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CHAPTER 5. TRAINING OF INSTRUMENT SPECIALISTS

5.1 INTRODUCTION

5.1.1 General

Given that the science and application of meteorology are based on continuous series of measurements using instruments and systems of increasing sophistication, this chapter is concerned with the training of those specialists who deal with the planning, specification, design, installation, calibration, maintenance and application of meteorological measuring instruments and remote-sensing systems. This chapter is aimed at technical managers and trainers and not least at the instrument specialists themselves who want to advance in their profession.

Training skilled personnel is critical to the availability of necessary and appropriate technologies in all countries so that the WMO Global Observing System can produce cost-effective data of uniform good quality and timeliness. However, more than just technical ability with instruments is required. Modern meteorology requires technologists who are also capable as planners and project managers, knowledgeable about telecommunications and data processing, good advocates for effective technical solutions, and skilled in the areas of financial budgets and people management. Thus, for the most able instrument specialists or meteorological instrument systems engineers, training programmes should be broad-based and include personal development and management skills as well as expertise in modern technology.

Regional Training Centres (RTCs) have been established in many countries under the auspices of WMO, and many of them offer training in various aspects of the operation and management of instruments and instrument systems. Regional Training Centres are listed in the annex. Similarly, Regional Instrument Centres (RICs) and Regional Marine Instrument Centres (RMICs) have been set up in many places, and some of them can provide training. Their locations and functions are listed in Part I, Chapter 1, Annex 1.A, and Part II, Chapter 4, Annex 4.A and are discussed briefly in sections 5.5.1.2, and 5.5.1.3, respectively.

5.1.2 Technology transfer

Training is a vital part of the process of technology transfer, which is the developmental process of introducing new technical resources into service to improve quality and reduce operating costs. New resources demand new skills for the introductory process and for ongoing operation and maintenance. This human dimension is more important in capacity building than the technical material.

As meteorology is a global discipline, the technology gap between developed and developing nations is a particular issue for technology transfer. Providing for effective training strategies, programmes and resources which foster self-sustaining technical infrastructures and build human capacity in developing countries is a goal that must be kept constantly in view.

5.1.3 Application to all users of meteorological instruments

This chapter deals with training mainly as an issue for National Hydrometeorological Services. However, the same principles apply to any organizations that take meteorological measurements, whether they train their own staff or expect to recruit suitably qualified personnel. In common with all the observational sciences, the benefits of training to ensure standardized measurement procedures and the most effective use and care of equipment, are self-evident.

5.2 APPROPRIATE TRAINING FOR OPERATIONAL REQUIREMENTS

5.2.1 Theory and practice

Taking measurements using instrument systems depends on physical principles (for example, the thermal expansion of mercury) to sense the atmospheric variables and transduce them into a standardized form that is convenient for the user, for example, a recorded trace on a chart or an electrical signal to input into an automatic weather station. The theoretical basis for understanding the measurement process must also take into account the coupling of the instrument to the quantity being measured (the representation or “exposure”) as well as the instrumental and observational errors with which every measurement is fraught. The basic measurement data is then often further processed and coded in more or less complex ways, thus requiring further theoretical understanding, for example, the reduction of atmospheric pressure to mean sea level and upper-air messages derived from a radiosonde flight.

Taking the measurement also depends on practical knowledge and skill in terms of how to install and set up the instrument to take a standardized measurement, how to operate it safely and accurately, and how to carry out any subsequent calculations or coding processes with minimal error.

Thus, theoretical and practical matters are closely related in achieving measurement data of known quality, and the personnel concerned in the operation and management of the instrument systems need theoretical understanding and practical skills which are appropriate to the complexity and significance of their work. The engineers who design or maintain complex instrumentation systems require a particularly high order of theoretical and practical training.

5.2.2 Matching skills to the tasks

Organizations need to ensure that the qualifications, skills and numbers of their personnel or other contractors (and thus training) are well matched to the range of tasks to be performed. For example, the training needed to read air temperature in a Stevenson screen is at the lower end of the range of necessary skills, while theoretical and practical training at a much higher level is plainly necessary in order to specify, install, operate and maintain automatic weather stations, meteorological satellite receivers and radars.

Therefore, it is useful to apply a classification scheme for the levels of qualification for operational requirements, employment, and training purposes. The national grades of qualification in technical education applicable in a particular country will be important benchmarks. To help the international community achieve uniform quality in their meteorological data acquisition and processing, WMO recommends the use of its own classification of personnel with the accompanying duties that they should be expected to carry out competently.

5.2.3 WMO classification of personnel

The WMO classification scheme¹ identifies two broad categories of personnel: graduate professionals and technicians (WMO, 2001). For meteorological and hydrological personnel, these categories are designated as follows: meteorologist and meteorological technician, and hydrologist and hydrological technician, respectively. The recommended syllabus for each class includes a substantial component on instruments and methods of observation related to the education, training and duties expected at that level. The WMO classification of personnel also sets guidelines for the work content, qualifications and skill levels required for instrument specialists. Section 7.3 of WMO (2001) includes an example of competency requirements, while WMO (2002) offers detailed syllabus examples for the initial training and specialization

¹ Classification scheme approved by the WMO Executive Council at its fiftieth session (1998), and endorsed by the World Meteorological Congress at its thirteenth session (1999).

of meteorological personnel. These guidelines enable syllabi and training courses to be properly designed and interpreted; they also assist in the definition of skill deficits and aid the development of balanced national technical skill resources.

5.3 **SOME GENERAL PRINCIPLES FOR TRAINING**

5.3.1 **Management policy issues**

5.3.1.1 ***A personnel plan***

It is important that National Meteorological Services have a personnel plan that includes instrument specialists, recognizing their value in the planning, development and maintenance of adequate and cost-effective weather observing programmes. The plan would show all specialist instrument personnel at graded levels (WMO, 2001) of qualification. Skill deficits should be identified and provision made for recruitment and training.

5.3.1.2 ***Staff retention***

Every effort should be made to retain scarce instrumentation technical skills by providing a work environment that is technically challenging, has opportunities for career advancement, and has salaries comparable with those of other technical skills, both within and outside the Meteorological Service.

5.3.1.3 ***Personnel development***

Training should be an integral part of the personnel plan. The introduction of new technology and re-equipment imply new skill requirements. New recruits will need training appropriate to their previous experience, and skill deficits can also be made up by enhancing the skills of other staff. This training also provides the path for career progression. It is helpful if each staff member has a career profile showing training, qualifications and career progression, maintained by the training department, in order to plan personnel development in an orderly manner.

5.3.1.4 ***Balanced training***

National training programmes should aim at a balance of skills over all specialist classes giving due attention to the training, supplementation and refresher phases of training, and which result in a self-sustaining technical infrastructure.

5.3.2 **Aims and objectives for training programmes**

In order to achieve maximum benefits from training it is essential to have clear aims and specific objectives on which to base training plans, syllabi and expenditure. The following strategic aims and objectives for the training of instrument specialists may be considered.

5.3.2.1 ***For managers***

Management aims in training instrument specialists should be, among others:

- (a) To improve and maintain the quality of information in all meteorological observing programmes;
- (b) To enable National Meteorological and Hydrological Services (NMHSs) to become self-reliant in the knowledge and skills required for the effective planning, implementation

and operation of meteorological data-acquisition programmes, and to enable them to develop maintenance services ensuring maximum reliability, accuracy and economy from instrumentation systems;

- (c) To realize fully the value of capital invested in instrumentation systems over their optimum economic life.

5.3.2.2 ***For trainers***

The design of training courses should aim:

- (a) To provide balanced programmes of training which meet the defined needs of the countries within each region for skills at graded levels;
- (b) To provide effective knowledge transfer and skill enhancement in National Meteorological Services by using appropriately qualified tutors, good training aids and facilities, and effective learning methods;
- (c) To provide for monitoring the effectiveness of training by appropriate assessment and reporting procedures;
- (d) To provide training at a minimum necessary cost.

5.3.2.3 ***For trainers and instrument specialists***

The general objective of training is to equip instrument specialists and engineers (at graded levels of training and experience):

- (a) To appreciate the use, value and desirable accuracy of all instrumental measurements;
- (b) To understand and apply the principles of siting instrument enclosures and instruments so that representative, homogeneous and compatible datasets are produced;
- (c) To acquire the knowledge and skill to carry out installations, adjustments and repairs and to provide a maintenance service ensuring maximum reliability, accuracy and economy from meteorological instruments and systems;
- (d) To be able to diagnose faults logically and quickly from observed symptoms and trace and rectify systematically their causes;
- (e) To understand the sources of error in measurements and be competent in the handling of instrument standards and calibration procedures in order to minimize systematic errors;
- (f) To keep abreast of new technologies and their appropriate application and acquire new knowledge and skills by means of special and refresher courses;
- (g) To plan and design data-acquisition networks, and manage budgets and technical staff;
- (h) To manage projects involving significant financial, equipment and staff resources and technical complexity;
- (i) To modify, improve, design and make instruments for specific purposes;
- (j) To design and apply computer and telecommunications systems and software, control measurements and process raw instrumental data into derived forms and transmit coded messages.

5.3.3 **Training for quality**

Meteorological data acquisition is a complex and costly activity involving human and material resources, communication and computation. It is necessary to maximize the benefit of the information derived while minimizing the financial and human resources required in this endeavour.

The aim of quality data acquisition is to maintain the flow of representative, accurate and timely instrumental data into the national meteorological processing centres at the least cost. Through every stage of technical training, a broad appreciation of how all staff can affect the quality of the end product should be encouraged. The discipline of total quality management (Walton, 1986, and Imai, 1986) considers the whole measurement environment (applications, procedures, instruments and personnel) in so far as each of its elements may affect quality. In total quality management, the data-acquisition activity is studied as a system or series of processes. Critical elements of each process, for example, time delay, are measured and the variation in the process is defined statistically. Problem-solving tools are used by a small team of people who understand the process, to reduce process variation and thereby improve quality. Processes are continuously refined by incremental improvement.

WMO (1990) provides a checklist of factors under the following headings:

- (a) Personnel recruitment and training;
- (b) Specification, design and development;
- (c) Instrument installation;
- (d) Equipment maintenance;
- (e) Instrument calibration.

All of the above influence data quality from the instrument expert's point of view. The checklist can be used by managers to examine areas over which they have control to identify points of weakness, by training staff within courses on total quality management concepts, and by individuals to help them be aware of areas where their knowledge and skill should make a valuable contribution to overall data quality.

The International Organization for Standardization provides for formal quality systems, defined by the ISO 9000 group of specifications (ISO, 2005, 2008, 2009, 2011), under which organizations may be certified by external auditors for the quality of their production processes and services to clients. These quality systems depend heavily on training in quality management techniques.

5.3.4 **How people learn**

5.3.4.1 ***The learning environment***

Learning is a process that is very personal to the individual, depending on a person's needs and interests. People are motivated to learn when there is the prospect of some reward, for example, a salary increase. Nonetheless, job satisfaction, involvement, personal fulfilment, having some sense of power or influence, and the affirmation of peers and superiors are also strong motivators. These rewards come through enhanced work performance and relationships with others on the job.

Learning is an active process in which the student reacts to the training environment and activity. A change of behaviour occurs as the student is involved mentally, physically and emotionally. Too much mental or emotional stress during learning time will be counterproductive.

Trainers and managers should attempt to stimulate and encourage learning by creating a conducive physical and psychological climate and by providing appropriate experiences and methods that promote learning. Students should feel at ease and be comfortable in the learning environment, which should not provide distractions. The “psychological climate” can be affected by the student’s motivation, the manner and vocabulary of the tutor, the affirmation of previously-acquired knowledge, avoiding embarrassment and ridicule, establishing an atmosphere of trust, and the selection of teaching methods.

5.3.4.2 **Important principles**

Important principles for training include the following:

- (a) *Readiness*: Learning will take place more quickly if the student is ready, interested and wants to learn;
- (b) *Objectives*: The objectives of the training (including performance standards) should be clear to those responsible and those involved;
- (c) *Involvement*: Learning is more effective if students actively work out solutions and do things for themselves, rather than being passively supplied with answers or merely shown a skill;
- (d) *Association*: Learning should be related to past experiences, noting similarities and differences;
- (e) *Learning rate*: The rate of training should equal the rate at which an individual can learn (confirmed by testing), with learning distributed over several short sessions rather than one long session being more likely to be retained;
- (f) *Reinforcement*: Useful exercises and repetition will help instil new learning;
- (g) *Intensity*: Intense, vivid or dramatic experiences capture the imagination and make more impact;
- (h) *Effectiveness*: Experiences which are satisfying are better for learning than those which are embarrassing or annoying. Approval encourages learning;
- (i) *Support*: The trainee’s supervisor must be fully supportive of the training and must be able to maintain and reinforce it;
- (j) *Planning and evaluation*: Training should be planned, carried out and evaluated systematically, in the context of organizational needs.

5.3.4.3 **Varying the methods**

People in a group will learn at different speeds. Some training methods (see section 5.4) will suit some individuals better than others and will be more effective under different circumstances. Using a variety of training methods and resources will help the group learn more rapidly.

Research (Moss, 1987) shows that, through the senses, our retention of learning occurs from the following:

- (a) Sight (83%);
- (b) Hearing (11%);
- (c) Other senses (6%).

However, we learn best by actually performing the task. Methods or training media in general order of decreasing effectiveness are:

- (a) Real experience;
- (b) Simulated practical experience;
- (c) Demonstrations and discussions;
- (d) Physical models and text;
- (e) Film, video and computer animation;
- (f) Graphs, diagrams and photographs;
- (g) Written text;
- (h) Lectures.

These methods may, of course, be used in combination. A good lecture may include some of the other methods.

Traditional educational methods rely heavily on the spoken and written word, whereas evidence shows that visual and hands-on experience are far more powerful.

Training for instrument specialists can take advantage of the widest range of methods and media. The theoretical aspects of measurement and instrument design are taught by lectures based on text and formulae and supported by graphs and diagrams. A working knowledge of the instrument system for operation, maintenance and calibration can be gained by the use of photographs with text, films or videos showing manual adjustments, models which may be disassembled, demonstrations, and ultimately practical experience in operating systems. Unsafe practices or modes of use may be simulated.

5.3.5 **Personal skills development**

A meteorological instrument systems engineering group needs people who are not only technically capable, but who are broadly educated and are able to speak and write well. Good personal communication skills are necessary to support and justify technical programmes and particularly in management positions. Skilled technologists should receive training so that they can play a wider role in the decisions that affect the development of their Meteorological Service.

There is a tendency for staff who are numerate and have practical, manual ability to be less able with verbal and written linguistic skills. In the annual personal performance review of their staff, managers should identify any opportunities for staff to enhance their personal skills by taking special courses, for example, in public speaking, negotiation, letter and report writing or assertiveness training. Some staff may need assistance in learning a second language in order to further their training.

5.3.6 **Management training**

Good management skills are an important component of engineering activity. These skills involve time management; staff motivation, supervision and performance assessment (including a training dimension); project management (estimation of resources, budgets, time, staff and materials, and scheduling); problem solving; quality management; and good verbal and written communication skills. Instrument specialists with leadership aptitude should be identified for management training at an appropriate time in their careers.

Today's manager may have access to a personal computer and be adept in the use of office and engineering software packages to be used, for example, for word processing, spreadsheets, databases, statistical analysis with graphics, engineering drawing, flow charting, and project management. Training in the use of these tools can add greatly to personal productivity.

5.3.7 **A lifelong occupation**

5.3.7.1 ***Three training phases***

Throughout their working lives, instrument specialists should expect to be engaged in repeated cycles of personal training, both through structured study and informal on-the-job training or self-study. Three phases of training can be recognized as follows:

- (a) A developmental, training phase when the trainee acquires general theory and practice at graded levels;
- (b) A supplementation phase where the training is enhanced by learning about specific techniques and equipment;
- (c) A refresher phase where some years after formal training the specialist needs refresher training and updates on current techniques and equipment.

5.3.7.2 ***Training***

For instrument specialists, the training phase of technical education and training usually occurs partly in an external technical institute and partly in the training establishment of the NMHS where a basic course in meteorological instruments is taken. Note that technical or engineering education may extend over both WMO class levels.

5.3.7.3 ***Specialist training***

The supplementation phase will occur over a few years as the specialist takes courses on special systems, for example, automatic weather stations, or radar, or on disciplines like computer software or management skills. Increasing use will be made of external training resources, including WMO-sponsored training opportunities.

5.3.7.4 ***Refresher training***

As the instrument specialist's career progresses there will be a need for periodic refresher courses to cover advances in instrumentation and technology, as well as other supplementary courses.

There is an implied progression in these phases. Each training course will assume that students have some prerequisite training on which to build.

5.4 **THE TRAINING PROCESS**

5.4.1 **The role of the trainer**

Most instrument specialists find themselves in the important and satisfying role of trainer from time to time and for some it will become their full-time work, with its own field of expertise. All trainers need an appreciation of the attributes of a good trainer.

A good trainer is concerned with quality results, is highly knowledgeable in specified fields, and has good communication skills. He or she will have empathy with students, and will be patient and tolerant, ready to give encouragement and praise, flexible and imaginative, and practised in a variety of training techniques.

Good trainers will set clear objectives and plan and prepare training sessions well. They will maintain good records of training prescriptions, syllabi, course notes, courses held and the results, and of budgets and expenditures. They will seek honest feedback on their performance and be ready to modify their approach. They will also expect to be always learning.

5.4.2 **Task analysis**

The instrument specialist must be trained to carry out many repetitive or complex tasks for the installation, maintenance and calibration of instruments, and sometimes for their manufacture. A task analysis form may be used to define the way in which the job is to be done, and could be used by the tutor in training and then as a checklist by the trainee. First, the objective of the job and the required standard of performance is written down. The job is broken down into logical steps or stages of a convenient size. The form might consist of a table whose columns are headed, for example with: steps, methods, measures, and reasons:

- (a) Steps (what must be done): These are numbered and consist of a brief description of each step of the task, beginning with an active verb;
- (b) Methods (how it is to be done): An indication of the method and equipment to be used or the skill required;
- (c) Measures (the standard required): Includes a qualitative statement, reference to a specification clause, test, or actual measure;
- (d) Reasons (why it must be done): A brief explanation of the purpose of each step.

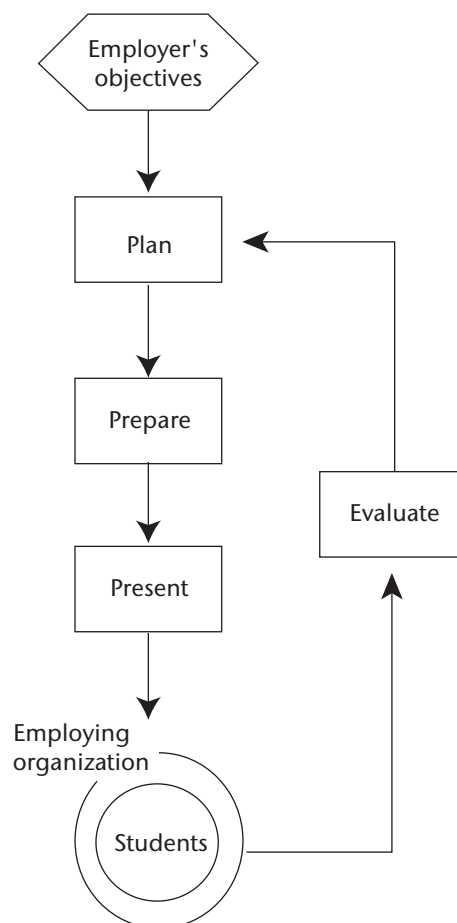
A flow chart would be a good visual means of relating the steps to the whole task, particularly when the order of the steps is important or if there are branches in the procedure.

5.4.3 **Planning the training session**

The training process consists of four stages, as shown in the figure:

- (a) Planning:
 - (i) Review the training objectives, established by the employing organization or standards-setting body (for example, WMO);
 - (ii) Analyse the features of the body of knowledge, task or skill that is the subject of the session;
 - (iii) Review the characteristics of the students: qualifications, work experience, language ability, specific problems;
 - (iv) Assess the required level of training (Which students may need special attention?);
 - (v) Determine the objectives for the session (What results are required? How can they be measured?);
- (b) Preparation:
 - (i) Select course content: Assemble information, organize it in a logical sequence;

- (ii) Determine training methods and media: appropriate to the topic, so as to create and maintain interest (see section 5.4.5);
 - (iii) Prepare a session plan: Set out the detailed plan with the time of each activity;
 - (iv) Plan evaluation: What information is required and how is it to be collected? Select a method and prepare the questions or assignment;
- (c) Presentation:
- (i) Carry out training, using the session plan;
 - (ii) Encourage active learning and participation;
 - (iii) Use a variety of methods;
 - (iv) Use demonstrations and visual aids;
- (d) Evaluation:
- (i) Carry out the planned evaluation with respect to the objectives;
 - (ii) Summarize results;
 - (iii) Review the training session for effectiveness in light of the evaluation;
 - (iv) Consider improvements in content and presentation;



Stages in the training process

- (v) Write conclusions;
- (vi) Apply feedback to the next planning session.

All training will be more effective if these stages are worked through carefully and systematically.

5.4.4 **Effectiveness of training**

5.4.4.1 **Targeted training**

With the limited resources available for training, real effort should be devoted to maximizing the effectiveness of training. Training courses and resources should be dedicated to optimizing the benefits of training the right personnel at the most useful time. For example, too little training may be a waste of resources, sending management staff to a course for maintenance technicians would be inappropriate, and it is pointless to train people 12 months before they have access to new technology.

Training opportunities and methods should be selected to best suit knowledge and skills requirements and trainees, bearing in mind their educational and national backgrounds. To ensure maximum effectiveness, training should be evaluated.

5.4.4.2 **Evaluating the training**

Evaluation is a process of obtaining certain information and providing it to those who can influence future training performance. Several approaches to evaluating training may be applied, depending on who needs the information among the following:

- (a) WMO, which is concerned with improving the quality of data collected in the Global Observing System. It generates training programmes, establishes funds and uses the services of experts primarily to improve the skill base in developing countries;
- (b) The National Meteorological Service, which needs quality weather data and is concerned with the overall capability of the division that performs data acquisition and particular instrumentation tasks within certain staff number constraints. It is interested in the budget and cost-benefit of training programmes;
- (c) The training department or Regional Training Centre, which is concerned with establishing training programmes to meet specified objectives within an agreed budget. Its trainers need to know how effective their methods are in meeting these objectives and how they can be improved;
- (d) Engineering managers, who are concerned with having the work skills to accomplish their area of responsibility to the required standard and without wasting time or materials;
- (e) Trainees, who are concerned with the rewards and job satisfaction that come with increased competence. They will want a training course to meet their needs and expectations.

Thus, the effectiveness of training should be evaluated at several levels. National and Regional Training Centres might evaluate their programmes annually and triennially, comparing the number of trainees in different courses and pass levels against budgets and the objectives which have been set at the start of each period. Trainers will need to evaluate the relevance and effectiveness of the content and presentation of their courses.

5.4.4.3 **Types of evaluation**

Types of evaluation include the following:

- (a) A training report, which does not attempt to measure effectiveness. Instead, it is a factual statement of, for example, the type and the number of courses offered, dates and durations, the number of trainees trained and qualifying, and the total cost of training. In some situations, a report is required on the assessed capability of the student;
- (b) Reaction evaluation, which measures the reaction of the trainees to the training programme. It may take the form of a written questionnaire through which trainees score, at the end of the course, their opinions about relevance, content, methods, training aids, presentation and administration. As such, this method cannot improve the training that they receive. Therefore, every training course should have regular opportunities for review and student feedback through group discussion. This enables the trainer to detect any problems with the training or any individual's needs and to take appropriate action;
- (c) Learning evaluation, which measures the trainee's new knowledge and skills, which are best compared against a pre-training test. Various forms of written test (essay, short answer questions, true or false questions, multiple-choice questions, drawing a diagram or flow chart) can be devised to test a trainee's knowledge. Trainees may usefully test and score their own knowledge. Skills are best tested by a set practical assignment or by observation during on-the-job training (WMO, 1990). A checklist of required actions and skills (an observation form) for the task may be used by the assessor;
- (d) Performance evaluation, which measures how the trainee's performance on the job has changed after some time, in response to training, which is best compared with a pre-training test. This evaluation may be carried out by the employer at least six weeks after training, using an observation form, for example. The training institution may also make an assessment by sending questionnaires to both the employer and the trainee;
- (e) Impact evaluation, which measures the effectiveness of training by determining the change in an organization or work group. This evaluation may require planning and the collection of baseline data before and after the specific training. Some measures might be: bad data and the number of data elements missing in meteorological reports, the time taken to perform installations, and the cost of installations.

5.4.4.4 **Training for trainers**

Trainers also require training to keep abreast of technological advances, to learn about new teaching techniques and media, and to catch a fresh vision of their work. There should be provision in their NMHS's annual budget to allow the NMHS's training staff to take training opportunities, probably in rotation.

Some options are: personal study; short courses (including teaching skills) run by technical institutes; time out for study for higher qualifications; visits to the factories of meteorological equipment manufacturers; visits and secondments to other NMHS and RICs; and attendance at WMO and other training and technical conferences.

5.4.5 **Training methods and media**

The following list, arranged in alphabetical order, contains only brief notes to serve as a reminder or to suggest possibilities for training methods (more details may be found in many other sources, such as Moss (1987) and Craig (1987)):

- (a) Case study:
 - (i) A particular real-life problem or development project is set up for study by individuals, or often a team;
 - (ii) The presentation of the results could involve formal documentation as would be expected in a real situation;

- (b) Classroom lecture:
 - (i) This is most suitable for developing an understanding of information which is best mediated in spoken and written form: basic knowledge, theoretical ideas, calculations, procedures;
 - (ii) Visual media and selected printed handout material are very useful additions;
 - (iii) There should be adequate time for questions and discussion;
 - (iv) Lectures tend to be excessively passive;
- (c) Computer-assisted instruction:
 - (i) This uses the capability of the personal computer to store large amounts of text and images, organized by the computer program into learning sequences, often with some element of interactive choice by the student through menu lists and screen selection buttons;
 - (ii) The logical conditions and branching and looping structures of the program simulate the learning processes of selecting a topic for study based on the student's needs, presenting information, testing for understanding with optional answers and then directing revision until the correct answer is obtained;
 - (iii) Some computer languages, for example, ToolBook for the IBM personal computer and HyperCard for the Macintosh, are designed specifically for authoring and presenting interactive training courses in what are known as "hypermedia";
 - (iv) Modern systems use colour graphic screens and may include diagrams, still pictures and short moving sequences, while a graphical user interface is used to improve the interactive communication between the student and the program;
 - (v) Entire meteorological instrument systems, for example, for upper-air sounding, may be simulated on the computer;
 - (vi) Elaborate systems may include a laser video disc or DVD player or CD-ROM cartridge on which large amounts of text and moving image sequences are permanently stored;
 - (vii) The software development and capital cost of computer-assisted instruction systems range from modest to very great; they are beginning to replace multimedia and video tape training aids;
- (d) Correspondence courses:
 - (i) The conventional course consists of lessons with exercises or assignments which are mailed to the student at intervals;
 - (ii) The tutor marks the assignments and returns them to the student with the next lesson;
 - (iii) Sometimes it is possible for students to discuss difficulties with their tutor by telephone;
 - (iv) Some courses may include audio or video tapes, or computer disks, provided that the student has access to the necessary equipment;
 - (v) At the end of the course an examination may be held at the training centre;
- (e) Demonstrations:
 - (i) The tutor demonstrates techniques in a laboratory or working situation;

- (ii) This is necessary for the initial teaching of manual maintenance and calibration procedures;
 - (iii) Students must have an opportunity to try the procedures themselves and ask questions;
- (f) Distance learning:
- (i) Students follow a training course, which is usually part-time, in their own locality and at times that suit their work commitments, remote from the training centre and their tutor;
 - (ii) Study may be on an individual or group basis;
 - (iii) Some institutions specialize in distance-learning capability;
 - (iv) Distance learning is represented in this section by correspondence courses, television lectures and distance learning with telecommunications;
- (g) Distance learning with telecommunications:
- (i) A class of students is linked by special telephone equipment to a remote tutor. They study from a printed text. Students each have a microphone which enables them to enter into discussions and engage in question and answer dialogue. Any reliable communications medium could be used, including satellite, but obviously communications costs will be an issue;
 - (ii) In more elaborate and costly systems, all students have computers that are linked to each other and to the remote tutor's computer via a network; or the tutor teaches from a special kind of television studio and appears on a television monitor in the remote classroom, which also has a camera and microphones so that the tutor can see and hear the students;
- (h) Exercises and assignments:
- (i) These often follow a lecture or demonstration;
 - (ii) They are necessary so that students actively assimilate and use their new knowledge;
 - (iii) An assignment may involve research or be a practical task;
- (i) Exhibits:
- (i) These are prepared display material and models which students can examine;
 - (ii) They provide a useful overview when the real situation is complex or remote;
- (j) Field studies and visits:
- (i) Trainees carry out observing practices and study instrument systems in the field environment, most usefully during installation, maintenance or calibration;
 - (ii) Visits to meteorological equipment manufacturers and other Meteorological Services will expand the technical awareness of specialists;
- (k) Group discussion/problem solving:
- (i) The class is divided into small groups of four to six persons;
 - (ii) The group leader should ensure that all students are encouraged to contribute;

- (iii) A scribe or recorder notes ideas on a board in full view of the group;
 - (iv) In a brainstorming session, all ideas are accepted in the first round without criticism, then the group explores each idea in detail and ranks its usefulness;
- (l) Job rotation/secondment:
- (i) According to a timetable, the student is assigned to a variety of tasks with different responsibilities often under different supervisors or trainers in order to develop comprehensive work experience;
 - (ii) Students may be seconded for a fixed term to another department, manufacturing company or another Meteorological Service in order to gain work experience that cannot be obtained in their own department or Service;
 - (iii) Students seconded internationally should be very capable and are usually supported by bilateral agreements or scholarships;
- (m) Multimedia programmes:
- (i) These include projection transparencies, video tapes and computer DVDs and CD-ROMs;
 - (ii) They require access to costly equipment which must be compatible with the media;
 - (iii) They may be used for class or individual study;
 - (iv) The programmes should include exercises, questions and discussion topics;
 - (v) Limited material is available for meteorological instrumentation;
- (n) One-to-one coaching:
- (i) The tutor works alongside one student who needs training in a specific skill;
 - (ii) This method may be useful for both remedial and advanced training;
- (o) On-the-job training:
- (i) This is an essential component of the training process and is when the trainee learns to apply the formally acquired skills in the wide variety of tasks and problems which confront the specialist. All skills are learnt best by exercising them;
 - (ii) Certain training activities may be best conducted in the on-the-job mode, following necessary explanations and cautions. These include all skills requiring a high level of manipulative ability and for which it is difficult or costly to reproduce the equipment or conditions in the laboratory or workshop. Examples of this are the installation of equipment, certain maintenance operations and complex calibrations;
 - (iii) This type of training uses available personnel and equipment resources and does not require travel, special training staff or accommodation, and is specific to local needs. It is particularly relevant where practical training far outweighs theoretical study, such as for training technicians;
 - (iv) The dangers are that on-the-job training may be used by default as the “natural” training method in cases where more structured training with a sound theoretical component is required to produce fully rounded specialists; that supervisors with indifferent abilities may be used; that training may be too narrow in scope and have significant gaps in skills or knowledge; and that the effectiveness of training may not be objectively measured;

- (v) The elements necessary for successful on-the-job training are as follows:
 - a. A training plan that defines the skills to be acquired;
 - b. Work content covering the required field;
 - c. A work supervisor who is a good trainer skilled in the topic, has a good teaching style and is patient and encouraging;
 - d. Adequate theoretical understanding to support the practical training;
 - e. A work diary for the trainee to record the knowledge acquired and skills mastered;
 - f. Progress reviews conducted at intervals by the training supervisor;
 - g. An objective measure of successfully acquired skills (by observation or tests);

- (p) Participative training:
 - (i) This gives students active ownership of the learning process and enables knowledge and experience to be shared;
 - (ii) Students are grouped in teams or syndicates and elect their own leaders;
 - (iii) This is used for generating ideas, solving problems, making plans, developing projects, and providing leadership training;

- (q) Peer-assisted learning:
 - (i) This depends on prior common study and preparation;
 - (ii) In small groups, students take it in turns to be the teacher, while the other students learn and ask questions;

- (r) Programmed learning:
 - (i) This is useful for students who are not close to tutors or training institutions;
 - (ii) Students work individually at their own pace using structured prepared text, multimedia or computer-based courses;
 - (iii) Each stage of the course provides self-testing and revision before moving on to the next topic;
 - (iv) Training materials are expensive to produce and course options may be limited.

Good teaching is of greater value than expensive training aids.

5.4.6 **Television lectures**

Some teaching institutions which provide predominantly extramural courses broadcast lectures to their correspondence students over a special television channel or at certain times on a commercial channel.

5.4.7 **Video programmes**

Video programmes offer a good training tool because of the following:

- (a) They provide a good medium for recording and repeatedly demonstrating procedures when access to the instrument system and a skilled tutor is limited;
- (b) The programme may include pauses for questions to be discussed;
- (c) A video programme can be optimized by combining it with supplementary written texts and group discussions;
- (d) Although professionally made videos are expensive and there is limited material available on meteorological instruments, amateurs can make useful technical videos for local use with modest equipment costs, particularly with careful planning and if a sound track is added subsequently.

5.5 RESOURCES FOR TRAINING

Other than the media resources suggested in the previous section, trainers and managers should be aware of the sources of information and guidance available to them; the external training opportunities which are available; the training institutions which can complement their own work; and, not least, the financial resources which support all training activities.

5.5.1 Training institutions

5.5.1.1 *National education and training institutions*

In general, NMHSs will be unable to provide the full range of technical education and training required by their instrument specialists, and so will have varying degrees of dependence on external educational institutions for training, supplementary and refresher training in advanced technology. Meteorological engineering managers will need to be conversant with the curricula offered by their national institutions so that they can advise their staff on suitable education and training courses. WMO (2001, 2002) give guidance on the syllabi necessary for the different classes of instrument specialists.

When instrument specialists are recruited from outside the NMHS to take advantage of well-developed engineering skills, it is desirable that they have qualifications from a recognized national institution. They will then require further training in meteorology and its specific measurement techniques and instrumentation.

5.5.1.2 *The role of WMO Regional Instrument Centres in training*

On the recommendation of CIMO,² several WMO regional associations set up RICs to maintain standards and provide advice. Their terms of reference and locations are given in Part I, Chapter 1, Annex 1.A.

RICs are intended to be centres of expertise on instrument types, characteristics, performance, application and calibration. They will have a technical library on instrument science and practice; laboratory space and demonstration equipment; and will maintain a set of standard instruments with calibrations traceable to international standards. They should be able to offer information, advice and assistance to Members in their Region.

Where possible, these centres will combine with a Regional Radiation Centre and should be located within or near an RTC in order to share expertise and resources.

² Recommended by the Commission for Instruments and Methods of Observation at its ninth session (1985) through Recommendation 19 (CIMO-IX).

A particular role of RICs is to assist in organizing regional training seminars or workshops on the maintenance, comparison and calibration of meteorological instruments and to provide facilities and expert advisors.

RICs should aim to sponsor the best teaching methods and provide access to training resources and media which may be beyond the resources of NMHSs. The centres will need to provide refresher training for their own experts in the latest technology available and training methods in order to maintain their capability.

Manufacturers of meteorological instrumentation systems could be encouraged to sponsor training sessions held at RICs.

5.5.1.3 ***The role of WMO-IOC Regional Marine Instrument Centres in training***

On the recommendation of the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology,³ a network of RMICs has been set up to maintain standards and provide advice regarding marine meteorology and other related oceanographic measurements. Their terms of reference and locations are given in Part II, Chapter 4, Annex 4.A, respectively.

RMICs are intended to be centres of expertise on instrument types, characteristics, performance, application and calibration. They will have a technical library on instrument science and practice, laboratory space and demonstration equipment, and will maintain a set of standard instruments with calibrations traceable to international standards. They should be able to offer information, advice and assistance to Members in their Region.

RMICs will assist in organizing regional training seminars or workshops on the maintenance, comparison and calibration of marine meteorological and oceanographic instruments and will provide facilities and expert advisors.

RMICs should aim to sponsor the best teaching methods and provide access to training resources and media. In order to maintain their capability the centres will arrange refresher training for their own experts in training methods and the latest technology available.

Manufacturers of marine meteorological and oceanographic instrumentation systems could be encouraged to sponsor training sessions held at RMICs.

5.5.2 **WMO training resources**

5.5.2.1 ***WMO education and training syllabi***

WMO (2001, 2002) include syllabi for specialization in meteorological instruments and in meteorological telecommunications. The education and training syllabi are guidelines that need to be interpreted in the light of national needs and technical education standards.

5.5.2.2 ***WMO survey of training needs***

WMO conducts a periodic survey of training needs by Regions, classes and meteorological specialization. This guides the distribution and kind of training events sponsored by WMO over a four-year period. It is important that Member countries include a comprehensive assessment of their need for instrument specialists in order that WMO training can reflect true needs.

³ Recommended by the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology at its third session (2009) through Recommendation 1 (JCOMM-III).

5.5.2.3 **WMO education and training publications**

These publications include useful information for instrument specialists and their managers. WMO (1986*b*) is a compendium in two volumes of lecture notes on training in meteorological instruments at technician level which may be used in the classroom or for individual study.

5.5.2.4 **WMO training library**

The library produces a catalogue (WMO, 1986*a*) of training publications, audiovisual aids and computer diskettes, some of which may be borrowed, or otherwise purchased, through WMO.

5.5.2.5 **WMO instruments and observing methods publications**

These publications, including reports of CIMO working groups and rapporteurs and instrument intercomparisons, and so forth, provide instrument specialists with a valuable technical resource for training and reference.

5.5.2.6 **Special WMO-sponsored training opportunities**

The Managers of engineering groups should ensure that they are aware of technical training opportunities announced by WMO by maintaining contact with their training department and with the person in their organization who receives correspondence concerning the following:

- (a) Travelling experts/roving seminars/workshops: From time to time, CIMO arranges for an expert to conduct a specified training course, seminar or workshop in several Member countries, usually in the same Region. Alternatively, the expert may conduct the training event at a RIC or RTC and students in the region travel to the centre. The objective is to make the best expertise available at the lowest overall cost, bearing in mind the local situation;
- (b) Fellowships: WMO provides training fellowships under its Technical Cooperation Programme. Funding comes from several sources, including the United Nations Development Programme, the Voluntary Cooperation Programme, WMO trust funds, the regular budget of WMO and other bilateral assistance programmes. Short-term (less than 12 months) or long-term (several years) fellowships are for studies or training at universities, training institutes, or especially at WMO RTCs, and can come under the categories of university degree courses, postgraduate studies, non-degree tertiary studies, specialized training courses, on-the-job training, and technical training for the operation and maintenance of equipment. Applications cannot be accepted directly from individuals. Instead, they must be endorsed by the Permanent Representative with WMO of the candidate's country. A clear definition must be given of the training required and priorities. Given that it takes an average of eight months to organize a candidate's training programme because of the complex consultations between the Secretariat and the donor and recipient countries, applications are required well in advance of the proposed training period. This is only a summary of the conditions. Full information and nomination forms are available from the WMO Secretariat. Conditions are stringent and complete documentation of applications is required.

5.5.3 **Other training opportunities**

5.5.3.1 **Technical training in other countries**

Other than WMO fellowships, agencies in some countries offer excellent training programmes which may be tailored to the needs of the candidate. Instrument specialists should enquire about these opportunities with the country or agency representative in their own country.

5.5.3.2 ***Training by equipment manufacturers***

This type of training includes the following:

- (a) **New data-acquisition system purchase:** All contracts for the supply of major data-acquisition systems (including donor-funded programmes) should include an adequate allowance for the training of local personnel in system operation and maintenance. The recipient Meteorological Service representatives should have a good understanding of the training offered and should be able to negotiate in view of their requirements. While training for a new system is usually given at the commissioning stage, it is useful to allow for a further session after six months of operational experience or when a significant maintenance problem emerges.
- (b) **Factory acceptance/installation/commissioning:** Work concerned with the introduction of a major data-acquisition facility, for example, a satellite receiver or radar, provides unique opportunities for trainees to provide assistance and learn the stringent technical requirements.

Acceptance testing is the process of putting the system through agreed tests to ensure that the specifications are met before the system is accepted by the customer and despatched from the factory.

During installation, the supplier's engineers and the customer's engineers often work together. Other components, such as a building, the power supply, telecommunications and data processing, may need to be integrated with the system installation.

Commissioning is the process of carrying out agreed tests on the completed installation to ensure that it meets all the specified operational requirements.

A bilateral training opportunity arises when a country installs and commissions a major instrumentation system and trainees can be invited from another country to observe and assist in the installation.

5.5.3.3 ***International scientific programmes***

When international programmes, such as the World Climate Programme, the Atmospheric Research and Environment Programme, the Tropical Cyclone Programme or the Tropical Ocean and Global Atmosphere Programme, conduct large-scale experiments, there may be opportunities for local instrument specialists to be associated with senior colleagues in the measurement programme and to thereby gain valuable experience.

5.5.3.4 ***International instrument intercomparisons sponsored by the Commission for Instruments and Methods of Observation***

From time to time, CIMO nominates particular meteorological measurements for investigation as a means of advancing the state of knowledge. Instruments of diverse manufacture and supplied by Members are compared under standard conditions using the facilities of the host country. An organizing committee plans the intercomparison and, in its report, describes the characteristics and performance of the instruments.

If they can be associated with these exercises, instrument specialists would benefit from involvement in some of the following activities: experimental design, instrument exposure, operational techniques, data sampling, data acquisition, data processing, analysis and interpretation of results. If such intercomparisons can be conducted at RICs, the possibility of running a parallel special training course might be explored.

5.5.4 **Budgeting for training costs**

The meteorological engineering or instrumentation department of every NMHS should provide an adequate and clearly identified amount for staff training in its annual budget, related to the Service's personnel plan. A lack of training also has a cost: mistakes, accidents, wastage of time and material, staff frustration, and a high staff turnover resulting in poor quality data and meteorological products.

5.5.4.1 **Cost-effectiveness**

Substantial costs are involved in training activities, and resources are always likely to be limited. Therefore, it is necessary that the costs of various training options should be identified and compared, and that the cost-effectiveness of all training activities should be monitored, and appropriate decisions taken. Overall, the investment in training by the NMHS must be seen to be of value to the organization.

5.5.4.2 **Direct and indirect costs**

Costs may be divided into the direct costs of operating certain training courses and the indirect or overhead costs of providing the training facility. Each training activity could be assigned some proportion of the overhead costs as well as the direct operating costs. If the facilities are used by many activities throughout the year, the indirect cost apportioned to any one activity will be low and the facility is being used efficiently.

Direct operating costs may include trainee and tutor travel, accommodation, meals and daily expenses, course and tutor fees, WMO staff costs, student notes and specific course consumables, and trainee time away from work.

Indirect or overhead costs could include those relating to training centre buildings (classrooms, workshops and laboratories), equipment and running costs, teaching and administration staff salaries, WMO administration overheads, the cost of producing course materials (new course design, background notes, audiovisual materials), and general consumables used in training.

In general, overall costs for the various modes of training may be roughly ranked from the lowest to the highest as follows (depending on the efficiency of resource use):

- (a) On-the-job training;
 - (b) Correspondence courses;
 - (c) Audiovisual courses;
 - (d) Travelling expert/roving seminar, in situ course;
 - (e) National course with participants travelling to a centre;
 - (f) Computer-aided instruction (high initial production cost);
 - (g) Regional course with participants from other countries;
 - (h) Long-term fellowships;
 - (i) Regional course at a specially equipped training centre.
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ANNEX. REGIONAL TRAINING CENTRES

<i>Country</i>	<i>Name of centre</i>	<i>WMO Region</i>
Algeria	Hydrometeorological Institute for Training and Research (IHFR), Oran	I
Angola	Instituto Nacional de Meteorologia e Geofísica, Luanda	I
Egypt	Egyptian Meteorological Authority, Cairo	I
Kenya	Institute for Meteorological Training and Research, Nairobi; and Department of Meteorology, University of Nairobi, Nairobi	I
Madagascar	École supérieure polytechnique d'Antananarivo, University of Antananarivo; and École nationale d'enseignement de l'aéronautique et de la météorologie, Antananarivo	I
Niger	African School of Meteorology and Civil Aviation (EAMAC), Niamey; and Regional Training Centre for Agrometeorology and Operational Hydrology and their Applications (AGRHYMET), Niamey	I
Nigeria	Meteorological Research and Training Institute, Lagos; and Department of Meteorology, Federal University of Technology, Akure	I
South Africa	South Africa Weather Service, Pretoria	I
China	Nanjing University of Information, Science and Technology, Nanjing; and China Meteorological Administration Training Centre, Beijing	II
India	Central Training Institute and National Water Academy, Pune; India Meteorological Department Training Centre, New Delhi; and Indian Institute of Technology Roorkee, Roorkee	II
Iran (Islamic Republic of)	Islamic Republic of Iran Meteorological Organization, Tehran	II
Iraq	Iraqi Meteorological Organization, Baghdad	II
Qatar	Qatar Aeronautical College, Doha	II
Republic of Korea	Korea Meteorological Administration, Seoul	II
Uzbekistan	Tashkent Hydrometeorological Professional College, Tashkent	II
Argentina	Department of Atmospheric and Ocean Sciences, University of Buenos Aires, Buenos Aires; and Department of Education and Training of the National Meteorological Service, Buenos Aires	III
Brazil	Department of Meteorology, Federal University of Pará, Belém	III
Peru	Universidad Nacional Agraria La Molina, Lima	III
Venezuela (Bolivarian Republic of)	Department of Meteorology and Hydrology, Central University of Venezuela, Caracas	III
Barbados	Caribbean Institute for Meteorology and Hydrology, affiliated with the University of the West Indies, Bridgetown	IV
Costa Rica	Section of Atmospheric Physics, School of Physics, University of Costa Rica, San José	IV
Indonesia	Meteorology, Climatology and Geophysics Agency, Tangerang; and Research Centre for Water Resources, Bandung	V
Philippines	Department of Meteorology and Oceanography, University of the Philippines; and Training Centre of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Quezon City	V

<i>Country</i>	<i>Name of centre</i>	<i>WMO Region</i>
Israel	Postgraduate Training Centre for Applied Meteorology, Bet Dagan	VI
Italy	National Research Council Institute of Biometeorology, Florence	VI
Russian Federation	Roshydromet Advanced Training Institute, Moscow; Moscow Hydrometeorological College, Moscow; and Russian State Hydrometeorological University, St Petersburg	VI
Turkey	Turkish State Meteorological Service, Ankara	VI

Note: For the most recent information on RTCs and their components, please visit: <https://www.wmo.int/pages/prog/dra/etrp/rpcs.php>.

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