whiteboard feed from the interactive projector is presented to the students on their device. Students can either (a) view only, (b) view and annotate or (c) control the whiteboard. Controlled access allows the student to view, manipulate and create whiteboard content, including editing, highlighting and adding images, while the ability to remove content and access changing projector modes (e.g. presentation, whiteboard) is restricted. This has allowed students to use their device to highlight areas of the presented material that were unclear and that required further explanation, and also to answer questions interactively while following the whiteboard presentation.

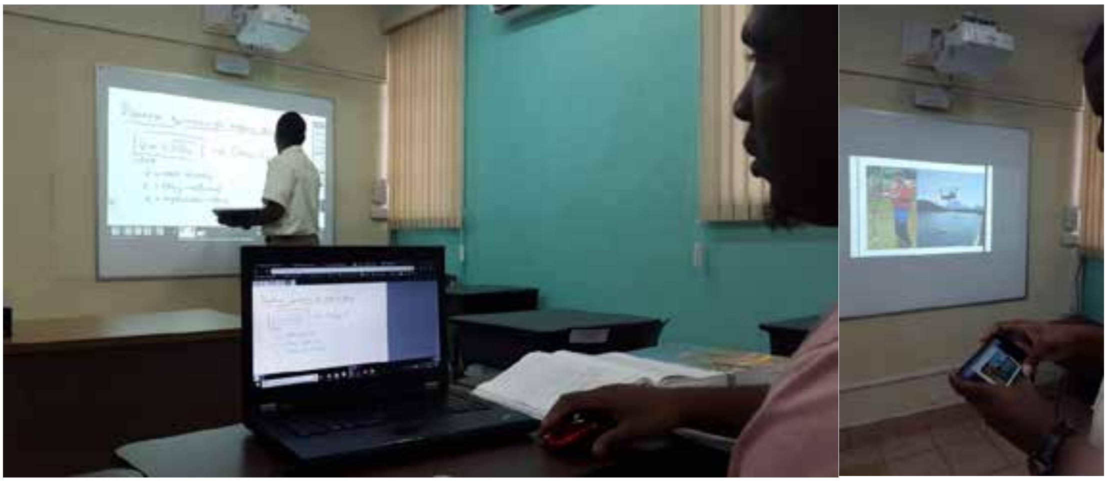

Figure 7.2. Interactive projector and smart board

The instructor can connect to the interactive projector via a dedicated smartphone application that allows him/her to (a) control the interactive projector remotely, (b) add new content to the virtual whiteboard, (c) manipulate existing content on the virtual whiteboard, (d) access and display content stored on the smartphone, (e) display internet resources and (f) display and capture a live feed from the camera app on the smartphone. This provides the instructor with additional flexibility during class and limits the dependence on the PC provided in the classroom. In any event, regardless of the source, content displayed is captured and integrated into the virtual whiteboard presentation. This has proven to be a useful feature. Very often in hydrology training there is a need to present and discuss complex workflows and diagrams. These range in complexity from the full hydrological cycle to density dependent flow and transport vectors under varying groundwater pumping scenarios. Diagrams published in journal articles and fundamental texts can also be captured via the smartphone and added to the virtual whiteboard content. These captured images can be further manipulated and marked up during class as necessary to improve understanding. All virtual whiteboard content associated with the session is made available to the students for download at the end of the class via the URL. Feedback from the students has been positive to date and will be incorporated at the end of the course evaluation in order to further enhance the hydrology training programme.

7.3 Online learning

The creation of the myCIMH eLearning portal has led to the development and delivery of several online hydrology continuing professional development courses including (a) Introduction to Geographical Information Systems (GIS), (b) Hydrological Modelling with HEC-HMS, (c) GIS for Hydrological Technicians, (d) Environmental Impacts Related to Hydrological Systems (Figure 8.3) and (e) Flood Hazard Mapping. These courses have continued to be attractive to staff at NMHS and related agencies. The courses are managed through the Moodle learning management system, the content of which contributes to the face-to-face hydrology training programme and provides support to online course delivery.

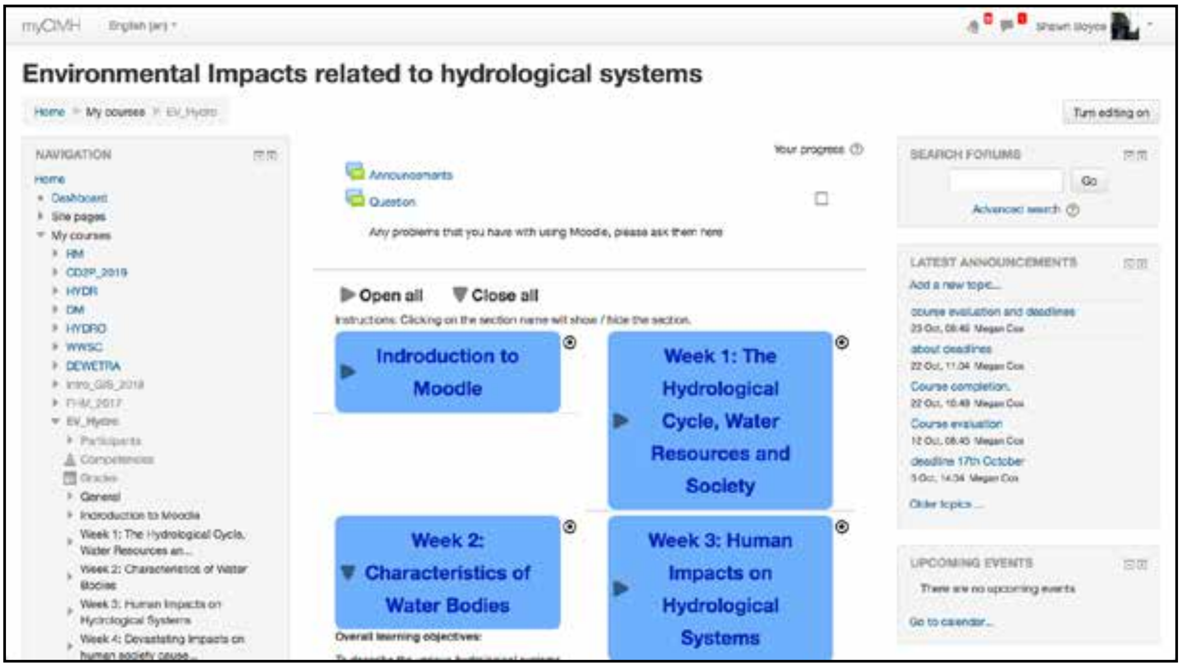

Figure 7.3. Environmental Impacts Related to Hydrological Systems

The Moodle platform offers several activity modules for course development and delivery. Of particular interest to the Hydrology Section is the lesson activity module. This module allows the trainer to deliver content and implement activities in a flexible way. Examples of content that can be delivered through a lesson activity includes text, images, videos and links. The lesson workflow can be controlled in ways linked to the ability of the student to correctly answer questions or to the amount of time spent on the lesson. For example, correctly answering a question or series of questions allows the student to move on to the next task while incorrect answers direct the students to an alternative workflow which may include additional information aimed at furthering their understanding. Essentially, the lesson format provides a methodology for adaptive learning that can be customized to suit the learning needs of students. Such innovative interventions allow students to learn at their own pace while fostering greater interaction during online delivery.

The Environmental Impacts Related to Hydrological Systems course offered by CIMH is a four-week course that examines anthropogenic processes and their impacts on the management of surface and groundwater resources, the migration of pollutants such as oil, pesticides, landfill leachate into aquifers and environmental monitoring. In previous years, the course was delivered face-to-face. However, in 2018, the course material was revised, and the course was delivered through the myCIMH eLearning portal. Course content was delivered to participants through a series of lesson activities in order to encourage greater interaction between the participants and the material, while allowing self-paced learning. Thirty persons enrolled in the course with 40% of the enrolled participants completing the required activities.

The five persons who completed the course evaluation provided some useful insights. Four respondents indicated that the overall content of the course was excellent. However, responses to the least enjoyable aspects of the course clearly indicated that the amount of content needed to be carefully managed when using lesson activity modules that require completion to grant access to subsequent content. The course duration must be carefully considered, especially when targeting participants who are employed full-time. Lessons need to be carefully planned in advance in order to make the best use of the tools available in the lesson activity module. Finally, a reliable Internet connection is essential to allow participants to maintain connections to the server.

7.4 Future plans

The use of smart classrooms at CIMH has enhanced the delivery of the training programme. The ability for teachers and students to interact with the virtual whiteboard provides greater flexibility in the classroom. Connections to the interactive projector are through the LAN at CIMH, but connections can also be through the VPN service offered by CIMH, which provides a secure connection to the LAN. Therefore, it would be possible for students who are not physically present to interact with the virtual whiteboard and participate fully. Through such technology, CIMH will be able to expand the target audience for its professional development courses to include participants from other regions.

The incorporation of videoconferencing tools available at CIMH will support the synchronous delivery of courses. Essentially, it will be possible to deliver a face-to-face course while having other students participate online with full access to the virtual whiteboard regardless of their physical location. A blended-learning programme will be developed within which students will be required to spend an agreed number of hours on campus while having the flexibility to follow the course remotely. Online modules for each topic will be developed within the myCIMH eLearning portal. These online modules when combined will be delivered as short courses and will support the enhancement of the face-to-face courses. The use of adaptive learning techniques possible through the lesson activity on the Moodle platform will greatly enhance the delivery of the online content and manage access to the course material. Currently, the Hydrology Section is revisiting the content of the online professional development courses to facilitate more adaptive learning workflows. It is expected that these courses will be delivered in 2020.

8. Expanding the reach of COMET/WMO distance-learning hydrology training

Matthew Kelsch and Elizabeth Page, University Corporation for Atmospheric Research (UCAR), The COMET® Program

Abstract

Starting from the 1990s, the COMET Program has made substantive progress in the design and implementation of training courses in different aspects of meteorology that were geared particularly to the United States National Weather Service. In recent years, however, more and more training lessons have been delivered online in a variety of geoscience topics to learners drawn from all over the world. Groups of lessons have been identified for use in online, multi-week courses. This brief report shares experiences, challenges and lessons learned in the delivery of online courses in hydrologic sciences in different WMO Regions. Overall, significant levels of success have been recorded in all the Regions in the use of online training for distance-learning courses. However, because some training is out of date, either in the scientific content or the technology used in the lesson, development of new online modules will be an important part of advancing the effectiveness of distance-learning courses in the future.

8.1 Introduction

Most of the courses conducted in the 1990s by the COMET Program at the University Corporation for Atmospheric Research (UCAR) were usually in the classroom and geared towards the United States National Weather Service. They were generally referred to as residence training. The classroom training of those years was highly rated, but it was not designed to reach a large and diverse audience of learners.

In addition, those who undertook COMET distance-learning training until the end of 1998, during the first decade of the COMET Program, did not do so through the convenience of a web browser. By 2019, however, the typical user of COMET training material would have had their learning experience through self-directed interactive online lessons in a variety of geoscience topics. Online lessons from the COMET Program are accessed through the COMET MetEd website (www.meted.ucar.edu).

MetEd offers more than 800 hours of self-paced online training in a wealth of topical areas, including meteorology, hydrology, climate science, oceanography and space science. More than a half-million learners are registered on the MetEd website including about 190 000 from outside the United States. These numbers include learners from about 2 100 universities worldwide.

The following summarizes the use and acceptance of COMET online courses in hydrologic sciences among World Meteorological Organization (WMO) Regions and international audiences. Some challenges encountered in their implementation and lessons learned that will guide future up-scaling of the scheme are also discussed

8.2 Developing an effective distance-learning approach

8.2.1 Development trend

The distance-learning international hydrologic training courses that have been offered since 2009 are a product of COMET's unique position with a large library of online training modules and the ability to leverage innovations in communications technology and instructional methods. During the period 2005–2007, the COMET Program, with sponsorship from the United States National Oceanic and Atmospheric Administration (NOAA), developed an online course in basic hydrologic sciences that featured 11 specific modules (online lessons). Those and other COMET lessons were used by international audiences in 2009 and 2011.

Figure 8.1. Course website for The COMET Program *Basic Hydrologic Sciences: International Edition*

It was recognized that a potentially large worldwide audience existed for this course if the lessons had more international examples and the courses offered some interactions with experts, particularly experts from the same region as the learner. With help from WMO, the original course was revised and *Basic Hydrologic Sciences: International Edition* became available in 2011 (Figure 8.1). A residence course called *Train the Trainer* was offered at the COMET facility in 2011 and was attended by potential training experts from selected WMO Regional Training Centres (RTC). The course demonstrated the use of the open-source learning platform called Moodle for delivering interactive international courses and defined the role of the regional experts during these distance-learning experiences.

Although the distance-learning training that followed beginning in 2013 was based on lessons from the COMET Program, the WMO RTCs were encouraged to include regionally relevant training material as appropriate. Region II, headed by the National Water Academy in India (NWA), has been particularly active with integrating regionally relevant content into the training experience.

8.2.2 Challenges and lessons learned with implementation

As soon as the distance learning (DL) courses were offered, the problem of limited Internet access experienced in many countries had to be tackled. This problem varied from country to country but was a significant barrier for attendees needing to complete the lessons. The most obvious solution to help the course attendees was to provide a flash drive with all of the lessons. Quizzes for each lesson still required online access so that the course facilitators could track the quiz completions, but all attendees appeared to be able to access the Internet for quiz completion at least a couple of times per week.

The courses are multi-week and a common problem was that attendees fell behind in the first couple of weeks and then dropped out. Course instructors routinely posted words of encouragement to boost enthusiasm and improve the completion rate. Although the courses were organized in weekly sections, assignments for each week remained available for the attendees to complete throughout the course.

The lessons, quizzes and written assignments were all done in English, which posed a language barrier in many countries. This likely reduced the amount of discussion in the course forum and added an extra challenge for some attendees. Since the course began, Google Translate has improved, and both attendees and instructors are now occasionally using it to facilitate communication.

In the most recent of the DL courses developed, *Hydrology Technicians*, attendees were required to perform field assignments. This requirement was too burdensome and reduced the number of successful completions. In the second version, we replaced field work assignments with virtual options. That innovation improved the completion rate.

8.3 The hydrological science DL courses

In addition to the 2011 *Train the Trainer* residence course for RTC professionals, there were 16 distance-learning courses from 2009 until the end of 2018, 13 of those since the *Train the Trainer* course (Table 8.1). Attendee evaluations of how well the course met expectations began in 2014 with all ratings between 4.26 and 4.88 on a scale of 1–5 (5 is the highest rating), although not all attendees provided an evaluation.

Table 8.1. COMET/WMO hydrology courses 2009–2018. The fourth column from the left shows the percentage of course participants that completed all the required assignments (and fraction of total completions/total enrollments). The last column shows the participant rating.

Course title	Year	WMO Region	% Completion	Rating
Basic Hydrologic Sciences	2009	Multiple	30 (17/56)	
Hydrology II	2011	RA VI (Europe)	66 (29/44)	
Basic Hydrologic Sciences	2011	RA V (Pacific)	37 (10/27)	
Train-the-Trainer (Residency class in Boulder, USA)	2011	All	100 (13/13)	
Basic Hydrologic Sciences	2013	RA I (Africa)	92 (46/50)	
Basic Hydrologic Sciences	2013	RA II (Asia)	91 (39/43)	
Basic Hydrologic Sciences	2014	RA II (Asia)	85 (44/52)	4.48/5.00
Advanced Hydrologic Sciences	2015	RA II (Asia)	78 (38/49)	4.53/5.00
Basic Hydrologic Sciences	2015	RA I (Africa)	62 (13/21)	N/A
Basic Hydrologic Sciences	2015	RA II (Asia)	91 (39/43)	4.39/5.00
Advanced Hydrologic Sciences	2016	RA II (Asia)	83 (44/53)	4.29/5.00
Basic Hydrologic Sciences	2017	RA II (India only)	60 (38/63)	4.52/5.00

Course title	Year	WMO Region	% Completion	Rating
Basic Hydrologic Sciences	2017	RA II	83 (60/72)	4.26/5.00
Basic Hydrologic Sciences	2017	RA II (India only)	85 (41/48)	4.43/5.00
Advanced Hydrologic Sciences	2018	RA II	83 (77/93)	4.29/5.00
Hydrologic Technicians	2017	RA V (Pacific Islands)	20 (10/50)	4.44/5.00
Hydrologic Technicians	2018	RA I (Africa)	49 (18/37)	4.88/5.00
Basic Hydrologic Sciences	2019	RA-II (Asia)	NA	

There are three distinct courses that emerged from the 2009–2018 experience: (a) *Basic Hydrologic Sciences*; (b) *Advanced Topics in Hydraulics, Hydrologic Sciences and Hydrometeorology;* and (c) *Hydrology Technicians*.

For the *Basic Hydrologic Sciences* and the *Advanced Topics in Hydraulics, Hydrologic Sciences and Hydrometeorology*, the completion rates averaged 44% up to the 2011 *Train the Trainer* class and have been averaging 84% since then. The *Train the Trainer* class focused on using the latest innovations in instructional technology to maximize student engagement. It appears that the courses became more effective at reaching larger and more diverse audiences as a result.

The *Hydrology Technicians* course is more hands-on and had a low completion rate of 20% in the first offering in Region V. Revisions were made for the second offering that focused on using technological tools to reduce the need for in-field measurements and replace them with virtual experience (through photos, video, and instructor input). The second offering in Region I saw the completion rate improve to 49%.

Although some attendees did not complete the requirements for a course certificate, many partially completed the material and were exposed to the existing training resources for future use.

8.3.1 Basic Hydrologic Sciences

The *Basic Hydrologic Sciences* course is based on the COMET series *Basic Hydrologic Sciences: International Edition* along with several other COMET lessons. For the Region II version, several additional lessons were included, which were developed by the National Water Academy (NWA) in Pune, India.

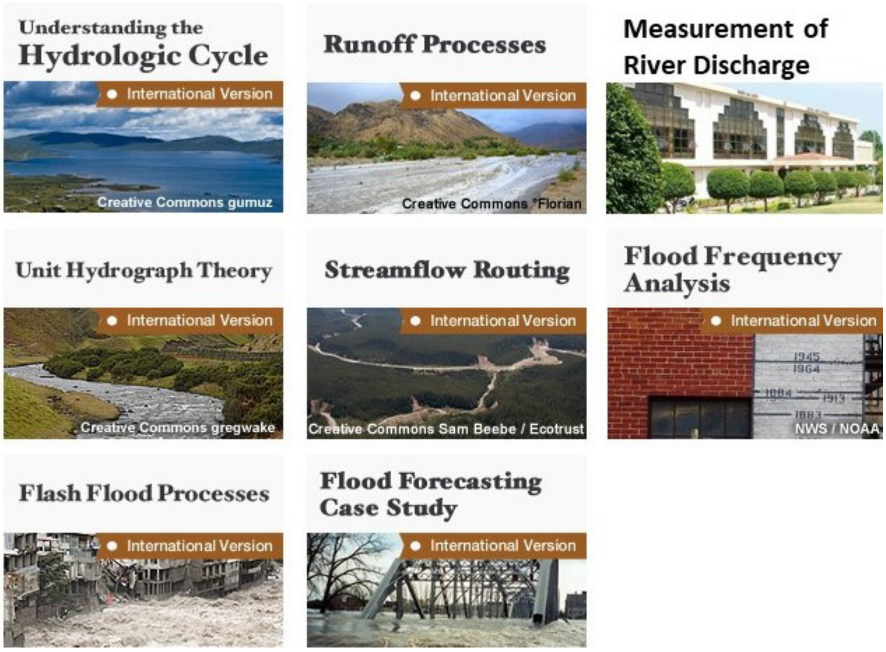

Figure 8.2. Required modules for the *Basic Hydrologic Sciences* course

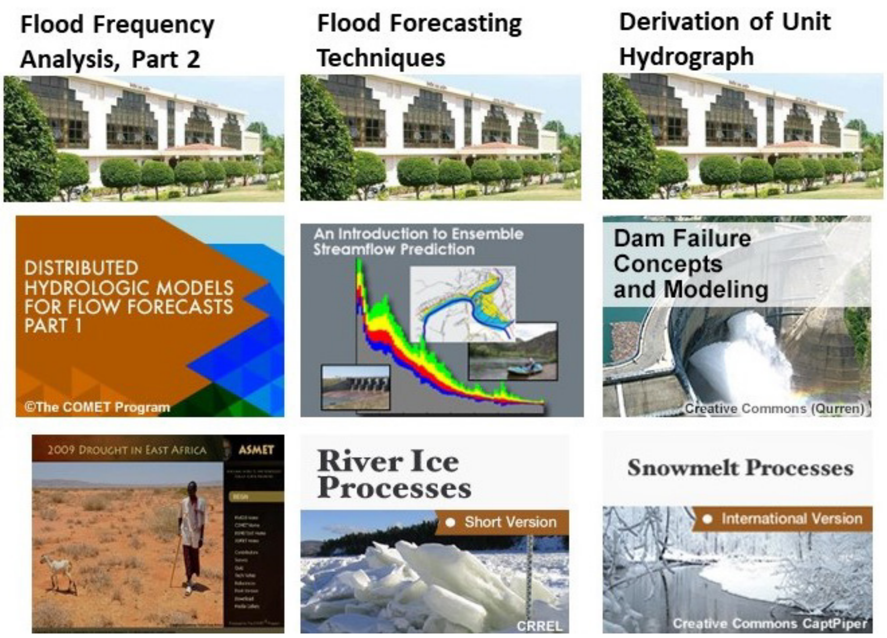

Figure 8.3. Optional modules for the *Basic Hydrologic Sciences* course

Although it varies slightly from region to region, the recent course run seven weeks with instructors available throughout. There are eight required modules in the first three weeks (Figure 8.2). In the fourth week, two additional modules are required out of a choice of nine (Figure 8.3). This allows attendees to choose module topics that may be most relevant to their expertise and/or regional concerns. Week five allows the attendees to catch up on completing module quizzes.

In weeks five and six, the attendees write a 1500-word report on a specific topic relevant to their position and region. They are given three assignment options and a diagram showing the grading criteria (Table 8.2). The assignment options are based on course topics. Week seven allows time for instructors to grade the written assignments and encourage completion of course requirements for those who are close but not quite finished.

Table 8.2. Grading criteria for the final written assignment for both the *Basic Hydrologic Sciences* and the *Advanced Topics in Hydraulics, Hydrologic Sciences, and Hydrometeorology* courses

Criteria	Unsatisfactory 0 points	Satisfactory 5 points	Good 15 points	Excellent 20 points	Score
1. Length					
2. Addressed options; original content					
3. Organized, easy to follow, includes summary					
4. Used graphics and tables as appropriate					
5. Referred to course topics					
Total					

Grading Criteria for Written Assignments

Region II starts and ends its course with a live webinar conducted by the RTC experts in India and COMET facilitators. Regions I and V courses initially used the live webinar approach, but limitations in bandwidth and Internet access made this unproductive. A recorded video is made available for orientation for those who cannot join a webinar and in regions where live webinars were not useful.

To keep students engaged in the learning, RTC instructors routinely post to the course forum and require attendees to post as well. Weekly questions (not quizzes) are provided to reinforce learning topics.

8.3.2 Advanced Topics in Hydraulics, Hydrological Sciences and Hydrometeorology

The idea behind a more advanced version of *Basic Hydrologic Sciences* was tested with a course called *Hydrology II* in 2011 (Region VI). Following the *Train the Trainer* residency course in 2011, the more advanced training evolved into *Advanced Topics in Hydraulics, Hydrologic Sciences and Hydrometeorology*. It was offered three times between 2015 and 2018 for Region II with assistance from experts at the NWA.

The course runs six weeks with instructors available throughout that time. There are ten mandatory online modules and two additional required modules out of six options (Figures 8.4 and 8.5). Like the *Basic Hydrologic Sciences* course, the last two weeks allow attendees to complete a 1500-word written report. The attendees are given a couple of possible options for the assignment topics based on the course material.

Figure 8.4 Required modules for the *Advanced Topics in Hydraulics, Hydrologic Sciences and Hydrometeorology* course

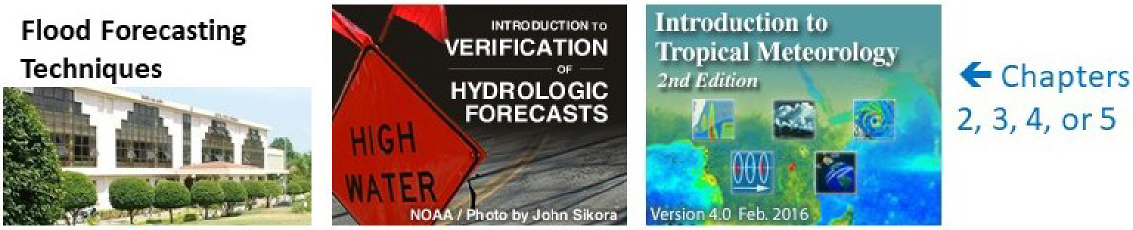

Figure 8.5. Optional modules for the *Advanced Topics in Hydraulics, Hydrologic Sciences and Hydrometeorology* course

There is overlap in the selection of online modules between this course and the *Basic Hydrologic Sciences* course. Both are based on existing learning material from the COMET Program and NWA. Some of the more difficult lessons that were optional in the basic course are required in the advanced course. The advanced course introduces additional topics such as dam failure hydraulics, verification techniques, remote sensing, climate change and tropical meteorology. We have seen a tendency for many of the written assignments to focus on dam management or dam failure, and on climate change topics.

The optional *Introduction to Tropical Meteorology* series caters to those with a strong interest in the meteorology side of hydrometeorology.

8.3.3 Hydrology Technicians

The *Hydrology Technicians* course has only been offered twice up to the end of 2018, once to Region V in 2017, and once to Region I in 2018, after significant revision of the content. In two important ways this is a different training experience to the first two courses discussed. First, it is not based on existing online modules from the COMET Program. It is based on a series of lessons, worksheets and short videos developed by the National Institute for Water and Atmospheric Research (NIWA) in New Zealand. Second, although the other courses involve computer-based interactions, the *Hydrology Technicians* course requires actual or virtual field measurement and evaluations.

Figure 8.6. *Hydrology Technicians* course website for Region V

With support from a NIWA expert, the course covers a number of topics that generally fall into the following categories:

1. Site hazards
2. Hydrological controls
3. Staff gauges
4. Rain gauges
5. Site visits and inspections
6. Streamflow discharge measurements
7. Station surveying and levelling checks
8. Available resources

The first offering was planned as a 10-week course for Region V (Figure 8.6). Although a number of attendees started out enthusiastically, the site visit requirement was too demanding for many. In addition, some participants in small island nations did not have appropriate sites to perform activities such as streamflow discharge measurements. The instructor provided additional material to those facing these challenges. In the end, 10 out of 50 completed the course requirements.

Figure 8.7. *Hydrology Technicians* course website for Region I

In 2018 the course was revised for Region I (Figure 8.7) with input from the Kenyan Meteorological Department. Some material was removed or reduced. The requirement for field measurements was an option, but photographs and video were provided to enable virtual field work. Many photographs were shared among attendees via the course forum. In this way, the COMET facilitators and the NIWA instructor were able to leverage existing resources and technology to create a virtual hands-on field experience. The eight-week course saw 18 out of 37 participants complete all requirements, a completion rate that was more than double the completion rate of the first offering. Course attendees rated the course at 4.88/5.00, the highest of any of the 16 courses described in this report.

8.4 The reach of DL (2009–2018)

From 2009 until the end of 2018, there were 563 distance-learning attendees who completed all required assignments for one or more of the courses (see Table 8.1). Another 103 completed most assignments (>50%). These successful course attendees come from 93 countries across the WMO Regions (Figures 8.8a–e). The strong role of the Region II RTC in India can be seen on the regional maps below (Figure 8.8b) which show the number of successful completions per country. India accounts for nearly half of the successful completions, and Region II accounts for over 70% of the worldwide completions.

Figure 8.8a. Completion of distance-learning courses from Region I countries

Figure 8.8b. Completion of distance-learning courses from Region II countries

Figure 8.8c. Completion of distance-learning courses from Region III and Region IV countries

Figure 8.8d. Completion of distance-learning courses from Region V countries

Figure 8.8e. Completion of distance-learning courses from Region VI countries

8.4.1 Avenues of innovation and success

Back in 2011, we recognized the possibility of bringing online training to professionals across the globe, with an innovative approach that uses emerging technologies and distance-learning modules. But we also recognized that active instructors and facilitators are needed to guide the attendees through the difficulties and challenges that arise, both science-based and technological.

The approach to delivering a successful course has evolved over the years. Modules are provided to attendees via a flash drive to accommodate those who have limited access to the Internet. Quizzes and other assignments need to be completed online, but the flash drives allow attendees to work through lessons when they are not connected to the Internet.

Written assignments associated with the *Basic Hydrologic Sciences* and *Advanced Topics in Hydraulic, Hydrologic Sciences and Hydrometeorology* courses are a means to allow attendees to demonstrate what they have learned and apply it to the topics in class. It also allows instructors to learn more about the local hydrologic concerns, patterns and procedures, and that knowledge can then be used in subsequent courses. This, along with the course forum interactions, fosters the exchange of experience between attendees and instructors, which is often lost in the distance-learning format.

The revision of the *Hydrology Technicians* course to include field assignments in a virtual format allowed attendees to share photos and videos of field sites which added greatly to the learning experience of attendees and instructors.

8.4.2 Building on the success

We will continue to build on the success of the distance-learning experience that we built up from 2009 until 2018. The following considerations are important for continued and improved success in expanding the availability of hydrology-related training, whether it is with future offerings of currently developed courses, or with new topic areas in hydrology:

1. Learn from the success of the Region II RTC (National Water Academy-India) with respect to regionalizing the training and delivering it in a way that encourages participation. The National Water Academy held two *Basic Hydrologic Sciences* courses in 2017 that were just for Indian professionals and did not require facilitation from COMET. The National Water Academy continues to contribute to region-wide training.

2. Continue to embrace new technologies and methodologies in communication and learning sciences. These new approaches can continue to enhance the way we conduct virtual activities, improve online learning and minimize language barriers.

3. The 2011 *Train the Trainer* course was an important part of developing these distance-learning courses. There have been new advances and experiences since then. Another in-person *Train the Trainer* course could be very useful.

4. We need new and updated distance-learning modules. The distance-learning courses to date have depended on the existence of relevant online training. Some training is out of date, either in the scientific content or the technology used in the lesson. Development of new online modules will be an important part of advancing the effectiveness of this form of distance-learning courses.