WORLD
METEOROLOGICAL
ORGANIZATION

WEATHER CLIMATE WATER

Global Campus Innovations

Volume I – New Pedagogical Approaches

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WEATHER CLIMATE WATER

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Preface
Petteri Taalas

Times of rapid change call for the ability to quickly respond to newly arising needs and opportunities with innovative ideas. This is clearly true in regard to education and training in a changing world. New workplace needs and roles demand new skills and flexibility in how to gain them. The research agenda is also growing and evolving to respond to the changing climate and population distribution, while sciences recognize the need to become more multidisciplinary in their approaches. Developing new skills demands effective and efficient methods, on a scale appropriate to the needs, to help the Members of the World Meteorological Organization (WMO) stay apace.

In 2019, the Eighteenth World Meteorological Congress endorsed the WMO Global Campus initiative to promote collaboration, cooperation and sharing of experiences among education and training institutions, as one important way to increase education and training capacity to meet the needs of all WMO Members. I am very happy to see this publication as one output of the initiative.

An impressive range of institutions serve WMO as sources of initial and advanced degree programmes to prepare people to enter the workforces of the services represented by our Members. Training partners also help ensure the continued professional development of the workforce. The papers by these critical partners collected in this publication provide an opportunity to learn about the innovations they have implemented to achieve the increased capacity or effectiveness required by our evolving services and research agendas.

I wish to take this opportunity to thank all education and training institutions that serve our Members, and assure you that WMO will continue to encourage and promote more innovations, such as those described here, to help us all reach our goals for a well-coordinated system of services across the globe to help save lives and property, protect resources and the environment and support socioeconomic growth. Considering the recent consequences of COVID-19 on the way that we do business, the onus is on all of us to continue to work together for innovative ways of delivering education and training for the benefits of present and future generations. With your help and with your inspiring ideas, I assure you that the Secretariat will give this challenge high priority as it renews its strategies for programme delivery.

Prof. Petteri Taalas
Secretary-General

Acknowledgements

WMO Global Campus Innovations
Patrick Parrish

With workplace changes occurring more rapidly each day, now is a time for significant innovations in the way we educate and train people for their professional careers. Traditional modes of teaching and learning served us sufficiently before the digital age and the ensuing emergence of global and digital economies. These new economies call for fluidity, resilience and readiness for rapid reskilling to meet changing demands. Many skills required today will become irrelevant to the jobs of the near future due to changing technological capabilities such as automation and artificial intelligence, and changing societal demands, such as those imposed by a changing climate, increasing populations, and urbanization.

I write this introduction at the time of an explosive pandemic of the novel coronavirus (COVID-19). It is unclear exactly how deep the global impact will be in terms of number of infections and associated fatalities, yet the societal and economic impact of the risk of infection alone are already evident. As if the changing work and learning landscapes were not already clear indicators of the need for innovation; as if the changing climate did not already demonstrate the interrelatedness of human and natural systems and the need for novel approaches to growth; and as if the fluid interconnectedness of the world's peoples, industries and governments was not already clear in the marketplaces where we shop and in the organizations in which we work; a pandemic that disrupts these global interactions shows also how fragile the current infrastructures, including our education and training infrastructures, can be. Resilience through innovation is more critical than ever.

Innovation is possible only with a workforce that possesses the background skills, determination and creativity to innovate. It is by no means certain that traditional education and training systems have done what is necessary to prepare for rapid innovation. Education systems are notoriously resistant to change, being deeply embedded in the cultures in which they function—geographical, social and professional cultures (Parrish & Linder-VanBerschot, 2010). Classrooms of today often look nearly the same as classrooms of 50 years ago, with rows of desks facing a teacher controlling the flow of information. But there are alternatives. Some are subtle, and some more radical.

In 2019, the Eighteenth World Meteorological Congress decided to support the WMO Global Campus initiative to promote collaboration, cooperation and sharing among the many education and training institutions. This decision was made because current systems are not sufficiently bridging the large and growing gap in learning opportunities among Members. Gaps exist not just in terms of inequality in socioeconomic development among WMO Members, but also as a result of the rapid changes occurring within the environmental services represented by WMO that impact ALL Members. It was recognized that only through increased collaboration it would be possible to bridge these gaps. Sharing of experiences in implementing innovations in education and training – the goal of this publication – was one of the original aims of the WMO Global Campus initiative.

The papers collected in this publication are just a small sample of the innovations being explored in education and training around the world. Many of these were originally intended to increase access for learners, to make learning more efficient, and to increase the impact of training initiatives to ensure that the investments by learners and teachers are rewarded.

The papers represent innovations growing within the small community that includes educators and trainers preparing learners to work in meteorology, hydrology, climate services and related fields, as well as the communities that these professionals serve. It is just a snapshot of what is possible, but an eye-opening picture nonetheless.

The innovations described are organized under four general categories and contained in four volumes to facilitate access for readers. These categories are: *New Pedagogical Approaches* (new methods of teaching and learning), *Curriculum Advancements* (changing or reprioritizing what is taught to learners), *Collaboration in Education and Training* (seeking partners to better serve learners and their employers), and *Technology-enhanced Learning* (applications of novel technologies to create new possibilities for teaching and learning). These categories overlap, and the volumes could be easily organized in other ways. For example, new pedagogies often depend on technology, and new technologies often require pedagogical adjustments. Collaboration often enables curriculum changes, and some curriculum advancements are in line with needs driven by new pedagogical approaches. Efforts were made to find the central thrust of each paper and arrange them accordingly, but you are encouraged to look outside your particular interest areas to find other useful innovations to explore.

The process of collecting contributions for this publication began in late 2018. A wide call for proposals elicited submissions from many key training partners of WMO. In all, over 50 submissions were received. These were reviewed and ranked for appropriateness by a panel of three external experts and the Chief of the Training Activities Division in the WMO Education and Training office. Very few proposals were considered inappropriate for the publication, therefore, nearly all proposers were sent requests to further develop the papers for inclusion. Both general and specific guidelines were provided to the authors to ensure relevance to the publication.

General guidelines included:

- Provide clear descriptions with examples so that people can apply your innovation themselves if they choose to;

- Do not assume a high level of background knowledge in the reader;

- Be sure to define your terminology clearly;

- Please use the paper to share and teach about the implementation of an innovation;

- Within the space available, do your best to teach us how to do what you did;

- Do not focus on future plans, but on those innovations you have already implemented;

- End with conclusions and next steps.

After draft manuscripts were received, two contributing editors and the managing editor divided the manuscripts into three groups to review the first drafts and provide feedback on the content and clarity of the paper (the managing editor was the Chief, Training Activities Division, Education and Training Office, Member Services and Development Department at WMO). This first round of reviews and revisions was carried out in one or two steps, as

necessary. A final review cycle was conducted by the managing editor to ensure consistent quality, while respecting the style of the individual authors.

The editors wish to thank all contributors for their cooperation and patience in this process to produce the best publication possible.

Innovation processes in education
Patrick Parrish

Innovation defies precise definition (and due to its highly contextual nature, rightly so), but it can be characterized as purposeful implementation of change with a view to expected improvements in products or processes. Some have declared that it is no longer enough to predict or anticipate the future, but that one must actively invent the future through innovation. Implicit in this statement is the idea that innovation does not involve small change but change that perturbs the system in which it is implemented, opens opportunities, and perhaps ruffles some feathers. But innovation can occur at many scales, because organizations exist at many scales, with varying levels of experience and cultural backgrounds. This section is intended to provide a lens with which to view the papers in this publication on education and training innovations, as well as guide the additional innovations they may inspire. It will examine several models of innovation and design processes and derive some principles regarding good innovation practices. A running theme will be the state of flux that describes the theory and practice regarding innovation.

Innovation requires "design thinking" (for example, see Rowe, 1987 and Rowland, 2014), which is a process of creative problem solving or, as some prefer, creative invention of a method or product, and not always a process for solving a problem per se. So, models of design provide a useful background to innovation. But innovation requires additional attention to gaining acceptance of the change to ensure successful implementation. It also requires attention to change management and an even deeper emphasis on context analysis, often taking the form of a business plan or some other strategic planning. This is because innovation implies confrontation with the status quo or with competitors and changing the expectations of customers. Many models of innovation processes exist, and most are directed at the business environment, where introducing new products and services are critical to gaining and maintaining a competitive edge. These offer many parallels to education and training, and so they are worth considering. This section first explores some design models, then moves to a variety of innovation models.

Innovation has both extrinsic benefits to organizations, leading to process and product changes that might increase efficiencies and/or enhance outcomes. But it also has several intrinsic benefits aside from the direct outcomes. Innovation calls for management to create safe spaces for invention, allowing for failures to produce learning opportunities, conditions not often present in normal, more regimented working conditions. Innovation can also stimulate creativity within individuals and work teams that can be of benefit outside the particular innovation implemented to solve everyday problems. Innovation can foster teamwork due to the multidisciplinary nature of implementing complex innovations, acclimatizing staff members to environments of collaboration and sharing. Finally, innovation creates opportunities for personal and team growth in many areas such as problem solving, communication, planning and project management.

Design models

Most design models include a preliminary study of the context followed by iterative steps that allow for learning during the process, revising and updating previous decisions, and for gradual improvements. This is due to the complexity of the human and technological systems in which and for which the design is made, a complexity not easily fully grasped at once.

Here is a common instructional design model that is applicable to innovation (learning is change after all), but perhaps it lacks a few critical surface details because it is so generic. The ADDIE model (Figure 1) is one that those working in education and training, but also in software design (see Garbanzo-Salas and Jimenez-Robles, in this publication), might be familiar with since it has been around for over 50 years. Its generic nature means that it stays relevant, although the model is not without its detractors. Arguments against it mostly arise from assumptions based on a superficial reading. Interestingly, one should recall that in the 1960s ADDIE (and the practice of instructional design that it represents) was itself a disruptive innovation, and still is in many contexts.

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┌──────────┐      ┌──────────┐      ┌──────────┐      ┌──────────────┐      ┌──────────┐
│ Analysis │ ▶▶  │  Design  │ ▶▶  │Development│ ▶▶ │Implementation│ ▶▶ │Evaluation│
└──────────┘      └──────────┘      └──────────┘      └──────────────┘      └──────────┘
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Figure 1. The ADDIE process

It is better to consider the boxes as overlapping phases, not separate, lockstep elements. These include Analysis (understanding learners, the learning context and, most importantly, the learning needs), Design (generating plans for the development and implementation of training, including strategies, formats and activities, based on learning needs and learner characteristics), Development (building resources to be used in training), Implementation (conducting the training, and evaluating what works and doesn't work), and Evaluation (including evaluation of the impact of the training, but also evaluation of the training development process itself along the way).

Some mistakenly interpret this model as linear and not iterative—in other words, the arrows are not indicating a one-way street. The process as discussed in the instructional design literature points out the need for opportunities to test, reflect, look backward and modify earlier decisions as they are being tested in the later phases through formative evaluation. Formative evaluation (including testing with users, experts and clients) is not explicitly shown in the general model, but it is recommended that it take place throughout the process to encourage reflection and improvements. Some authors of ADDIE variations have drawn additional backward arrows to make this iteration more explicit (see especially Dick, Carey & Carey, 2004), but common sense does not require such complications in the depiction.

However, many feel strongly that the iterative aspect (including "agile" methods) should be more explicitly reinforced. Alternative models have evolved as digital instructional media and have become easier to revise, with SAM (Successive Approximation Model) as one popular alternative. This model compresses ADDIE to three high-level phases: the background Analysis is called (1) Preparation Phase; this is followed by (2) the Iterative Design Phase, with Design, Prototype and Review as a circular sub-process, and (3)an Iterative Development Phase, composed of Develop, Implement and Evaluate as a second circular sub-process. Alternatively, prior to SAM, the iterative nature of ADDIE was sometimes drawn more simply as a single circular process with Evaluation in the centre as a repeated element of the process; a Formative Evaluation component was on a line above the other steps, feeding into each of them, or depicted as having a pervasive role in other ways (for a summary of these depictions, see Gustafson and Branch, 2002). Depictions of

SAM can be found in many locations.[1] For those interested in even more elaborate infusion of agile methods, The SCRUM Framework offers a detailed structure for work processes that emphasizes the same values as SAM, but goes so far as to prescribe team roles for flexibly delivering complex products.[2] It seems particularly applicable to innovations, but is difficult to depict in a simple diagram.

However, it is difficult to argue that sequencing the general phases is not useful and indicative. Some analysis of the needs and context is required before designers understand their constraints, and development cannot proceed until at least some general design decisions have been made (unless one proceeds on assumptions, such as according to tradition). Furthermore, implementation does not occur until at least some development has been accomplished.

Linear processes are not always negative, by the way. One example is a consultant that requires sign-off of stages of their work or terms of reference to avoid costly revisions due to clients changing their mind. Another example is the design of complex media, such as film, in which iteration simply costs too much to be an acceptable occurrence. Some plans need to be decisive and, in an innovation process, one has to consider when revising decisions will be too costly to allow. If management, stakeholders or suppliers, for example, need to move forward on the basis of your progress in implementation, making major revisions can jeopardize the success of an innovation. If nothing else, too many revisions can generate mistrust or lack of faith. However, in most cases, complete linearity can hinder results, and some degree of flexibility should be built in.

Below is a design model focused on the creative elements of the process (Figure 2). It comes from IDEO, a global design company working in many disciplines, which also offers advice on design thinking for educators.[3]

Discovery → Interpretation → Ideation → Experimentation → Evolution

Figure 2. The IDEO design thinking model

While the emphasis differs, with the words borrowed from artistic processes rather than engineering, the overlaps are obvious. These are clearly phases, not locked steps. Discovery and Interpretation correspond to the Analysis stage in the ADDIE process, and often include both needs assessment (a form of discovery) and needs analysis (interpretation of the identified needs). Ideation is the earliest and most creative phase of Design, while Experimentation reflects the assessment of highly iterative Design/Development phases, similar to those promoted by the rapid prototyping movement. Evolution suggests evaluation and continuous improvement or new directions for innovation. Again, the earlier phases provide input to the latter phases of the process, but any suggestion of linearity is

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[1] See https://daslater.wixsite.com/elearning/single-post/2016/1/11/ADDIE-vs-SAM-Model, and https://www.slideshare.net/alleninteractions/leaving-addie-for-sam

[2] https://www.scrum.org/

[3] https//designthinkingforeducators.com/design-thinking

only an artefact of the clean depiction. Experiment and Evolution are simply flattened depictions of the loops made explicit in SAM.

Innovation models

Now let's look at an explicit innovation process, offered by Kaya (Figure 3) through its Humanitarian Leadership Academy.[4]
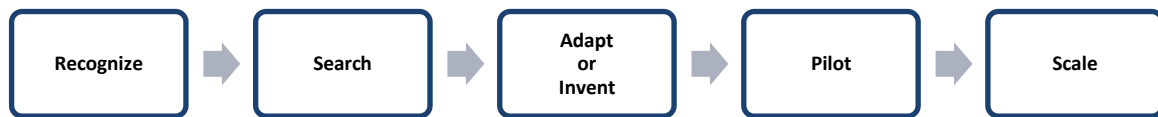
Figure 3. The Kaya Innovation Management "six-step" process

Not coincidentally, the three processes shared so far each have five phases (Adapt and Invent in the Kaya process are choices, based on a design decision to *adapt* an innovation used elsewhere or *invent* a completely new one). The five phases in the three models shown, more generally stated, include (1) an impetus to take action, (2) analysis and planning, (3) refining and building, (4) putting into action, and (5) checking if it works and learning from this. This is a basic human response to life's challenges.

But the Kaya innovation process offers some new ideas:

- Recognize: Rather than Analysis, and closer to Discovery, the Recognize phase includes both addressing problems and identifying new opportunities—in other words, not just being responsive to needs, but also looking for new options that might bring benefit;

- Search: This phase emphasizes that we should not reinvent the wheel, but search for good examples or models as starting points first;

- Adapt: This is new to the models we have looked at, but is often considered as a part of the development phase in the ADDIE model (identifying existing texts as course resources, for example—see Dick, Carey & Carey, 2004). This emphasis recognizes that adaptation may be required to fit an innovation to a new context;

- Invent: This parallel path requires more creativity and the need for multidisciplinary teams to realize a radical innovation. This is the assumed path in design models;

- Pilot: This phase nicely captures the rapid-prototyping option and suggests that formative evaluation is inherent to the process (including potential testing with users and stakeholders). Kaya also includes a sub-step that considers possible retooling and potential "mothballing", or setting aside an innovation for a time, but saving the results for potential future use;

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[4] https://kayaconnect.org/totara/dashboard/index.php (requires free registration)

- Scale: A successful pilot leads to full implementation at the scale intended. (Note that this process model does not represent "learning" beyond the pilot phase, but it does not preclude it either.)

A final comparison can be made with the Cambridge Business Model Innovation Process (Geissdoerfer, Savaget and Evans, 2017), which offers only three high-level phases, but much more detail beneath. The depiction below (Figure 4) shows only two of three levels. The full model is available at the site indicated in the References section.

Concept design	Detail design	Implementation
•Ideation •Concept design •Virtual prototyping	•Experimenting •Detail design •Piloting	•Launch •Adjustment and diversification
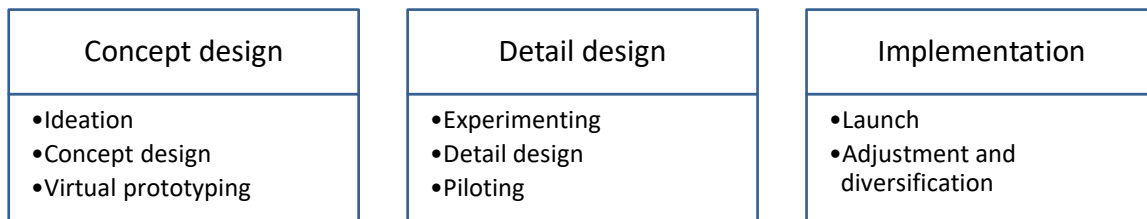
Figure 4. The Cambridge Business Model Innovation Process

There is not much that is new here, but it reassures us that we are exhausting the exploration of ideas about innovation processes. The only missing item is Analysis, but this is implicit in the third level under "concept design" (not depicted). What IS new is a strong emphasis on designing a concept prior to designing a product, in other words, ensuring that all assumptions regarding the context and the innovation are explicit before moving into tangible production. Another appealing element is the use of the term "experimenting" in the detail design phase, which indeed captures the spirit of rapid prototyping to avoid moving forward without testing.

Additional comparisons can be made, for example with the model of the organization named Fluidminds (www.fluidminds.ch), which describes itself as "a think tank for consultancy for strategic and disruptive innovations", as well as that of Business Value Design, https://businessvaluedesign.be/is-there-a-right-innovation-method/. Both these models stress the need to begin by looking at the current business plan and then revise that plan on the basis of the innovation implemented. They stress much more the need for both external and internal context analysis via the business plan, although this is not ignored in the other models presented.

Change management

One missing element in the high-level models depicted above is communication or other forms of change management. Innovation is by nature disruptive, perturbing the systems in which it is implemented. For this reason, it may require effort to gain buy-in, to facilitate acceptance of the need for change, and comforting communication that the innovation is not threatening, but opening opportunities for growth. It is mentioned, if at all, in lower levels of the models above, or in descriptions of them. In other words, it is not considered a critical element or step, but primarily a lateral requirement.

A representative change management model is the ADKAR model.[5] It consists of five steps or phases: Awareness (of the need for change), Desire (to bring about change and be a

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[5] https://www.prosci.com/adkar/adkar-model

participant), Knowledge (of how the change needs to be implemented), Ability (to incorporate the change into regular practice) and Reinforcement (to ensure it is implemented well and reinforced in practice).These phases are parallel to the ADDIE phases, except for an important new phase named Desire. However, each phase places communication in the forefront.

Some have recently been questioning the validity of change management processes in a time of such rapid and pervasive change—change as the "new normal" (Worley and Mohrman, 2014). Instead of seeing change as a project, a new ongoing process is proposed to serve continually changing contexts. Worley and Mohrman offer a cycle of Awareness, Design, Tailoring and Monitoring, with a Taoist yin/yang symbol composed of Learning and Engagement at its center. These are presented as ongoing activities, or activities ready to be taken up whenever they are required.

Summary

In summarizing, we can derive a set of principles for innovation processes in education and training, but we will not offer another model. We have enough of those to serve us:

- Human systems, including the technology they use, are complex. This means that any change perturbs the system in ways that cannot be fully anticipated;

- Ensure the innovation team has the skills and knowledge necessary to carry out an innovation of the scale intended, including design, project management, change management, content area expertise, communication and strategic planning;

- The context of an innovation demands careful analysis to understand the salient needs, constraints and opportunities as well as possible. This includes understanding goals, objectives and other elements of the strategic or business plan of the organization;

- Do not focus only on current needs or problems, but also look for opportunities than can improve your outcomes;

- Due to the complexity of introducing an innovation, formative evaluation and time for revision should be built into the innovation process. Testing or review at several stages should include, when possible, all stakeholders, including learners, experts and managers in the implementing organization;

- Include a small-scale pilot phase when possible to avoid costly revisions;

- When possible, design a conceptual or virtual prototype to be evaluated before investing in the design of a tangible prototype. But be sure that reviewers of the conceptual prototype are sufficiently experienced to judge it;

- To maximize resources, when possible, consider reusing existing materials and strategies rather than inventing new ones unnecessarily;

- Follow a design model that suits your organization, but make sure that the general components of a design thinking model are present;

- When possible, choose development tools that are easy to use, or within the skill sets of your staff members, and use media formats that are easy to revise;

- When purchasing new technologies to enable the innovation, look for ease of use and flexibility, but also compare options based on an analysis of user needs;

- Plan for communication with affected stakeholders to ensure acceptance of the implementation;

- Take advantage of the intrinsic benefits of innovation, including team building, enhancing creativity and development of new skills.

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Introduction
Patrick Parrish

Pedagogical[6] innovations are fundamental to education and training, because they reflect our theories of how people learn and, therefore, how best to teach. They can colour all the other choices we make in terms of learning methods and activities, technologies used and even what to teach.

The chapters in this volume focus on a wide range of innovations:

1.   Lauri et al. describe a research-oriented pedagogy that engages learners in the processes of knowledge creation, raising their status to that of teachers for some aspects of the learning experience;

2.   Charlton-Perez et al. explore the implementation of a flipped learning approach in their university courses, in which the emphasis is on how homework and classroom time is reversed;

3.   Connell et al. describe the building of a large, persisting learning community through the use of online regional focus groups for teaching, coaching and knowledge sharing, across social, cultural and political boundaries;

4.   Babb and Seman outline their strategies for reducing the perceived "transactional distance" in distance learning, which can reduce the sense of isolation felt by online learners;

5.   Parrish et al. address a similar topic, sharing their strategies for sustaining the active engagement of online learners during a long online course;

6.   Wu also touches upon how to learn online successfully, using a blended-learning approach that combines the best of online and face-to-face events to expand the reach of learning opportunities;

7.   Garcia et al. also offer their experience with implementing blended learning in Peru, building on experiences drawn from other institutions using blended modes, and addressing critical climate services learning needs;

8.   Baldi et al. describe the implementation of another blended-learning approach, also for building skills in the delivery of climate services. The authors also incorporate a

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[6] I avoid the often misused term *androgogy*, because it lacks a theoretical basis. In fact, the originator of this term, Malcolm Knowles, has himself questioned any distinction between how adults and children learn, noting instead that his use of "androgogy" refers to student-directed learning, which can be effective with learners of any age (Merriam, S. B., R. Caffarella and L. Baumgartner, 2007: *Learning in Adulthood: A Comprehensive Guide (3rd ed.)*. San Francisco, Jossey-Bass).

post-course component and the packaging of course resources for self-directed use by other learners;

9. Bourdelles relates the strategies used at the *École nationale de la météorologie* to increase active learning sessions for meaningful and practical learning experiences;

10. Timofeeva highlights the benefits of collaborative learning, in which students actively support one another to increase engagement in the educational process;

11. Ross-Lazarov and Mancus offer a strategy for reinforcing learning by asking questions to students after the primary learning event, using online methods;

12. Wegner et al. of the Globe Program describe their multi-level community education programmes on reducing the impact of the Zika virus, including a train-the-trainer approach combined with community education events;

13. Campos and Veeck describe an approach to teach weather forecasters by developing conceptual models of weather phenomena. An online *Workbook on the Application of Conceptual Models in Forecasting* forms the centrepiece of various learning opportunities and new projects;

14. Ross-Lazarov and Mancus walk the reader through the steps for implementing motivating games in classroom courses, in this case related to probabilistic forecasting;

15. Webster shares tactics for drawing students into a discussion to facilitate learning from his experience as a classroom instructor;

16. Finally, Wegner et al. describe another collaborative, community-based learning approach to facilitate engagement and professional development in the use of low-cost weather stations.

1. Research-oriented intensive courses foster multidisciplinary atmospheric science

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Abstract

We have developed a concept for a research-oriented intensive course, and have applied it in multi- and interdisciplinary atmospheric science teaching since 1996. The basis of the concept is research-based education in forestry in the 1980s. When the research-oriented intensive courses were opened for wider audiences in the early 2000s, the courses became international and even more multidisciplinary.

In the concept we present, the course includes a 10–12-day residency accompanied by pre- and post-assignments for students. Students are usually assessed on the basis of the work done during the residency and a written report prepared afterwards.

The process of a research-oriented course starts from a very general research problem. Before or at the beginning of the residency, the students are guided through relevant theories, measurement methods and instrumentation, aiming to divide the original research problem into smaller research tasks. Most of the residency period is then used to deal with the research tasks in groups optimally consisting of 4–6 students and 1–2 supervisors each.

The pedagogical approaches of the research-oriented intensive courses include a variety of activities supporting learning in groups, giving authentic research problems and real data for students, peer learning and the horizontal learning principle in diverse groups.

Over the years, several scientific discoveries have resulted from these courses. We present two examples: an analysis of new particle formation in the atmosphere, which subsequently formed the nucleus of a paradigm change in atmospheric aerosol science, and the idea and quantitative analysis of the feedback loop linking atmospheric CO_2 concentration, gross primary production, organic aerosol formation and atmospheric radiative transfer.

1.1 Introduction

Climate change and air quality are examples of modern supradisciplinary research fields related to today's Grand Challenges (Lappalainen et al., 2016). Traditional subject-specific knowledge of individual researchers is not enough in global change research (Mauser et al., 2013).

Multidisciplinary field stations, such as SMEAR stations (SMEAR = Station for Measuring Ecosystem-Atmosphere Relations; Hari and Kulmala, 2005), provide a continuous inflow of new data to tackle the complex research questions related to climate change and air quality. The importance of long-term continuous comprehensive observations (Kulmala, 2018) has been recognized also by the World Meteorological Organization (WMO).

In our view, education of the next generation of scientists for a truly multidisciplinary way of thinking is key to solving the Grand Challenges (Lappalainen et al., 2014; Lappalainen et al., 2018). At the University of Helsinki, part of our approach to this educational challenge has been organizing research-oriented intensive courses. So far, we have provided this kind of training for well over a thousand graduate and postgraduate students. The courses have made a strong contribution to nine national and Nordic centres of excellence in research as well as to more than ten EU projects. They have also served as the training component of several European research infrastructures such as the Integrated Carbon Observation System (ICOS), the Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS), Analysis and Experimentation on Ecosystems (AnaEE), and Long-term Ecosystem Research in Europe (eLTER). Furthermore, they have had a strong role in the expansion of atmospheric sciences in Finland both in terms of volume and multidisciplinarity.

1.2   History of the course concept

The research-oriented intensive courses started in October 1996 as joint educational activities in physical and ecological sciences. However, their roots can be traced to previous forest science field courses. Historically, field courses in forestry in Finland trained future foresters for the practical, usually heavy work of maintaining the forest: chopping wood, digging ditches, etc. After the Second World War, the idea developed into providing students with more knowledge about forests. The original model could be called the "cookbook model" – providing well-defined exercises following the tradition of chemical and physical experiments and demonstrations in the laboratory and classroom. The role of teachers was to share their expertise. In Bloom's taxonomy (Bloom et al.,1956), this approach corresponds to lower levels of learning, Knowledge and Comprehension, where students' aim is learning facts or skills and interpreting or using them in the given environment.

In the 1980s, there was another transformation as the forestry field course became more research based. Instead of providing detailed instructions and well-specified tasks, students were given a problem of scientific interest to work on in small groups. The work was supervised through daily course discussions and personal support. Courses included working on a research problem in a group, learning with and from other students, as well as learning transferable skills, such as practicing oral presentation skills and writing a group report. However, the students worked on problems within one field of science and based their study on experiments made during the course. The role of a teacher started shifting from that of an expert towards that of a supervisor.

Some students continued working on research problems raised during these courses in their master's theses. Learning was deepened to Bloom's taxonomy levels of Application or Analysis (Bloom et al., 1956), where knowledge is applied to concrete situations or understanding of relationships of separate parts within a complex idea.

The critical change of working on real multidisciplinary scientific questions occurred when teachers of physical sciences and forest ecology designed a joint research-oriented intensive course. The new course concept was the result of the introduction of joint

4

measurement stations, SMEAR I, in 1991 in Värriö, and SMEAR II in 1995 in Hyytiälä (Hari and Kulmala, 2005), and the need to strengthen research collaboration. This change was characterized by the use of comprehensive data measured at SMEAR stations, a clear increase in the number of teachers on the course, and an aim for interesting new findings from the courses to be developed into scientific manuscripts.

One of the ideas in this change was that the course would support the progression from student to scientist. Students' learning objectives were set to Synthesis of ideas and concepts as well as Evaluation of ideas in Bloom's taxonomy (Bloom et al., 1956). New pedagogical principles, also supporting the development of teachers, were introduced at this point.

Since 1996, we have given approximately 80 multidisciplinary intensive courses in atmospheric sciences, half of them with the pedagogical model described here, and the rest utilizing parts of it. When we opened the courses to all interested students in the early 2000s, an increasing number of students from other disciplines started to participate, and the courses became very international. Ever since, we have had participants from several universities and disciplines.

1.3   Research-oriented intensive course concept

The workload of the course corresponds typically to 5 European Credit Transfer System (ECTS) credits, including pre- and post-assignments, and a residency of 10–12 days. Field stations such as SMEAR II provide an excellent venue for research-oriented intensive work during the residency. Students are assessed on the basis of work done during the residency period and a report written after the residency. The course topics and research problems are defined in advance by the course leader(s).

Figure 1.1 shows the process of a research-oriented intensive course. An example of a research problem (at the top of the diagram) could be the formation of aerosol particles in the atmosphere. Due to its typically complex nature, the research problem cannot be fully studied in the scope of the course. Instead, the evolution of the research problem takes place step by step following the thick grey arrow in the diagram. First, the context (e.g. climate change) is studied by analysing and recognizing its necessary features. Second, the theory of the phenomenon in question is analysed paying special attention to concepts and connections between the concepts. Third, the appropriate measurement methods are studied. The available instrumentation, including its precision and accuracy, are determined. The context, theoretical analysis and features of the measurement methods are taken into account as the original research problem is divided into smaller research tasks. Data analysis is then used to complete the research tasks and thus, piece by piece, to analyse the research problem in order to define the necessary research process after the course. The data used in the courses comes from previously performed (often continuous and long-term SMEAR-site) measurements. The ecological theory according to the Guide-Dog approach (Tuomivaara et al., 1994) supports a similar step-by-step method.
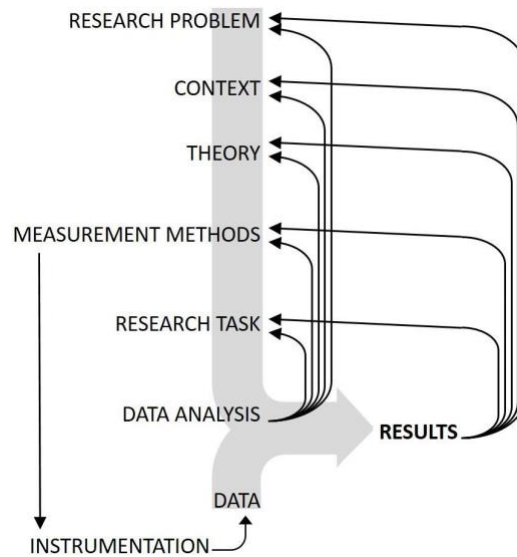
Figure 1.1. The process of a research-oriented intensive course. The thick arrow describes the process during the course, and the thin arrows describe the processes after each course.

During the residential course the emphasis is mainly on data analysis. However, the whole process described above, or part of it, is revisited whenever needed to provide students with the context of underlying theories and earlier observations. After the residential course the emphasis is on the formulation of the results. Data analysis is typically no longer required as part of the course after the residency

The supervisors and especially senior scientists on the courses have an important role in making sure that the need for revisiting the process is identified and that students learn to see their work in a wider context. The senior scientists also ensure that necessary parts of the course that are not tackled during the residential course take place afterwards (Figure 1.1, thin arrows), including report writing and more general development of theory, measurement methods and instrumentation. They ensure that results analysed further are published in relevant fora and included in subsequent courses when applicable; that next research tasks are identified and undertaken; that new measurements are designed and new instrumentation is implemented, and that sometimes even theories are reformulated.

Multidisciplinary research-oriented intensive courses can be a platform for simultaneously scanning the datasets from several disciplinary perspectives, a task that could not be done by a single person. The dialogic and collaborative atmosphere at the course enables new ideas to be fostered and tested immediately. At the same time, students learn, have an opportunity to develop, show and share their skills, and get involved in the scientific community. Several important transferable skills have been integrated into research-oriented courses (Ruuskanen et al., 2018). These skills include, for example, data analysis, oral presentation, scientific writing, project and time management, and teaching skills.

At the beginning of the residential course, the students are divided into small groups, optimally consisting of 4–6 students and 1–2 supervisors each, who work together in the same room. The supervisors are not only senior scientists, but also postdoctoral researchers and doctoral students. For collaborative learning, more than two people are needed to generate creativity and diversity of ideas, and the recommended number ranges from 3 to 6 (Burke, 2011). As pointed out by Jaques (2000), when there are more than six members in a group, the group becomes less flexible and more distant for the members, and the individual roles have to be specified in greater detail.

The length and nature of activities at the research-oriented course are designed to support work in groups. Figure 1.2 reflects the activities before, during and after the residential course. The schedule of the specific activities corresponds to the programme of the 10–day residential course arranged in March 2017 (Ruuskanen et al., 2018), but the pattern is rather general, and thus applies to many of the courses we have given. The daily pattern includes lectures, excursions and group work sessions in the morning and afternoon, and social activities in the evening. Most of the lectures are given at the beginning of the residential course, and they facilitate understanding of the course-specific research problems. Most of the data analysis is done in the middle part of the residential course, after the groups have formulated the detailed research tasks, following the process in Figure 1.1, and shared their ideas with the teachers as well as other groups.

The full process begins with the definition of the goals of the course (Figure 1.2, left) and ends with the report that the groups submit after the residential course (Figure 1.2, right). The research/scientific community (e.g. teachers and senior scientists on the course) is shown in the grey band at the top. It contributes before the course by formulating the research problem, and during the course by giving lectures on relevant topics (vertical teaching). Horizontal learning, in which both students and teachers play two roles, as learners and instructors, is initiated during the first few days of the residency. This is fostered by the group's work: building knowledge corresponds to the course process in Figure 1.1. The curved line in black in the middle of the diagram and its grey-shaded background correspond to the focus of the group work during the course (darker grey indicates greater emphasis). In the second row from the bottom, different activities carried out during the 2017 residential course are shown in a range of colours. The bottom row describes the development of group dynamics following the approach of Tuckman (1965) and Tuckman and Jensen (1977).
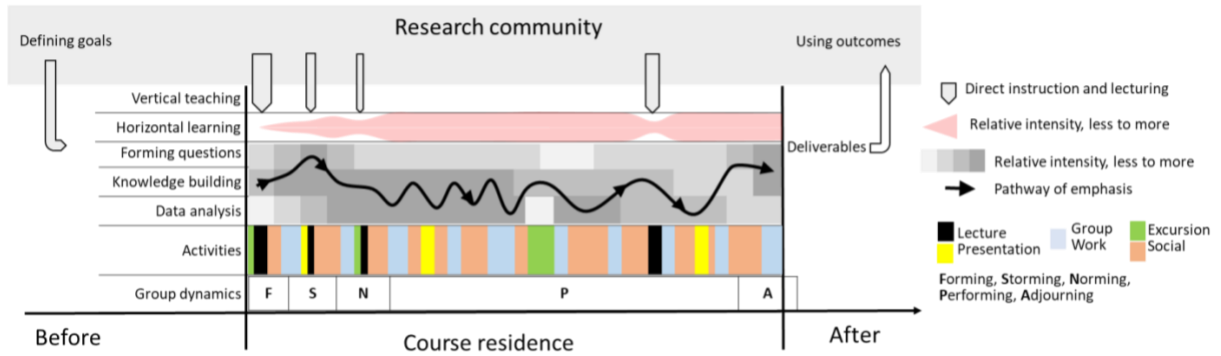
Figure 1.2. Learning and group dynamics timeline of a research-oriented intensive course

Testing and development of publishable research results in a multidisciplinary and international collaboration has helped increase the number of teachers and supervisors. Ruuskanen et al. (2018) found that in the research-oriented intensive course concept, use of real data and real research problems motivates both students and teachers. During the course, we minimize the number of lectures to leave more time for work done in small groups. It is important to devote a considerable amount of course time to free social interaction and informal discussions. Informal communication is important for successful group work and social learning, and emulates professional communities of practice (Faeron, McLaughlin, Eng, 2012). Also, Dugdale (2009) encourages use of formal and informal environments for best learning outcomes.

The main motivation for the more experienced scientists to join these courses stems from the new science that is made: new datasets are studied for the first time, new scientific questions are formed and addressed, and new results are discussed. This collaborative and open way enables criticism, multidisciplinary points of view, and development of new science. Some of the results or ideas from the courses have actually evolved to become scientific peer-reviewed papers, with students and teachers as authors. Due to the need for more comprehensive and longer datasets nowadays, writing a manuscript implies a significant workload after the course, and a leader (student or teacher) for the work.

1.4   Pedagogical approaches

The feeling of acquiring new skills increases the learner's motivation. In multidisciplinary courses, interaction with peers from different disciplines is also extremely important as a source of motivation for both students and teachers. Let us visualize the structure of learning of a single discipline as a triangle. We have adopted this approach from Kurki-Suonio (2011), who used the concept of ladders of understanding. According to this approach, the state of the art of a discipline can only be reached by building knowledge relying on what was learnt earlier. The disciplinary learning process starts from the base of the triangle and is built little by little relying on previously acquired knowledge. The state of the art stands on top of the triangle. The functioning of a multidisciplinary group of students and supervisors can now be seen as a set of triangles (see Figure 1.3). Each

triangle in the set represents one discipline, and a set of four triangles represents the knowledge of a multidisciplinary group. In our courses, these disciplines are often physics, chemistry, meteorology and biology.

Each triangle represents the traditional building of knowledge in a discipline, where the top is the state of the art. Horizontal learning among students as well as teachers and supervisors takes place on the platform represented by the outer circle. Building of new knowledge that can lead to science development within the research community is represented by the blending of knowledge within the inner circle. Multidisciplinary groups fully enable peer and horizontal learning during the course.
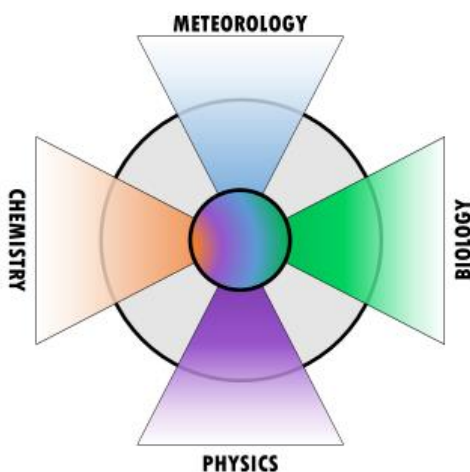
Figure 1.3. A set of four triangles representing a multidisciplinary approach in research-oriented intensive courses

We apply the horizontal learning principle where everyone plays two roles: the learner and the instructor (Paramonov et al., 2011). Here, students, supervisors and teachers from different disciplines share their knowledge and they both learn and teach while working together on the research problem. Thus, horizontal learning is not limited to peer-based learning. For example, a meteorology professor is likely to learn something new in discussions with a biology student in group work related to studying the effects of different meteorological conditions on photosynthesis. Interaction with a more advanced party supports learning in the zone of proximal development, which lies just beyond current capabilities (Vygotsky, 1978). Wass and Golding (2014) state that learning can be sharpened by assigning students tasks that they cannot do without assistance, and by supporting them just enough for them to learn to carry out the tasks on their own. They conclude that learning gains can be increased by working in a supportive environment that enables the students to do harder tasks than they could otherwise complete.

As pointed out by Korn Ferry (2019), diverse groups have the potential to outperform homogeneous groups. Development of group dynamics is often described as stages of forming, storming, norming, performing (Tuckman 1965) and adjourning (Tuckman and Jensen 1977), that is, the break-up of the formal group after it has achieved its goals (see

Figure 1.2). Getting to know the group members is supported at the beginning of the course, which needs to be long enough for the group to achieve the performing stage during the residency. This will support collaborative writing of the course report which is done remotely in the weeks following the intensive residency period.

We summarize the benefits and possible pitfalls of the main pedagogical tools we have adopted in the research-oriented intensive courses in the table below.

Essential pedagogical tools of the intensive research-oriented course, their benefits and best practices

Pedagogical tool	*Benefit*	*Best practices*
Group work	Integration into the research community and greater student motivation. It corresponds to real scientific collaboration on Grand Challenges, enables working on bigger questions and teaches sharing of responsibilities. It facilitates peer learning	Supervise the work so that it fosters collaboration, not competition. Make sure that the participants get to know each other; arrange icebreaker games at the start of the course and provide name tags. Support both students already familiar with most participants and those who haven't met anyone before the course.
Real research problems	Learning of transferable skills in real research work, for example, data analysis, oral and written presentation skills. Real research problems increase teachers' resources and motivate both teachers and students. They enable use of research funding to organize courses.	Leave enough time for the groups to plan, communicate and share responsibilities so that students know what their group's aim is and their responsibility in it. Do not sacrifice students' chances for learning for the benefit of getting fast results.

Real data, long time series	This prepares students for research on Grand Challenges in the future; enable work on real research problems, and help make generalizations from special case solutions.	It is important to know and understand the data used. For example, whether the data are quality controlled or unchecked raw measurements: what their systematic errors and accuracy are, and what is actually measured.
Residency	Social interaction during free time boosts integration of students (and teachers) into the research community and builds connections for collaboration between faculties/universities.	Keeping courses with residential period voluntary improves the course atmosphere and provides flexibility to students who have small children or other responsibilities or limitations.
Horizontal learning in multidisciplinary groups	This fosters collaboration among participants and among different fields of science.	Communication across fields of science can lead to misunderstandings due, for example, to different use of terminology. Foster an atmosphere of trust and respect and value knowledge from all fields of science.
Peer learning	When students teach they deepen their learning. This supports the spread of ideas, practical tips and best practices.	Check that participants have the required background knowledge before they come to the course. Do not judge who is best — support horizontal learning.

Writing the group report supports the process of growing into the role of an expert, and publishing with a research group is central to a scientist's work. Peer learning and peer review are known to help students learn how to write scientific articles, and writing groups are used in doctoral schools (Maher et al., 2008). Lee and Kamler (2008) observed that, as a pedagogical principle, peer review is a "horizontalizing" process that supports learning of written presentation skills as well as entering into a network of peer relations as researchers to be. Supervisors describe the final outcome format and help students agree on how the report should be written; they give feedback on the report usually a few weeks before the final version is submitted, leaving enough time to revise the report.

Typically, the end product is in the format of a scientific article and the work is divided so that each student writes a part describing their methods, findings and discussion, while the introduction and conclusions are written together. One student takes on the role of leading author or editor and is responsible for finalizing the report. This is an example where both the end product and process are equally important. Students and supervisors learn academic writing and peer evaluation skills in the process of documenting the findings of course work. The possibility of new scientific discoveries during the course heightens the motivation of students, supervisors and teachers.

1.5   Research outputs from the courses

New scientific discoveries have resulted from the courses we have given so far. An analysis of new particle formation in the atmosphere was performed during the first autumn school in 1996, and the results were published the following year (Mäkelä et al., 1997). Actually, the findings from the first autumn school formed the nucleus of a paradigm change in atmospheric aerosol science: this was the first publication showing the frequent occurrence of new particle formation in the atmosphere. So far, the paper has been cited well over 200 times.

Another remarkable example of research outputs from the courses given so far has been the idea and quantitative analysis of the feedback loop linking atmospheric carbon dioxide concentration, gross primary production, organic aerosol formation and radiative transfer of the atmosphere (Kulmala et al., 2013; Kulmala et al., 2014). The development and analysis of the feedback loop is one of the best examples showing both concept and results developed at research-oriented intensive courses. The feedback loop connects effectively the different datasets obtained from the SMEAR II station and is a good example for students of what one can do with comprehensive, continuous datasets.

The idea of quantifying this kind of feedback loop came up approximately five years before the final publication (Kulmala et al., 2014). The idea was first analysed and tested during one intensive course, where groups of students studied the effects of a five-degree warming on different aspects of biosphere-atmosphere interactions. In three subsequent intensive courses, one group of students focused on the terrestrial feedback loop. The concept was fine-tuned, numerical values were calculated, and the effect of other environmental factors filtered from the analysis. The main part of the work for the paper was done by authors outside the courses, but the courses were found to be an important place to test the hypotheses related to the research problems (Nieminen, 2019). All of the authors of Kulmala et al. (2013 and 2014) had worked as teachers or supervisors at one or several of those courses.

1.6   Conclusions

In the past 23 years we have seen that research-oriented intensive courses can both benefit students and boost research. The courses are a tool for building networks of students and researchers. We have identified a set of pedagogical tools as a key to

success in research-oriented intensive courses, and we encourage others to use some or all of them.

In the future, we intend to continue providing courses in collaboration with a wide range of experts in order to reach wider audiences and to include policy-relevant components, business thinking and entrepreneurship, and the arts.

Acknowledgements

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2. A flipped learning approach to teaching in meteorology

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Abstract

Although widely implemented in other disciplines, the instructional approach known as "flipped learning" has, to date, been infrequently used in meteorological education. This chapter provides a case study of the implementation of flipped learning in a standard upper Bachelors and Masters module on climate dynamics, in this case called "The Global Circulation". The motivation for the adoption of a different learning approach is reviewed, and the implementation for this case study is described in detail. Extensive quantitative and qualitative evaluation of the module is described and shows that the flipped learning approach adopted pushes students towards the higher levels of learning described by Bloom's taxonomy.

Keywords: Flipped learning, learning design, assessment of student learning

2.1 The problem

A core part of our BSc, MMet and MSc in Meteorology programmes is a module on Global Circulation which introduces students to the time-mean atmospheric circulation and climate dynamics. Traditionally, this module has been taught at Reading as a standard lecture module with a final written exam as the primary summative assessment. Peer-review comments from a colleague on the design of the final exam, as well as reviews of student exam papers, made us confront the reality that learning in this module was often limited to the lower levels of Bloom's taxonomy (remember and understand with some examples of apply) and failed to engage students sufficiently in class. An additional challenge for this particular module is that it is taught in the same classroom with the same basic course content but different learning objectives and assessment for BSc, MMet and MSc students.

2.2 Flipped learning as a solution?

As part of the development of a new curriculum framework for the University of Reading (University of Reading, 2020) we explored alternative approaches to module design and delivery in higher education. One approach we explored was delivery in a flipped learning mode. A simple way to think about a flipped classroom is that students complete their individual study of the lecture material outside of class time (the lower echelons of Bloom's taxonomy) and engage in more active, higher echelon learning while in the classroom.

Within the framework of flipped learning, a wide variety of approaches and designs with both large and small class sizes have been applied. A useful set of case studies can be found in the Flipped Classroom Field Guide (Coursera-partner community, 2020). The flipped learning approach has many of the benefits of other active learning approaches but is perhaps simpler to implement since much of the content needed for the flipped approach will have already been developed for a standard lecture-based module. Many meteorological education and training modules operate on a model very similar to flipped learning, with extensive workshops and seminars, so moving to this model of teaching requires only limited changes to module structure. Flipped learning doesn't require the module designer

to change the assessment for the module (unlike, for example, problem-based or enquiry-based learning), although in this case we did choose to do so.

There is quite a lot of evidence that flipped learning results in enhancement of student outcomes in studies where there is careful comparison of teaching methods (see, for example Crouch and Mazur, 2001, Deslauriers et al., 2011, and Freeman et al., 2014). A significant further benefit is the increased number of students taking active responsibility for their own learning.

2.3   Redesigning the module

As an exploration of the applicability of the flipped learning approach to teaching in meteorology, we decided to apply a flipped learning design to the Global Circulation module. The initial module redesign was undertaken in autumn 2015 and was run as a first test implementation in spring 2016 with nine students (all on BSc or MMet programmes). Subsequently the module was implemented with minor modifications in spring 2017 (35 students) and spring 2019 (21 students). In spring 2018, the module convener was on sabbatical, so the module did not run.

A schematic description of a module unit is shown in Figure 2.1. The module is divided into three units, in which module material is grouped thematically; each unit lasts three weeks. The first week of the ten-week teaching term is used for explaining the flipped learning approach and preparing students for the first at-home study the following week.

In each unit, the first two weeks have the same pattern. Students study extensive, bespoke lecture notes (written especially for this course) at home, supported by learning videos in our Virtual Learning Environment (VLE, in this case Blackboard). The learning videos are designed as short explanations of the most important and difficult concepts in each unit and typically last 5–7 minutes. Transcripts of the videos are available for students. At the end of each part of the notes there is a formative online quiz, designed to allow students to self-assess their knowledge.

In class time, students work on open-ended problems designed to extend and enhance what they learned at home. Activities are usually linked to a recent paper in the scientific literature (e.g., Can you explain recent observations of the broadening of the Hadley Circulation using the Held-Hou model of the tropical circulation?) and are different for BSc and MSc students. Students are encouraged to work closely together (although there is no formal allocation of working groups) and module staff, including the module convener, proactively approach students to direct and challenge their ideas.

In week three of each unit, students have no new material to work on at home, and choose instead one of the four problems that they worked on in the first two weeks of each unit to produce a short formal write-up in the style of a scientific letter 4–6 pages long. The element of student choice in their final submission for summative assessment is an important tool to enhance motivation and help students in their transition to autonomous learning. It is important that assessments are authentic, representing a meaningful, significant task similar to those that students will likely undertake in their working lives.

In class, in the third week of each unit, students are asked to review their colleagues' papers, modelling the process of peer review and feedback familiar to working scientists. The peer review, supported by an assessment rubric that we provide, is key to enhancing

the students' assessment literacy (Price et al., 2012). Following the oral feedback, students have time to revise their work before submitting for summative assessment. The three-week cycle then begins again.
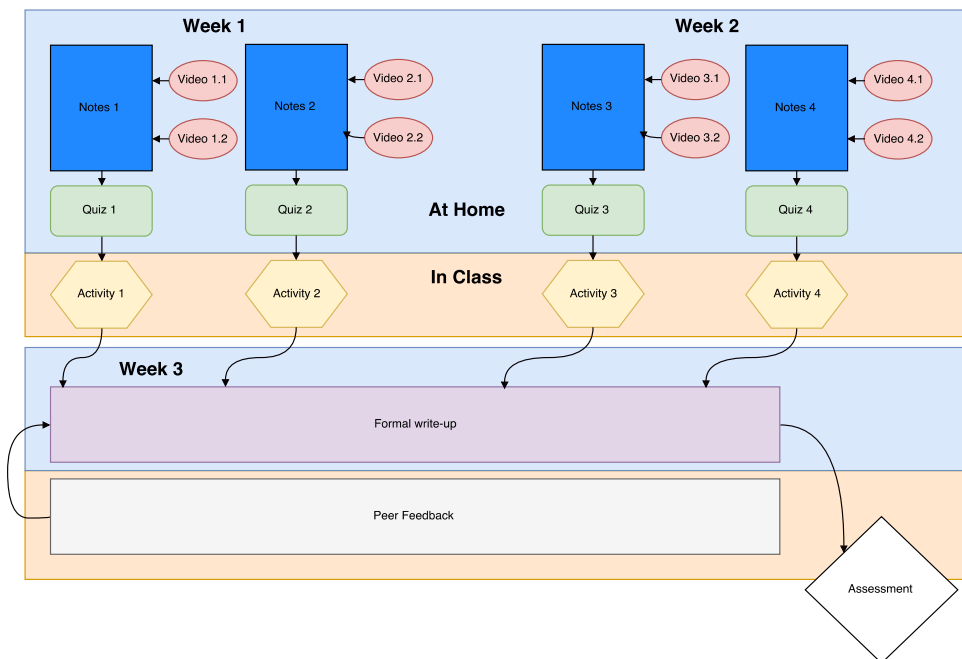
Figure 2.1. A redesigned module structure

2.4   Evaluating the impact of the flipped learning approach

2.4.1 What did students do?

Modules at the University of Reading have standard final student-feedback processes which provide an indicator of how students experienced and engaged with the module. In the standard course evaluations, the module was rated excellent for each term in which it was implemented, with ratings amongst the best in the department in each case. In order to evaluate the effectiveness of the module, however, it is important to also understand what impact the flipped learning style had on student learning. In the following section, we report on a number of additional evaluations of student learning, particularly for 2017 and 2019.

A key concern when implementing a flipped learning approach is that if students do not complete the at-home learning, they will be ill-prepared for the complex and demanding class tasks. In this case, it does not seem to have occurred. One way to measure students' engagement is simply to examine the number of hours they spend in the VLE, which is used to share notes, videos, quizzes and other module materials. The median time spent in the VLE for the 2017 and 2019 cohorts is above 20 hours per student (Figure 2.2), which is more time than previously spent in lecture classes in the standard implementation. Combined with the 20 hours students spent in class, this suggests that the flipped learning mode has greatly enhanced the study time a typical student spends on the module, if we assume that there was limited self-study in the standard implementation.
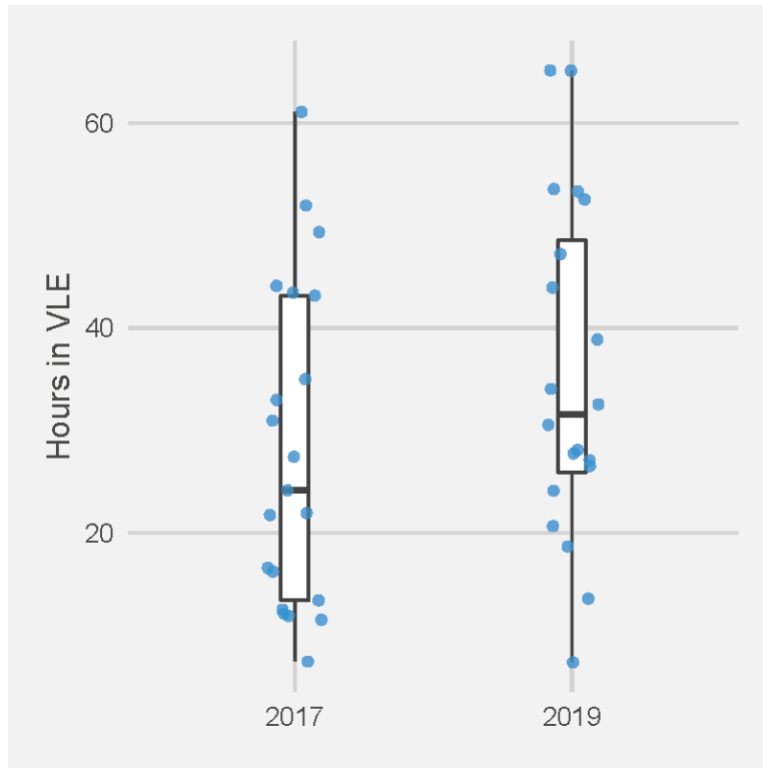
Figure 2.2. Total hours that students in the 2016/2017 and 2018/2019 cohorts spent in the Virtual Learning Environment. Each dot represents a student. Box and whisker plots show the interquartile range as a box, the range of data in whiskers and the median as a central solid line.

As well as knowing how much time students spent on the module, it is also interesting to understand where this time was spent. It is hard to monitor exactly where students spend their time, so, we asked students to self-report the percentage of their time spent on each activity once they had completed the module. Figure 2.3 shows this percentage for the 2018/2019 cohort. It is clear that student effort is well spread across different activities. Only around 25% of time is spent by students on reading the notes or watching videos; much more time is spent on active learning tasks, such as the quizzes and working on and writing up the class problems. This means that assessment activities are a significant part of and support student learning (Gibbs and Simpson, 2004).
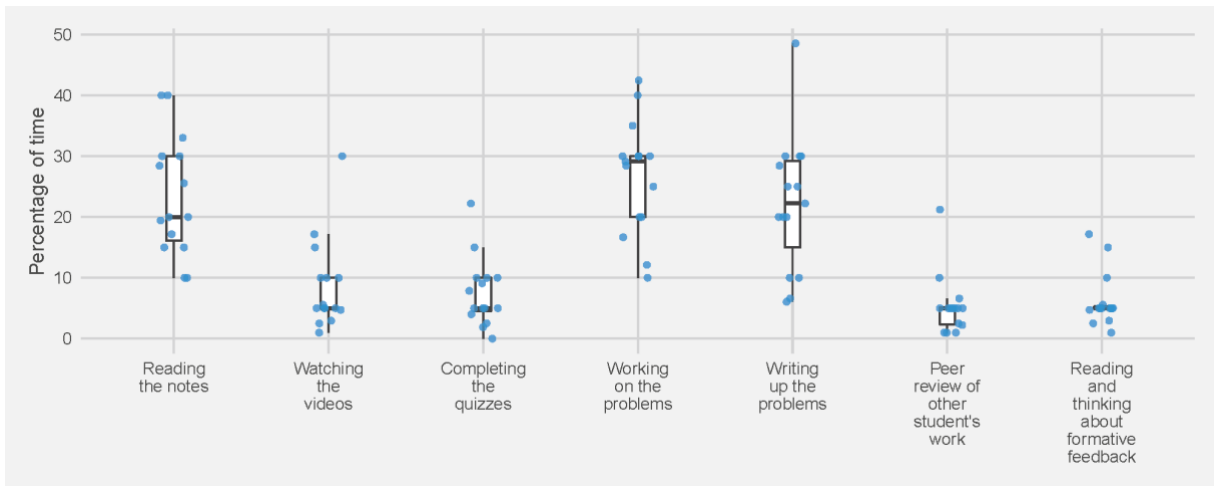
Figure 2.3. Self-evaluated fraction of time spent on each activity for the 2018/2019 cohort. Each dot represents a student.
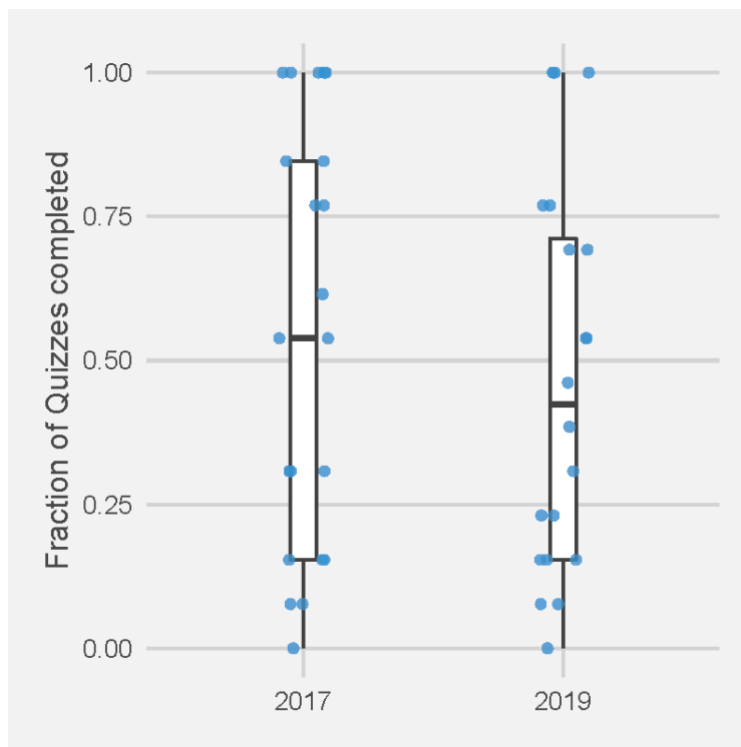
Figure 2.4. Fraction of quizzes each student completed in the 2016/2017 and 2018/2019 cohorts. Each dot represents a student.

As in all higher education modules, retaining student attention and effort throughout the module is challenging, particularly in the final weeks of the module when there are many competing demands on students' time (Harland et al., 2015). The flipped learning approach suffers from this problem too, as measured by the fraction of quizzes that students complete (Figure 2.4). The median for both the 2016/2017 and 2018/2019 cohort is around 50%, and many students complete fewer quizzes as the module progresses.

2.4.2 How did students learn?

In addition to the effort and attention students give to the module, it is also important to understand the extent to which the flipped learning approach results in the desired change to learning practice, towards more active forms of learning. To assess the impact that the flipped learning approach had on student learning, we asked students in the 2018/2019 cohort to assign different learning verbs from those in the modified version of Bloom's taxonomy to each of the activities in the module. Students were able to enter one or more learning verbs for each of the activities. Figure 2.5 shows the cognitive verbs, according to Bloom's taxonomy, that students reported using. According to the figure, it is clear that the in-class activities involve higher-level, more active forms of learning. Interestingly, the in-class activities also seem to encourage students to deepen their understanding of the material (see, for example, the high level of 'Understanding' students indicated when working on the problems). Although no similar analysis is available for the standard version of the module, it seems reasonable to expect that the higher-level learning verbs would have been used much less frequently, and that learning was confined to the assessed learning tasks. By allowing students freedom to experiment with their knowledge, under reduced assessment pressure, the flipped format helps students develop the critical analytical, scientific and communication skills they need for their future employment (Charlton-Perez et al., 2018).
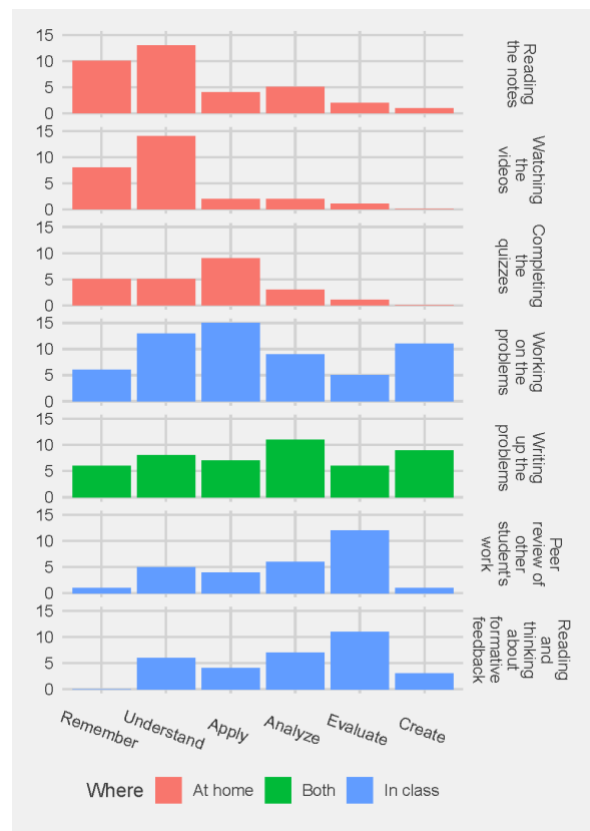
Figure 2.5. Self-reported learning type covered in each activity for students in the 2018/2019 cohort. Bars show the total number of responses in each category for the 15 students who completed the survey.

Anecdotal evidence of the high level of learning that is promoted by the flipped approach is shown in Figure 2.6, which offers an example of the way students in the 2015/2016 cohort used classroom resources to think about one of the problems. The students are clearly combining mathematical, physical and logical reasoning to understand a complex topic (physical driving of the mid-latitude jet and annular modes) described in a recent paper. There was no input from module staff into this analysis or discussion; students independently combined three different topics from their notes in order to understand the problem at hand.

While it is hard to quantify this kind of learning, such an example shows how empowering for students the flipped learning approach can be. This deep learning is also apparent in the high-quality assessment work that the students produced. The same colleague who reviewed the standard examination task also reviewed the revised module assessments and commented on the extent to which the flipped learning approach has deepened the engagement of students with the course material.
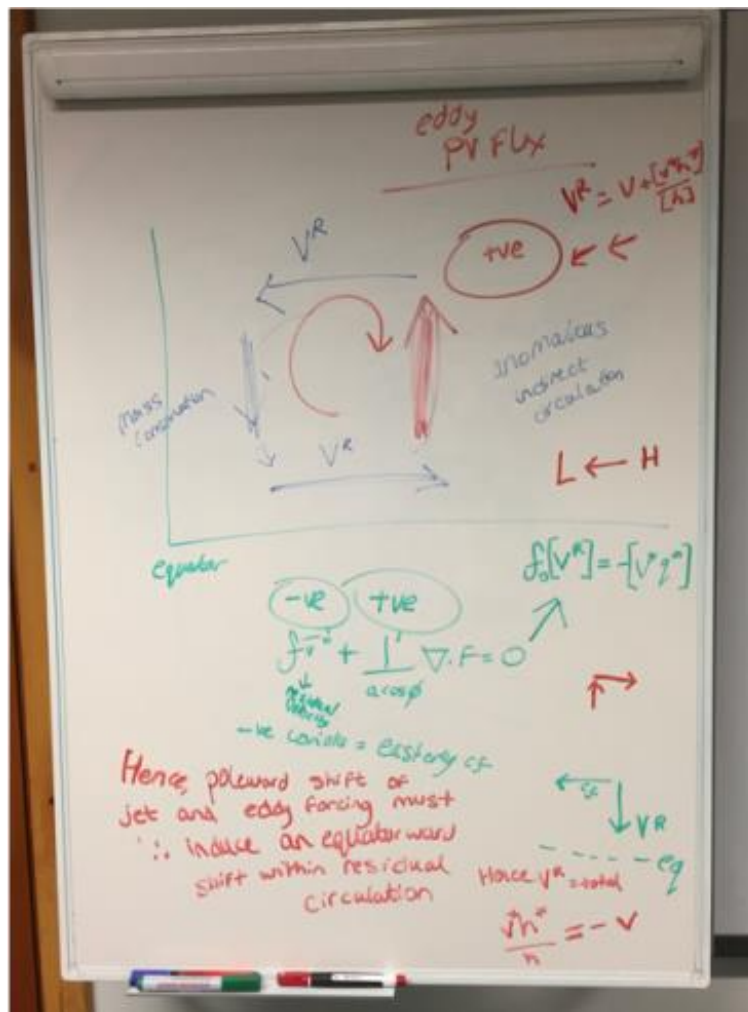
Figure 2.6. An example of student work generated in classroom discussion during the module

2.5   Reflection

Having now implemented the flipped learning approach with three student cohorts, it is clear that there is a great deal of potential to use this learning style more widely within meteorology. The main benefits of this approach are that it allows students easier and more frequent access to more active and higher-level learning.

Although some initial work to redesign the module and construct learning resources is required, over the lifetime of a typical module (5–10 years) this initial investment is balanced by a reduction in staff effort for later implementation of the same material. In our experience of the flipped learning approach, we found the prior learning reported by practitioners in other fields to be very relevant to designing a successful module—particularly the "Golden Rules for Flipping".

In the future, we plan to think about how we might reduce the drop-off rate for the quiz elements in the module. One approach may be to include small amounts of credit for them, but before contributing to an even greater student-assessment load, it will be important to engage with students in order to understand the reasons for dropping off.

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3. Enhancing long-term impacts of training through international collaboration: The case of the VLab Regional Focus Group of the Americas and Caribbean

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Abstract

The Regional Focus Group (RFG) of the Americas and the Caribbean has led monthly online continuing-education sessions for 15 years (2004–present). The RFG weather and climate briefings have connected diverse people from over 40 countries and enabled them to view satellite imagery, share information on global, regional and local weather patterns, hurricanes, severe weather, flooding, volcanic eruptions and other significant events.

The RFG sessions have helped build capacity for learning and have promoted sharing of knowledge and applications across social, cultural and political boundaries. The programme has also established a network through which we can introduce new Geostationary and Low Earth Orbiting Satellite imagery and products.

This chapter describes our journey of developing and offering the RFG online sessions, including instructional design, supporting technology, insights into encouraging and maintaining participation, and examples of session content. As we look at strategies to continue adapting to new data and technologies, we will also be looking for the next generation of leaders and participants to continue to adapt and utilize this valuable training approach. Furthermore, we will strive to maintain the thriving community of practice that has grown up around this programme.

Keywords: Meteorological satellite training, meteorological remote-sensing training, continuing education, online learning, professional development, community of practice, capacity building, international collaboration

3.1 Background and initiative for the Regional Focus Group

Up until the mid-1990s, WMO was the main international provider of training on the use and interpretation of satellite imagery, training 20–30 people a year in workshops. In order to increase usage of satellite applications for operational meteorological and hydrological forecasters in WMO member States and territories, the WMO Executive Council recommended that the satellite operators collaborate with WMO-designated Regional Training Centers to develop an education and training initiative. Through these efforts, the WMO Virtual Laboratory for Education and Training in Satellite Meteorology (VLab) was established in 2000 (Purdom et. al, 2016).

With increased Internet capabilities in the early 2000s and limited funding for conducting in-person training, the newly formed WMO VLab explored new ways to enhance learning opportunities on an ongoing basis. One of the initiatives promoted was the establishment of a virtual Regional Focus Groups (RFG) to address gaps in continued learning opportunities beyond the workshops. After a two-week training course at the Centre of Excellence (CoE) of Barbados in December 2003, the Americas and the Caribbean held their first online session in March 2004. In the first year, we experienced a very steep learning curve in how to conduct the sessions: how to use existing technology to allow everyone to view the satellite imagery and hear the discussions, and how to attract participants. It was the beginning of a long collaboration between the US National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS)/Office of the Chief Learning Officer (OCLO),[7] NOAA/NWS/Weather Prediction Center (WPC),[8] the Cooperative Institute for Research in the Atmosphere (CIRA), and the CoEs in Barbados and Costa Rica, later joined by CoEs in Argentina and Brazil. In the first year, the sessions were conducted in English and occurred on a monthly basis. After a WMO workshop held in Costa Rica in March 2005, the RFG expanded tremendously and the sessions were held in English and Spanish.

The RFG of the Americas and the Caribbean is unique because it has led ongoing monthly sessions for 15 years, and has been a model for other RFGs run by CoEs in Australia, Barbados, South Africa, Morocco and Russia, which have reached many additional countries in other regions as well. Our RFG weather and climate briefings have regularly connected diverse people from 36 countries in Regional Associations (RA) III and IV and occasionally connected an additional 24 countries worldwide. It has enabled us to view satellite imagery, share information on global, regional and local weather patterns, hurricanes, severe weather, flooding, volcanic eruptions, and other significant events.

When the RFG started, the main organizers were not experts in pedagogy or instructional design and did not expect that the sessions would grow into a community of practice. In this chapter, we discuss what we believe are the key aspects for success and describe learning solutions and outcomes. The RFG sessions were initially promoted to provide reinforcement of what was learned through formal classroom training. The sessions support collaborative efforts to increase learning at many levels while at the same time leveraging a less formal aspect of mentoring.

3.2   Coordination + Collaboration + Trust = Persistence

Success over many years required that the workload be distributed among the partners. The key aspects to ensure this are:

1. Schedule, prepare, and send the session announcement;

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[7] OCLO is the current Office under NOAA/NWS that is responsible for training. Previously, training was under the NOAA/NWS Office of Climate, Water and Weather Services.

[8] WPC is the name of one of the nine service centres under the NOAA/NWS National Centers for Environmental Prediction. Prior to 2013 it was called the Hydrometeorological Prediction Center (HPC).

2. Prepare content;

3. Ensure the content is ready for viewing and that the software and hardware are functioning correctly, allowing the content to be viewed and discussions heard by all participants;

4. Moderate the session;

5. Lead the session;

6. Record, process and post the session on the web (http://rammb.cira.colostate.edu/training/rmtc/focusgroup.asp);

7. Track, reflect on and analyse participation.

From our experience, at least two people are required for running smooth sessions. The structure in place to prepare for and run the sessions evolved over time to meet the shifting challenges brought on by new technologies and data. It necessitated coordination, collaboration and trust among the partners. Experience and adaptability with technology, knowledge and content have enhanced the sessions in ways that are hard to measure but that we realize exist. As we discuss below, another recent major challenge and opportunity was adapting for the next generations of Geostationary and Low Earth Orbiting Satellite imagery and products.

In the first 13 years, imagery and products were displayed using VISITview, a teletraining and real-time collaboration tool that provides a "slideshow" format. This allows image animations, zooming and chalkboard capabilities, and connects one or more instructors to many students via the Internet (http://www.ssec.wisc.edu/visitview/). A VISITview server at CIRA provided the framework and real-time geostationary and polar orbiting imagery and products for viewing. Real-time imagery was created automatically from a RAMSDIS (Molenar et al., 2000) system. Initially, we made available only "standard" geostationary satellite images (visible, short- and long-wave infrared, and water vapor) on the site. These evolved to include specialized polar orbiting products such as total precipitable water from the Advanced Microwave Sounder Unit, rain rate and wind speed from the Special Sensor Microwave/Imager, sea-surface temperature, and the Day/Night Visible band from the Joint Polar Satellite System.

With the launch of the next generation of Geostationary Operational Environmental Satellites (GOES), along with an increase in image channels (from 5 on the previous GOES to 16 on the new GOES) and spatial and temporal resolution, came the need to receive, process and display the imagery in a different manner. The Cooperative Institute for Research in the Atmosphere developed the SLIDER application (Micke, 2018) to view the imagery; this has been used in the weather briefings since September 2017.

Before webinar software became available, we used VISITview software to view the imagery, and the Yahoo Conference feature provided voice-over-Internet and text messaging capabilities. Initially, low bandwidth prevented many countries from fully participating in the sessions. Some were able to view the imagery, but they were unable to hear the voice through Yahoo, or vice versa. We continued to look for better methods to view the imagery and hear the discussions. In June 2011, we switched to GoToWebinar to utilize the higher quality voice capability. We continued to use VISITview to display and to

draw on the imagery, as it allowed the presenter to demonstrate patterns. Being able to draw on the imagery, point out features, or draw on a blackboard has been a crucial part of the sessions (Figure 3.1a and 3.1b). With the advancement of webinar software, no recent updates to the VISITview software, and increasing security threats associated with Java, SLIDER almost entirely replaced VISITview in the Fall of 2017.

The sessions use a number of learning strategies: (1) Leader-centred discussion with occasional outside presenter discussions; (2) inquiry strategies; (3) experiential strategies that capture real-time experience, reflection, generalization and application; and (4) short versions of case-based strategies. The general content covered during the sessions has not changed significantly over the years. It begins with a climate overview followed by a discussion of the current weather and often includes the review of a significant weather or other environmental event that occurred in the past month. Products from the National Centers for Environmental Predictions (NCEP) Climate Prediction Center (for example, Sea Surface Temperature Average and Anomaly, and the Madden-Julian Oscillation (MJO) pattern) have been used for the climate overview. These products are provided by the session lead and were viewed via the VISITview software described above prior to Fall 2017 and have been viewed via PowerPoint presentations since then.

For real-time imagery with the previous GOES, we reviewed the large-scale synoptic pattern utilizing a single channel of water vapor imagery. Now, we view three water-vapor channels as well as the Airmass Red/Green/Blue (RGB) image composite that includes water vapor and other infrared channels.
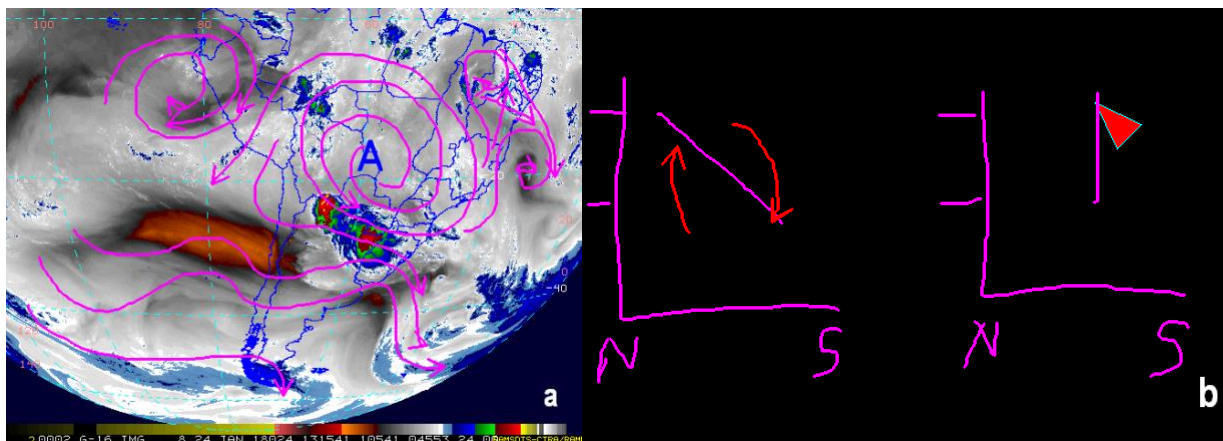
Figure 3.1. A recent VISITview image analysis activity

With the old generation of GOES, we investigated local weather patterns using imagery from one visible channel and the 3.9 µm and 10.7 µm infrared channels, alone and in combination. With the new generation of GOES, we often start with an RGB composite that represents true colour (the Geocolor product) and then use other RGB products to help distinguish cloud phases. We continue to use the single channel imagery and simple channel difference products to clarify or confirm the interpretation of the RGB or other observations.

We often supplement the satellite imagery with a conceptual model of a specific process, a model analysis field, or a quick hand drawing representing a process. To engage participants, the session lead asks questions such as: Where was convection expected to develop? What channels or products would you use to identify X (X= fire, smoke, dust,

water cloud, ice cloud, or other features)? What supplemental information can be used to support the feature identification? We encourage participants to make comments or ask questions, either through a text chat or verbally. An example of this, from the January 2018 session, is shown in Figure 3.1. The session leader, Michel Davison, drew the upper-level circulation pattern on the GOES-16 6.2 μm upper-level Water Vapor Imagery. He marked the centre of the upper-level high with an A and posed the question: Why is convection surrounding the high and not at the centre? After a hint from a participant, the answer was drawn on the blackboard for discussion (b). The typical vertical representation of the 200 hPa vs. the 500 hPa pattern (y axis) from the centre of the high outwards (here from North to South on the x axis) shows that upward motion is expected near the centre (N). What is occurring in this case is that the centres of the 200 and 500 hPa highs are stacked (on the right) and convection is inhibited. Check out the recording on the RFG web page listed above for further explanation. The National Oceanic and Atmospheric Administration International Training Desk at NCEP/WPC has provided stable leadership for the sessions through the work of Michel Davison and José Gálvez. The mission of the WPC International Training Desk is to provide visiting scientists from Central and South America and the Caribbean with meteorological training that emphasizes the operational use and application of numerical model products. The International Desk has been training visiting fellows since 1988 (30+ years!) and exposing them to a broad spectrum of meteorological products, analysis and forecasting techniques. There are 12 visitors each year; they spend four months in training at the Desk and are encouraged to participate in the RFG sessions. In 2015, the RFG sessions became an informal extension of their formal training. The sessions allow the Desk to stay in touch with former visitors and recruit new students, and frequently provide a source of ideas to investigate further. People that are unable to attend the sessions value the recordings, using them for individual study or classroom discussions.

3.3   Attracting participation and building capacity and community

As mentioned in the preceding section, the first year was challenging. In the second and third years, magical events started occurring. There was a training session in Costa Rica in March 2005, hosted by Professor Vilma Castro of the University of Costa Rica (UCR). The participants at the various workshops and the students at the Universities and Training Centers were grasping the importance of satellite imagery as well as the extended reach across social, political and cultural boundaries that the Internet provided. Michel Davison became the regular lead for the bilingual sessions, Tony Mostek (NOAA/NWS) organized the scheduling of the sessions and sent reminder and summary emails, Bernadette Connell (CIRA) arranged access for the real-time data and other content used during the sessions and helped troubleshoot audio or visual problems during the sessions. Vilma Castro from UCR and Selvin Burton from the Caribbean Institute of Meteorology and Hydrology (CIMH), Barbados, encouraged their students to participate. Kathy-Ann Caesar (CIMH) helped Selvin and later took over for Selvin when he retired. Figures 3.2a and 3.2b show a strong increase in both the number of countries participating and the total number of attendees, following the March 2005 workshop. Over 15 years, we have missed only four sessions. In 2007, there were often two sessions per month, one that was presented in Spanish only and another that was bilingual, in English and Spanish.

In 2006, the enthusiasm for the sessions was high and there was a good mix of students, forecasters, trainers and researchers participating. In April of that year, more than 63 individuals from 19 countries participated in two consecutive sessions; 15 persons attended both sessions. The countries and number of attendees were Antigua and Barbuda (2),

Argentina (2), Barbados (1), Bolivia (2), Brazil (2), Chile (1), Colombia (4), Costa Rica (8), Dominican Republic (14), El Salvador (5), Guyana (1), Honduras (2+ forecasters), Jamaica (1), Mexico (2), Panama (1), Paraguay (1), Trinidad and Tobago (1), Peru (2+ workshop) and Venezuela (10). The highlight of the year was in October, when the WMO VLab held an Online High-profile Training Event. Throughout the week, presentations on satellite data applications were given in multiple languages and scheduled to take account of the local time of the participants, to increase accessibility. More than one thousand people participated around the world. In addition to the scheduled presentations, a demonstration of the RFG was also given. We held two RFG sessions that attracted a total of 23 countries and 184 participants.

a
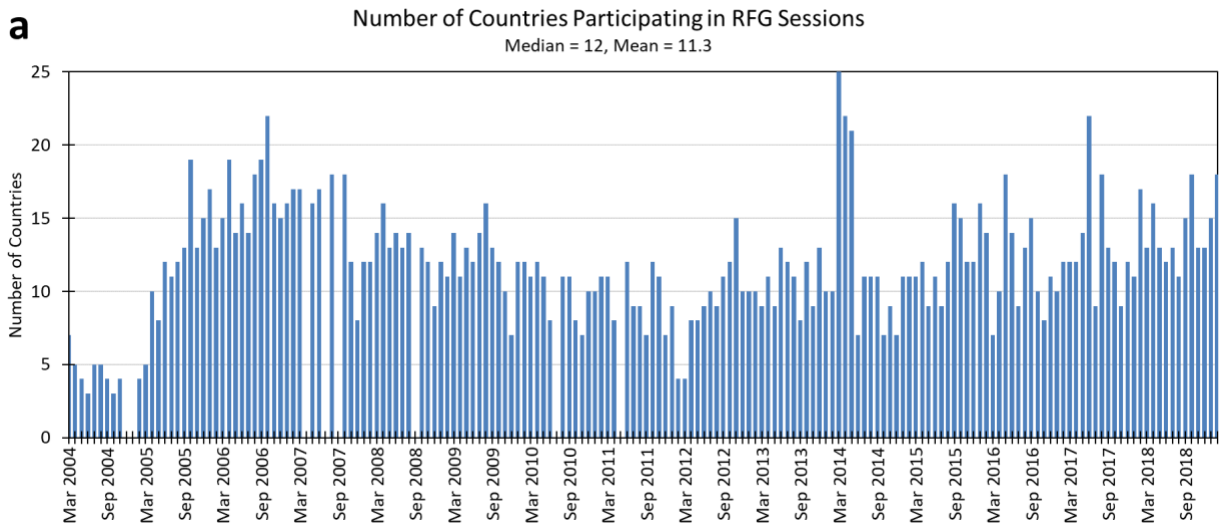
Figure 3.2a. Number of countries from the Americas and the Caribbean that participated in monthly RFG sessions from March 2004 to February 2019

b
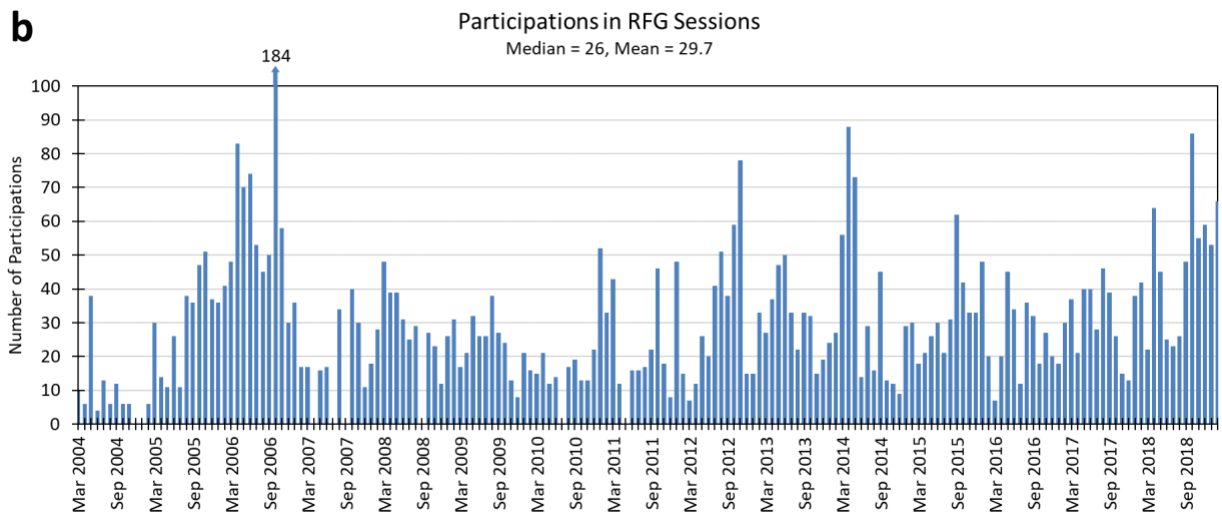
Figure 3.2b. Number of participants in the RFG sessions during the same 15-year period

Looking closely at the number of countries and the number of participants over time, there are cycles of higher and lower attendance. Sometimes the low attendance was due to our inadvertent scheduling during or close to holidays. Over the 15-year period, 4 sessions were cancelled and records are missing for 4 other sessions (total missing monthly values=8). Higher attendance occurred when an instructor introduced their class or workshop at the sessions, when new imagery or a new product was introduced, when the weather was transitioning from one pattern or season to another (for example dry to wet season or neutral to El Niño conditions), at the beginning of an academic period, or in association with a visitor to the WPC International Desk.

In March 2014, José Gálvez introduced the Gálvez-Davison Index in two sessions that attracted 56 participants from 25 countries. In April 2014, there were three sessions: the regular climate and weather RFG session, a session on the Suomi National Polar-orbiting Partnership (NPP) and one on the Community Satellite Processing Package (CSPP) software, which attracted a total of 88 participations from 22 countries. There were two sessions in May 2014, the regular RFG session and a presentation from the US National Hurricane Center, which attracted a total of 73 participants from 21 countries. In September, October, and November 2018, the CoE in Argentina contributed to the sessions on the topics of downslope wind events, the low-level jet, cold fronts and the RELAMPAGO field campaign. These topics reflected courses being offered at the time and research being carried out in northern Argentina. The intent was to introduce more forecasters to the RFG sessions. October was a particularly busy month as Trinidad and Tobago experienced a heavy rain event and shared that during the session. The October session brought together 88 participants from 18 countries.

Over the years, we noted the progression of CoE or University students to forecasters or researchers, and further to teachers, trainers and managers – and quite a few continued to participate in the sessions. We initially interpreted the connections being built as building capacity for WMO Regions III and IV. Now an additional concept comes to mind: the informal pedagogical approach of building a community of practice.

Figure 3.3a shows the countries from RA III and RA IV that have participated in the sessions over the 15 years and their relative involvement. There are areas where a higher percentage (greater than 50%) of participation is expected over time, for example, those associated with the WMO/Coordination Group for Meteorological Satellites (CGMS) VLab CoEs in Costa Rica, Barbados, Argentina and Brazil; and there are a few "hot spots" of high participation that are less expected: El Salvador, Honduras and Panama in Central America, and Colombia and Peru in South America. The higher participation from Central American countries can be linked directly to the CoE in Costa Rica, in particular to the enhancement of data access and training efforts that occurred during 1999–2001. The National Oceanic and Atmospheric Administration and the US Agency for International Development supported these efforts in response to Hurricane *Mitch*, which hit the region in October 1998 (Connell and DeMaria, 2001). The high participation from Colombia and Peru is strongly linked to individuals who were either students at the University of Costa Rica and/or participated in WMO in-person training events.
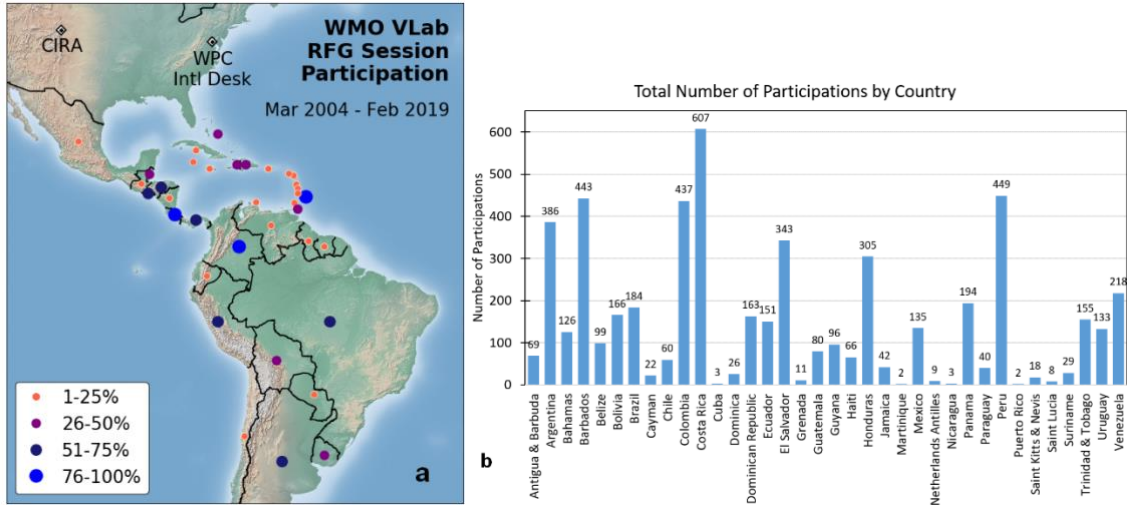
Figure 3.3a. Relative country participation in the WMO-CGMS VLab Regional Focus Group of the Americas and Caribbean over the 15-year period, from March 2004 to February 2019.

Figure 3.3b. Total number of RFG sessions attended by trainees (by country) from the Americas and the Caribbean over the 15-year period.

Figure 3.3b shows the total number of sessions for the countries in WMO Regions III and IV over the 15-year period. Countries with higher total numbers of participants are similar to those with high participation rates of Figure 3.3a. Based on our own perceptions, this reflects the effort of persistent leaders or liaisons that encouraged others to participate and also reflects individual initiative. These data led to the following questions: How were the individuals introduced to the sessions? How long have they participated in them? What factors contributed to continued or lack of participation? We approached this in two ways: through a survey in 2017, and through further analysis of the session metrics.

In late 2016, we developed a survey to be distributed in January 2017. The survey contained 16 questions focussing on the impact of RFG activities on the use of satellite data and images by meteorological personnel. There were 50 respondents: 32 Spanish-speaking participants and 18 English-speaking participants. We present the responses to three of the questions in Figure 3.4.
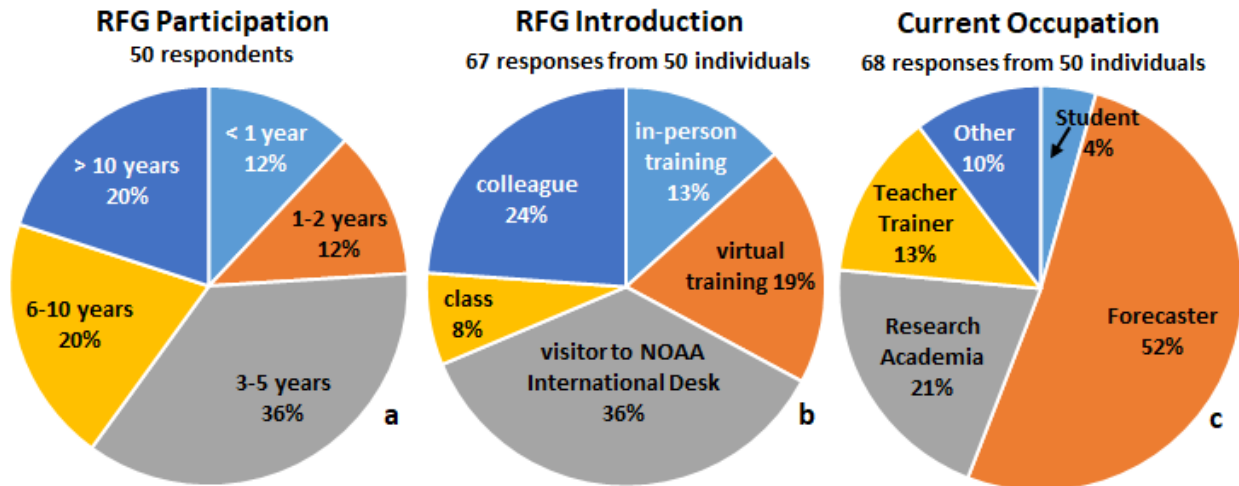
Figure 3.4. Survey results representing the responses from 50 individuals (32 Spanish- and 18 English-speaking) to three questions: a. How long have you been participating in the Americas and Caribbean Regional Focus Group (RFG)? b. How did you find out about the RFG? c. At present, what category best describes your occupation?

By 2016, conducting the Regional Focus Group sessions had become a habit. We recognized that there were long-term participants but did not know how many. We each had a different perspective of how people had been introduced to the RFG sessions and what their occupations were. With the survey, we aimed to gather information to address these questions and to define the scope and content of the sessions in the future. At first, we were surprised to see that 88% of the respondents had participated for more than a year, and 75% of the respondents had participated for more than 3 years (Figure 3.4a). In retrospect, these results are not surprising as the people most likely to respond to the survey are those that most value the sessions.

To the question "How did you find out about the RFG?", multiple responses were allowed, reflecting the fact that people were exposed to the RFG sessions in several ways. The most common response was as a visitor to the NOAA WPC International Desk. In 2015, the guidelines to evaluate visitors to the Desk were modified to follow WMO Competencies (NOAA WPC International Desk, 2015). Desk Competency III requires the meteorologist to "Become a weather forecasting instructor and mentor." Visitors to the Desk are exposed to the RFG and when they return to their home country, they continue participating and encourage others in their offices to participate as well.

To the question "At the present time, what category best describes your occupation?", the most common responses included forecaster (52%), academia and research (21%), and teacher/trainer (13%). These three areas overlap, especially with the introduction of new GOES and Joint Polar Satellite System (JPSS) imagery in recent years. Trainers and forecasters both continue to increase their understanding and usage of the products over time. Researchers provide expertise on image and product strengths and limitations and are interested in how the products are used in the operational setting.

In response to new questions asked after the survey, we took a further look at session metrics with respect to individual participation. After the switch to the GoToMeeting

software in 2011, the registration process made the tracking of participants relatively easy. Before 2011, we tracked participation manually. Our list is not complete, and participation related to specific individuals is currently only available from August 2007 onward. The available data, as represented in Figure 3.5, indicate that in the Americas and Caribbean 52 individuals from 21 countries have participated in 12 sessions, 22 individuals from 16 countries have participated in 24 sessions, and 11 individuals from 8 countries have participated in 36 sessions. We expect the number of participants in these categories to rise with the addition of session data prior to August 2007.
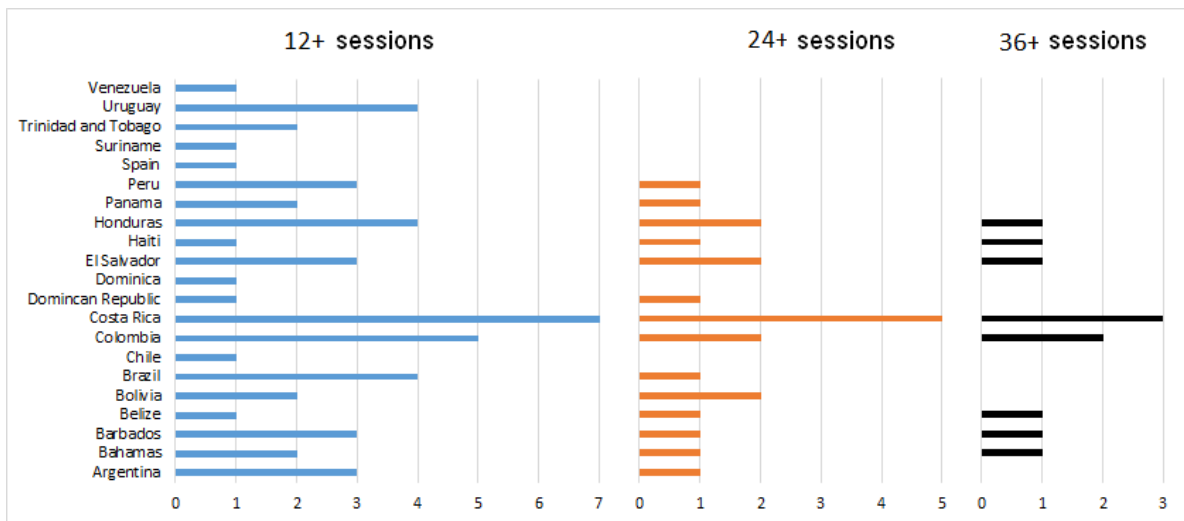
Figure 3.5. Number of individuals and respective countries that have attended 12, 24 and 36 unique monthly sessions.

The countries from which the long-term participants generally come overlap with countries with high participation rates shown in Figures 3.2 and 3.3, but there are some surprising exceptions. Figure 3.3 indicates 66, 99 and 126 total sessions attended by Haiti, Belize, and the Bahamas, and Figure 3.5 indicates that there are individuals that have participated in more than 36 sessions from all three of these countries. The individuals who have participated over the long term are teachers and trainers, private and government forecasters, and weather enthusiasts. We interpret this as demonstration of the RFG as a valued form of continued professional development. Although not indicated in this graph alone, the involvement of so many individuals in the RFG over 15 years leads us to believe that we have identified a community of practice that is worth sustaining.

3.4   Summary

To summarize, many collaborations exist and continue to develop between the main organizers and attendees of these online RFG sessions for WMO Regions III and IV. Our RFG sessions promote continued learning, hence continued professional development when participation is spaced over time. The approach of introducing individuals to the RFG through structured classroom events, visiting forecaster positions and virtual training events has so far sustained the RFG sessions as a community of practice. Learning methods include the use of climatic indices, conceptual models and real-time or recent applications of satellite imagery integrated with other observations and NWP products. These activities have helped to build capacity for learning and have promoted sharing of knowledge and

applications across social, cultural and political boundaries; they have also inspired similar RFGs to grow in other regions. Other recognized benefits include having an established network that can be utilized for introducing new Geostationary and Low Earth Orbiting Satellite imagery and products. As we look at strategies to continue adapting to new data and technologies, we will also be looking for the next generation of leaders and participants to continue to adapt and utilize this valuable training approach.

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4. Minimizing transactional distance in online meteorology education

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Abstract

All education endeavours involve some degree of "transactional distance", which describes the gap in understanding and communication between teachers and learners. This gap is exacerbated in distance education settings because of the inherent geographic distance involved, as well as the asynchronous nature of many distance learning environments. This increased transactional distance can often lead to feelings of isolation, frustration and eventually attrition for some distance education students. Therefore, educators often seek ways to reduce transactional distance. For nearly two decades, the Department of Meteorology and Atmospheric Science at The Pennsylvania State University has been delivering online meteorology education to students worldwide, and from this experience, our faculty and staff of instructional designers have adopted several best practices that help minimize the transactional distance in our online courses. Reducing transactional distance requires distinctive procedures in instructional design and the facilitation of interaction between faculty and students. In this chapter, we cite four key factors that facilitate student success in our online programmes: sound instructional design, engaging asynchronous activities, strong instructor presence and a "learn by doing" philosophy. Such approaches are critical for success in our online meteorology educational programmes and can serve as the basis for success in any online education endeavour.

Keywords: online learning, distance education, transactional distance

4.1 Introduction

Transactional distance is a pedagogical concept describing the cognitive space separating teachers and students. Although all education endeavours inherently involve some degree of "transactional distance" (Rumble, 1986, as cited in Moore and Kearsley, 2005, p. 224), increased physical distance and potential temporal barriers of distance education settings can profoundly widen the gap between teachers and learners. This increase in transactional distance can ultimately lead to students' feelings of isolation, reduced engagement and eventually attrition. Moore and Kearsley (2005, p. 223) state that in distance learning environments, instructors and course designers must strive to minimize transactional distance "through distinctive procedures in instructional design and the facilitation of interaction." In nearly two decades of delivering online meteorology education in the Department of Meteorology and Atmospheric Science at The Pennsylvania State University, our experiences have helped us develop a set of best practices to minimize transactional distance.

While the application of these best practices may appear novel in the online environment, their underlying basis is simply good pedagogy. In particular, four key factors have helped us facilitate student success in our online programmes: sound instructional design, an emphasis on asynchronous activities, a strong instructor presence and a "learn by doing"

philosophy that engages students in real-life problem-solving. Below we discuss these concepts in more detail, tailored to online meteorology education.

4.2   Sound instructional design

The online classroom is considerably different from its face-to-face counterpart. The differences created by varying instructional delivery methods extend deep into the pedagogical structures of the course and, in turn, influence the experience of students navigating those structures. Instructors and designers must understand the special considerations that are required for online courses, and that those considerations differ from courses offered in a face-to-face setting. One of the prominent challenges that educators of WMO Members will face is the transformation of traditional face-to-face training materials to content that will be as effective for distance learners. This transformation requires overcoming both technical hurdles and pedagogical challenges that arise in distance learning environments.

The first priority in any online educational experience is student engagement. Online students must not be viewed merely as passive participants in the learning process, and adult students in particular are largely accustomed to having some degree of self-direction. Research has shown that when accounting for formal and informal learning, over two-thirds of all adult learning activities are planned, implemented and evaluated primarily by learners (Tough, 1979, as cited in Merriam and Brockett, 1997, p. 138). Therefore, adult students must be afforded the opportunity to make choices centred on how they approach the material, activities and assessments. Providing localized control does not mean, however, that students create their own learning objectives as in the most radical constructivist tradition. Rather, educators can use technology to provide multiple learner pathways and reinforcing activities that allow students to assemble key concepts and skills in the framework best suited to their learning style and prior experience.

The design of online learning materials must begin with clear objectives that form the foundation for content that engages learners by leveraging the strengths of a variety of media. Content that is properly segmented and clearly aligned with the stated learning objectives can be presented in various forms and will likely be more effective if developed with student cultural norms and learning expectations in mind. A variety of formats, ranging from low-level technologies (written words/images) to high-level technologies (video, animations, etc.), allows for a more diverse set of learner pathways and appeals to various learning styles. Accessibility within bandwidth and technology limitations further necessitates the need for content diversity, as well as judicious consideration of high-level technology usage. In addition to content, frequent reinforcing activities and authentic assessments that align with lesson objectives provide students opportunities to practice key skills and receive timely feedback.

In addition to well-formed content and assessments, a communication plan is essential in online education. In our experience, employing several different communication platforms works best to accommodate student needs. Having public spaces to build community, along with a private means of communication, such as email, generally strikes an appropriate balance. As we will discuss in the next section, we favour asynchronous communication; however, in some cases, real-time communication platforms (chatrooms, video conferencing, etc.) can provide advantageous interactions as well. As with the content

design, an effective communication plan considers learner needs as well as cultural norms, technology availability and the communication goals.

Finally, sound instructional design does not occur without strong partnerships between Subject Matter Experts (SMEs) and instructional designers. Such partnerships are born out of respect for each other's skills. Subject Matter Experts must recognize that although they may be experienced traditional instructors, most instructional designers have superior experience in online learning and applying instructional technologies. We have found that close collaborative relationships take time to form but are well worth the effort in that they produce the best results. In cases where faculty are reluctant to work with instructional designers, such partnerships must often be strongly encouraged (even mandated) at an institutional level.

4.3   Emphasis on asynchronous activities

The delivery of materials and activities in online education falls into two major categories – synchronous and asynchronous. Synchronous activities require the real-time presence and participation of students. Examples of synchronous online learning include lectures or discussions conducted via teleconferencing, real-time map discussions by students and/or faculty, chatroom discussions and virtual "office hours". Asynchronous materials and activities, on the other hand, are those in which the students can access and participate at times convenient to their schedules and in a manner consistent with their learning styles. Examples might include pre-packaged course materials and pre-recorded lectures, discussion forums, blogs and email communications.

Each delivery category has distinct advantages and disadvantages, so choosing the types and proportions of each type of activity is crucial. Course objectives, technological considerations, geographic distribution of students and cultural norms should play a role in such decisions. However, other factors make the choice more complex.

When considering synchronous activities, the obvious advantage is the immediacy of the instructor-student and student-student interactions. Synchronous learning can better simulate the typical atmosphere in traditional classrooms and may better conform to student expectations for those who have only experienced traditional educational settings. Furthermore, synchronous learning tends to more easily form a sense of community through the rapid exchange of ideas, questions and concerns.

The disadvantage of synchronous activities is the need to coordinate the diverse schedules of students and faculty, in many cases spread across the globe. According to Young and Norgard (2006, p. 113), providing flexibility is crucial because convenience is the most common reason students cite for choosing to learn online. Therefore, we have chosen to require mostly asynchronous activities in our courses. This decision allows our students to explore material, complete assessments and communicate with classmates at their discretion, within a defined deadline structure to keep learners in step. We believe that a small sacrifice in immediacy and community is more than compensated by the flexibility offered by asynchronous online delivery. However, making optional synchronous opportunities for communication available, such as virtual office hours, can minimize transactional distance for students who occasionally desire such interactions.

Perhaps the largest drawback in asynchronous learning is communication at a distance. While every student is familiar with some forms of asynchronous learning, like textbooks, we find that online students often miss the dialogue with instructors and other students found in traditional classrooms. To that end, we encourage students to engage via discussion forums. Forums offer students a "public" space to ask questions and receive responses from both instructors and fellow students. We find that although responses are not as immediate as in face-to-face discussions, students who might not speak up in a traditional classroom are sometimes more confident when writing their questions, particularly those not fluent in the course language. In required discussion activities, forums provide a written record of a student's contributions and development over the course of the semester.

4.4   The importance of strong instructor presence

While traditional, face-to-face education offers students opportunities for direct interaction with a course instructor through lectures or other in-person meetings, such opportunities can be lacking in distance education settings. Because online and other types of distance education inherently include some degree of geographic distance, the perceived transactional distance between teachers and learners can be an issue in any distance learning setting (Vella, 2002, xiii). Thus, the development of a strong instructor presence through the design of learning activities, the facilitation of discussion, and through direct instruction at times, is essential.

Distance educators can strengthen their instructor presence, thus working to minimize transactional distance, by designing and executing learning activities that encourage interaction between students and instructors. Regular (at least weekly) pre-lesson course announcements can set the framework for upcoming learning activities and provide reminders about assignment deadlines, and informal discussion postings about current weather patterns or other events can provide opportunities for learners to apply course materials to real atmospheric events. When students have questions, either about formal course materials or about other weather-related topics, responding in a timely fashion also works to foster a strong instructor presence. Regularly engaging with students sends the message that the instructor is available and willing to help, which can combat feelings of isolation that can occur in distance learning settings. In our online meteorology programmes at Penn State, we advise instructors that course emails and discussion postings should be addressed on a daily basis, so that students do not have to wait more than 24 hours to receive a reply (and in practice, the response time is usually less than 24 hours).

Much educational research indicates that a strong instructor presence is "crucial for realizing intended learning outcomes" (Garrison & Archer, 2007, p. 80). Even very self-directed learners benefit from learner-instructor interaction because all learners are "vulnerable at the point of application" of new concepts; they do not know whether they are applying new concepts correctly or as deeply and broadly as possible (Moore and Kearsley, 2005, p. 141). In online interactions, students often need the instructor's guidance and intervention to lead discussion toward deeper understanding and other desired pedagogical outcomes (Garrison & Cleveland-Innes, 2005, p. 143). In our online meteorology courses, we advocate the use of Socratic-style questions in the facilitation of asynchronous discussions. Socratic-style questioning guides students toward correct conclusions without simply stating those

conclusions, and research has shown that such an approach can drive students to exhibit greater critical thinking (Yang et al., 2005).

While developing strong instructor presence aids in achieving learning outcomes, instructors must be careful not to dominate all class interactions. As Garrison and Cleveland-Innes (2005) state, "It is not educationally desirable or reasonable from a time-management perspective to have the teacher respond to each comment. But it is crucial that the teacher moderate and shape the direction of discourse" (p. 145). Because student-instructor interaction can be quite time-intensive for the instructor, it can limit course scalability as course enrolments grow. Therefore, designing discussion-based activities to encourage students to respond to other students and deciding how frequently to provide guidance to students is an exercise in constantly trying to achieve balance between time constraints and fostering necessary, but not overwhelming, teaching presence.

4.5   Learning by doing

Throughout our programme, courses emphasize the application of new learning. Not only are students exposed to multiple case studies providing examples of atmospheric processes, but multiple forms of course assessment make use of real weather data for analysis purposes. Many "lab exercises" require students to collect real weather data from various websites and perform their own analyses, which gives them opportunities to apply new concepts to real-time weather. Moore and Kearsley's observation that all students are "vulnerable at the point of application" (2005, p. 141), is certainly true of students learning about weather analysis and forecasting. Therefore, it is critical that students also receive feedback when analysing real-time weather data, so that they can learn from their mistakes and identify details that they may have missed.

The emphasis on using real weather cases (both past and present) to teach meteorological concepts throughout the programme lays the foundation for students being able to perform more complete analyses and forecasts by the end of the programme. In the capstone course, students are exposed to a forecasting "practicum" environment, in which they are responsible for creating short-term forecasts for maximum and minimum temperature, maximum sustained wind speed, and liquid precipitation. In this environment, students have to apply any number of concepts from past courses toward the creation of quality forecasts. Students' forecasting performance is assessed and is part of their final grade. The quality of students' forecasts, however, is not judged in a vacuum. Students are also assessed and given feedback on their participation in online asynchronous forecast discussions, as well as on post-mortem analyses of forecasts that did not work out as planned.

Student feedback indicates that after their forecasting practicum experience, students recognize the value of such "learning by doing." After all, an educator can expose students to many case studies, but can never present them with the infinite variety that the atmosphere provides. Having students create and analyse their own forecasts provides very personal lessons about the atmosphere that other forms of assessment cannot match. For this reason, we consider "learning by doing," after the development of a solid conceptual foundation, to be the most advanced form of learning in the realm of weather analysis and forecasting.

The emphasis on assessment that focuses on real-time weather analysis, however, does require substantial instructor time. While general aspects of assessments and some case studies are reused in multiple course offerings, assessments based on current weather cases require some degree of customized feedback and analysis on the part of the instructor. Overall, in our view, the time commitment required to provide customized feedback (when necessary) greatly benefits students.

4.6 Conclusion

While all distance education endeavours contain challenges of transactional distance, educators can take steps to minimize the effects of transactional distance to the benefit of student learning outcomes and satisfaction. Differing cultural norms and learning goals rule out a single, universal solution for minimizing transactional distance. However, making educational decisions that are grounded in sound instructional design principles, appropriately weighing the benefits and drawbacks of both synchronous and asynchronous approaches, favouring the development of strong teaching presence, and allowing students to learn by doing in a guided setting can all contribute to the minimization of transactional distance. Furthermore, while technological advances have changed methods of execution of these strategies, the underlying strategies themselves remain unchanged. A focus on sound pedagogy not only informs our day-to-day teaching decisions in interacting with our students, but it enables us to identify areas for improvement as we move forward. Such approaches are critical for success in our online meteorology educational programmes and can serve as the basis for success in any online education endeavour.

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5. Strategies for sustaining learning engagement in a lengthy online course

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Abstract

This chapter describes the design of a 5–9 week, fully online course for trainers, offered by WMO since 2014. It focuses on the various strategies used to maintain a high completion rate by active participants, including offering a clear course design, providing relevant content, requiring a course project, using active learning approaches, acknowledgement of incremental achievements, and regular communication and rich feedback. The course had been delivered in four languages and completed by 333 participants by the start of 2020. In addition to introducing good training practices, as embodied in the WMO Competencies for Education and Training Providers, to so many training professionals from WMO Members, one of the significant benefits of the course has been the expansion of a global community of trainers in WMO-related disciplines who continue to share with and learn from one another beyond the boundaries of the course.

5.1   Motivation to deliver training online

The WMO Education and Training Office has offered courses for trainers of regional and national training centres for over 20 years. Early courses focused on enhancing content area knowledge, but in the mid-2000s the courses became more focused on core competencies for training, rather than content. Initially, these were conducted as two-week residential courses for about 20–25 participants. However, in 2014, after the approval and publication of WMO *Competency Requirements for Education and Training Providers for Meteorological, Hydrological and Climate Services* (see *Compendium of WMO Competency Frameworks* (WMO-No. 1209)), and after the publication of *Guidelines for Trainers in Meteorological, Hydrological and Climate Services* (WMO-No. 1114), based on the competency framework, closer alignment and more complete coverage of the knowledge and skills required for competency was expected. Generally, developing training competency is related to an increased knowledge of the complexity of effective training design when it is well designed. This required a longer course, one that offered practice in carrying out the whole training planning process, which was not feasible for us in residency mode due to logistics and cost.

Going online also meant that we could reach more of the training community. This is partly due to the elimination of boundaries of physical location and travel costs. But online learning also simplifies delivery in other languages because facilitators can be located anywhere, and second language facilitators can take more time to read and compose responses, sometimes using machine translation as an aid. The average number of students completing the course has increased to 37 per offering—a 60% increase—at a cost reduction of at least 85%. In the nine offerings conducted since 2014, in English, Russian, French and Spanish, a total of 333 certificates of completion have been granted. And as will be shown below, the course has quite rigorous requirements for certificates of completion. While many expected that it would be difficult to sustain engagement in such an online course, especially in regions with challenges to Internet access, the number of completions has been quite gratifying, especially when the very first offering in 2014 for Regional Association I (RA I,Africa) saw

35 successful completions, despite worries that most participants might give up due to Internet access problems.

A final motivation to move the course online had to do with promoting the use of online learning and new online tools for engaging learners, such as discussion forums, simulations, games and various media. The course has exposed many more trainers to the possibilities of online learning, and provided many examples of active learning approaches, which should influence their training practices in general. More online training translates into meeting more WMO Members' capacity development needs. Indeed, based on statistics provided by WMO Regional Training Centres, the number of online learners has nearly doubled in recent years, from 600 students served in 2014–2015 to 1128 students served in 2016–2017. We suggest that part of this increase can be attributed to exposure to the online course for trainers.

Initially we feared the usual drawbacks associated with converting a classroom experience into an online environment—losing engagement, lower knowledge and skill gain, lower number of people enrolled, etc. But none of these fears turned out to be justified. In fact, by redesigning the course from scratch as an online experience, we can reliably say that we gained in each of these areas.

5.2   Format of the course

The WMO Online Course for Trainers is almost entirely asynchronous, meaning it does not rely on facilitators and participants being online at the same time. They access the course website, view resources, contribute to discussions and participate in activities whenever they can. This not only provides significant flexibility for participants and facilitators to fit the course into their schedules, but it allows the course to be run with students in any time zone. While the offerings do focus on one or two regions, participants come from nearly all regions during some offerings. Language is a stronger impediment than geography. Indeed, the French language 2018 course offering saw participants and facilitators from five different WMO Regions. However, one downside of the asynchronous approach is that participants, and especially their managers, may give the course less attention than a residential course that must be attended on-site. While the nomination form asks that the Permanent Representative with WMO agrees to a 6–8 hour per week of release time from duty during the course, our experience is that only about 50% of learners are allowed this time, and they simply fit the course into their personal time, after-hours and on weekends. Many also respond that 8 hours is not enough to complete the work even if they are granted release time, partly because the course work is not in their mother tongue. The next section on engagement strategies addresses potential reasons why they do complete the course nonetheless.

In most years, the online course has been followed by a WMO Training Development Workshop—a residency workshop that up to 40% of the online participants have been invited to attend (participants were chosen on the basis of highly successful completion and distribution across WMO Members, with an emphasis on developing countries). However, we do not consider this the second component of a blended course. The Training Development Workshops that have been offered were not integral to the training, but an extension of it to deepen knowledge and experience.

The course has evolved and been improved over time, and the recent 2019 edition had a narrower focus on blended learning. The last full versions of the course (2017 and 2018) were offered in 9 units of 1 week each, grouped into 3 modules, with two breaks of at least one week between modules (allowing for holidays and time to catch up on assignments). A pre-course preparatory period of about 2 weeks is also offered, which orients participants to the course and acts as an ice-breaker, allowing participants and facilitators to get to know one another—establishing important social engagement and commitment.

The course units are mapped to the competency framework for education and training providers. Some competencies are addressed by more than one unit. Like all competency-based training, course completion does not suggest that participants are fully competent after training, but that they have been offered practice and feedback on applying the underlying skills and that they now have the required background knowledge.

5.3   Engagement strategies

Such a long online course requires careful design to maintain the engagement of participants. While many are concerned that distance learning inevitably leads to high dropout rates, the WMO Online Course for Trainers has over a 75% completion rate. The majority of the remaining 25% leave the course in the first few weeks, or do not start at all. While no thorough analysis has been conducted to determine the primary reasons for leaving or not starting, the large number who go missing in action before or during the first weeks indicates that the format is unexpected by some of those who register. Even though clearly described in announcements, some may be curious to see what the course looks like before they decide that they prefer not to learn online at the time. After the first 2 weeks, the percentage of participants who do not complete the course is very small, less than 10%, often due to conflicts with work assignments. However, this 10% of applicants gained from their partial participation in the course nonetheless, and no investment was lost in the offering.

How does the course keep an average of 37 participants engaged without once meeting in person? It takes a number of factors working together.

5.4   Relevance

Engagement begins by offering relevant content and learning activities. Learners need to value what they are learning and know that it can make an impact on their work performance. From the start of the course, we introduce the WMO Competency Requirements for Education and Training Providers, and learners self-assess their current level of competence. This stimulates their curiosity and expectation for reward.

Materials are also designed at the right level for those new to the study of training as a discipline. While many complex topics are taught, such as needs assessment processes, learning assessment and the design of practical learning activities, the writing and discussion are kept to a level and length that avoid overwhelming learners with too much jargon and information.

In addition, much of the content is provided in the form of worksheets and other take-aways that can be used later on the job. In other words, some content is embedded in tools for application.

5.5   Project-based learning

The activity that has most relevance is the creation of a Training Development Plan (TDP), based on a template provided at the start of the course. In fact, this assignment is the glue that ties the course together (see Figure 5.1). While many will never have planned training in the method taught, all will have had to make similar training decisions.

For the TDP, participants are asked to choose a training project in which they have been or are currently involved or one they need to accomplish in the near future. The result could potentially be a valuable product, leading to a new or improved course design.

The TDP is developed incrementally starting from the first week and is based on content and skills learned in each unit. Feedback is also provided incrementally by coaches, allowing improvements throughout.

The TDP must be submitted first for feedback on the nature of the project, audience and goals. Then reviewed by coaches at least 3 more times as the other sections are completed. Individualized feedback is provided at each of these development stages. The sections of the plan correspond directly to the WMO Competencies, or subcomponents of these.

Figure 5.1. Pages 1 and 2 of the Training Development Plan template used in 2019

The TDP scope and length make this a major assignment—often 10 to 20 pages. While potentially intimidating, the incremental production and feedback makes it manageable for nearly all participants. To aid understanding of what is expected, examples of TDPs from past projects are provided for guidance, and a grading rubric describing expectations for each section is indicated. While the TDP is challenging, this challenge is one of the most successful engagement strategies. Our belief is that effort that offers meaningful rewards is the first secret of engagement and motivation to follow through on lengthy tasks. The relevance and reward for working on the TDP is shown by the frequent reports that participants adopt the TDP in their job practice after the course, as well as by its adoption for projects in several offices of the WMO Secretariat.

5.6   Additional active learning approaches

The TDP project is just one active learning approach used in the course. Many people think of online learning as downloadable readings and recorded lectures, with only occasional testing and opportunities for questions and answers. While this is not bad in itself, it does not exploit the potential of distance learning for teaching skills and knowledge and sustaining engagement. Nearly any activity that you can use in a classroom can be replicated in some form online.

The WMO Course for Trainers does offer many readings, perhaps too many in some participants' judgement, but just right for many according to course evaluations, which contain few suggestions for shortening the course. Some of the readings are divided into required sections and optional in-depth sections only for those more curious. Many readings include reflection questions that become topics for discussion forums, so the readings are not entirely passive. Readings also frequently include examples to help ground them in practice and may be accompanied by worksheets or templates that can be used to help design instruction during and after the course. Examples include worksheets for designing learning activities, performing an organizational context analysis, and conducting formative assessment.

But many activities require substantial input from participants with only minimal reading. Each of the nine units includes at least one activity in addition to the TDP. Each of these provides an opportunity for feedback to participants on their learning. Below are a few popular examples.

1.   *Think-Do-Feel Table*: This analysis exercise asks trainers to analyse their audience and identify desired learning outcomes by considering what learners think, do and feel now about the topic or job task, and what you would like them to think, do and feel after training.

2.   *Stories of most powerful learning experiences*: At the start of the course, one ice-breaker activity asks each participant to share a powerful personal learning experience—either from a formal learning programme or an informal experience. This helps learners think critically about how we learn best.

3. *Visual presentation redesign*: In a unit on design processes, with one part focused on visual design principles, participants follow guidelines to share the redesign of one of their instructional slide presentations, or a single complex slide from it.

4. *Using an online training simulation*: Using an online simulation tool developed at EUMETSAT, participants are shown a forecast simulation asking them to make a forecast decision after viewing a variety of products and within time limitations.

5. *Sharing evaluation examples*: Participants share and discuss the surveys or other methods they use to gain feedback from participants in their courses.

5.7 Clear design

The 9-unit course naturally contains many resources and activities, and its clear organization is critical. Moodle, the popular open-source virtual learning environment used to offer the course, allows the units to be displayed one at a time, as well as providing an overview of the entire course on the home page. Clicking on a unit from the home page reveals all resources and requirements for that unit/week. This tidy structure aids learners in their weekly planning.

Each unit is designed to be completed in approximately 6-8 hours over one week, and contains no more than 6-7 readings and activities, in addition to course project work. To clarify requirements, a unit introduction is made via forum post or online video each week. This introduction shows the links between what is being learned from week to week and provides clear guidance on the unit requirements.

While many varied activities are conducted, each unit has the same basic structure to avoid confusion. A new student might take a week or two to feel comfortable, so during the Pre-course period we also provide a Course Orientation (the goals, learning outcomes and encouragement), an Assessment Guide (explaining how grades and completion will be awarded), a Guide to Learning Online (for those who might be new to the demands of self-regulation in an online course), and a Study Calendar, which shows the expectations for each unit in terms of independent readings, collaborative activities and items required for assessment.

The Moodle environment offers the option for completion tracking so that learners have a visual indicator of their progress within a unit. A check box appears to the right of all required readings and activities, and completion is automatically checked based on conditions set by the course instructors. Completion might require downloading a reading, submitting a response to a discussion forum, or completing a quiz or other exercise. Past participants have shared that the check marks that appear as they progress can be rewarding and motivating (see Figure 5.2).

The regular, but not boringly repetitive, structure helps to establish a pace with which most students become comfortable, which is critical for maintaining engagement.

Finally, module summaries are offered at three points in the course to help learners reflect on the general structure and feel a growing sense of achievement by being reminded what they have accomplished.

Figure 5.2. A portion of Unit 2 contents in the 2019 Online Course for Trainers

5.8   Recognition of incremental achievement

As described above, the regular structure provides a rhythm for learners to work within. So even with significant time requirements and potentially unfamiliar content to grapple with, learners can form regular habits that make the course more manageable. One key element to this rhythm is regular recognition of achievement.

In addition to the check boxes for completion, each unit offers a final quiz. The quizzes are not difficult, and so are not a critical assessment element, but they demand that learners attend to all the course content. However, quizzes can be retaken until a passing score is achieved, which motivates the learner to review content they missed or did not understand. Completion of the Unit Quiz and having all required check boxes completed for those required items earns the learner a digital badge for the unit (Figure 5.3). A badge can be earned for each unit and this, although less than a course completion certificate, is an important award.

Figure 5.3. An example of unit open badge

The Open Badge initiative[9] promotes the use of "micro-certification", a new trend in life-long learning for continuing professional development. Open, digital badges provide a more rigorous and definitive designation of accomplishment of continued learning than many standard certificates. They can be collected across many learning opportunities and stored in a personal "backpack", which helps to provide managers and future employers with evidence of skill development, including metadata that can offer a transcript of what was learned and accomplished. Open badges are also a form of "gamification" of learning. Gamification is the use of motivational methods similar to those employed in entertainment games, but within non-gaming environments, such as incremental achievements (like "power ups" or "beating levels or bosses" within a long, complex computer game).

5.9   Regular communication and feedback

Online study can be lonely, especially for sociable people. The course audience (all of whom are trainers) is quite often highly sociable. Overcoming this potential downside of distance learning is critical to sustaining engagement. This requires regular and open communication. If communication is too limited or too formal, distance is magnified. To bridge the "transactional distance" (see Babb and Seman in this publication), communication must be plentiful, welcoming, stimulating and helpful, as well as balanced and respectful of time constraints.

The WMO Online Course for Trainers begins its Guide to Learning Online with a description of the characteristics of productive and respectful communications within course discussion forums, the principal means of communication during the course. From the beginning, principles of good online communication are taught, demonstrated and practiced. Very early on in the course, it is clear that most participants have become quite comfortable with the discussion forums, and each week there can be hundreds of posts and responses in the unit forums. Over the duration of the entire course, Moodle statistics will show nearly 10 000 interactions of various sorts. It is clear from the high level of conversation that takes place that course participants (and facilitators) feel rewarded by the opportunity to interact with peers from other institutions and countries with similar professional responsibilities.

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[9] https://openbadges.org/

Forums are set up to generate emails to participants in each post. Because this can be overwhelming for some people, there is an option to receive a daily digest of posts in a single email, or to turn off emails and just read the forum posts when visiting the course website. To keep the discussions from becoming confusing, separate forums are used for general, logistical questions about the course (grading, schedules, etc.) and topic-oriented forums for each unit. In addition, some activities are run as separate forums with their own rules and structures. For example, the Facilitator's Gym is a specialized forum in which participants suggest solutions to problematic behaviour of students they might encounter in their courses (Figure 5.4). Each person reads a scenario of a problematic situation and then offers a solution that a teacher can take. Only after submitting a solution can a course participant see the solutions offered by the other participants. This activity gains a high level of input given its placement at the end of a lengthy course.

Figure 5.4. A scenario for discussion in the Facilitator's Gym

The most important form of communication is feedback on performance in learning assignments. Without this critical communication, learning is diminished. The key to regular and timely feedback in a course this size is, of course, having a sufficient number of good facilitators. Luckily, we have had a regular pool of volunteer facilitators with a high level of expertise that they enjoy sharing with others. Because of the high number of participants and our emphasis on responding to forum posts within 24 hours, the course has at times had as many as 20 active facilitators. If it were only for forums, this number is actually higher than necessary, but because the course project (the TDP already described) requires careful review and feedback, the high number of facilitators is particularly important, especially without a fully dedicated instructor. We have developed a Guide for Facilitators (available before the course) which helps them prepare for the challenge of teaching online and providing good feedback and support. Other forms of guidance for facilitators are provided, such as grading rubrics for participants' assignments.

5.10   Additional outcomes

In the process of repeated offerings, a community of practice of trainers in WMO disciplines has formed. Some stay in contact for other forms of interaction. Many course participants

have been supported to attend the International Conference on Computer-aided Learning and Distance Learning in Meteorology (CALMet), where they interact with other trainers on more advanced topics. This introduces them to CALMet, an active community of practice for trainers in meteorology and related disciplines.

This community includes, of course, the facilitators as well. Up to half of the volunteer facilitators helping with forums and coaching on course projects are past participants in the course. Becoming a facilitator in subsequent courses helps them to expand their knowledge and skills as trainers and allows them to offer services to the international community. The course always feels new to them—new participants bring new questions and ideas, new facilitators bring new viewpoints and offer new answers to questions based on their varied experience. In many ways, the course, with the social venue it offers to trainers, is a catalyst for the expansion of the profession. This further demonstrates the lasting engagement that emerges during the course.

Finally, a highly valuable outcome of the WMO Online Course for Trainers is the WMO Trainer Resources Portal.[10] All resources, worksheets, templates and examples used in the course are now gathered together in one open website for anyone to access. We hope to use this portal in numerous ways in the future: as support for a massive open online course (MOOC) or a resource pool for a community of practice, linked to CALMet and other trainer communities, such as the European Meteorological Computer-assisted Learning (Eumetcal) Programme; or as a repository of resources for capacity-development projects in developing countries that need to set up their own training programmes. The WMO Trainer Resources Portal has the potential to contribute to all of these.

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[10] https://etrp.wmo.int/course/view.php?id=30

6. Meteorological Service of Canada/COMET Blended Winter Weather Course

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Abstract

The blended-learning format is an innovative and ideal training solution combining the virtues of an in-person workshop with online instruction. In our course format, a student could take either the online-only version or the combined online and residential course. Because of the online-only option, this training course can reach more students than its residency-only equivalent while limiting travel costs. While this approach has been around for a number of years, it is a relatively new concept at the Meteorological Service of Canada (MSC) that is gaining popularity.

In the fall of 2018, MSC and the COMET Programme jointly offered the first iteration of the Blended Winter Weather Course (BWWC). The 2018 BWWC was an overall success based on the results from the pre- and post-course tests along with the course surveys.

This chapter examines the success of the offering and the lessons learned, and hopes to inspire other National Hydrological and Meteorological Services (NHMS) and training institutions to explore and adopt this format because of its effectiveness and benefits.

6.1 Background

The MSC/COMET Winter Weather Course (WWC) had been offered on an annual basis since 2000 in a residency-only format. Participants included operational meteorologists from Asia, Africa, Europe and North America. The course offered a unique, operationally oriented learning experience, giving participants the opportunity to practice advanced meteorological concepts in the context of winter weather scenarios.

In 2018, the WWC was changed to a blended format. The new online component spanned a period of seven weeks followed by a one-week residency portion. While financial pressure on travel was one of the main motivators for change, there were at least two benefits for the participants. Firstly, the inclusion of the online segment made it possible to expand the reach of the course by inviting more international students. Secondly, reduction of in-person time to only one week shortened the time attendees would be away from their families and workplace.

It was of paramount importance to the training organizers that the quality of training should not be adversely affected by this change to a blended format. Therefore, different strategies were used to ensure the best training: a large-scale needs assessment, multi-faceted online instruction, and application-based in-person lab sessions.

This particular blended approach was unique to MSC in several ways. While the blended format became increasingly popular at MSC in the last couple of years, and included prerequisite online lessons and in-person train-the-trainer workshops, the BWWC went beyond a mixture of different delivery methods, which will be discussed in the blended format section below. The combination of instructional design expertise from COMET along

with operational experience from MSC also led to an optimal learning environment for the participants.

6.2   Needs assessment

6.2.1 Survey population

In order to ensure that the new format would suit the target audience, a thorough needs assessment was performed to pinpoint key training gaps at MSC and other NHMSs. Survey respondents consisted of forecasters, training leads, operations managers, and client services personnel in hydrometeorological agencies, including 68 MSC respondents and 52 international respondents. To further explore and validate the results, we held a series of focus group discussions.

6.2.2 Main survey findings

The key findings from the survey helped guide the overarching learning objective of the BWWC. The main gap was knowing how to add value to numerical weather prediction (NWP) output through better understanding of NWP. This learning objective aligned with the World Meteorological Organization (WMO) Public Weather Service (PWS) competencies (see *Compendium of WMO Competency Frameworks* (WMO-No. 1209)), ensuring that the participants received training that met WMO standards.

6.3   Blended format

After determining the overarching learning objective of the BWWC, we developed the schedule and training activities to match this goal. There were four main parts to the course schedule:

1.   Online prerequisite readings

2.   Online course with video lessons, webinars and assignments

3.   Residential course

4.   Post-course activities

The blended BWWC included a mix of online and residency components, along with the flipped classroom approach for the different components. Students did not watch lectures during the synchronous webinars since this would not be an optimal use of synchronous time. Instead, short videos were viewed by the students to gain the necessary understanding of the content. Then participants brought questions from the videos to the synchronous webinars, similar to the use of office hours offered in universities. This allowed for open discussions amongst members of the group to bring everyone up to the same level. It also enriched their experience through learning as a community and built their confidence by showing that others had similar questions. Finally, assignments were completed after the webinars to apply the acquired knowledge. This process was then repeated for each online session.

Participants had a choice of completing the online-only course or continue by attending the residential course and post-course as well. Those who completed the online-only portion received the online completion certificate, while the students who completed the full course received the full completion certificate.

6.4   Course webpage

The course webpage was the main interface for registered students to access the material. The course webpage housed all the prerequisite lessons, recorded lectures and PowerPoint slides, information for synchronous sessions and recordings, pre- and post-course tests, assignments (handouts as well as submissions), and the class discussion board (Figure 6.1). The webpage provided a one-stop shop, and participants could even visit this page for reference after the course ended.
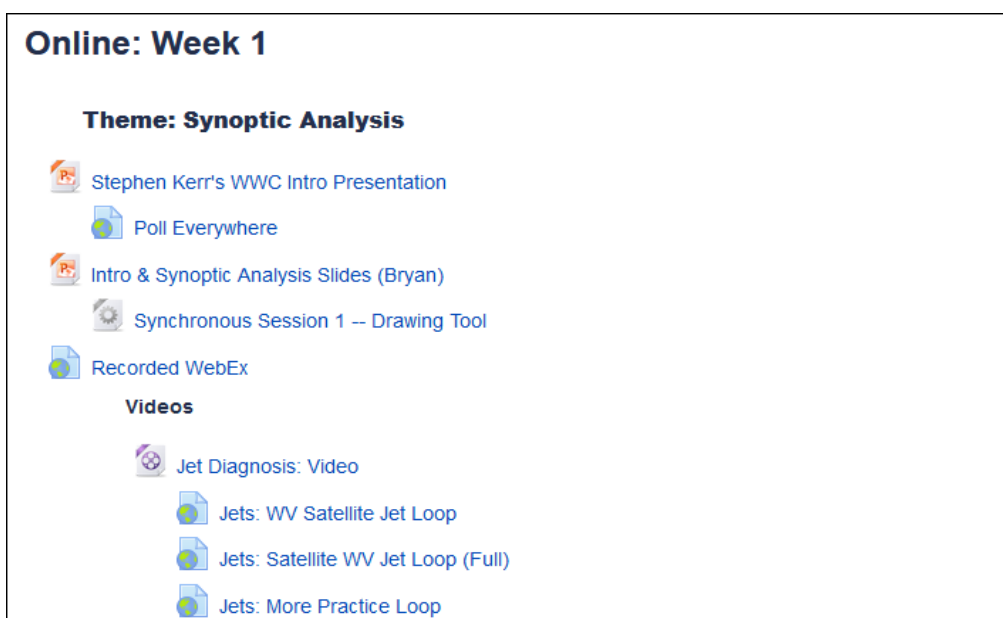
Figure 6.1. Screenshot of the course webpage

6.5   Online prerequisite readings

We assigned a number of relevant COMET self-directed online lessons as prerequisite readings to ensure that the students had the correct level of background knowledge to fully participate in and benefit from the course. Most of these lessons were highly interactive and contained quizzes to help students remain engaged and check their understanding.

The estimated completion time for the prerequisite lessons was communicated to the students in advance so that they could plan accordingly. There was no set schedule for completion; the only requirement was that prerequisite lessons be completed before the first webinar. Furthermore, participants took a pre-course test shortly before starting the online course.

6.6   Online course with video lessons, webinars and assignments

The online component of the course consisted of a series of five synchronous webinars conducted over the course of five weeks (Figure 6.2). Prior to attending a webinar, students watched short video lessons to learn the topic. The webinars were approximately two hours long and consisted of a short presentation by an instructor, a hands-on analysis, followed by discussions related to the video lessons, assignments or other related topics. To engage the audience, online polls, open discussions, web interactions (e.g., drawing on satellite imagery in a web interface) and live demonstrations over the webcam were used. The content built from one webinar to the next and the difficulty increased as students progressed through the online course. The webinars were recorded and posted on the course webpage for participants unable to attend live or those who wished to consult it later.

Depending on the content, the assignments could be analysis and diagnosis of weather charts or imagery, forum posts or short essays. Participants were encouraged to read posts from other students and give feedback to others as a way of learning together.

	Week 1 (Sept 9 - 15)	Week 2 (Sept 16-22)	Week 3 (Sept 23-29)	Week 4 (Sept 30 - Oct 6)	Week 5 (Oct 7 - 13)
Synchro Session	Kick-off & Synoptic Analysis	Mesoscale Analysis	NWP: How to Effectively Use DPS and EPS	Adding Value to NWP at Synoptic Scale: WV/PV Analysis and Modification	Adding Value to NWP at the Mesoscale/Local Scale
Work:	**Videos**: Vort Max, Vort Min, Jets **Assignments**: WV Analysis: Conveyor Belts, Vort Maxs and Mins, and Jetstreaks	**Videos**: Def Zones, Frontal Types **Assignments**: WV Analysis: Def Zones, Frontal Types, Surface Analysis: Fronts	**Videos**: Models Resolution and Scales of Motion **Discussion Posts**: Your model information and uses, Using DPS and EPS data differently. **Assignments**: Identify appropriate model usage ranges (DPS and EPS), Which types of models would need to be used for "X" phenomenon.	**Videos**: PV Intro, Example PV/WV Comparison, Modifying NWP PV, Modifying Surface NWP Fields, Modifying NWP Total Column Fields **Assignments**: NWP/Obs Mismatches: PV, Total Column, and Surface Fields	**Videos**: Impacts of SLR, Impacts of Post-processing **Discussion Posts**: List three situations where NWP was limited by parameterizations, Discuss a local feature that isn't resolved, and how to resolve it better **Assignments**: Change log for a forecast shift

Figure 6.2. Schedule for online component

Flexibility was built into the webinars to allow for opportunities to revisit concepts that required further clarification or additional practice. Furthermore, the level of detail and difficulty of the topics covered were adjusted in real time on the basis of student feedback.

6.7   Residential course

As noted before, a subset of the course participants attended the residential course. This group was determined when participants were registered, on the basis of their profiles (e.g. operations or research, frequency of winter weather experienced at their location), their preferences, and availability of seats. The main purpose of the residency component was to practice their new skills by working through cases, live weather analyses and small group discussions (Figures 6.3 and 6.4).

Times \ Days	Day 1	Day 2	Day 3	Day 4	Day 5
Morning	Course Intro **In-class Discussion:** Forecasting with NWP	Synoptic Scale NWP/Obs Mismatch Lab	Synoptic Scale NWP/Obs Mismatch Lab	Synoptic Scale/Mesoscale NWP/Obs Mismatch Lab	**In-class Discussion:** What is necessary to learn about NWP to get better at adding value to NWP.
Afternoon	**In-class Discussion:** Adding value to NWP forecasts	Feedback & Verification	**In-class Discussion:** how do you determine the most plausible outcome in conflict situations?	Feedback & Verification	**In-class Discussion:** What information do you need when a model changes? Course Summary

Figure 6.3. Residential course schedule

Figure 6.4. Lab exercise at the residential course

While the comprehensive online component of the course enhanced uptake of the material, the in-person aspect of the residency segment had many additional benefits and provided an opportunity for the students to increase their mastery of the content. These advantages included leveraging the face-to-face time for hands-on exercises and in-depth discussions with experts and fellow students (Figure 6.5), reducing communication barriers and building a sense of community amongst the participants through extracurricular activities after class.

Figure 6.5. Small group discussion amongst residency students

6.8   Post-course activities

The components leading up to and including the residential course represented the bulk of the training. However, the post-course segment provided an opportunity to assess the effectiveness of training through post-course tests.

6.9   Course surveys

Gathering feedback both during and after the course helped improve the current offering and those planned to follow. Short online surveys were given at the end of each activity, both online and residential, so that facilitators could adjust the content in real time. In order to assess the satisfaction of the entire course, the focus was placed on the overall course surveys, and only a subset of the survey results is shown in Table 1 below.

Table 1. Course survey results. Blue indicates the online portion and orange the residency segment

Effectiveness	Online-only (out of 4) Total responses = 9	Residency group (out of 4) Total responses = 12
Online component	2.22	2.17
Webinars	2.33	2.5

Short video lessons	**3.56**	**3**
Graded assignments	2.67	2.33
Course technologies	2.89	3.08
Residency component	N/A	2.58
Labs	N/A	2.33
Discussions	N/A	**3.17**

The data indicated the perceived effectiveness of the various online and residency components of the course. The results were quite similar between the online-only and residency groups. The most effective online elements were the short video lessons. Meanwhile, discussion was the most effective element in the residential course.

On the basis of verbal feedback and survey comments, the short videos were considered effective because the instructor could describe the phenomena verbally and elaborate through drawings. These resources contained bite-size information, and the recorded video format allowed participants to rewind and watch the content until it was understood. As a result, a number of these videos were packaged into standalone COMET lessons to benefit others beyond the BWWC, as seen in the Modifying NWP Output Course and the Frontal Diagnosis Course.

Discussions were likely considered effective because students could hear different perspectives from other participants and identify common challenges in the group.

Regarding rated usefulness of the various topics, the results are listed in Table 2 below, from most to least useful.

Table 2. Most useful course topics

Topic	Online-only (out of 4) Total responses = 9	Residency group (out of 4) Total responses = 12
Synoptic scale weather analysis	**3.67**	**3.33**

Mesoscale weather analysis	**3.67**	3.25
Effective usage of ensemble products	3.33	3.08
Adding value to NWP at synoptic scale	3.22	3.17
Adding value to NWP at meso/local scales	3.22	3.17

The online and residency groups had very similar results. They felt synoptic scale weather analysis to be the most useful topic for them as forecasters, followed by mesoscale weather analysis. The three topics on NWP trailed the first two by a close margin.

6.10   Lessons learned and improvements

The comparison of pre- and post-course test scores along with course surveys served as a basis for determining whether the objectives of the course were met. Overall, they were met quite well. There were also a number of improvements suggested to make future iterations of the BWWC even more successful, especially because this was the first blended format of the long-standing residential course.

One way to improve the online portion of the course was to evaluate the webinar schedule. Eight out of 21 participants indicated that a webinar once a week for five consecutive weeks was not conducive to their operational shift schedules. At the recently completed 2019 course, a more compact schedule was used. Webinars were held over two weeks, with the first two on the Monday and Tuesday of the first week, followed by three sessions on Wednesday to Friday of the second week. While the participants of the 2019 course did not have issues with the more compressed schedule, some commented that they did not have sufficient time to complete the course work between each webinar.

Other minor adjustments were implemented to ensure that assignments and lab exercises fitted with the synchronous webinars regardless of whether the webinar took place at the start or end of the day for the student. In the 2018 course, some participants benefitted by attending the webinar prior to completing the videos, whereas others did not. This problem arose because of the synchronous nature of the webinars and the fact that students were in different time zones, as the online component included attendees from around the world. Additional synchronous webinars were considered because some time slots may work for participants from Western Europe and North America, but not for those in Asia. Ultimately, webinars were not conducted in 2019 because the recordings were sufficient.

In the 2018 course, students had the freedom to complete the prerequisites in their own time. While this was good in theory, some participants ended up using a lot more time to complete the prerequisite readings than others. For the 2019 course, they still had the same option, but a completion guide of the prerequisites was shared so that time could be spent more effectively. All of the readings and assignments were posted earlier as well so that the students could better plan their time to complete the online portion.

Another challenge was the limited amount of case-study practice received by online-only participants. While those attending the residency portion benefited from additional hands-on practice through labs and live weather discussions, the online-only students did not. To address this in the 2019 course, a full case along with more application exercises were incorporated into the online sessions. Furthermore, online-only students were offered two extra webinars after the main online component for additional practice. The participants of the 2019 course welcomed these changes.

6.11   Conclusion

The 2018 MSC/COMET Blended Winter Weather Course was an overall success. The results from the pre- and post-course tests along with the course surveys supported this finding. While the course was a success, a number of improvements were proposed and most of them have been implemented in the 2019 course.

Transitioning to a blended approach is an important first step in adapting the course to meet new challenges, financial or pedagogical. While the fully residential format has been fruitful for nearly two decades, the benefits of online and in-person instruction can be exploited and leveraged to optimize the learning experience for the participants. Moving forward, the course will evolve on the basis of student feedback and the needs of the participating organizations to ensure that the course remains relevant and provides a rich learning experience for all.

7. Implementing blended learning at the Regional Training Centre in Peru

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Abstract

In 2011, a Regional Training Centre (RTC) of the World Meteorological Organization (WMO) was established in Peru with the aim of strengthening the capacities of professionals in meteorology and climatology in the Andean region. La Molina National Agrarian University and the Peruvian National Meteorological and Hydrological Service (SENAMHI) took on the role of RTC, which requires that the training it provides reaches beyond the borders of Peru and addresses the training needs of the wider geographic region.

This chapter presents the steps that were taken to establish blended learning at the RTC in Peru. We illustrate these steps by means of the training course on Seasonal Climate Forecasting held in a blended format at the RTC. The great number of participants from countries other than Peru and the high evaluation by the participants demonstrate the great success of that course, similar to other blended courses developed in a similar way. In addition, we present some lessons learned, such as the importance of well-allocated resources (both for participants and trainers), the importance of fostering communication in online training, and technical issues.

Keywords: Blended training, capacity development, lessons learned, Regional Training Centre, e-learning, meteorology, climate services

7.1 Introduction

Today more than ever, society demands that National Meteorological and Hydrological Services (NMHSs) provide high-quality meteorological, hydrological, climatological and agrometeorological information and services. In order to meet these requirements, the professionals working at the NMHSs need to be prepared and strengthen their capacities. With the aim of providing training for the Andean region, a Regional Training Centre (RTC) of the World Meteorological Organization (WMO) was established in Peru in 2011. The RTC was first hosted by the La Molina National Agrarian University (UNALM) in Lima, which received support from the Peruvian National Meteorological and Hydrological Service (SENAMHI). While the University generally focuses on the formal education of meteorologists, SENAMHI concentrates on developing the skills of professionals through advanced training.

The training provided by an RTC must reach beyond the host country's borders and address the training needs of the wider geographic region. Therefore, the RTC first envisaged training solutions such as the development and use of e-learning resources. However,

experts in the field suggest the adoption of blended training solutions (Reinmann-Rothmeier, 2003, S. 29 f.; Reimer, 2004; Graham, 2006; Güzer and Caner, 2014; Salinas et al., 2018). Blended training uses in-person training and e-learning, with the advantages of both training types. Advantages of online training such as flexibility and independence of time, place and person (Baumgartner et al., 2002, p. 15) can be combined with the advantages of classroom training, which predominantly relate to the social aspect (Sauter et al., 2002) and its effect on the participants' motivation. Face-to-face courses help participants to share their experience and their particular cases, and facilitate integration into a classroom group by offering individuals an opportunity to contribute their unique geographical and national realities. Blended training is nowadays promoted by many institutions, such as universities, as well as by the Education and Training Program (ETRP) of WMO.

7.2   Developing a strategy to implement online training and blended learning

In 2014, the RTC in Peru had already access to tailored e-learning training material. An example is the course on basic climatology (Brönnimann et al., 2015) developed by the University of Bern in the first phase of Climandes, a project of the Swiss Agency for Development and Cooperation (SDC), which evolved under the umbrella of the Global Framework for Climate Services (GFCS). However, several constraints at the RTC-Peru limited the first attempts to include e-learning material in the training provided by the RTC. Such constraints included language issues (e-learning training material is often in English); lack of human resources resulting, for instance, in lack of administrative personnel at the computing centres of the National Agrarian University La Molina (UNALM); personnel lacking experience in the use of e-learning training material as a resource; inadequate internal dissemination of the available material; as well as the fact that e-learning training is not formally accepted at UNALM.

To overcome some of these constraints and foster appropriate use of e-learning training, a blended workshop to develop a strategy on the use of e-learning for the RTC-Peru was conducted in the second phase of the Climandes project. Owing to the limited human resources at the University, the RTC-Peru was mainly represented through SENAMHI and not through its academic host at that time. Hence, the results presented in this chapter describe mostly efforts done at the SENAMHI weather service.

The workshop group identified the specific needs with regard to e-learning training. At SENAMHI, these needs encompass the reduction of training costs, simple accessibility of training material, its massive dissemination, and the flexibility to attend training during working hours. Further, SENAMHI has a clear goal: to increase knowledge and the capacity of its personnel at headquarters and in the decentralized offices, as well as of representatives of local governments and other stakeholders. After the identification of needs, the workshop group defined practical milestones such as the installation of a Moodle platform at the institution and the offering of the first blended training courses. Moodle as a learning management system was chosen since it is most widely used worldwide, it is free of charge, and has a large user community. Furthermore, the fact that WMO ETRP uses Moodle allowed for technical support by ETRP experts and facilitated the exchange of material.

7.3   Implementing the first blended training courses

In the Peruvian Andes, a demand study based on interviews with local farmers performed in 2015 revealed the need for improved climate forecasts at the seasonal scale. Efforts in the second phase of the Climandes project thus focused on improving the seasonal forecasts issued by SENAMHI, the training of professionals in the field, and communication to end users.

The initial idea for a "Seasonal Climate Forecasting" course arose from the need to strengthen the capacities of professionals of SENAMHI and several other NMHSs in the region with regard to seasonal climate forecasting, its uncertainties and verification, as well as its communication to end users. The idea was further inspired by courses (for example, TOP, 2017) held regularly at the RTC in Italy at the Institute of Biometeorology (IBIMET). The conceptual framework of the course, "Seasonal Climate Forecasts," was developed in the form of a training development plan within the training development course offered by WMO and RTC-Argentina in 2016. On the basis of this framework, the course was run in three modules from 2017 to 2018.

In the first entirely virtual module called Synoptic Climatology of South America, a total of 68 specialists participated, 41% of whom represented NMHSs from Regional Associations III and IV apart from Peru (Argentina, Bolivia (Plurinational State of), Chile, Colombia, Ecuador, Guyana, Paraguay, Uruguay, Venezuela (Bolivarian Republic of); Belize, Costa Rica, Dominican Republic, El Salvador, Guatemala, Mexico and Panama). The second module, Numerical Models and Seasonal Climate Forecasting, consisted of a virtual phase with 68 participants (41%),[11] and an in-person phase with 33 participants (30%). The third module, Practical Applications of Climate Information for Resilient and Sustainable Agriculture, hosted 78 participants in the virtual phase (36%), and 33 participants (30%) in the in-person phase. The instructors belonged to prestigious international institutions (the US National Oceanic and Atmospheric Administration (NOAA), the Centre for Weather Prediction and Climate Studies (CPTEC), the Institute of Biometeorology (IBIMET), MeteoSwiss, MeteoDat, Florida Universities, and AgexTec) and Peruvian national institutions (SENAMHI, Geophysics Institute of Peru (IGP) and an insurance company), representing the diverse climatic realities and expertise of the Latin American and Caribbean Region.

At SENAMHI, the strengthening of capacities in the development of training courses, the support of the institutions' authorities, the financial resources of Climandes, as well as the incorporation of information and communication technology, made it possible to jump from traditional to blended teaching and to incorporate innovative practices. Online presentations and discussions as well as monthly technical exchanges on seasonal forecasts were held for the first time, addressing a large number of participants from the Spanish-speaking community in Regional Associations III and IV. Through the online approach, a large community of scientists from South America and parts of Central America was brought together for regular contact, pursuing the same interests in developing skills with their peers, advisors and experts in the region, thereby strengthening also the institutional capacities of the NMHSs.

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[11] Numbers in brackets indicate percentage of participants coming from NMHSs apart from Peru.

In addition, other blended courses on forecast verification, application of reanalysis datasets for climate services, and use of the R-package ClimIndVis supporting the production of climate information, were conducted under the lead of SENAMHI. In recognition of all these and many other previous training initiatives, SENAMHI was officially designated as the second component of the RTC-Peru in June 2018 by the WMO Executive Council.

7.4   Lessons learned

One year after the installation of the Moodle platform and with the experience of several blended courses, a half-day retrospective workshop revealed a variety of lessons learned. In general, the above-mentioned blended courses disseminated at the regional level (South America, Central America, and the Caribbean) were well received, with participants from almost all Latin American countries. The high representation of countries, especially in the e-learning parts of the courses, underlines the need for training in climatological topics within the Spanish-speaking community in Regional Associations III and IV. In contrast to other studies from developing regions (for example, Tshabalala et al., 2014), no technical or other constraints related to e-learning hindered the participants. Perception issues or problems such as those related to access to computers or computer skills of the participants or lectures did not pose any barriers to the blended learning approach. This might be because meteorology nowadays is a discipline strongly dependent on models and computers, therefore specialists in meteorology and climatology are accustomed to computer technology.

With regard to the specific e-learning training activities, the following were generally well received by the participants: presentations accompanied by explanations with audio; tasks and feedback on tasks; webinars (specialized conferences and talks); monthly briefings with South American NMHSs on seasonal climate forecasts; as well as the abundant reading material.

On the other hand, a variety of e-learning activities needs to be improved. For instance, the interaction between trainers and participants through the forums should be more active. To improve the forums, we suggested developing easy-to-answer entry questions (for example, personal presentation at the beginning of the course), launching more discussion topics during the course, encouraging very active participation of the trainers (such as responding to questions and/or comments from participants within 24h), and making forums mandatory.

Furthermore, we observed that communication about the time required to complete activities should be clear. It would be helpful to provide Permanent Representatives of countries whose NMHSs are participating in the training courses, with clear information about the time required for tasks in the virtual course so that they can have adequate and fair criteria for the allocation of facilities and time to participants during the learning experience. For instance, the abundant reading material in the form of scientific publications was mistakenly understood as mandatory and therefore considered excessive by the participants, underlining the importance of clear communication.

The intended interactions in e-learning sequences presuppose the budgeting of adequate time for trainers as well. We observed that the number of participants in guided online training needs to be limited relative to the number of available trainers. In order to

strengthen the capacities of the trainers in e-learning teaching, it would be beneficial to hold pre-course preparation and regular coordination meetings. Furthermore, ways to compensate trainers for the work they do in the courses should be clarified.

Recommendations were made with regard to technical support for the production of audiovisual material, such as having an in-house video-conferencing system (for example, a plugin to Moodle https://moodle.org/plugins/mod_bigbluebuttonbn) and most importantly having a Moodle back-up server. In addition, other resources in the field of meteorology and climatology, such as the material provided by MetEd (https://www.meted.ucar.edu/index.php) and the COMET programme (http://www.comet.ucar.edu/) will in future be more extensively used for the development of new courses.

7.5   Further recommendations

Future implementation of blended-learning courses that benefit the region requires the support of institutional structures through the creation of an in-house training unit at SENAMHI-Peru. This implies permanent administrative and technical support of SENAMHI Moodle Platform and the availability of professionals who are responsible for the e-learning part of the training, fostering blended courses and giving support to trainers. Moreover, RTC-Peru should develop an official strategy on blended learning.

An important step in implementing blended learning at the RTC would have been its full implementation at UNALM. Challenges such as time constraints and shortage of human resources, however, have so far impeded this. Future steps should include the development and formalization of a strategy for blended learning at UNALM, the recognition of blended learning within the curriculum of the University, and the setting up of monitoring tools to measure the impact of e-learning.

7.6   Links to resources

The Moodle platform of SENAMHI is found at http://campusvirtual.senamhi.gob.pe/. Note that registration is only possible through attendance in a course.

Acknowledgements

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8. Climate change adaptation and disaster risk reduction in agriculture: Lessons learned from an innovative training programme

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Abstract

The content and capacity-building relevance of a training programme on Climate Change Adaptation and Disaster Risk Reduction in Agriculture (PACC-RRC) conducted by the Institute of BioEconomy, a WMO Regional Training Centre (RTC) in Italy, are described and evaluated in this chapter. The training was delivered to staff members of technical services in West African countries. The innovative method adopted for the training consisted of three consecutive phases: a distance learning pre-course (DLC) phase, a classroom course phase, which consisted of a blend of theoretical and practical sessions, and a post-course phase. Each of the three phases presented strengths and weaknesses to be considered when planning future training programmes. Participants found the comprehensive training experience to be an important step towards improving knowledge and skills that would enable them to be more effective in supporting the farming community to reduce the impact and risk of climate change and disasters in agricultural practices in their respective countries. Overall, the three-phase solution was considered very effective by participants, and they made good use of knowledge acquired during DLC and classroom course in their post-course activities. In order to build long-term sustainability of the project results, the learning materials developed within the project will be catalogued, each module classified on the basis of the competency addressed, reorganized and finally made available for further use by different institutions. The reorganization of the resources collected will involve the creation of course packages (for example, the Training and Operational Principles (T.O.P) Seasonal Forecast Course Package) to be shared.

Keywords: Blended learning, learning strategy, training delivery mode, learning solutions, distance learning, Moodle

8.1 Needs addressed with the training programme

This chapter presents and evaluates an innovative approach adopted during the training programme on Climate Change Adaptation and Disaster Risk Reduction in Agriculture (PACC-RRC). The programme was developed to build capacities of national technical services in some African countries to support sustainable development in response to climate change and its associated risks, and to strengthen the Regional network.

With the general objective of reducing the impacts of natural disaster and climate change on the agricultural sector in West Africa, the specific objective of the programme was to improve the capacity of West African governments, through their national technical services, to support government actions in sustainable development and food security, in response to the risks of climate change and natural disasters. In particular, PACC-RRC had the following two expected results:

1. Enhanced technical and scientific knowledge of climate change adaptation (CCA) and disaster risk reduction (DRR) of the technical services' staff of the participating countries.

2. Strengthened Regional network that brings together the community of technical services involved in CCA and DRR for better collaboration and improved technical and scientific cooperation among National Meteorological and Hydrological Services, other technical services and regional and international institutions.

The training objectives of the courses offered during the programme required a multidisciplinary approach. Thus, the training sessions focused on specific topics that were approached from different points of view to create and consolidate a base for the exchange of ideas and multidisciplinary understanding among the different stakeholders.

8.2 The innovative training programme

During the programme, the hosting Institution (Institute of BioEconomy) adopted a new learner-centred and participatory training method. This blended method consisted of three consecutive phases: a distance learning pre-course (DLC) phase, a classroom course phase, which consisted of a blend of theoretical and practical sessions, and a post-course phase.

For the duration of the course, all the materials, as well as a discussion forum and the tests and exercises where made available on a Moodle platform with a layout setting and font styles specifically customized for the project (Figure 8.1).

ABOUT PACC 2018

PACC-RRC TRAINING PROGRAMME
CLIMATE CHANGE ADAPTATION AND
DISASTER RISK REDUCTION IN AGRICULTURE

International Training Course
Climate Change Impacts: Assessment and Communication

Distance Learning Course: 28 May - 22 June 2018
Workshop Florence - Italy: 25 June - 6 July 2018

Welcome to the International Training Course on "Climate Services for Disaster Prevention". This is the thrid course of the Training Program on Climate Change Adaptation and Disaster Risk Reduction in Agriculture (**PACC/RRC**), funded by the Italian Agency for Development Cooperation and realized by the World Meteorological Organization in collaboration with the Regional Training Center in Italy IBIMET-CNR and the AGRHYMET Regional Centre in Niger.

Figure 8.1. First page of the module platform (https://rtc.ibe.cnr.it/course/view.php?id=55**)**

The first phase of the course, the DLC, was fully conducted on the Moodle platform. Figure 8.2 shows the set-up of the DLC. The DLC was divided into a number of consecutive units activated following a specific time schedule, and included quizzes and exercises, and each unit had a forum where trainers answered the questions of trainees. A final test was completed by trainees in order to evaluate their perception of the course.

Figure 8.2. The set-up of the distance learning course (https://rtc.ibe.cnr.it/course/view.php?id=56**)**

The classroom phase allowed the coordinators of the courses to adopt different learning solutions such as direct interaction (Figure 8.3), focus group and plenary discussion, guided exercises and practical learning approaches, such as case studies, which were always extremely effective as they ensured the full participation of all trainees.

Figure 8.3. In a learner-centred approach, students are encouraged to contribute. Discussion is facilitated and guided, and students help each other when difficulties come up.

During the learner-centred practical sessions of the classroom phase, participants had the opportunity to share and discuss their own needs and difficulties, often arising from case studies. As an example, one of the courses included a session focused on communication with lectures, discussions and a practical exercise. During the practical session, the trainees were actively involved in (a) creating a message on the impact of climate change on crop

yields from agroclimatic simulations, designed for different end users (media, decision-makers, general public); and (b) preparing a presentation describing how the message was created. The class was broken into five small groups, and in each of them, in collaboration with trainers and facilitators, learners experienced how to communicate and prepare a message through teamwork (Figure 8.4). Professional networking started among the trainees and their respective institutions during these sessions. This was consolidated during the final conference of the programme.
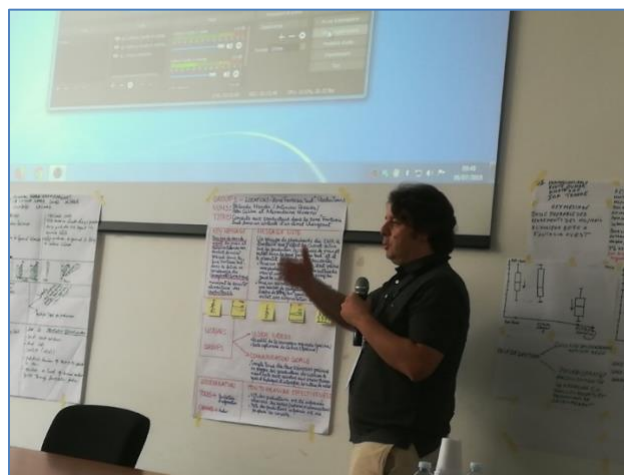
Figure 8.4. Discussion (bottom) about the communication posters (top) produced by the working groups

The third phase consisted of two follow-up activities to be completed by participants when back home. The first was for participants to share the knowledge gained during the course within their home institutions through organized local courses, short seminars or mentoring activities with colleagues. The various means by which participants planned to share their knowledge in their respective countries were rated via a course questionnaire. The top methods they planned to use included organizing a training workshop (11 of 12), delivering a presentation to colleagues (10), sharing training materials from the courses (8) and organizing a structured training initiative in their home institution (6).

Participants were asked to report to the project team and other participants on the follow-up activities they intended to carry out. The other post-course activity was for each participant to prepare a typical conference poster describing the application of the acquired knowledge to a case study in his or her country. As an incentive to complete the activity, posters were evaluated, and authors of the best posters invited to illustrate them during the final conference of the programme (Figure 8.5).

Figure 8.5. Presentation of the post-course activities

The three phases kept participants engaged for a period longer than the usual 1 or 2 weeks, increased their motivation and promoted the sharing of knowledge and experience, which provided fertile ground for the onset of collaboration. The learning process consisted of active involvement of trainees, stimulating their own questions and answers. Learning opportunities were thus created by sharing new information together with analytical methodologies discussed in light of participants' work experiences.

Continuous mentoring was a critical part of the training to ensure long-term impacts of the project. Thus, participants were given some follow-up activities for completion and were asked to report to the project team and to other participants. A typical activity that has significant impact is requesting participants to report on how they shared the acquired knowledge at their home institutions, via local courses or seminars, or by mentoring colleagues.

8.3   Training activity evaluation, its strengths and weaknesses

Participants found the comprehensive training experience to be an important step towards improving knowledge and skills that would enable them be more effective in supporting the farming community to reduce the impact and risk of climate change and disasters in agricultural practices in their countries. Overall, the three-phase solution has been considered very effective by participants, and they made good use of the knowledge acquired during DLC and classroom course in their post-course activities.

Each of the three phases (online, classroom and post-course activities) presented strengths and weaknesses to be considered when planning future training programmes. These are discussed below.

Concerning the online training course (DLC), its success, as highlighted also from past experiences, strongly depends on the technical difficulties that the participants face when they access the online learning environment. In our RTC experience, lack of Internet access in participants' home countries is always an issue that arises when delivering a distance-learning course. Therefore, an insufficiently fast and stable Internet connection is an issue to be taken into account, as it could be one of the reasons why the DLC was not completed by the majority of the participants. In addition, limited access to the platform can prevent wider use of further online training initiatives.

To overcome this challenge, a solution adopted during the training programme was to make the lessons fully downloadable so that they could be used offline. Furthermore, since the philosophy behind the DLC was to bring all the trainees as much as possible to the same entry level of knowledge when starting the classroom phase, some synchronous activities, such as live presentations or webinars, were not included at all, because their success depends on the availability of good Internet connection, which was not readily and equally available to all participants.

Some other solutions to overcome these technical constraints might be investigated in the future, especially because interaction in online discussion forums is one of the main tools for communication among trainees and between learners and facilitators, and also because the completion of the assignments online and live webinars will become important parts of the DLC.

The classroom phase certainly represented the core of the training and, as expected, was the most appreciated by the trainees. This is because during this phase, participants from different countries, but with common learning needs and goals, gathered with teachers who were prepared to help them.

As in previous courses, the learner-centred practice sessions, organized in plenary or in small groups of 3 to 5 participants, were always highly appreciated by the trainees. While the abilities of trainers and facilitators are critical, the success of the classroom sessions depends mostly on the attitude of learners to learning by thinking, understanding and applying new concepts. With respect to the third phase of the training programme, it was not easy for trainers and facilitators to motivate participants to complete the post-course activities, despite their apparent willingness and enthusiasm to complete them, due to many reasons. The main reason given by many participants for not completing this phase was

that once they returned to their countries, they had to resume their job activities, which left them limited time to complete this last phase, which is not their primary assignment.

The completion of the post-course activities is possible only if participants feel fully involved in the programme and if they are strongly supported at home by their supervisors/directors who consider this phase also an important training opportunity for personnel in their own institutions. For example, in the cases presented during the training course (as exemplified in Figure 8.5), the completion of the post-course assignment was only possible if the whole training programme was conceived with the post-course activities in context, and with the support of the Permanent Representatives (PRs) of the involved countries who recognized the importance of training for their staff.

A specific monitoring and evaluation system was put in place in order to assess the efficacy of the whole learning process: participants received a badge for each competency acquired, a certificate of attendance, a badge for completion of post-course activities, and a total score. In addition, participants have been asked to evaluate the course and share their comments.

8.4 Further implementation: The reuse of resources

Training programmes, like the one discussed in this chapter, always offer an opportunity to design and produce high-quality training material, which can be the building blocks of new instructional content—a strategy aimed at increasing its dissemination and usage in other contexts. The idea behind reuse of resources is to switch from course enrolment and completion to competency-based learning, which refers to assessment and grading systems where students demonstrate competency development by completing a course.

In order to build long-term sustainability of the project results, as was recommended during the final conference of the training programme, the learning materials developed within the project will be catalogued, each module classified on the basis of the competency addressed, reorganized and finally made available for further use by different institutions. The reorganization of the resources collected will involve the creation of course packages to be shared. The efficacy of this solution is demonstrated by the development of the Training and Operational Principles (T.O.P) Seasonal Forecast Course Package (Figure 8.6) by the same WMO-RTC with materials derived from previous courses.
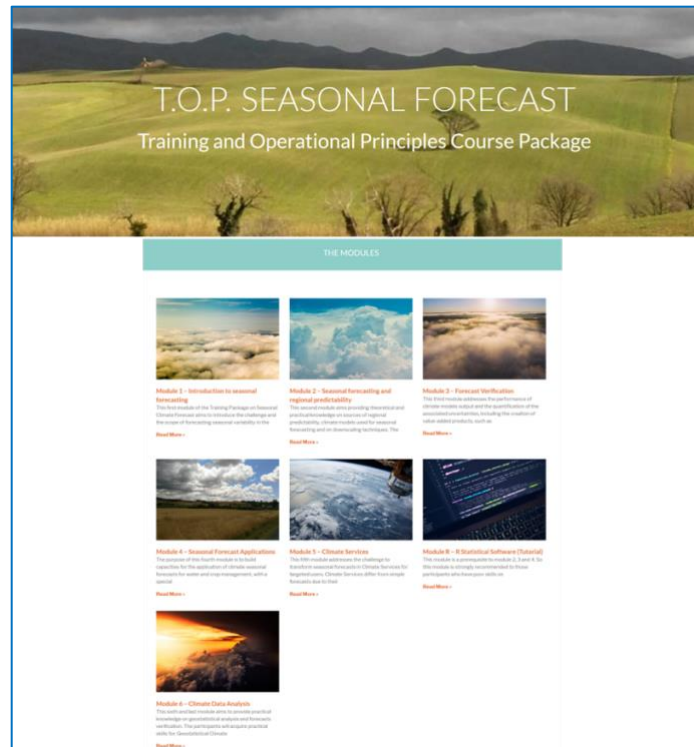
Figure 8.6. The Seasonal Forecast Course Package T.O.P.
(https://training.climateservices.it/rtc-ibimet/t-o-p-seasonal-forecast/**)**

Finally, a customization of the Moodle platform in order to allow competency-based learning will be needed, while more work will be necessary to design an evaluation system for participants enrolled in the online course package, in self-directed format, to utilize an Open Badge System. This will not only contribute to the appreciation of the value of the materials produced, but also to the delivery of courses and learning materials on a longer-term basis and for a wider audience beyond the direct project beneficiaries, thereby extending the impact of the project itself.

Acknowledgements

9. Engaging students in active learning at the *Ecole nationale de la météorologie*

Barbara Bourdelles and the educational team of the National School of Meteorology (Ecole nationale de la météorologie (ENM)), France

Abstract

In recent years, ENM diploma courses have been redesigned using a competency-based approach. This has led training managers and teachers to express learning outcomes in terms of performance. Expressing training content in relation to job tasks and competencies has helped both teachers, in building training sessions, and students, in finding meaning in learning. At the start of their training, students have lectures and labs, but they are put in professional-like positions as soon as possible. Challenges that emerge when engaging students in these active-learning sessions can be of several kinds: the weather situation itself, financial constraints, but also more psychological points. Innovation in pedagogy cannot be imposed on teachers. Active-learning methods are demanding and must be chosen by teachers once they have reflected on their own work. Engaging students means changing their lives and habits too, and it takes time for them to become happy with this new way of learning. Changing to active-learning methods also leads to a change in assessment: using grids with rubrics for more complex activities, while keeping the usual 0-20 scale for knowledge assessment.

Keywords: Active-learning projects, transforming a curriculum, challenges of change, competency-based programme, rubric assessment.

9.1   Background and purpose

The *Ecole nationale de la météorologie* (ENM) is the French school of meteorology, training meteorological technicians and meteorologists. Many of them will work with Météo-France, while others will be employed by private companies or by the French Army.

In recent years, ENM diploma courses have been redesigned using a competency-based approach. There is a strong national and international context to make such a change. For example, the French organization in charge of accrediting schools issuing diplomas asks every training centre to design training based on job skills and training gaps. A survey of future/potential employers revealed that they seek individuals who not only have a high level of knowledge, but who will also become efficient professionals, with a wide range of skills enabling them to adapt to the wide range of activities they may be faced with during their careers. As students stay at ENM over a two- to three-year period, we have time to foster change.

Thinking about training as a means to achieve performance in the workplace led training managers and teachers to express learning outcomes in terms of performance. So, to assess students' performance, the need to have them actively involved became obvious.

Moreover, we wanted students to reflect on their own training process and gain a better understanding of their skills and knowledge. Giving sense to the training they receive has been a means to achieve this goal. Therefore, expressing training content in relation to job tasks and competencies helped both teachers, in building training sessions, and students, in finding meaning in learning.

Engaging students in active learning requires us to think of training in terms of higher levels of cognitive taxonomy. The usual "lecture and labs" delivery mode often leads to low levels, such as remembering or applying, while active sessions reflect verbs such as analysing, reflecting, synthesizing or deciding. Therefore, when we design instruction material starting from job tasks and leading to specific skills and knowledge, we choose one of the higher-level cognitive strategies as a basis for design. The cognitive strategy we choose should fit the objective of the training.

Increasing levels of engagement (from passive to active, constructive, interactive) imply an increasing cognitive load for students. So, when the passive level is enough to achieve the learning objective, for example, remembering a list of codes, there is no reason to go to a higher level. But when it comes to using these codes to describe real-time observed weather, using a more active training design is valuable.

These considerations led us to offer students a wide range of activities during their training time. In this chapter, we are going to focus on a few of them and analyse achieved results and challenges faced.

9.2   Active-learning projects

At the start of their training, students have lectures and labs, of course, but they are put in professional-like positions as soon as possible, be it observing clouds, maintaining a measuring station, coding to create a web application or analysing numerical weather prediction models outputs. They regularly present met briefings in front of other students and teachers. They are assessed on their ability to analyse weather situations, to forecast the next days' weather and also on their communication skills. All of these competencies are expected of a professional meteorologist.

Later in their training, students can be involved in forecasting briefings to real customers. For example, some ENM students take part in a sailing race organized every year by other university students. They themselves race on one of the boats, but they also share with other teams their analysis of the present weather and their forecast for the coming days. They participate in improving race safety and experience direct contact with customers. They also receive direct feedback from these customers and adapt their communication to the context. The students usually come back to school even more engaged, as they have seen how important their work can be.

In the past, ENM students have also had the opportunity to support a team in a hot-air balloon race or a glider race. In these cases, students' understanding of small-scale atmospheric phenomena and their consequences in terms of safety has been improved.

ENM students are also regularly involved in research campaigns.

For example, at the end of their training at ENM, students are involved in an activity combining various aspects of a meteorologist job: during an airborne measurement session, depending on the research data to be collected, they forecast the weather in order to decide whether the plane could fly the next day and which area would be most suitable to get the intended results. Some of the students fly on the research plane, which is equipped with many sensors. Other students stay on the ground, following the weather situation and preparing the next stage: analysing the collected data. To this end, they code useful tools to clean the data, analyse them and produce relevant graphs. On the other hand, they run a short-range non-hydrostatic numerical model for the day of the flight and they later

compare model results and collected data. We can also conduct projects like this using drones instead of a plane, as the Météo-France research centre regularly deploys research drones.

Another example of engaging students in real-life activities is having them go into the field with colleagues during international research campaigns. The students can be involved in various aspects of field work, but their main activity is to produce weather forecasts and deliver briefings to the research teams. As they are in the field, they can observe the weather during the whole day and compare it with their forecast. They also feel first-hand the impact that their work can have on other people.

Teachers can observe students while these activities are performed so that assessment can be done, when needed.

Another example of our active-learning methods is a Moodle forum that we use as a permanent tool to communicate internally on climate and meteorology. About 750 students, teachers and also colleagues all around Météo-France discuss observed weather, study extreme weather cases, compare them to climatology, explain satellite imagery or tricky forecasts, share photographs, or assess the past month's climate, including records. Sometimes we organise game-like quizzes.

9.3   Challenges

Challenges that emerge when engaging students in these active-learning sessions can be of several kinds.

The weather itself can be a source of trouble when it is not as expected. Some activities can be postponed so that weather conditions match with training targets, but when severe weather happens during real research campaigns, it is necessary to adapt the training plan in light of the current hazards.

Sometimes, large groups of students are involved in the activity and it becomes hard for teachers to find a role for every single student or small group of students.

Money can also be an issue, and it is sometimes impossible to organize the intended activities.

Apart from these pragmatic issues, we should also consider some psychological points.

Active-teaching methods do not necessarily require technology. Too often both are promoted together. Of course, technology can be of help in offering customized training to students, but a teacher can make students active with pen and paper.

Innovation in pedagogy cannot be imposed on teachers. The decision to innovate should stem from teachers' own reflection on their professional practice and results. Forcing someone to become "modern" is not effective, as it could lead to applying recipes without thinking. Often, beginner teachers reproduce teaching strategies they experienced as students—mainly lectures and labs. Active-learning methods are demanding and must be chosen by teachers once they have reflected on their own work. These methods require creativity and for teachers to get out of their comfort zones. Starting to implement active-learning methods can be especially difficult, as a teacher needs to change and think from

another perspective. Nevertheless, because these active methods are effective in enhancing students' learning results, they are rewarding for those teachers who engage in changing the way they design their training.

Therefore, one of the challenges we have faced has been resistance to change. Some teachers consider active pedagogy difficult and time-consuming. They think it is not worth the effort, as students' results are not showing great improvement. Others have tried to change their practices, but feel their efforts are not acknowledged enough and they prefer to stay in their comfort zone.

Nevertheless, because we teach to future colleagues in a professional school, most teachers are convinced that engaging students in active learning is useful and rewarding.

Evolution to active-learning methods involves both teachers and students. So, engaging students means changing their life and habits too. Often students have been used to more passive training for years, and becoming active is not easy for them either. They usually appreciate being involved in real work activities such as those described above, but they sometimes feel that being active all the time is tiring and requires much more energy than lectures and labs. Some students even think that working on a topic and explaining it to the rest of the group means doing the teacher's work! It takes time before students realize that teaching others is a very effective way to learn.

For these reasons, the move to active learning at ENM has not been enforced but promoted and helped. The school's board set the goal with a commitment to reducing the number of traditional sessions.

9.4   Assessment and evaluation

Engaging students in active learning has had an impact on the way we assess students. Traditionally, we assessed lectures and labs using time-limited assignments, graded with a numerical scale ranging from 0 to 20. When it comes to more complex activities, using higher levels on the scale of cognitive taxonomy, it is difficult to grade with such a numerical scale. We have begun brainstorming at ENM, in order to change to a different kind of assessment. We could use grids with rubrics for more complex activities, while keeping the usual 0–20 scales for knowledge assessment.

One of the advantages of rubrics is that they make providing feedback to students easier and they help students to improve. A simple number does not pinpoint what is good and what needs to be improved. Using rubrics defines beforehand what is expected from students and describes afterwards the quality of their work.

Our current process for evaluating the training consists of several steps. We first ask students what they think of the training they received. They usually give positive feedback about the activities offered during their initial training at ENM. The students are mostly employed by Météo-France, so they can easily keep in touch with the school. We again ask the students and their managers about their training about 18 months after graduation.

At the moment, it is too early to say whether engaging students in more active training has had a positive effect, for several reasons. First, the change is quite recent; second, even before this change, managers were already happy with their new colleagues' competencies; third, a recent change has occurred in the curriculum of the high school the students

attended before coming to ENM, so students and their background knowledge and behaviour are different.

For all these reasons, it is difficult to compare the performance of students before and after the changes, so we cannot yet conduct a summative evaluation of the training effectiveness. However, we are confident that engaging students in active training is on the right track at ENM, and students and teachers are increasingly engaging to make this change successful.

10. Collaborative learning to engage students and improve learning

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Abstract

Nowadays, many students are not truly interested in their future profession and leave University in the first one to two years. Collaborative learning can help engage students in the education process, but its potential is underused in practice. This chapter presents experiences of implementation of this approach while teaching Basic Hydrology to undergraduate students at the Russian State Hydrometeorological University. It shows how a current course, which includes several assignments and a course project, can be redesigned with the use of active-learning approaches. Solving authentic problems in a near on-the-job environment, including collaboration with others, helps engage students in the educational process and achieve required practical outcomes. The main challenges and benefits of collaborative learning for both students and teachers are described.

Keywords: assignment, active learning, collaboration, collaborative learning, engagement, hydrology education.

10.1   Why collaborative learning?

In recent years, the number of students entering technical Universities, who are truly interested in their future profession, has decreased dramatically. Students at the Russian State Hydrometeorological University (RSHU) are not an exception. Many students do not become deeply engaged in the education process and leave the University in the first two years. Analysis has shown that the situation can be improved both through organizational and pedagogical changes, including implementation of approaches to increase engagement.

One of these is collaborative learning. This is an umbrella term for a variety of educational approaches involving joint intellectual effort by students or students and teachers together (Smith and MacGregor, 1992). It has been shown that through collaborative learning students may learn effectively, but its potential is underused in practice (Johnson et al., 2007), particularly in science education (Nokes-Malach and Richey, 2015). There are several explanations for this. First, due to a wide range of technical resources for individual learning, most trainees are less interested in communicating with their fellow students or teachers. In addition, university teachers are often too busy or do not have the pedagogical knowledge to implement such innovative approaches.

In undergraduate hydrology education, the most effective forms of collaborative learning seem to be project-based learning, working in small groups and solving problems in case studies. The results of these approaches depend on the learning outcomes envisaged, the content taught and the students' individual abilities. It has been found that students in group settings achieved significantly better with respect to conceptual understanding than students in individual settings. In addition to these cognitive benefits, collaborative learning helps develop the social skills needed for future professional work in the field of science (Linton et al., 2014).

My ten-year teaching experience at RSHU lets me conclude that this approach is currently applied only during field practice, when students have to work in groups on real tasks. Most students enjoy these practical sessions very much and consider them the most engaging activities during their studies. This suggests that collaborative learning should be considered more widely during the entire academic process.

10.2   How to implement collaborative learning?

Implementing collaborative learning is rather challenging, since a typical teacher-centred process must be transformed into a learner-centred one. This requires significant shifts and changes at each step of the training process. First, learning outcomes, goals and objectives should be discussed and agreed with students. Teachers themselves are more like assistants of the learning process than the typical transmitters of knowledge. In addition, direct instruction and lecture-style classes are mostly replaced by collaborative activities, discussions and active work with the course material. Technologies make collaborative learning easier and their use should be considered while redesigning existing courses or creating new ones with collaborative learning components.

To achieve effective and reliable results, students will need to become accustomed to collaborative learning. This takes time. Usually, a course lasts a semester or two, which is a constraint if this is the first time a student is engaged in such an approach. A teacher has to redesign the typical teaching plan. Performance benefits have been reported in both lab and classroom tasks when collaboration is supported by carefully prepared and implemented tasks prior to collaboration with peers (Blumen and Rajaram, 2008; Gaudet et al., 2010). These tasks might include flipped-classrooms, focused discussions and other active group activities. Simply telling students to work together collaboratively without preparation does little to support the cooperative behaviour that produces educational benefits (Andrews and Rapp, 2015).

The type of task for collaboration is also important. Researchers report that collaborative work on complex tasks enhances learning more than dealing with simple tasks (Kirschner et al., 2011; Lou et al., 2001). Collaborative learning in higher education should be designed for challenging and relevant tasks that build shared ownership with students (Scager et al., 2016). However, solving complex and authentic tasks takes more time and effort for both students and teachers.

Collaborative learning groupings can be flexible, with group membership varying on the basis of friendship, mixed academic abilities (to allow more capable students to help those less capable) or common interests. Students jointly work each step of the way to meet the goal set: for example, they choose proper calculation methods, get data from new databases or try to use new types of data, learn how to use GIS or other software, or how to present the results obtained. In this way, peer teaching occurs, which engages all in the teaching and learning processes.

Some students do not like working in groups. If so, a combination of individual and joint work is also possible, in which each student is required to contribute, share their individual findings and collaborate to achieve the learning goals successfully.

Students' backgrounds also matter. The less advanced students are, the more difficult it will be to achieve learning outcomes. If a discipline is taught for two semesters, but the first semester was not a complete success, then the existing gaps must be filled during the second semester, which can complicate collaboration strategies.

Knowledge and skills gained during collaborative activities can afterwards be applied in students' individual projects. Peer assessment of such projects could be a proper final joint effort to complete the collaborative learning process. Thus, students work together throughout the course or course series and are likely to become more engaged in learning.

Some best practices for implementing collaborative learning include:

1. Collaborative groups of students should be given every opportunity to solve problems, discuss and think with their peers without being influenced by the teacher.

2. All collaborative learning tasks should be directly related to the course content and to the development of professional competence expected of the course.

3. Student groups should contribute to tasks equally; collaborative learning should not be an opportunity for students to rely on the brightest or most hard-working person in the group to complete the task (Maryland Public Television/Thinkport, 2008).

10.3   Collaborative learning while teaching an undergraduate hydrology course

The Basic Hydrology course at RSHU takes place in the fourth and fifth semesters of the Bachelor programme and includes weekly lectures and practice classes. The course ends with project work and the exam. The number of students in a group is about 15. The Basic Hydrology course is one of the first oriented to a professional discipline that hydrology students experience. That is why delivering this course is considered to be very important. However, the current course content is a bit overwhelming and the best teaching practices are frequently not used. This could be one of the reasons why students often do not perform well at exams. To improve the situation, high-impact learning strategies, including collaborative learning, have been applied.

Five regular practical assignments, which were previously explained in detail and supplied with all the necessary data, were transformed into activities with elements of collaboration, aimed at achieving more authentic learning outcomes and making students more competent and competitive in their future profession. The level of collaboration in each practical activity is different, and it is applied at different stages of the activity, depending on the intended results.

For example, peer-assessment was used after the two first assignments were completed, before they were checked by the teacher. These assignments include creating a lot of graphics, which can be easily checked by peers. From the very beginning, students understand that their products will be checked carefully more than once and that the course is not going to be easy. The next three assignments are merged into one small project. All the students work with the same river, but separately study its water balance, snow-melt processes in its catchment and main hydrological events and their characteristics for

different years. For the third assignment students have to get monthly data from the meteorological and hydrological e-databases. For the fourth assignment they have to get daily and hourly data. Peer teaching by the most capable students helps to get over many of the difficulties and misunderstandings. The extensive theoretical content needed for this work is studied in flipped-classroom mode with the use of the COMET/MetED e-lesson "Snowmelt processes" as homework (The COMET Program, 2011). When students tried to complete the English version of the e-lesson, even though its Russian version was available, they helped each other, resulting in another form of collaborative learning. For successful completion of the fifth assignment, students have to apply new Excel skills and complete it collaboratively. All the practical products form a student's portfolio, which is assessed by peers (in small groups) and a teacher. This approach is more effective if the groups consist of students with different levels of knowledge and understanding. Peer-assessment has been demonstrated to be an effective collaborative learning technique (Kollar and Fischer, 2010, Lu et al, 2018).

Students' experience gained during the first semester is expected to provide a reliable basis for the next semester. The first part of the course is considered to be preparation for the individual project undertaken during the second part of the course. The main collaborative event in the second semester is calculating a lake's water balance. Students are divided into small groups of 2 or3. Each group is required to get parameter data or to explore calculation methods. Then they share results and complete their individual assignments. This year students were especially active and communicated with specialists from the Estonian Weather Service, who provided all the data required. For the students, it was their first international professional collaboration. I expect that this success will increase their interest in hydrology as their future profession.

Such practice of collaborative learning has been applied for three years at different levels and this year to a large extent. As these methods are applied more widely, it is expected that students' learning will improve and that they will become more motivated and better team-players. Their feedback has been quite positive and has even contained advice on how to improve the course in its collaborative dimensions. Interestingly, students who were engaged in collaborative learning performed better at exams in other disciplines as well, not only in hydrology. It has been observed that many students who have been involved in collaborative learning value their sense of achievement and learning processes more than their grades. Some of them plan to continue their projects as Bachelor's thesis.

However, to achieve sustainable results, the faculty needs an agreed upon strategy, which should support wider use of such high-impact approaches, including collaborative learning. This does not require new resources but does require additional time and effort and has been demonstrated to work.

10.4   Challenges and benefits of collaborative learning

Current reviews of collaborative learning highlight that collaboration can impact learning both positively and negatively. Collaborative learning relies on students' active participation, responsibilities and outcomes. Some students are unwilling to do their share of the assigned work or prefer to work alone, and the rest of the group has to cope with this. The grouping process itself and facilitating group work can become challenging. Hall and Buzwell (2012) found that "free riding", or over-relying on other members of the group, was a concern in

collaborative learning across disciplines. In addition, during joint activities students can produce both accurate and inaccurate information, leading to misconceptions, and some students may not understand collaborative exercises clearly.

In spite of the disadvantages, according to the Department of Education and Training, Melbourne (2017), an effect size for collaborative learning varies from of 0.41 to 0.59, which indicates a moderate but reliably positive impact. Studies show that variations in effect size are associated with the content area, students' ages and their cultural backgrounds (Kyndt et al, 2013).

Collaborative learning is socially and intellectually engaging and involves students in the learning process more deeply than traditional methods. Nowadays, most scientific research is interdisciplinary, and papers are written primarily in co-authorship. People work in public places and have to collaborate to achieve successful results. Thus, learning how to collaborate is necessary for students' future.

The table below presents some challenges and benefits of collaborative learning for both students and teachers. The biggest challenge for teachers might be the need to accept changing classroom roles, to reshape the content and to step out of the comfort zone of their traditional methods.

Benefits	*Challenges*
For students	
Involves students in the learning process	Students' readiness and attitude towards collaboration
Enhances learning and improves performance	Lack of prior experience in collaborative learning
Provides support from both teachers and peers	Stepping out of the comfort zone of passive learning or learning independently
Allows more flexible timing	"Free-riding" students, especially at the beginning of collaboration
Increases self-esteem	Individual background not clearly understood
Develops learning communities, social bonds	Improper allocation of roles in a group
Promotes critical thinking skills	Unfair workload while working in a group
For teachers	
Enhances students' learning	Time and effort required to redesign existing courses

Benefits	Challenges
Utilizes a variety of assessments	Lack of confidence in managing group learning
Builds understanding of diversity among students and teachers	Providing additional support throughout learning and after assessment
Develops professional and pedagogical skills	Stepping out of the comfort zone of lecture mode
Develops a near on-the-job environment	Lack of methodological and administrative support at Faculty and University levels

Even though collaborative learning can be implemented successfully, it is necessary to understand that problems with student comprehension and engagement remain rather deep and cannot be dealt with only by changing teaching styles.

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11. Increasing learning retention by using questions after instruction

Tsvetomir Ross-Lazarov and Tony Mancus

Abstract

By asking questions after instruction, trainers can assist learners in recalling and practicing the skills that were part of the instructional event. To accomplish that, trainers need to create after-training booster questions that ask learners to recall, apply and analyse information, and directly address the learning objectives of the training event. Building a functionality for booster questions into online lessons has enabled the COMET Program to support thousands of learners who want to remember more from COMET instructional offerings. In this way, the COMET Program systematically assists learners after they have completed an instructional event, supporting their learning goals and overall retention, and in many cases providing an indication of how the learning is being applied.

Keywords: learning retention, support after instruction, reinforce learning, booster questions, engagement, recall, practice

11.1   Introduction

Learning does not stop at the end of an instructional event. Whether online or in-person, learners need to continue recalling information and practicing the skills from a training session in order to remember them over the long term. Educational psychology research indicates that the process of retrieval and practice, where learners recall and practice new skills from the training they've received, is crucial for the creation and maintenance of new memory networks.

The idea of asking questions after instruction emerged from research by Peter Brown, Henry Roediger and others. By providing questions based on the essential content from a learning experience, learners are given the opportunity to put retrieval and practice to use. As elaborated by Brown et al. (2014):

> "The act of retrieving learning from memory has two profound benefits. One, it tells you what you know and don't know, and therefore where to focus further study…Two, recalling what you have learned causes your brain to reconsolidate the memory, which strengthens its connections to what you already know and makes it easier... to recall in the future… In one study, participants who were asked questions after reading a passage were able to recall 50% more information than participants who simply read the material.… Another experiment found that after one week a study-only group showed the most forgetting of what they initially had been able to recall, forgetting 52 percent, compared to a repeated-testing group, who forgot only 10 percent." (Brown, Roediger, & McDaniel, 2014, p. 19–39)

One of the significant findings is that active retrieval of information strengthens memory. The more effort learners put in retrieving information from memory the larger the benefit (Brown et al., 2014, p. 19). One way to understand these results is to consider the effort learners expend in recalling information and using flight instruments in a flight simulator

versus the effort involved in reviewing slides after a lecture on how to fly a plane. When reviewing slides, the learner reads the information and recalls what the lecturer said about how to use flight instruments. When flying in a simulator, the learner first has to recall the function of each flight instrument and how to use it, then the learner has to put all that knowledge into action and read subtle cues in the instruments or the atmosphere around them in order to adapt to the situations that are developing. Therefore, the questions need to be somewhat challenging and cannot be answered by eliminating implausible answers for example.

11.2   Question types and usage

By asking questions after instruction, trainers can assist learners in recalling and practicing the skills that were part of the instructional event. To accomplish that, trainers need to create questions that ask learners to recall, apply, synthesize and evaluate information and directly address the learning objectives of the training event. While most trainers feel comfortable creating recall questions, many are challenged by creating questions that reach the levels of application, synthesis and evaluation.

In its simplest form, trainers can send questions to learners at set periods after instruction. The first questions can be about recall of factual information presented during instruction. Our memory of a learning event begins to fade as we move away from it in time, and questions about factual information help us recall the knowledge and ideas in the training. As learners may not have the chance to apply their new skills in the days immediately after a training event, these questions can also serve as reminders about ideas that learners can try to implement in their daily work. These questions can be multiple choice or another objective format (for example, multiple select, multiple True/False, ordering questions, etc. See, for example, Figure 11.1).
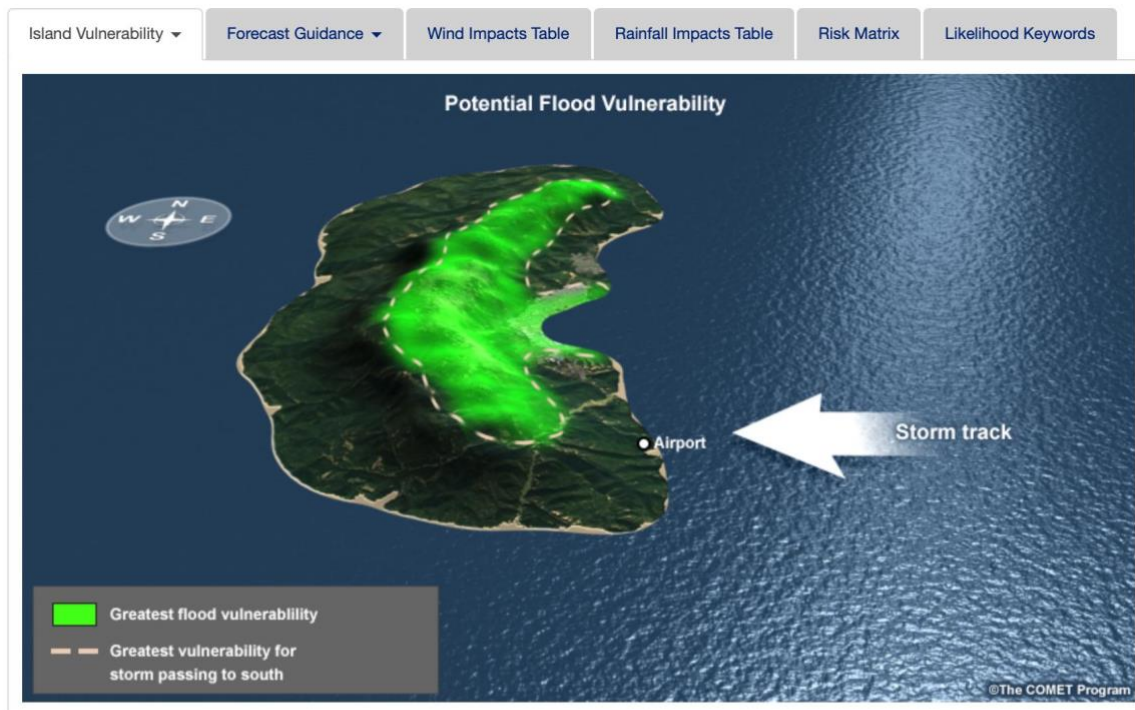
Place the steps of the Impact-based approach to forecast and warning services in the correct order. Use the selection box to choose correct number for each statement.

Use impact tables to determine severity of potential impacts for each hazard

Click here for the list of answers

Create Warning using wording from risk matrices and impact tables

Click here for the list of answers

Review meteorological and hydrological guidance

Click here for the list of answers

Monitor weather event and update Warning appropriately

Click here for the list of answers

Determine if and when hydrometeorological hazards will threaten an area

Click here for the list of answers

Determine likelihood impacts could occur

Click here for the list of answers

Review vulnerability information for location or area

Click here for the list of answers

Create forecast for desired period

Click here for the list of answers

Use risk matrix to determine level of threat posed by each hazard

Click here for the list of answers

Figure 11.1. Example of a question in which learners have to place the steps of impact-based forecast and warning services in the correct order.

As the learners move farther away in time from the training, the provided questions should be focused on the application of the skills gained from instruction. Application questions can be asked at this stage because ideally the learners will have tried to implement some ideas from the instructional event. However, in order to implement this approach, the instruction needs to be designed to contain relevant and applicable training. Application questions should contain scenarios that learners may encounter during their normal activities. As the learners apply effort in recalling and solving these scenario-based questions, they strengthen their memories from the training event and must think more intentionally about ways to use their knowledge.

Figure 11.2 below shows a booster question in which the learner needs to review guidance and then decide on the most appropriate message to share with the affected population.

Figure 11.2. A scenario-based booster question

The final question our learners receive, which will be presented about two months after instruction, is a generative question, asking how the students have used the knowledge and skills. The learners have to generate an answer as opposed to selecting an answer from a list. The learners who share how they have used what they learned in COMET lessons also have the opportunity to see how others have answered the question. In this way, they can get ideas about other ways to use the information from a lesson.

11.3   Learning effectiveness

By providing space for learners to share how they've used what they've learned, we are able to see some of the impacts of our instruction. In one instance, a learner reported using their satellite analysis skills to question an NWP forecast for strong winds over a major US

airport. Instead of following the NWP forecast, the learner trusted their own analysis and did not issue a strong wind warning that would have shut down the airport for half a day. This airport handles cargo traffic of US$ 100 million per day. The learner's forecast was correct, and by not issuing the warning the learner kept the airport operating.

Other learners have reported using their knowledge to implement new safety procedures to protect their colleagues and students from hazardous weather. Below is a small sample of the learner self-reports.

1. "To provide more accurate weather and storm information to the network of individuals and agencies charged with protecting our local and regional community."

2. "These questions have encouraged me to keep current with information and expand my knowledge of the science of weather and how I can better prepare to assist during emergencies and help others stay safe."

3. "I am constantly aware of cloud formations and weather situations in order to be weather ready. I also track local NWS reports and see when spotters may need to be activated. I am ready to send in reports when needed."

4. "I use them every day. This course was very helpful to me to give me a basic background in understanding gravity. The booster questions have been very helpful in keeping my mind on the topic."

5. "I'm a flight instructor in a management/leadership position. Weather principles, along with how to spot and avoid hazardous weather, are key safety "teaching points" that I try to pass on to both students and other instructors."

6. "All of this content let me improve my forecast skill during Mei-Yu season."

7. "Used the information recently on a fire assignment, so knowledge beforehand helped tremendously".

11.4 Implementing booster questions

Implementing booster questions after instruction was a new facet of COMET's existing work processes. The majority of the COMET Program's efforts are focused on creating new content for clients and expanding our coverage of topics. Adding these types of questions after instruction created two challenges.

First, we had to figure out a way to incorporate the creation of these questions into the overall workflow. Our teams are primarily focused on creating error-free scientific content that engages the learners, and implementing after-training questions created an additional step. To overcome this challenge, we developed different versions of an online tool to integrate booster questions into the project flow and gathered feedback from COMET staff about the ease of use of the tool. We also developed the interface which provided sign-up, an introduction to booster questions, and the space to view them.

The second challenge was to fold the creation of questions and use of the new tool into the existing process without adding to the cost of the project. The main goal for the programming team was to make the addition of booster questions quick and easy. To solve the second challenge, the tool that the programming team created has the capability to reuse questions that our project staff have already created for the pre- and post-tests that are associated with the online lessons. Instead of having to write a third set of questions that would require additional review and vetting, our staff was able to utilize questions that they had already created as booster questions. Additionally, using these questions ensured that the after-training follow-up aligned with the learning outcomes, as they were constructed to meet the goals of the existing training.

Some questions may not function well based on assessment statistics. Since this is a known issue, the programming team created the capability for automatic updates of booster questions if project staff have made updates to pre- and post-test questions. Those updates are carried through to the booster questions when they are made, requiring no additional work.

Another task was the creation of a scheduling and tracking mechanism that sends the questions at specific times to users and tracks the time remaining before sending the next one. This required significant programming and testing in order to integrate seamlessly with COMET's existing software infrastructure. The COMET tool sends booster questions to subscribers two days, two weeks, and two months after the instructional event. The first question arrives two days after instruction, followed by two more questions spaced evenly over the next two weeks. At two weeks, the tool sends another set of questions spaced evenly over the next two months. The process is repeated after two months.

Once the tool was created, an instructional designer organized short training events in which COMET staff explored the research behind the creation of booster questions. Two of COMET's instructional staff experimented with adding questions to their lessons. They found that the longest part of the process was identifying and selecting the appropriate type and cognitive level of questions to send at the different time intervals. Over time, all project staff began to include booster questions for their lessons.

The team also had to identify the most appropriate way for learners to obtain the questions, given the constant assault of spam email and the potential frustration learners might encounter if they were automatically enrolled to receive these questions without having chosen to receive them. With this in mind, the team decided to allow learners to subscribe to booster questions on their own rather than forcing them to receive the questions automatically. COMET provides a quick video to encourage learners to subscribe by citing the benefits for long-term recall. And while all learners can benefit from receiving such questions, there are some who may not be very interested in content they had viewed or in some cases were required to view. This measure of learner control has contributed to a self-selected pool of people who actually want to receive the questions.

11.5 Conclusion

At the time of writing, over 6000 users have subscribed to receive booster questions. The vast majority of learners report that the questions have helped them remember more from the instructional event. This one-time development investment has enabled COMET to

support thousands of learners who want to remember more from COMET's instructional events. Building functionality for booster questions into our lessons was a new opportunity for our group to systematically support learners after they had completed an instructional event, thereby extending their engagement with our products, supporting their goals and overall retention, and in many cases providing us with a clear indication of how the learning is being applied.

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12. The GLOBE Zika Education and Prevention project: Citizen science for global health

Kristin Wegner, Tony Murphy, Lyn Wigbels, Mindi DePaola and Sara Herrin (The GLOBE Implementation Office)

Abstract

Through the support of the U.S. Department of State, the Global Learning and Observations to Benefit the Environment (GLOBE) Program is leading the GLOBE Zika Education and Prevention citizen scientist project (globe.gov/mosquitoes). The project enlists thousands of students, teachers and community members to collect data on mosquitoes for a global mapping project. It focuses on three GLOBE regions: Africa, Asia and Pacific, and Latin America and Caribbean, encompassing more than 65 countries. Between May and June 2018, GLOBE trained over 110 Country Coordinators and Master Trainers in more than 65 countries on the Mosquito Habitat Mapper app and how to engage their countries in this project through national and local workshops using a train-the-trainer model. Also, between June 2018 and February 2019, 27 GLOBE countries conducted Country Mosquito Trainings. Project participants include scientists, public health officials and other government officials. In the training sessions, participants learn to identify mosquito larvae, and citizen scientists learn to carry out actions to eliminate artificial mosquito breeding sites and the spread of Zika, and report the data to the GLOBE database. The training utilizes new technologies (apps and database visualization) to address new and emerging content needs. The project increases participation across the GLOBE community by leveraging in-country expertise and utilizing technology, such as webinars and e-Training modules, in addition to face-to-face workshops, in keeping with WMO Competency Requirements for Education and Training Providers. This also provides an opportunity for wide geographic reach, including urban and rural areas across project countries, by using methods that increase the reach of teaching and training to more learners.

Keywords: citizen science, apps, Zika, mosquitoes, NASA, community-based, Earth system science, climate health impacts

12.2   12.1 Introduction

The Zika virus was first detected in Brazil in 2015, when it became the first country to report on the connection between Zika and microcephaly (WHO, 2019). As of 2019, Zika has been reported in a total of 86 countries (WHO, 2019). Reliable information on mosquito data and good knowledge about preventive measures are important for reducing its spread. In order to prevent the spread of Zika, the World Health Organization's "Zika Strategic Response Framework" calls for multiple interventions, such as advancing research, developing and strengthening surveillance systems and vector control strategies, strengthening capacity to test for the Zika virus, and strengthening support of affected children and families (WHO, 2019). In particular, global data collection will provide the information needed to help international scientists and public health officials predict new outbreaks, better control mosquitoes, and reduce mosquito-borne infectious disease, thereby curtailing the spread of the virus. Through the support of the U.S. Department of State, the Global Learning and Observations to Benefit the Environment (GLOBE) Program is

leading the GLOBE Zika Education and Prevention citizen scientist project (globe.gov/mosquitoes).

This chapter highlights the contribution of the GLOBE Program to the training and guiding of citizen scientists in Africa, Asia and Pacific, and Latin America and Caribbean to identify potential breeding sites for mosquitoes and increase their understanding of the ways the Zika virus and other mosquito-borne diseases are transmitted so that they can take actions to stay healthy. It describes the methodological approach adopted for data collection, training types and the training technologies (apps and database visualization) employed to enable international scientists and public health officials predict new outbreaks, better control mosquitoes, and reduce mosquito-borne infectious disease.

12.3   The Mosquito Habitat Mapper app: the source of the idea for the innovation

The GLOBE Program is an international science and education programme that provides students and the public worldwide with the opportunity to participate in data collection and the scientific process, and to contribute meaningfully to the understanding of the Earth system and global environment. The programme trains educators, students, researchers and community members on the use of GLOBE protocols in four study areas (atmosphere, biosphere, hydrology and pedosphere) to investigate and collect environmental data.

Community members upload their data to the GLOBE database. Data can be retrieved for scientific and student research which helps verify the data's accuracy. Community members are able to access the data through the GLOBE website and visualize the data using GLOBE tools. The programme provides robust tools for citizen science inquiry. Data in the GLOBE database is open for community members to better understand their environment, identify trend and use data location information to map environmental data points.

In 2016, GLOBE developed the GLOBE Observer app. This app allows citizen scientists to understand and collect data on an increasing number of GLOBE protocols, which include Clouds and Contrails, Land Cover, and the Mosquito Habitat Mapper (MHM) (Figure 12.1).

The MHM tool allows citizen scientists and others to be trained in the GLOBE Mosquito Protocol by showing them how to identify potential breeding sites for mosquitoes, sample and count mosquito larvae and use smartphone equipment lenses to examine, photograph and identify the genus of specimens. The citizen scientists are also guided to eliminate mosquito breeding sites and report the elimination of the sites to the GLOBE database, which aligns with the strategic response of research and surveillance goals of the World Health Organization (WHO).

The MHM tool is further supported by the GLOBE "mosquito protocol bundle," which includes hydrology protocols (water temperature, pH, turbidity, salinity, dissolved oxygen) and atmosphere protocols (air temperature, rainfall, rain pH, relative humidity).

Figure 12.1. The GLOBE Observer app: Mosquito Habitat Mapper tools

Changes in temperature, rainfall and relative humidity have potential to enhance vector development, reproductive and biting rates, shorten pathogen incubation period and encourage adult longevity. In addition, changes in wind direction, velocity and frequency will have an impact on adult mosquito populations, affecting dispersal, survival and aspects of the general behaviour of many species. The complex interplay of all these factors determines the overall effect of climate on the local prevalence of mosquito-borne diseases.

12.4   The train-the-trainer model

12.3.1 Theoretical basis

Tracking the Zika virus requires a large dataset of citizen science collected data. The GLOBE Zika Education and Prevention citizen scientist project (globe.gov/mosquitoes) enlists thousands of students, teachers and community leaders to collect data on mosquitoes for a

global mapping project by using the MHM tool. The project focuses on thirty countries in three of GLOBE's six regions: Africa, Asia and Pacific, and Latin America and Caribbean. Data collection on this scale can provide the information needed to help international scientists and public health officials predict new outbreaks, better control mosquitoes, and reduce mosquito-borne infectious disease.

The key project objectives are:

1. Engage hard-to-reach, at-risk populations in the ways the Zika virus and other mosquito-borne diseases are transmitted and encourage them to take actions to stay healthy, such as identifying disease-carrying mosquitoes and eliminating their artificial breeding areas;

2. Create regional networks of schools, organizations and public health officials to maintain changes in individual and community behaviour and limit the spread of the diseases;

3. Gather, use and disseminate crowdsourced data to improve tracking and control of Zika and other mosquito-borne viruses, both in focus countries and globally through partners.

In order to increase the GLOBE community's participation in the project, GLOBE employed and supported a train-the-trainer model that it has developed and has been using for over 20 years. Thus, the theoretical basis of the project was a train-the-trainer approach integrated into three phases, Regional Mosquito Training (RMT), Country Mosquito Training (CMT) and Local Mosquito Workshops (LMWs) through multiple levels of the GLOBE Program via a multi-tiered approach (Figure 12.2).
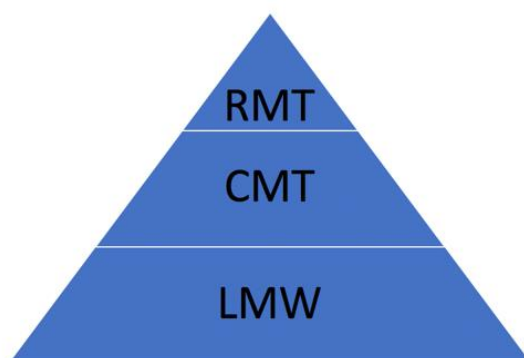
Figure 12.2. The train-the-trainer model

Each level of training is distinct in that there are different types of trainers and participants. The Regional Mosquito Training produced "Master Trainers", the GLOBE Program region-specific Country Coordinators and regional Public Health Officials. The Country Mosquito Training produced "T1 Trainers", public health officials and other individuals trained and authorized to train other community members and to partner with other community organizations to organize local mosquito training workshops. T1 Trainers are additionally

eligible to work with Country Coordinators and Regional Offices to create proposals and apply for mosquito training and education grants.

The table below describes the multi-tiered training approach, types of trainer, participants and outcomes.

Tiered training: trainers, participants, outcomes

	Type of trainers	Participants	Outcomes
Regional Mosquito Trainings (RMTs)	GLOBE Implementation Office staff, Master Trainers in mosquito science, the app, and project implementation	Country Coordinators and Regional Public Health Officials	Participants are trained in mosquito science, GLOBE resources (the app, visualization system, protocol bundle), and how to implement the project in their countries.
Country Mosquito Trainings (CMTs)	Country Coordinators and Regional Public Health Officials	Trainers, Public Health Officials	Participants are trained in mosquito science, GLOBE resources (the app, visualization system, protocol bundle), and how to implement trainings across their country.
Local Mosquito Workshops (LMWs)	Trainers	Teachers, Community members, Public Health Officials	Participants are trained in mosquito science, GLOBE resources (the app, visualization system, protocol bundle), and participate in the project (Mission Mosquito Campaign, student submissions to the GLOBE International Virtual Science Symposia)

Figure 12.3. GLOBE trainer Dorian Janney of NASA Goddard conducts a hands-on training on the MHM app

12.3.2   Training content: Science and hands-on training

The GLOBE community has nearly 25 years' experience in developing relevant, hands-on training for trainers and teachers. For the GLOBE Zika Education and Prevention project, GLOBE partnered with NASA and the Institute for Global Environmental Strategies to develop training materials that could be used across the participating countries, including science content slide decks and learning activities. GLOBE scientists contributed to the development of the app and the Application Programming Interface (or API), which supports the exportation of GLOBE data.

For the training, GLOBE also collaborated with scientists from Thailand and the United States to develop hands-on sessions on the app and database (Figures 12.3 and 12.5). During training, the scientists used a projector to demonstrate how to use the MHM. The overall balance between science content and hands-on practice can be found in Figure 12.4.

Figure 12.4. Expected training outcomes

The training sessions utilized new technologies (apps and database visualization) to address new and emerging content needs. The trainings aimed to increase participation across the GLOBE community by leveraging in-country expertise and utilizing technology, such as webinars and e-Training modules, in addition to face-to-face sessions, in keeping with WMO

Competency Requirements for Education and Training Providers. This approach also provided an opportunity for wide geographic reach, including urban and rural areas across project countries, by using methods that increase the reach of teaching and training to more learners.

12.3.3   Detailed description of the training

The following is a more detailed description of each level of training.

Regional Mosquito Training: RMT sessions consisted of two-day meetings that introduced the participants to the project, provided training and facilitated discussions and development of plans to implement the project in their countries. Between May and June 2018, GLOBE trained over 110 Country Coordinators and Master Trainers from more than 65 countries on the Mosquito Habitat Mapper tool and on how to engage their countries in this project through national and local workshops using a train-the-trainer model. Project participants included scientists, public health officials and other government officials. Training participants learned to identify mosquito larvae through hands-on sessions on the MHM tool, learned to carry out actions to eliminate artificial mosquito breeding sites and contain the spread of Zika, and to report the data to a database. Participants also learned about associated GLOBE protocols for measuring environmental parameters that impact mosquito breeding sites, such as precipitation, air temperature and surface temperature. The goal of RMT was to provide the tools, skills and background necessary for Master Trainers to conduct training in their countries. The participants, therefore, developed and presented country implementation plans that adapted the project to their community structures and training models. A major outcome of RMT was the encouragement of participating Master Trainers to design country-level training, called Country Mosquito Training (CMT).

Figure 12.5. GLOBE scientist Dr Mullica Jaroensutasinee of Thailand interacts with participants in hands-on training

Country Mosquito Training: Thirty countries participated in the CMT phase. Countries were eligible to apply for and receive mini grants to conduct three to six CMT sessions in their country. In order to increase the geographic distribution of the mosquito data collected, GLOBE encouraged countries to conduct CMT in regionally diverse areas, including rural and hard-to-reach locations. In the first year of the project (May 2018–May 2019), 30 GLOBE countries conducted over 120 CMT sessions and trained nearly 2 500 trainers.

At this level of training, it was important to encourage the GLOBE community to be innovative in its approach to developing tailor-made training to meet the needs of the local context. GLOBE Country Coordinators adapted CMT to their own train-the-trainer models. The Country Coordinators and community demonstrated creativity and resourcefulness in tailoring resources and the overall learning experience by using their diverse skills and considering competency levels of the participants, as exemplified in the adaptation of training material to local languages, use of technology, international collaboration and the leveraging of other events. The following are some examples:

1.   *Language*: Many countries translated the training materials into their local language (i.e. Spanish, Thai, Dutch in Suriname, and French).

2.   *Technology*: Some countries utilized technology in order to provide training to meet the needs at the country level. For example, the Peru Country Coordinator facilitated and recorded virtual training sessions via Zoom that could be used by other Spanish-speaking countries in the GLOBE Latin America and Caribbean region.

3.   *International collaboration*: At the CMT level, GLOBE countries engaged in international collaboration to develop and facilitate training that transcended geographic borders. In particular, the GLOBE Latin America and Caribbean region designed two triple-frontier workshops in order to support participants in identifying areas at the highest risk of Zika transmission and to work with representatives from neighbouring countries in order to mitigate the risk of the Zika virus in the region:

     1.   Brazil, Argentina and Paraguay held a joint CMT in Ciudad del Este - Itaipú, a city in the tri-border area, in which there were 63 participants.

     2.   In May 2019, Colombia, Brazil and Peru organized a "Triple Frontier" CMT workshop in Leticia, Colombia, in which over 130 individuals participated.

4.   *Leveraging other events*: The GLOBE community held CMT in conjunction with other events to make more people aware of the project. For example, GLOBE Philippines conducted a presentation and training at the "2018 SMART City Summit" in Quezon City, in October 2018. The audience included national and international government officials, members of the business sector, non-governmental organizations (NGOs) and the general public.

The main outcome of CMT was that participating trainers gained access to the skills, tools and mini-grant support to carry out the project in their local areas.

Local Mosquito Workshops: Participating countries that attended CMT were eligible to apply for and receive Community Action Grants to carry out local-level training, called Local Mosquito Workshops. The workshops consisted in one-day training sessions conducted at the local level. Participants included teachers, community members and local public health officials. Trainers adapted the science content and training materials from the CMT tier for the LMW level.

12.4   Participation of Regional Public Health Officials

Regional Public Health Officials (RPHOs) also participated in RMT, CMT and LMWs. Their involvement provided participants with relevant connections between mosquito science and public health. For example, in the GLOBE Africa Region, two African RPHOs (one francophone the other anglophone) participated in training sessions. In Benin, the francophone RPHO gave a science presentation on Zika at the CMT. The RPHO teaches students how to write scientific papers and conducted one LMW with plans for more LMWs. The anglophone RPHO supported an LMW in Rwanda. By including RPHOs in the training sessions, participants can learn more about the local context for mosquito-borne diseases, gain experience in research and learn how to convey results.

12.5   Virtual training via webinars

In order to further engage the community and provide support in the implementation of training at multiple levels, GLOBE organized three regional webinars for the three regions of the project in 2019. The webinar objectives were to support Country Coordinators during the Local Mosquito Workshop project phase, reinforce GLOBE resources available to trainers (such as local action grants, the workshop tutorial videos, the GLOBE Community Support Team or helpdesk), provide information about upcoming GLOBE events and campaigns (the International Virtual Science Symposium, Annual Meeting, Mission Mosquito), and brainstorm on regional strategies for communicating with trainers and keeping them engaged during the LMW project phase.

The webinars provided project status updates and offered support and resources for countries to organize and carry out LMWs. The webinars encouraged participants to engage in the Mission Mosquito Campaign and utilize the GLOBE Mosquito Protocol Bundle in data collection. Finally, the webinars concluded with participants sharing strategies to successfully support recently trained trainers in developing local networks of support and organizing community training. Regional Public Health Officials from Africa and Latin America and Caribbean regions participated in their respective regions' webinars.

12.6   Evaluation of Regional and Country Mosquito Training and Local Mosquito Workshops

The GLOBE community regularly develops and conducts evaluations to assess the effectiveness of its training. In order to assess the effectiveness of the GLOBE Zika Education and Prevention project components (app and database technology, training materials, etc.), GLOBE worked with the National Opinion Research Council (NORC), an outside evaluator based at the University of Chicago. The National Opinion Research Council conducted an online pre- and post-workshop survey using an online platform in ten of the

thirty participating countries. It translated the survey into several languages and provided regional training to Master Trainers responsible for administering the survey.

In order to gain informal feedback from the community to evaluate the effectiveness of materials and resources, GLOBE held webinars with the Regional Country Coordinators and Country Coordinators. Regional Coordination Offices (RCOs) also held regional webinars and meetings with other RCOs and Country Coordinators to gain informal feedback.

12.7 Scientific research and community engagement

12.7.1 Community engagement

The GLOBE Mission Mosquito Campaign, led by the NASA Goddard Space Center and the Institute for Global Environmental Systems, began in September 2018 as a way to further engage the broader GLOBE community in collecting and sharing mosquito data, connect scientists and public health officials to the GLOBE community and promote the GLOBE Zika Education and Prevention project. Project participants have been encouraged to participate in the campaign as a way to support their project implementation, and for their trainers, teachers and community members to connect with other members of the GLOBE community to collaborate on research.

The ultimate goal of Mission Mosquito is to facilitate scientific research on mosquito vectors of disease, including research by students and scientists (citizen and professional).

The goal of the Mission Mosquito Campaign is to:

1.   Identify and create a baseline (2018–2021) for range and distribution of vectors such as *Aedes aegypti* and *Aedes albopictus*;

2.   Identify seasonality of local mosquito vectors: first sighting, last sighting, period of greatest number of observations;

3.   Quantify change in mosquito frequency and distribution at local, regional, national and global scales with specific reference to prevailing environmental parameters, such as precipitation, land cover, surface temperature and soil moisture.

The campaign holds two webinars per month (one for teachers, one for citizen scientists) in order to increase the opportunities for community engagement, which facilitates informal learning.

12.7.2 Student engagement and student research projects

Multiple training methods have been incorporated to involve GLOBE students. Primary, secondary and university-level GLOBE students continue to be engaged in the project by conducting research using the MHM tool. Students present their research virtually and at face-to-face conferences. For example, students from the 30 countries participating in the GLOBE Zika Education and Prevention project submitted a total of 18 mosquito-related research projects for the GLOBE 2019 International Virtual Science Symposium.

The student reports offered a wide range of research topics, including mosquito behaviour analysis (combining protocols from the GLOBE mosquito protocol bundle); collecting mosquito species-type and quantity data over diverse geographic regions; and providing community-specific education and engagement recommendations to reduce the spread of mosquito-borne diseases. Two student teams from each of the three regions participating in the Zika project were selected to present their mosquito research at GLOBE Annual Meetings. Additionally, student groups participated in video technique courses, as part of a Virtual Exchange Program supported by the U.S. Department of State and GLOBE. Students received cameras, learned about video storytelling and submitted videos about how their research impacted their community.

12.7.3   Moving forward

The GLOBE community consistently exhibits high levels of enthusiasm, creativity and commitment to participating in community engagement efforts that contribute to meaningful science. This commitment is demonstrated by continued plans to carry out national and local training workshops. Additionally, GLOBE teachers plan to continue to support their students in learning about mosquitoes by using the MHM tool to conduct locally relevant research and share their research in the GLOBE International Virtual Science Symposia.

Community members collectively added tens of thousands of mosquito-specific data points to the GLOBE database through the GLOBE Observer Mosquito Habitat Mapper tool. Combined with coordinated partnerships, such as Mission Mosquito, the knowledge base, data, research and community engagement continue to grow.

Resources

Project website: https://www.globe.gov/web/globe-mosquito-project.

Protocol Bundle: https://www.globe.gov/web/earth-systems/community/mosquito-bundle.

GLOBE Mission Mosquito Campaign: https://www.globe.gov/web/mission-mosquito/overview.

13. From research to operational training: Conceptual models empower young professionals

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Abstract

Innovation is believed necessary to enable training providers to address changing demands for skills, knowledge and unarticulated needs[12] in all fields of work. While the term "innovation" seems to call for something remarkably modern and technologically advanced, one should not forget that innovations are based on creativity and the usually understated qualities of a committed team of professionals.

The innovation in training presented here has not used the most sophisticated learning technologies available, but it is unique in the sense that it achieved clear outcomes by translating scientific research into operational training. It was the combination of creative ideas, timely actions and informed pedagogical choices that made it a successful initiative. This innovation is centred on the *Workbook on the Application of Conceptual Models in Forecasting*, available in Spanish under the title *Prácticas para Pronosticadores*, which became the centrepiece for various training opportunities and new projects of the WMO Regional Training Centre (RTC) and VLab Centre of Excellence (CoE) in Argentina.

13.1 Developing conceptual models in the southern hemisphere

There is a consensus about the importance and usefulness of conceptual models (CMs) as diagnostic tools in weather forecasting and training, but very few conceptual models of southern hemisphere synoptic and mesoscale weather events had been developed until 2013. This fact prompted training managers in the WMO/Coordination Group for Meteorological Satellites (CGMS) Virtual Laboratory for Education and Training in Satellite Meteorology (VLab)[13] to suggest an innovative collaboration for the VLab Centres of Excellence (CoEs) situated in the southern hemisphere, following the European example of the *Manual of Synoptic Satellite Meteorology - Conceptual Models* (or CMs SatManu)[14].

Steered by the VLab and managed by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the first phase of the Conceptual Models for the Southern Hemisphere (CM4HS) project started in 2013, involving the VLab CoEs in Argentina, Australia, Brazil and South Africa. Phase two of the project, which started in 2015, counted on additional collaborations in partnership with the Meteorology, Climatology and Geophysics Agency (BMKG) in Indonesia. The aim of this project was for operational forecasters to improve warnings and awareness of weather risks through the use of CMs.

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[12] https://cognitive-edge.com/blog/unarticulated-needsdirections/

[13] https://www.wmo-sat.info/vlab/

[14] http://www.eumetrain.org/satmanu/index.html

These CMs were specifically structured to help forecasters integrate and interpret satellite data in combination with numerical model outputs and conventional observations.

The CM4SH project provided solid foundations for a successful innovation in training. Project management was done online and played a crucial role in the success of this collaboration. It consisted in defining the structure and planning lessons, defining milestones and guiding the development of local cases in the local language and in English. Academic support was always present. Communication was active, including scheduling a series of online meetings, sharing documents and exchanging emails. The interaction between collaborators was essential to support and monitor progress. Project management also included the coordination of external reviewers, technical revisions of case presentation formats, and the organisation of a final face-to-face meeting to wrap up achievements.

Major two-way benefits of CM4SH:

1.   Researchers faced challenges regarding application of CMs to real situations. They established contact with operational forecasters and prepared cases at various levels of complexity;
2.   Operational forecasters could incorporate the CMs originating from research into their analyses, adding value to forecasts and confirming that research can actively support operational work.

Among the many unexpected benefits of CM4SH, the following were identified:

Human resources:

1.   Improved relationship among those who participated in the project: university researchers, senior students and professionals from National Meteorological and Hydrological Services (NMHS);
2.   Enhanced regional and international relations among project collaborators;
3.   Good practices and further developed organizational and communication skills;
4.   The interaction among the different groups that participated in the project, including university researchers, senior students and professionals from NMHS, was enriching to all, improving the relationship between academia and operational professionals;
5.   Beginning of regional and international relations among project collaborators;
6.   Good practices and further developed organizational and communication skills set a new standard.

Meteorological and technical improvements:

1.   Utilization of new technologies in meteorology and consideration of new parameters in the forecasting process;
2.   Analysis of new case studies;
3.   Increased research efforts.

The participants in this project valued the experience provided, particularly the openness and equality promoted among experts and less experienced researchers. They also welcomed the opportunity to learn about free access to digital learning materials and tools that are considered Open Educational Resources (OER), clarifying copyright practices and

reusability policies. These have been adopted and promoted by project collaborators since then.

After the successful completion of this project it was perceived that although the CMs represented a valuable resource, they had not been as readily utilized by operational forecasters as intended, indicating that a further step was needed to reach the goal: turning CMs into interactive training resources to be utilized by the growing number of forecasters in the South American region.

13.2 *Workbook on the Application of Conceptual Models in Forecasting*

The VLab CoE in Argentina identified that forecasters required updated training on local weather events and their impact, delivered in Spanish, to be widely accessible in their region. The CMs developed in the CM4SH project could be used to this end, but the training resources needed to include activities that required "getting into the forecasters' own shoes," focusing on the challenges that require solving problems, making decisions about what steps are both important and urgent. Competency-based training has proved most useful for operational forecasters and includes challenging learners to solve real problems they face at work.

Following the recommendations of the WMO Education and Training Programme (WMO-ETR) on the use of active-learning approaches that are engaging and immersive, a Workbook for forecasters was designed by the VLab CoE in Argentina, on the basis of the four CMs they developed in CM4SH, and making use of simulations to resemble job conditions. Simulations can be powerful learning activities, improving forecasters' performance as a result of requiring them to think deeply and to take timely actions. Because simulations allow forecasters to try to solve problems and check the results of their actions, they quickly became very popular among forecasters in Argentina.

The Workbook was created by a task team formed by two aeronautical forecasters under the supervision of an experienced researcher from the University of Buenos Aires (UBA) and a distance learning advisor. A group of reviewers, including meteorologists from academia and forecasters from operational settings, was consulted to identify areas that could be improved. An evaluation form was also added to the Workbook, allowing users to provide feedback after using the material.

The Workbook focuses on the application of CMs and the effective use of satellite images combined with other data to improve forecasting. It contains a variety of activities (Figure 13.1) intended to engage the learners in working past the initial set of ideas and into more advanced thinking to consider new ways to approach problems.
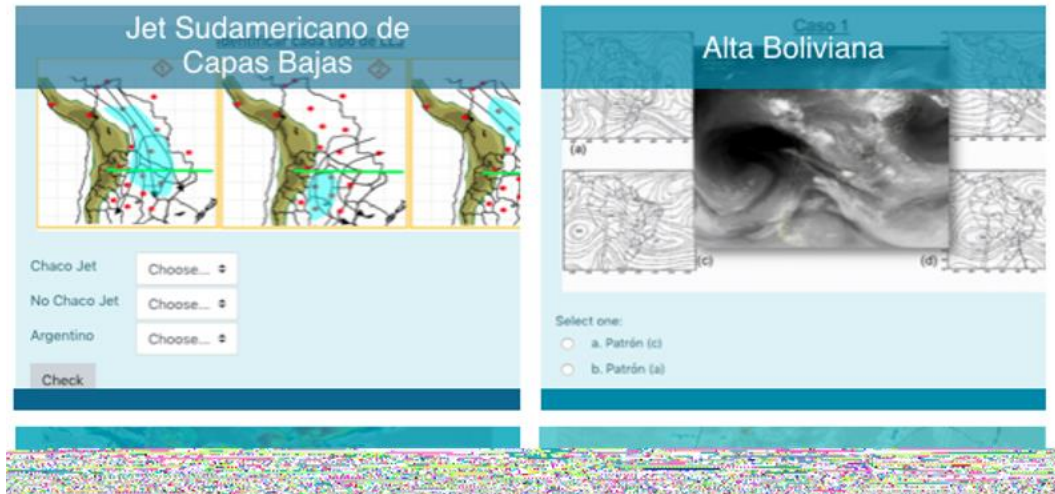
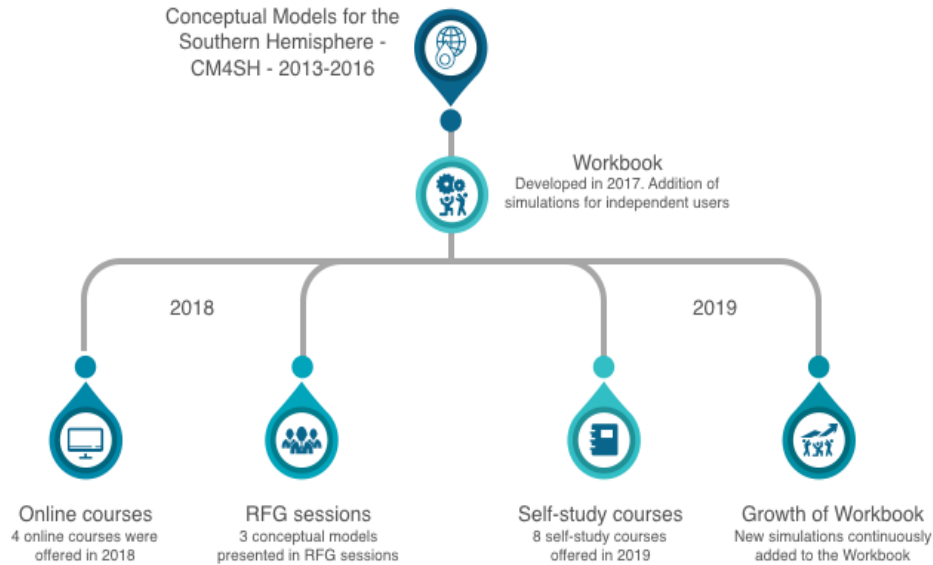**Figure 13.1. Examples of activities in the Workbook**

This Workbook is an OER, carrying the Creative Commons Atribución 2.5 Argentina (CC BY 2.5 AR).[15] It was conceived to be shared within the WMO Global Campus community, so that others could reuse and adapt it to their own needs. We believe that the exchange of experience and knowledge drives positive change, and we want to be part of this change. The Workbook is available to forecasters, university students and teachers at the WMOLearn website[16] (see Collaborative Projects > Completed Projects), in the WMO Global Campus E-Library,[17] or directly at the SMN Moodle site (https://crf.smn.gob.ar/course/view.php?id=16).

The evaluation of the Workbook has been very positive. We received excellent reviews from aeronautical forecasters, public weather forecasters and students and lecturers from several universities across Latin America. We also received recognition from heads at the National Meteorological Service of Argentina. It soon became evident that it would be valuable to more actively promote the availability of this OER among operational forecasters in WMO Regional Associations (RAs) III (South America) and IV (North America, Central America and the Caribbean), particularly, but not only, in Spanish speaking countries. The actions taken to this end created far more training opportunities than we first envisaged (Figure 13.2). Below are the results of our efforts to apply and promote further use, adaptation and reuse of the Workbook.

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[15] https://creativecommons.org/licenses/by/2.5/ar/

[16] https://public.wmo.int/en/resources/training/wmolearn#

[17] https://library.wmo.int/index.php?lvl=etagere_see&id=157#.X4_cY9AzY2w

Figure 13.2. Sequence of training projects (RFG = Regional Focus Group, see below)

13.3 Online courses using the Workbook as the main training resource

In 2018, the Workbook became the core learning resource for four short courses delivered online in Spanish, for participants from WMO RAs III and IV. These courses engaged forecasters in competency training focused on high-impact weather. The Workbook provided training activities to address all learning outcomes set for the courses. Because these courses were facilitated by trainers, this was a great opportunity to expose the Workbook to their scrutiny. They naturally became very involved and enriched the course by including additional resources, updated examples based on the new generation of satellites (GOES 16), and by developing summative assessments. The courses attracted numerous Spanish-speaking forecasters in the Regions, creating a sense of belonging. In the forums there were lively open discussions as forecasters and trainers shared valuable experiences from their shifts. These courses generated growing regional attention to the Workbook.

## 13.4 Participation in Regional Focus Group sessions

In 2018, trainers of the online course mentioned above were encouraged to make a presentation on a current weather situation representing the CMs they were teaching. The presentations were made in the sessions of the VLab Regional Focus Group (RFG) of the Americas and Caribbean[18] (Figure 13.3). This RFG meets online on a monthly basis to view and discuss satellite imagery and share information on global, regional and local weather events. The sessions are bilingual (Spanish and English) and conducted by experienced facilitators, who move fluently from one language to another, in a very natural way. These facilitators from the Cooperative Institute for Research in the Atmosphere (CIRA) and the National Oceanic and Atmospheric Administration (NOAA) are also experts in the use of

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[18] http://rammb.cira.colostate.edu/training/rmtc/focusgroup.asp

satellite images in operational meteorology, making the sessions a great opportunity to expose users to the new generation of satellite data.

The collaboration between trainers of the CM courses and RFG facilitators resulted in mutual benefits: trainers were supported in the organization of material to present, in the selection of current weather situations to show the application of the conceptual models, and in the use of visualization tools such as a slider (a tool for comparing two satellite products over the same geographic area to reveal features otherwise difficult to see). The RFG facilitators had additional presenters contributing to the sessions as well, which broadened the available expertise. There was also the added bonus that continues to benefit all participants in this VLab RFG—the inclusion of new participants who were exposed to this learning opportunity and were motivated to keep attending the monthly sessions as part of their continuing professional development.

All sessions of the RFG of the Americas and Caribbean are recorded and made available on the RFG website shortly after the events.
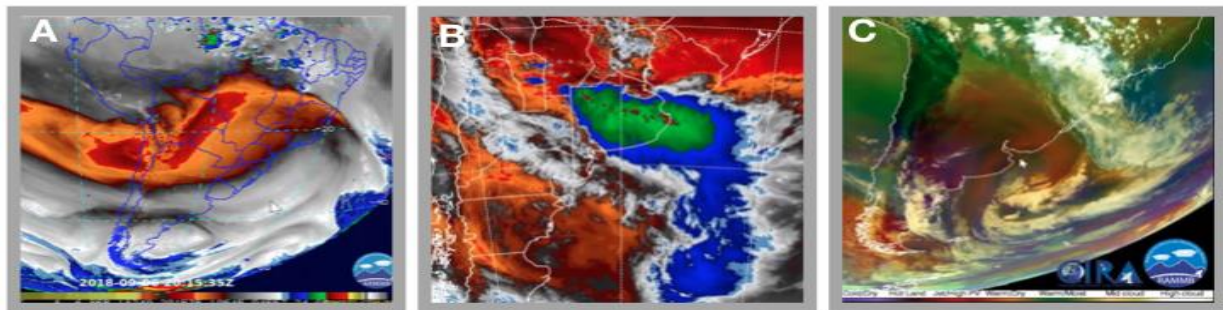
Figure 13.3. Presentations in RFG sessions: (A) Zonda case (September 2018), (B) Low-level jet (October 2018), and (C) Cold fronts (November 2018)

13.5   Self-study courses based on the Workbook

Due to budget restrictions and the desire to offer this learning opportunity to a larger number of participants, it was decided to turn the four online courses described above into self-study courses. While the self-study courses were not facilitated by trainers, they still offered the opportunity for practice, as the simulations were kept as main course activities.

Another important decision to make when changing the course format, from online to self-study, was related to assessment. Course participants highly valued the possibility of being assessed and receiving a certificate as evidence of their achievements. Not only course participants but also their managers appreciated that possibility, because it helped them keep track of training needs and skill development of their staff.

As a result of all these considerations, eight self-study courses were delivered over two semesters in 2019. Because each of the four courses could be completed easily within one week of self-study, participants were offered one month each semester to complete the set of four courses. This provided flexibility, allowing the participants to study at the time it was most convenient for them and to take more time to try all course activities. At the end of

the month-long timeframe, those who completed all the activities were offered the possibility to take the assessment. They had two assessment dates to choose from. Assessments took place online, and they were also conducted in the format of a simulation (to be completed within 1.5 hours).

13.6   The continuous growth of the Workbook

The original Workbook, adapted for self-study in 2019, has been continuously modified since then. This is because every time the self-study courses are offered, the new cases used for the assessments are subsequently added to the course material as new activities (simulations). This means that the self-study course material is continuously enriched with new activities for users to practice their skills.

While this strategy was mainly intended to keep the self-study courses up-to-date and relevant, the process of regularly and intentionally looking for interesting new cases with which to create assessments generated an additional benefit—weather events of various intensity and impact are now not only noticed by forecasters, but are also recorded in great detail, adding significantly to corporate knowledge.

Another benefit is that operational personnel have widened their expertise through involvement in the development of the simulations to be used as part of the self-study course assessments. For example, in 2019, two young aeronautical forecasters were taking turns designing the new assessments. This provides the opportunity for personnel to develop their own skills, while also exposing operational offices to the value of using conceptual models and simulations in training and continuing professional development.

13.7   Some final words

The benefits from all these efforts were far greater than expected. Young professionals had the opportunity to be involved in a variety of tasks related to training. Some worked on transfer of scientific research to operations when developing CMs, others developed activities and simulations for the workbook, while another group of young professionals became trainers in the online courses, and many actively participated in the courses as learners and in the RFG discussions as colleagues. In addition, 648 course participants have been trained since 2018.

In our experience, innovation in training proved to be challenging and demanding and therefore engaging for researchers and operational meteorologists alike. There were many unexpected obstacles that had to be dealt with for the continuation of the project. We learned that successful innovations can reinforce and encourage positive behaviours, such as collaboration between professionals from various organizations—local, regional and global. Coordination was key in order to align all the diverse elements that were part of this training innovation, and once the team was set on making a difference to drive positive change, ideas connected and accumulated. Collaboration made space for creativity and generated new ideas for future projects. Working as part of a team, managing difficult situations, coordination, organization and collaboration are but a few of the transferable skills acquired and practiced by all the professionals involved in this innovation.

We often hear that "variety is the spice of life", and this is also true for sparking creativity. New experiences, knowledge and skills also enable the brain to form a much larger combination of connections, resulting in more original ideas. So, we can envision how this sequence of positive learning experiences will trigger other useful learning projects. It takes just a few innovators who care to get it started, and a very dedicated and enthusiastic team to coordinate the efforts to make it happen (see Figure 13.4).

Figure 13.4. The workbook team: (from left to right) Henrique Repinaldo, Denise Auzmendia, Bárbara Lapido, Luciano Chiappari, Pablo Talarico, Rodrigo Cortes

Acknowledgements

14.   Steps for implementing learning games about probabilistic numerical weather prediction products in in-person courses

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

Abstract

This chapter highlights the design and implementation of a learning game for an in-person course. The risk management game helped the learners practice the appropriate interpretation and use of various probabilistic products for winter weather events. After selecting an appropriate model for a risk management game, the COMET team used an iterative design and development model to create, test and refine the rules of the game. The team also wrote and tested a story to guide the players in their roles as emergency managers preparing a city for an approaching weather event. As indicated by the learners' comments and their test improvements, the learners' active engagement increased their understanding of and confidence in the skills they need and actions they must perform while forecasting. The players' experience of the pressures under which decision-makers take preparedness actions can also help meteorologists to empathize and build stronger, collaborative relationships with their external partners. When designed well, learning games can be an effective approach to challenging topics such as interpreting probabilistic guidance because they engage learners and provide real-life context, challenge, activity and feedback. While COMET used winter weather, the game can be adapted to any weather event that requires preparations by emergency managers.

Keywords: game-based learning, serious learning games, game design, learning benefits, increasing engagement, storyline, reflection, context, challenge, activity, feedback, probabilistic products, ensemble products, risk management, impact-based decision support.

14.1   Introduction

Creating an engaging and effective instructional game is difficult and requires careful design choices, yet the benefits for learning can be significant. A meta-analysis of forty-five research reports that compared trainees using simulation games to trainees using other instructional methods found some of the following results:

> "Trainees gain higher confidence in applying learning from a training session to their jobs when the training is simulation-game…

> Trainees participating in simulation game learning experiences have higher declarative knowledge, procedural knowledge, and retention of training material than those trainees participating in more traditional learning experiences...

> Trainees learn more from simulation games that actively engage trainees in learning [*taking actions with new knowledge*] rather than passively conveying the instructional material [*via text and videos*] …

Instructional games should … include debriefing and feedback so the learners understand what happened in the game and how the events support the instructional objectives." (Kapp, p. 87–102)

The commercial gaming world provides many examples of big-budget games that failed due to poor gameplay, confusing rules or lack of player engagement. As trainers, when we consider such expensive failures, we find it hard to imagine that we can create a successful game with our limited game design skills and small budgets. However, if we focus on some fundamental game components, it is possible to create learning games that appeal to learners and do not require large budgets. In our experience, creating an effective, engaging and fun instructional game requires the identification of a specific learning problem, the selection of an appropriate gameplay model, the writing of good gameplay rules and a convincing storyline, iterative testing to refine the gameplay and rules, and finally a reflection exercise with learners about the game experience. By taking these steps when constructing and implementing "serious learning games" for in-person settings, it is possible to create an engaging and fun game because the design team will be working on the critical elements that make a successful game (Allen, 2016 p. 333).

14.2   Game design

The most important factor that affects the success of a learning game is establishing good rules for the game. One game designer summarized the idea like this: "Good rules-good game; poor rules-poor game." (Zimmerman's 2009 presentation as quoted in Allen, 2016, p. 333). For a learning game (or any game) to function well, the designers need to establish clear rules of play (the things that players can and cannot do) as well as clearly defined and impactful outcome rules that fully capture the way the game responds to user actions. For example, consider the game tic-tac-toe (a.k.a. naughts and crosses, Figure 14.1). It's a straightforward game with simple and direct rules that have made the game a classic. "No graphics, animations, sound effects, story, scoring, levels, or leader board required. What more do you need than a napkin and pencil? The rules." (Allen, 2016, p. 334) One rule of play for tic-tac-toe is that: "If it is Player 1's turn, then Player 1 must place one and only one X marker in an empty cell." An outcome rule states that: "If a player has placed three markers in a row (horizontally, vertically or diagonally), then that player wins, and the game is over." (Allen, 2016 p. 335)

Figure 14.1. Tic-tac-toe, aka. noughts and crosses

As players become familiar with both sets of rules, they begin to develop strategies and actions in order to advance and hopefully win the game. In order for learners to be able to develop their strategies and actions, the game rules must provide options. The learners evaluate their options and take actions in order to win. This is very similar to what we do naturally when presented with a problem we have not encountered before. We evaluate each possible course of action, select one and try it, then we observe the results. If we are not successful, we reflect and select a different action until the problem is solved. When designers create successful game rules (rules of play and outcome rules) that spur learners to adopt strategies that they would need to use in real life, the game designers have created a "serious learning game."

Our design process included iterative design and development phases. During each phase, we designed, tested and refined the rules of play and outcome rules for the game as well as the support materials that needed to be created. Graphically, the process we used is represented in Figure 14.2.
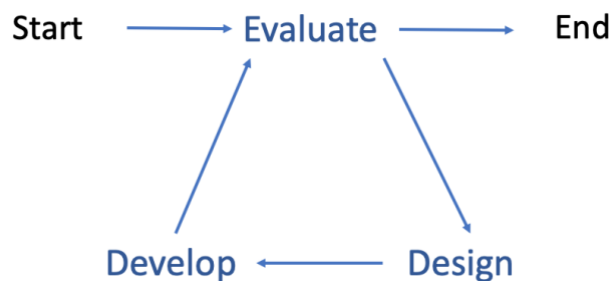
Figure 14.2. Successive approximation model for e-learning development

14.3   The challenge

After several iterations of a lecture on the topic of interpreting probabilistic guidance were poorly received by participants, COMET decided to create a game in order to give learners practice in this topic. The primary intention behind shifting from a lecture to a game was the realization that meteorologists wanted to become better at interpreting the guidance in order to improve their forecasts. They were not interested in learning the calculations that are used to generate the products. This became our primary instructional objective for the game. A secondary objective of the game was to let players experience how to make preparedness decisions based on meteorological data. The participants in the game come from a weather service that is transitioning towards providing decision support to their external partners. Our design team thought that it would be good to let the participants experience a weather event from the point of view of their partners in order to become familiar with a simplified set of the pressures and decision processes.

14.4   Iterative design phase

Since this was COMET's first experience designing and offering a game for an in-person course, one team member studied gameplay models that would be suitable for a risk-management game. The team selected a game model in which the learners must balance making costly preparedness decisions versus the public's perception of the effectiveness of

those decisions and fiscal responsibility (expressed through confidence points). The team then created the following rules of play:

1.   Players must interpret the probabilistic guidance.

2.   Players must then review a particular city's preparedness thresholds for snow amounts.

3.   Players must select the level of preparation for that city and enter the cost of preparation in their worksheet.

4.   At the end of each round, the players report their level of preparation and the game facilitator lets them know how the game will react to their actions.

The last rule is where the game's outcome rules come into play (the way the game responds to the player). The team developed the outcome and game rules simultaneously. The game reacts to the learners' actions in this way: if the learners have underprepared for the event, they must expend money to rescue people and repair city infrastructure. This negatively affects the public's perception of their effectiveness, and they lose confidence points. If the learners have overprepared, public confidence in their effectiveness and fiscal responsibility would diminish, again impacting their confidence points. By selecting the correct preparedness level, learners incur no rescue and repair expenditures and the public's perception of their effectiveness increases, which is shown by gaining confidence points.

The key strategy is for players to make an informed decision about how to balance these competing demands by correctly interpreting probabilistic guidance. The rules of play match the main strategy for winning the game with the main learning objective of interpreting probabilistic guidance correctly. The outcome rules address the secondary learning objective of making preparedness decisions based on meteorological data and experiencing some of the pressures their partners face. In addition, participants understand the role of preparedness thresholds and later can work together with their partners to provide weather information that directly pertains to the thresholds.

A team of COMET designers and experts created, reviewed and refined various permutations of these game rules. We settled on the amount of funds for the different elements of the game: the starting budget, the different levels of preparedness, and expenditures for rescue and for infrastructure repair. The team also tested different gains and losses of confidence points that would enable the learners to win if they selected the appropriate level of preparation or lose if they underprepared or overprepared. Another consideration was to create outcome rules that allowed learners to remain hopeful of success even if they made two incorrect decisions at the start of the game. The team wanted all players to remain engaged and continue interpreting probabilistic guidance for every round of the game instead of giving up because they could not win. We introduced a reward for selecting the correct preparedness action for a city. In this way, players could regain funds and confidence points and have a chance of success.

A choice that we made early on was to allow learners to discover the outcome rules as they played rather than explaining them in detail ahead of time, which added an element of

discovery and risk to the game and increased learner motivation. By not presenting the outcome rules in detail ahead of time, the game draws parallels to real life, where often we do not realize the real consequences of our actions until quite a bit later.

In summary, our rules of play indicated that learners needed to select the appropriate probabilistic product and interpret it correctly. With this information, the learners reviewed the threshold criteria for each city and decided on the level of preparedness actions to initiate. Like in real life, the learners needed to select relevant products and interpret them correctly. To make this a challenge, the game provided some products that were irrelevant to the particular decision. If the learners selected the appropriate suite of probabilistic products for the problem, successfully interpreted them and the thresholds for each city, they would then select a preparedness action at the appropriate level.

The outcome rules specified the amount of funds that learners had to spend on rescue and recovery efforts depending on the levels of preparedness they chose. In order to win, the learners had to have the lowest budget deficit and the highest public confidence in their ability to prepare the city for potential impacts. On the basis of these criteria, the teams were ranked at the end of the game and received a small edible reward. This competition is not a central element of the game and does not appear until the end. Its primary function is to inject a bit of fun at the conclusion of the game.

With this game model in mind, we identified three winter weather events and gathered relevant meteorological data for them. The three events enabled us to play three rounds of the game and fit them inside the timeframe available during the training course. While the team used winter weather events, the game can be adapted to any weather event that requires preparations by emergency managers.

14.5   Iterative development phase and improvements

The next crucial step was to test the various gameplay and outcome rules with actual users. In early testing, we found that many tried to go through the full forecast process of analysis, diagnosis and prognosis (ADP) to generate a meteorological forecast based on the probabilistic information and then make a preparedness decision. Generating a forecast required a lot of time and caused some frustration because the products distributed in the game did not provide sufficient information for the ADP process. After encountering this issue, we adjusted the game rules by directly stating that a winter event is possible over the selected location during a specified period of time. Then the learners were tasked with using the probabilistic guidance to estimate the potential snow accumulation. This focused the learners' attention on interpreting the probabilistic guidance and making a preparedness decision based on it, rather than on completing the ADP process and determining whether snow would occur over the location and when.

We incorporated this updated scenario into a handout that was given to learners at the start of the game. In addition to the weather scenario, we also prepared a table with critical thresholds, action levels and their respective costs (shown in Figure 14.3).

To Win: Incur the smallest budget deficit and gather the highest number of confidence points.

Scenario 1 – Location

You are preparing for a possible winter weather event between 29th to 30th of December. The ensemble guidance available to you is from 28th of December. Estimate the 18 hr accumulation between 12Z on 29th of December and 06Z on 30th of December.

Critical Thresholds	Required actions	Cost
1-8 cm of snow	No action	0
9-14 cm of snow	Level 1 action (basic preparation)	1,000
15-20 cm of snow	Level 2 action (moderate preparation)	3,000
>20 cm of snow	Level 3 action (comprehensive preparation)	5,000

Figure 14.3. Weather scenario, thresholds, preparedness actions and their cost

During the tests, we also discovered that some of our testers were unfamiliar with the probabilistic products in the game. Since many of our potential learners could be in the same situation as the people who were testing the game, we prepared a quick introduction to each product that explained its purpose and how to interpret its output (see Figure 14.4).

Figure 14.4. The questions that students needed to answer during the introduction to the probabilistic tools.

14.6 Creating an engaging story

We created a story to guide the players in the roles that they would play. The story naturally wove in the game rules so that players understood the balancing challenge that was before them.

"You are a new hire at the brand-new National Preparedness Agency. You were hired because of your meteorological experience and because meteorologists are known for handling risk very well.

Your main goal is to decide what levels of preparedness action you will initiate in order to prepare various cities for impending winter storms. This is not a forecasting exercise - it is a decision-making and risk management exercise."

Thus, in the context of the game, the players took on the role of decision-makers. Inhabiting the point of view of their partners allowed the learners to struggle with the complexities involved in preparing a city for a potential weather event. As mentioned earlier, the secondary goal of the game was to give forecasters the experience of making preparedness decisions based only on the information contained in a standard forecast briefing. Emergency managers are interested in the impact of a weather event and the probability that various scenarios may occur. On the basis of this, they have to decide what actions to take to prepare the population.

14.7 Implementing the game in the classroom

In order to encourage discussion among players, the participants are divided into teams of two. In pairs, players can assist each other with interpreting products, generating alternative ideas about the possible preparation levels, and discovering the optimal strategies so that their team could win the game. This embeds active communication within the gameplay (see Figure 14.5). In order to win, the pair must successfully strategize together to select the correct products and interpret them correctly and must realize that they contain uncertainties. The decisions each pair of players makes must be balanced. The team cannot overspend and go into deficit, thus losing credibility with the public as these outcomes could signal the team's loss of the round or the game.
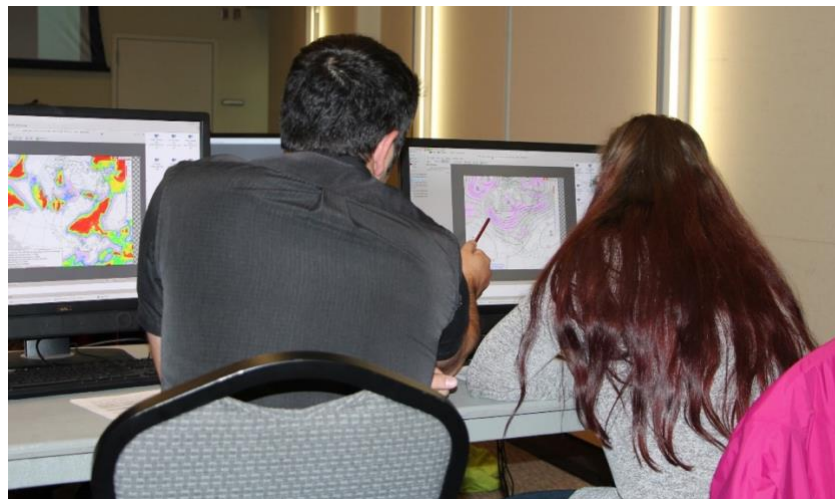
Figure 14.5. Team interpreting probabilistic products

To increase the perceived risk for the players during the live play, the game facilitator counts down time and notifies players that the media is gathering to hear and publicize their decision. The addition of the countdown and media hype generated many laughs and brought forth some tension in the players. Fun and tension are both crucial elements in engaging gameplay. They heighten our sense of accomplishment when we successfully complete the game: "Games energize us primarily by putting us at risk and rewarding us for

success. Although it is easy to point to the rewards of winning as the allure, it is also the energizing capabilities of games that make them so attractive. It feels good to be active, win or lose. Risk makes games fun to play." (Allen, 2016, p.144) In the image below, you can see the winning teams celebrating their success. How often do forecasters jump out of their seats and celebrate because they have learned how to use a probabilistic product (Figure 14.6)?

Figure 14.6. Celebrations at the end of the game.

At the conclusion of the game, the game facilitator tallies up the various team scores and gives awards to the top three teams. After the scores have been tallied, the facilitator engages the learners in a reflection exercise about the players' experience interpreting probabilistic guidance and making preparedness decisions based on probabilities. During the reflection period, participants share their strategies for selecting products and how they used the information in them to choose the level of preparedness. Occasionally, they would give suggestions to each other on the interpretation of the guidance or share previous experiences answering emergency management's questions about a weather event.

The reflection concludes by asking the participants to identify ways in which they can use probabilistic products in the analysis, diagnosis and prognosis process. Some researchers have suggested that "reflection is a form of practice… Reflection can involve several cognitive activities that lead to stronger learning: retrieving knowledge and earlier training from memory, connecting these to new experiences, and visualizing and mentally rehearsing what you might do differently next time." (Brown, Roediger, & McDaniel, 2014, p. 26) The team purposefully decided to include the reflection period at the end of the game rather than at intervals during the game in order to maintain the players' immersion in the game world.

14.8 Learning effectiveness

To evaluate the learning effectiveness of the game, the team included questions about interpreting probabilistic guidance in the pre- and post-tests for the course. After playing the game, the post-test results indicated an average improvement of 10 percentage points.

In addition to the pre- and post-test scores, the in-person game session has been consistently rated highly by learners over four course offerings. These ratings were higher than many of the lectures and lab sessions offered during the weeklong courses. Some of the comments that learners shared include:

1. "Overall well done. It gave me a familiarization with some EPS products that I was not already familiar with. I also gained an appreciation for what my decisions mean to decision making for emergency measures groups."

2. "Understand risk management and emergency management. I like the stories shared in discussion. Very impressive."

3. "I like the game play very much. I also liked that we were working towards incentives and there were penalties if we got things wrong. It made it seemed that there were things at stake, which is a very real feeling working at the weather office."

4. "Nice to play a game and to not be a forecaster, instead the decision maker." "Loved it. Was a neat way to view new ensemble products and put it into real life scenarios."

5. "This game was excellent because it dealt with the ramifications of our forecast decisions…"

The risk management game helped the learners practice the appropriate interpretation and use of various probabilistic products for different winter weather events. While COMET used winter weather, the game can be adapted to any weather event that requires preparations by emergency managers. As indicated by the learners' comments and their test improvements, the learners' active engagement increased their understanding of and confidence in the skills they need and the actions they must perform while forecasting. The experience of the pressures under which decision-makers take preparedness actions can also help meteorologists to empathize and build stronger, collaborative relationships with their external partners.

When designed well, a learning game can provide real-life context, challenge, activity and feedback that can make learning challenging topics, such as interpreting probabilistic guidance, effective and fun.

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15. Reflections on interactive meteorological instruction

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Abstract

Educators in meteorology often use a traditional lecture-style method where they address learners with little or no interaction. But this form of instruction is not very effective for developing skills, changing behaviour or achieving learning to any significant depth. Such educators would become more effective by adapting and implementing the interactive approaches presented in this chapter, drawn from my practical experience of teaching a wide variety of learners.

Keywords: interactive, teaching, lectures

Those who enter the field of meteorological education often come from a background as scientists rather than teachers. The two roles do not necessarily coexist naturally in the same individual, and the educator is inclined to follow (or feels an obligation to follow) a traditional lecture style where they address the learners with little or no interaction. What skills could help instructors implement a more interactive approach to their teaching?

This submission, based on a presentation at CALMet 2017 (Webster, 2017), will attempt to answer this question by drawing on the author's experience teaching college students, aircrews, university graduates and professionals from disciplines related to meteorology (e.g. hydrologists, IT specialists and mariners).

The WMO *Guidelines for Trainers in Meteorological, Hydrological and Climate Services* (WMO, 2013, pp. 43-45) describes in Section 6.4 an instructional strategy where material on concepts or facts is delivered, often with little direct engagement. This is how a lecture has been traditionally delivered. As in the trainer-centred instruction described in Section 6.5 of the WMO Guidelines, the learners must go along with the content of the lecture and the pace of delivery – they have a passive role and are expected to just accept what has been presented. As the Guidelines point out, this form of instruction is not very effective for developing skills, changing behaviour or achieving learning to any significant depth.

I prefer to follow an interactive teaching approach. This resembles the learner-centred approach described in Section 6.5 of the WMO Guidelines, in that the trainer acts rather as a facilitator of learning activities than a source of knowledge. The learner is actively involved in the process, whether it be a brainstorming session, a debate about an issue, or a joint problem-solving activity. To explain my preference for this style, I will share personal reflections drawn from years of experience as an instructor. The philosophy behind these reflections can be transposed to online learning.

Most of the skill in face-to-face instruction is being aware of where the learners are at. This requires engagement from both sides.

To enhance this engagement, I encourage instructors to think of the classroom dynamic in terms of one instructor interacting simultaneously with multiple learners on a one-to-one

basis, rather than one instructor interacting with a group. Thus, when starting a class, say "Good morning. How are you this morning?", rather than "Good morning everyone. How are you all this morning?"

Continuing along this line, when inviting feedback, rather than ask "Does anyone have a question?", say "There must be some questions by now" or, with a pinch of humour, "I love questions!". If someone is frowning, ask them politely "Jane, you look like you have a question". Rather than ask "Does that make sense?", which usually makes learners feel obliged to answer "Yes" whether they understand or not, ask the more open version: "How do you feel about that?" Alternatively, since learners don't usually understand everything about a new topic, the instructor may prefer to ask "What would you like me to go over again?"

It took many years of instructing before I fully understood the difference between lecturing from course notes and instructing. Course notes cover the scientific material and are a key reference during a course. But time spent on discussing/brainstorming challenging topics and exploring applications/implications of concepts is completely different and, when done well, is the most fertile means of achieving learning outcomes. In the same way that "flipped classes" (WMO, 2013, p. 49) aim to optimize the time that learners spend in direct contact with their instructors through increased practice and feedback, the use of explanation, illustration, questioning, clarifying examples and story-telling is a more effective teaching method than simply reading course notes. This is not to say that well-written course notes do not go a long way to achieving learning. Rather, the experience of one person earnestly interacting with another is both primal and authentic, and therefore provides a more powerful way to teach.

Here is an example of facilitating understanding. Divergence is expressed mathematically as $\nabla \cdot V$, and in course notes the unit is traditionally given as s^{-1}. But what does this mean? The instructor can explore the concept by explaining how the components of divergence are terms like $\partial u/\partial x$, with units of m s^{-1} m^{-1}, along with words to describe the terms. Thus, we can understand divergence as the change of velocity per metre, which the instructor can illustrate with examples of objects speeding up or slowing down to create a divergent field.

What follows is some additional practical advice on interactive instruction gained through experience:

1. To build trust between instructor and learner, avoid or minimize use of expressions such as "of course", "obviously", "clearly", "it's easy to see that…", "it's simple to…". Such expressions make the learner feel inferior.
2. Use brief stories and occasional non-personal or self-deprecating humour to increase engagement.
3. It is respectful to the learner to properly clean whiteboards before a session – on too many occasions in my university education I have been duped by a residual dot that changed an intended velocity to an unwanted acceleration!
4. In the classroom, use coloured markers in a consistent fashion, ensuring that all the learners can see the colours used. Be similarly consistent when designing diagrams for course notes or distance learning.

5.   One of the most effective instructional techniques is to ask review questions at the start of a session. These provide feedback on understanding, focus the learners' minds on the upcoming topic, and can be prepared well beforehand and reused.
6.   Have breaks often – try not to go more than 45 minutes without one; just a two-minute stretch can be enough.
7.   Structure sessions and units well by giving outlines, both visually and verbally so that they reinforce each other.

Some history and etymology often interest learners and help to break up the monotony of a theoretical topic. For example: "What does *iso* mean?" → "So, what's an *isotach*?". "Now, what's a *barometer*?" → "So …*meter* means what?" "What's an *odometer*?" "So, what might *odo* mean? (Greek 'hodos' = way)" "Now what's a *barograph*?" → "Ok, putting all this together, what might we call a plot of the 'way' air moves above a point?" → *hodograph*. "Now let's plot one."

In the above exchange, the answer has largely been drawn out of the learners' prior knowledge.

When sketching cross-sections and plan views, try to draw in the *x-y* or *x-z* axes, to avoid confusion. What may be obvious to the instructor will be less clear to the learner.

When in the classroom, use physical models whenever possible. For example, a matchbox wrapped in paper with a magnet taped to the back becomes a very useful air-parcel for a magnetic whiteboard. When developing a distance learning course, consider creating a video or animation of the physical illustration.

In conclusion, I have shared in this submission insights into practices that have and have not worked, and I have challenged the traditional image of the lecturer. Traditional lecturers may not agree with the motivation behind this interactive approach. The learners will, however, and they will benefit from it.

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16.   Conducting community-based professional development with 3D-printed automatic weather stations

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Abstract

Communities all over the world want access to their own local environmental data. Weather stations can provide real-time data to help inform local decision-making, such as in agriculture, land use and disaster management. Rapid innovations in technology, such as 3D-printing and low-cost, single board computers, also make weather stations an engaging tool for Science, Technology, Engineering and Math (STEM) learning. In order to meet the high level of interest among diverse communities, The GLOBE Program (globe.gov) collaborated with community groups from the United States and Kenya to develop and facilitate collaborative, community-based engagement and professional development using low-cost weather stations.

Keywords: 3D-printed automatic weather stations, 3D-PAWS, community-based training, meteorology, Raspberry Pi, STEM education

16.1   Introduction

The reasons for owning, collecting and analysing local environmental data are as diverse as the local communities that seek to obtain them. Communities may want to manage their natural resources, make farming decisions, reduce the risk of weather-related disasters and learn about local environments. Thanks to recent advancements in hardware and software, a team of UCAR scientist and engineers designed a 3D-printed automatic weather station (3D-PAWS) that uses locally available materials, micro-sensor technology, a low-cost single board computer and a 3D printer. The 3D-PAWS sensors currently measure pressure, air temperature, relative humidity, wind speed, wind direction, precipitation and visible/infrared/UV light. The system uses a Raspberry Pi single-board computer to acquire and process environmental data in one-minute increments, which it then sends to a database. The 3D-PAWS stations have been installed in Kenya, Barbados, Zambia, Senegal, Uganda, Curacao, Austria, Germany, Turkey and the United States.

To build needed capacity for the global deployment of the 3D-PAWS systems, the GLOBE Program partnered with UCAR to develop and facilitate training sessions for the systems. GLOBE is an international science and education program that provides students and the public worldwide with the opportunity to participate in data collection and the scientific process, and to contribute meaningfully to our understanding of the Earth system and global environment. Students and citizen scientists participate in the programme by investigating their local environment, sharing their data through the programme database, and participating in data collection campaigns and research events, such as the Clouds Challenge. Students can contribute their research through the International Virtual Science

Symposium (IVSS). Educators gain skills through face-to-face training and e-Training online modules.

In 2015, GLOBE collaborated with UCAR's 3D-PAWS initiative to install automatic weather stations at schools participating in The GLOBE Program. Since then, many students, teachers, STEM professionals and community groups in the United States and internationally have reached out to GLOBE to learn more about 3D-PAWS technology as a way to input their local environmental data into the GLOBE database and to learn how to use the technology as a classroom and community tool.

Between 2018 and 2019, GLOBE leveraged existing partnerships to increase and facilitate 3D-PAWS professional development opportunities. Coupled with its environmental protocols, GLOBE elaborated and facilitated informal professional development models for diverse groups of teachers, students and other community members. The aim of these sessions was to provide schools with access to atmospheric observations of their local environment. The overall objectives of the hands-on training were to: (a) gain familiarity with the technology (software and hardware designs); (b) understand how to access, analyse and visualize environmental data; and (iii) support participants in making relevant connections between 3D-PAWS data and technology and community needs (such as connections to science standards in a public school or local decision-making in a community).

This chapter describes the GLOBE 3D-PAWS professional development sessions as they addressed each of the six competency requirements of the World Meteorological Organization (WMO) for education and training providers for meteorological, hydrological and climate services. It highlights the training model approach and shares lessons learned from the East African experience.

16.2 Training model

The model adopted for the training sessions stems from conducting community-based professional development through collaborations that focused on: (a) tailoring of professional development to meet diverse needs; (b) designing, developing and delivering learning solutions; and (c) real-time evaluation to align the training approaches with the WMO competency requirements.

Through leveraging community partnerships, GLOBE co-created unique professional development models that were tailored to the diverse needs of participants. These collaborations contributed to enhanced training models for participants and served as a professional development opportunity for GLOBE facilitators.

The training model recognizes that different groups have different training objectives and skills requirements that must be taken into account within the design of informal training sessions. This requires facilitators to tailor training by adapting skills and objectives to engage diverse participants. GLOBE leveraged existing partnerships with local non-profit organizations, universities and professional groups to better understand the unique objectives and needs of participants. This also helped the GLOBE facilitators identify the performance criteria and knowledge requirements goals for different trainee participants (WMO, 2015). Furthermore, collaborative partnerships can provide an opportunity to move

beyond "one-way" training models of information dissemination and knowledge sharing by providing facilitators with the context to learn and grow professionally.

16.2.1 Tailoring professional development to meet diverse needs

In order to design and develop learning activities and resources for the professional development workshops, GLOBE worked directly with personnel from the collaborating organizations and with representatives of the community where a 3D-PAWS had been or would be installed. GLOBE met with the collaborating organizations and community members in face-to-face meetings and video calls to assess the organizational context of partners (Competency 1), identify the learning needs and outcomes of the participants (Competency 2), to co-develop learning solutions with the collaborating organizations and community members (Competency 3), to design and develop learning activities and resources (Competency 4), and to deliver training and manage the learning experience (Competency 5).

Although the science and technology knowledge requirements are similar, the level of knowledge of the communities differed. The table below describes the varying needs, audience contexts, learning outcomes and training design decisions.

Tailoring professional development to meet diverse needs, contexts and outcomes

Primary audience	Competency 1. Analyse the organizational context and manage the training process	Competency 2. Identify learning needs and specify the learning outcomes	Competency 3. Determine a learning solution	Competency 4. Design and develop learning activities and resources	Competency 5. Deliver training and manage the learning experience
STEM professionals	GLOBE met with the organizers of the Intelligent Systems – Geosciences (IS-GEO) workshop to understand the context and goal of the workshop (IS-GEO 2018) and learned that the participants (scientists and engineers) were interested in hands-on experience of 3D-PAWS installation.	GLOBE exchanged with workshop organizers to understand the conference participants' needs. **Knowledge requirements:** Weather and climate, software/hardware, software installation, big data, and understanding micro-climates in Hawaii (place-based in two different locations), cross-disciplinary collaboration.	Key personnel (GLOBE staff and workshop organizers) collaborated on the design of the learning solution and determined that it required multi-day hands-on sessions.	GLOBE developed the informal learning delivery method, community of practice.	GLOBE staff worked directly with the participants to share learning and expertise throughout the hands-on experience.

Primary audience	Competency 1. Analyse the organizational context and manage the training process	Competency 2. Identify learning needs and specify the learning outcomes	Competency 3. Determine a learning solution	Competency 4. Design and develop learning activities and resources	Competency 5. Deliver training and manage the learning experience
Middle- and high-school teachers	GLOBE leveraged a pre-existing collaboration with a project aimed to better understand and promote practices that increase student motivation and capacity to pursue careers in the fields of science, technology, engineering and mathematics, and that help attract more students in education pathways leading to STEM careers.	GLOBE received email requests from teachers asking for professional development sessions focused on 3D-PAWS, which shaped the learning needs and outcomes. **Knowledge requirements**: Weather and climate, software/hardware, teaching pedagogies, appreciation of multicultural interaction.	As part of the MULTI programme, teachers participate in monthly professional development sessions. Through collaboration with the MULTI team, GLOBE staff determined that they could develop one of the half-day professional development sessions to provide a brief overview of the technology and conduct a more detailed needs assessment for a more in-depth training in the future.	GLOBE adapted several hands-on activities (description below). As part of the workshop, GLOBE asked teachers to consider different ways to engage all learners in the classroom by asking them to think about "focal students" in their classroom – actual students that teachers focus on during the workshop who represent diverse learners (i.e. English language learners, students not typically represented in STEM).	GLOBE staff conducted the learning experience. New trainers were coached by MULTI professionals. MULTI developed an "inclusive pedagogy strategy" checklist for staff to reflect on (description below).

Primary audience	Competency 1. Analyse the organizational context and manage the training process	Competency 2. Identify learning needs and specify the learning outcomes	Competency 3. Determine a learning solution	Competency 4. Design and develop learning activities and resources	Competency 5. Deliver training and manage the learning experience
Multi-generation community members	GLOBE leveraged a pre-existing collaboration with the Olohana Foundation in Hawaii. GLOBE met with the community to determine the training process. It was important to the community that members belonging to different generations were included in the process.	The Olohana Foundation applied to the Youth Learning as Citizen Environmental Scientists (YLACES) Foundation for a 3D-PAWS. As part of its grant application, it conducted a needs sensing, which resulted in the following learning outcomes: (a) how to install the station, (b) how to access its data, and (c) how to use the data to further its environmental understanding. **Knowledge requirements:** STEM skills, including science (scientific research skills), technology (both hardware and software skills), engineering (such as how to design, assemble, build and install the weather stations), mathematics (computational thinking, data analysis), how to collaborate with communities and place-based knowledge.	As GLOBE was installing 3D-PAWS with community members from different generations, the team decided that the best model would be informal, interactive training over several days to ensure sufficient time. GLOBE staff and Olohana Foundation provided science, technology, and cultural awareness skills.	GLOBE worked with the Olohana Foundation to design and develop an interactive, "place-based" learning experience for trainers and participants. The Olohana Foundation incorporated lessons of the local environment and culture into the session.	The Olohana Foundation provided community engagement and place-based knowledge skills, and coached GLOBE staff.

Primary audience	Competency 1. Analyse the organizational context and manage the training process	Competency 2. Identify learning needs and specify the learning outcomes	Competency 3. Determine a learning solution	Competency 4. Design and develop learning activities and resources	Competency 5. Deliver training and manage the learning experience
Students	GLOBE Kenya partnered with 3D-PAWS to install several stations across Kenya. GLOBE Deputy Country Coordinator, Charles Mwangi, conducted several training and coaching sessions with teachers.	Using GLOBE protocol bundles, students learn about environmental parameters and participate in the Space Challenge of the Regional Centre for Mapping of Resources for Development (RCMRD). **Knowledge requirements:** STEM skills (science and research), technology (both hardware and software skills), engineering (designing, assembling, building, and installing the weather stations), and mathematics (computational thinking, data analysis) as well as teamwork/collaboration skills.	GLOBE Kenya met directly with teachers and students to identify various formats (formal training, informal training, mentoring of students). Additionally, GLOBE has partnered with RCMRD to organize the RCMRD Space Challenge (teacher training, student research projects).	GLOBE conducted hands-on training using multiple learning activities and data visualization.	GLOBE has partnered with RCMRD to organize the RCMRD Space Challenge. This entails training teachers who subsequently guide students in analysing weather data and later in presenting their research findings at student science fairs and International Virtual Science Symposium (IVSS).

GLOBE coordinated and collaborated with community groups in order to recruit facilitators that could provide different skills: cultural awareness and facilitation, place-based skills that ground learning activities in a local context and address local problems, and varying degrees of science and technology. The exchange between GLOBE and partner organizations contributed to increased knowledge and skills in these areas. For example, during the teacher workshop, GLOBE partner, Dr Janelle Johnson, created a "Facilitator Skills Checklist" for GLOBE staff to self-assess their facilitation skills after professional development and to guide the design of future professional development experiences.

16.2.2 Designing, developing and delivering learning solutions (Competencies 4 and 5) and evaluation in real-time

In this section, we describe contextual aspects of professional development experiences, including how the assessments were integrated throughout the sessions.

Middle and high-school teachers – The first training event was a half-day professional development workshop for elementary and middle-school teachers. The workshop was held at the Metropolitan State University (MSU), Denver, Colorado, United States, in February 2019. GLOBE began the teacher workshop with an ice-breaker that invited participants to guess the current outside temperature and then graphed the results to compare them to the actual temperature. The purpose of this ice-breaker was to help participants to understand that humans are also natural "sensors" that use a spectrum of technology to make decisions, and that human sensors also require calibration and a focus on precision.

The facilitators then provided an overview of weather and asked the entire group to share their stories of how they teach weather in order to develop relevant connections to weather and climate. Some of the high-school teachers said they guide students to consider the weather needs of local agricultural decision-makers as end users of the data. The stories provided the facilitators with a context in which to learn the needs of the teachers. The facilitators were then able to incorporate the teachers' comments as relevant connections throughout the training to keep them engaged. The facilitators then provided an overview of 3D-PAWS and how it can be integrated into the classroom.

The facilitators divided the teachers into small groups to facilitate hands-on activities in rotation. The following activities developed by educators from the UCAR Center for Science Education were included: Climate Postcards (UCAR, 2012*a*), an activity that follows a traveller in her adventures to different climates, and Weather Adds Up to Climate (UCAR, 2016), an activity from Elementary GLOBE, which helps students to gain experience describing and reporting weather and to learn how weather patterns over a long period of time are used to describe the climate of a location, were both completed by elementary and middle-school teachers; middle- and high-school teachers completed The Systems Game (UCAR, 2012*b*), which engages learners through kinaesthetic learning about dynamic systems and can be applied to weather. These activities were selected because they can be used with diverse students in classrooms. Furthermore, the activities demonstrated how weather instruction and weather data can be used for all ages of learners from primary through post-secondary education. After each of the activities, the facilitators asked teachers to consider different ways in which the activities could be used for different learners.

Throughout the session, GLOBE facilitators asked the teachers to pause in the middle of each activity and reflect on how it could be used in a classroom or would need to be adapted to meet the needs of their students. Some of the teacher feedback includes:

1.   (Hands-on graphing of data) "Having students collect weather data and build graphs with Legos and drawing them with crayons was a helpful way to visually represent weather and climate, which will connect to the visual learners."

2.   (Making sure resources were connected to standards) "We use data and compare climate in different places across the world."

3.   (Using weather data as an assessment) "Using weather station data can help assess weather graphing."

4.   (Using 3D-PAWS data for student-driven research projects) "Combining GLOBE protocols with weather station data can help students understand data collection, instruments, analysis, and deduction."

Informal training in the community – In Hawaii, two hands-on training events led to the installation of six 3D-PAWSs near Hilo. In order to determine the knowledge requirements prior to developing the training courses, GLOBE staff met with the community and project team several times. The facilitators discussed how to balance community needs, environmental factors and the overall learning process in order to create an environment that supports learning. Particular attention was given to understanding community needs related to data collection. Utilizing video calls, the facilitators and community were able to develop mutual trust and respect, which helped the facilitators prepare presentations and develop learning exercises that were flexible enough to accommodate potential environmental constraints (such as rain). These sessions also provided the facilitators with an opportunity to inquire about the community's environmental monitoring needs and to develop a strong collaborative framework. Through these sessions, it was clear that the Olohana Foundation had a distinct need for the weather station data for the Foundation's agroforestry initiatives, which are central to its climate adaptation and mitigation efforts.

Scientifically, the network of weather stations provides communities with access to real-time data from multiple microclimates across the island, as the six stations span humid tropical climates to arid and semi-arid climates. Given the range of climates experienced on Hawaii, having six stations collecting simultaneously weather data is critical to understanding changing weather patterns for agroforestry and climate resiliency.

In order to install the stations and conduct professional development training related to the weather stations, GLOBE staff travelled to Hawaii. The community chose the locations for the weather stations according to multiple criteria, including their weather data needs and access to the community centre. By working alongside the community, the facilitators learned about the local environment, weather and culture – such as decision-making processes. This place-based approach allowed GLOBE and the community to exchange and share knowledge and experience on multiple levels. This experience provided the facilitators with entry points into deeper learning opportunities, which will help them tailor the materials for future training.

During training, the team guided participants to assemble and install a 3D-PAWS system at a local site. The facilitators focused on the local needs for weather observation information to communicate the purpose of the weather stations and data analysis.

The workshop started with the facilitators providing hands-on training during the initial installation. They provided clear assessment of and guidelines on the hardware assembly and installation of 3D-PAWS. During training, the facilitators oversaw the entire installation of 3D-PAWS to assess learning, as well as evaluate and improve training. For example, sixteen-year-old students led the building of the 3D-PAWS frame with minimal support. Throughout the process, the facilitators oversaw their work and helped the students assess and evaluate their own learning in real time. Other community members helped with the building and installation and asked questions throughout the process. The facilitators and the students answered the questions, which helped reinforce the evaluation.

16.3   East Africa experience

During the period 12–16 August 2019, a UCAR scientist and engineer conducted training for a GLOBE team and selected teachers in Nairobi, Kenya, on the construction and installation of 3D-printed weather stations. Subsequently, students, teachers and local GLOBE partners in Kenya, and recently in Uganda, have been actively involved in the installations (Figures 16.1 and 16.2). Over 20 3D-PAWS have been built and installed by the GLOBE team based in Nairobi. Teachers and students participate in the preparation of the site, on-site assembling and installation of the station, and learn about 3D-PAWS sensors and how to maintain a site.

Figure 16.1. Paul Kucera explaining the instrumentation included in a 3D-PAWS at Sirua Aulo Secondary School in Kenya.

**Figure 16.2. Charles Mwangi, Kenyan GLOBE Coordinator,
finishing the installation of a 3D-PAWS system located
at the Magomano Girls High School, Kenya.**

The students also learned about GLOBE protocols, including the GLOBE Clouds protocol, air temperature and surface temperature during the station deployments. Students have access to all the 3D-PAWS observations to learn about weather and climate and to conduct research studies such as those carried out in the framework of the Space Challenge of the Regional Center for Mapping of Resources for Development (RCMRD). Additional training resources and analysis tools will be available to teachers and students after the upcoming workshop in Kenya.

16.4   Conclusion and recommendations

Many professional development models have incorporated 3D-PAWS in order to meet diverse training needs. One major take-away from these experiences is that communities are eager to access real-time data and are enthusiastic about the 3D-PAWS technology due to its low-cost and the possibility of localized support and maintenance. In general, we found that it is beneficial to tailor professional development training to meet the needs of the community. Additionally, we found that it is beneficial to work directly with a community partner to understand local community needs prior to professional On the basis of our observations and practical experience, we recommend the following for future development and use of 3D-PAWS for community-based professional development in meteorology:

1.   Continue the development of an educational kit and associated curriculum that community members, particularly teachers and students, can use to dive deeper

into various aspects of the technology (hardware, software) and data science via 3D-printers and Raspberry Pi micro-computers, computational thinking concepts such as citizen science, big data and relevant, hands-on and place-based learning about weather and climate.

2.   Data access tools should be discussed before, during and after working with communities. Some communities may want to develop or access platforms that incorporate multiple datasets from other communities, while others will want to make decisions on who has access to their environmental data or possibly even the GPS coordinates of the 3D-PAWS locations. In Hawaii, the indigenous community was very interested in "data sovereignty". Therefore, it would be beneficial to include a professional development component about data ownership.

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