Training on Dam Safety, Operation & Maintenance: some practical thoughts

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Introduction

In today's world, there is a need to create sustainability at all levels of engineering services, products and amenities, accounting for diminishing resources and environmental challenges. This can be achieved partially by ensuring appropriate and suitable educational programs for a competent engineering workforce.

In the developed world, the challenges are mostly to maintain the ageing engineering infrastructure, whereas in much of the developing world the available pool of engineering skills is typically below critical mass. Engineering professionals have always been challenged to keep up to date and to refresh their skills, therefore continued professional development has become an imperative. In addition, the active and progressive transfer of skills and knowledge in a diminishing workforce environment has become a crucial element to accelerate transforming and developing the younger generations scheduled to take over.

Based on practical experience, an analysis of different options of training is presented herein, mainly aimed at dam owners that are willing to train their personnel in matters related to dam safety, operation and maintenance. This paper presents and discusses customized on-site training, outlining the items typically accounted for in these training programs and sessions, the learning tools used, training frequencies, and overall benefits.

1. Capacity building in engineering

Before addressing the specific subject of training on dam safety, it is important to recall that it is usually part of a broader capacity building framework. In this regard, capacity building in the engineering environment is a dedication to the strengthening of economies, governments, institutions and individuals through education, training, mentoring, and the infusion of resources. It aims at developing secure, stable, and sustainable structures, systems and organizations, with a particular emphasis on using motivation and inspiration for people to improve their lives (WFEO [15]). In addition, engineering capacity is a must for the sustainability of countries, and this applies both to developing and developed countries.

It is generally accepted that success in capacity building can only be achieved through a systematic approach, taking into account a model that includes six essential "pillars", namely:

1. Individual − to ensure that the needs of the individual are met.
2. Institutional − to ensure that there are public or private institutions that can support the provision, operation and maintaining of infrastructure and services.
3. Technical − to ensure that there are technical standards, codes of practice and technical guidance.
4. Decision-making − to ensure that decision makers have the necessary knowledge and skills to make informed, logical and rational decisions.
5. Finance and funding − to ensure that adequate and affordable finance is available.

6. Resources, equipment, tools and supplies −to ensure that there is access to materials, equipment, tools and supplies for the designing, building, implementing, operating and maintaining of infrastructure and the provision of engineering services.

Apart from that, the World Federation of Engineering Organizations recommends a planning and implementation process for capacity building in engineering (WFEO [15]), shown in Figure 1, which is based on a traditional five-step approach of:

1. Determining applicability of capacity building to the project;
2. Planning the capacity building actions;
3. Implementing the capacity building actions at the project level;
4. Assessing the results of the planning and implementation of capacity building; and,
5. Incorporating feedback to continuously improve results on future programmes and projects.

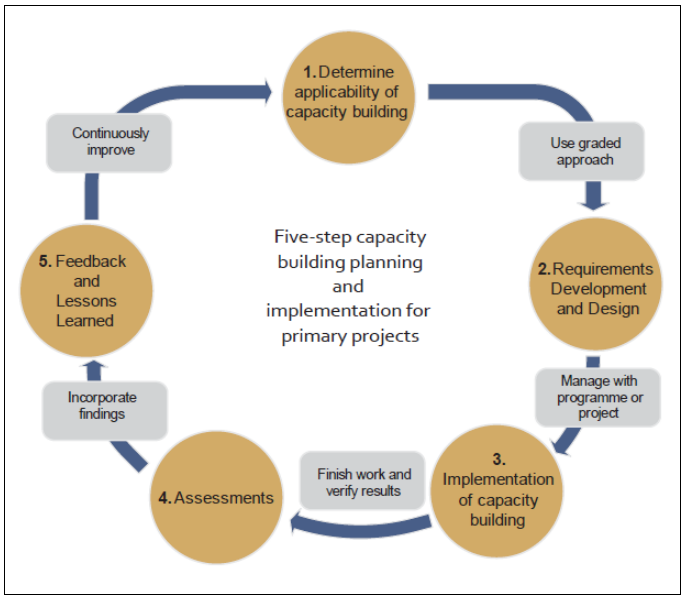

Fig. 1. Planning and implementation process for capacity building. Source: WFEO [15].

In general, capacity building is an expensive process and, in a broad sense, it usually requires a model for regional or industry cooperation to effectively increase human resource potential (Jones [10]). Instances of regional cooperation efforts in use as strategies for capacity building are the UNESCO cross-sectoral programs, such as the "African Network of Scientific and Technological Institutions" (ANSTI), which is an institutional network, or the "Consultative Group of International Agricultural Research" (CGIAR), as an example of networks of centres of excellence (Massaquoui [11]). At the industry level, we can find examples like the "Centre for Energy Advancement through Technological Innovation" (CEATI [2]), which is a user-driven organization committed to providing technology solutions by bringing together utility participants to collaborate and act jointly to advance the industry through the sharing and developing of practical and applicable knowledge, including the development of customized training solutions. Moreover, the "International Energy Agency Technology Cooperation Programme on Hydropower" (IEA [9]) is a working group of International Energy Agency member countries and others that have a common interest in advancing hydropower worldwide, with a mission based on encouraging through awareness, knowledge, and support the sustainable use of water resources for the development and management of hydropower.

In many cases, capacity building is for the purpose of supporting a project o programme, then it should be linked to executing and managing those projects or programmes throughout their lifecycle, from their initial conceptualisation right through to their successful completion and subsequent operation, maintenance and decommissioning phases (see Figure 2).

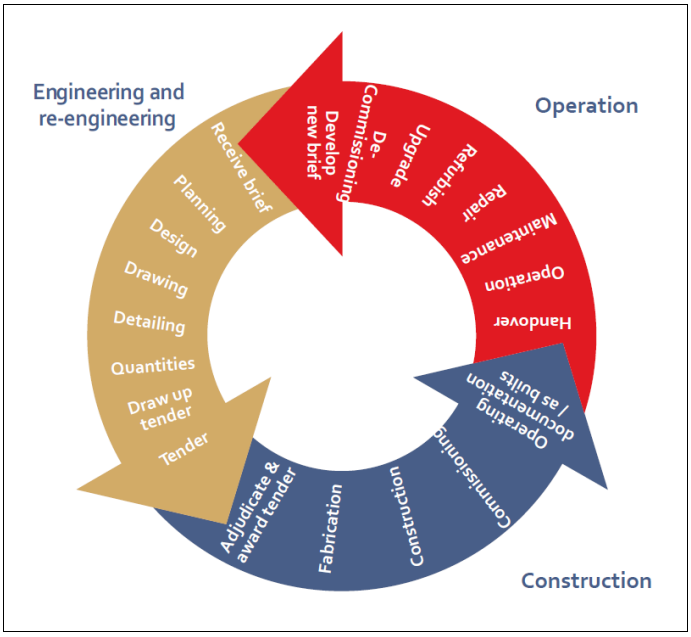

Fig. 2. The project cycle showing the skills that need to be acquired. Source: Allyson Lawless in WFEO [15].

Some of the modalities used in engineering capacity building are training (award of fellowships, seminars, workshops, etc.), the development of accreditation systems, the production of learning materials, raising awareness and facilitating the discussion of strategic issues, the exchange of visits and strengthening of research experience, entrepreneurial training, electronic learning, incubators for innovation, etc. Among them, this paper focuses on training and the development of engineering skills in the realm of dam safety, operation and maintenance.

2. Training and developing engineering skills

As previously mentioned, one of the main pillars of capacity building in engineering is a technical one which focuses on having an underpinning infrastructure including appropriate, relevant and up to date technical standards, codes of practice, procurement documents and procedures, regulations, as well as a developed statutory framework. In this context, training becomes one of the main tools available for effectively implementing capacity building within the industry, entailing a process by which professionals are taught the skills and knowledge that are needed for their job (FIDIC [6]). Capacity building needs to relate to specific norms and standards, the achievement of which is, or should be the objective of building the capacity, because there is really no point in building capacity for its own sake.

Furthermore, training is an important technique or procedure used in engineering capacity building. Conventional "training" is required to cover essential work-related skills, techniques and knowledge, and this term is often interpreted as the activity when an expert and learner work together to effectively transfer information[1] from the expert to the learner. Nowadays, many prefer to use the term "learning" instead, because it suggests that people are driving their own development, through relevant experience, beyond work related skills or knowledge and processes.

[1] At its most basic form, a piece of information about something is a "unit of awareness" about that thing. Typically, information evolves to knowledge when the learner gains context, perspective and scope about the information. In addition, skills are applying knowledge in an effective and efficient manner to get something done - one notices skills in an employee by their behaviour. A task is typically defined as a unit of work, that is, a set of activities needed to produce some result; they are sometimes referred to as functions. Moreover, a job is a collection of tasks and responsibilities that an employee is responsible to conduct, whereas a role is the set of responsibilities or expected results associated with a job (a job usually includes several roles).

"Learning" extends the idea of personal development to beliefs, values, ethics, integrity, and most important of all, to helping others to achieve their personal potential. In essence, "learning" describes a person growing whereas "training" commonly represents transfer of knowledge or skill for organisational gain. In this regard, another evolving issue is the expansion of learning beyond the learning of individuals, and the belief that groups and organizations can learn too, with the topics of organizational learning and knowledge management (Free Management Library [7]).

Training and learning thereby aim at developing specific engineering skills that are appropriate to make proficient, informed and anticipatory decisions; for the purposes of this paper, in the realm of dam safety. By way of illustration, the American Society of Civil Engineers (ASCE [1)] listed several areas of skill in terms of the body of knowledge that they envisage for the professional engineer of the year 2025, and the World Federation of Engineering Organizations (WFEO [15]) complemented it with some additional ones. On this basis, within the dam safety framework some of the skills that are deemed to be present in dam engineers and, if possible, to a reasonable extent in dam tenders/operators and related personnel include:

- Foundational skills: mathematics, natural sciences, humanities, social sciences, finance and funding.
- Technical skills: hydraulics, hydrology, geotechnics, geology, rock mechanics, materials science, mechanics, monitoring, risk and uncertainty, problem recognition and solving, application of research, design, sustainability, project management, how to develop and apply technology.
- Professional skills: communication, dealing with clients as well as owner and decision-makers, developing alternatives where resources are scarce, making informed decisions, assessing risks, understanding of cultural and ethical issues, transferring skills and mentoring, the ability to speak and read several languages, understanding politics and governance systems, operating in multi-skilled teams, operating in gender or religious sensitive environments, orientation in multi-disciplinary environments, entrepreneurship.

3. Some practices of training on dam safety

A number of institutions and organizations offer different training courses, seminars or workshops focused on dam safety related topics. Within the hydropower industry, for instance, we can find training opportunities facilitated by the CEATI Dam Safety Interest Group (CEATI [2]), which is composed of dam owners who jointly sponsor research & development projects with participants from Canada, the United States, Australia, New Zealand, Sweden, France, the United Kingdom, and Germany. In addition, part of the aforementioned IEA Hydro strategy relies on increasing the current wealth of knowledge on issues associated with hydropower by means of workshops and conferences.

Several government organizations and federal agencies in several countries also consider training on dam safety as part of their activities. One classic and well-known example is the "Training Aids for Dam Safety" (TADS) from the U.S. Federal Emergency Management Agency (FEMA [4]), which is a self-paced training course about dam safety practices. It encompasses a number of modules for engineers, technicians, dam owners and operators, water resource managers, dam safety program managers, public officials, and even the public. Part of the course is devoted to dam safety inspections, aimed at dam engineers and dam tenders. Another section is dedicated to dam safety awareness, organisation, and implementation, designed primarily for dam owners and operators. Finally, there are modules focused on data review, investigation, analysis and remedial actions for dam safety, having in mind dam safety program managers, dam owners and operators, and experienced engineers.

In Australia, the New South Wales Dams Safety Committee (DSC [3]) runs twice a year a "Dam Safety Surveillance Course" that enables the dam owner's operation and maintenance personnel to better understand the issues involved in dam safety surveillance, the reasons for the various requirements, and the detailed procedures for carrying out a dam safety surveillance inspection. This course runs for a total of four days and has a practical focus, involving a series of short illustrated talks, videos and slides followed by discussions on the topics covered. Certificates of attendance are awarded, including a thorough assessment, because the seminar is becoming aligned with an official certificate (the Water Industry Training Package).

Among regulators, there are also examples of active involvement in the organization of dam safety related training. For instance, the U.S. Bureau of Reclamation and the Army Corps of Engineers (USBR/USACE [14]) jointly

develop a five-day training course that details their best practices currently in use for estimating dam and levee safety risks. The United States Federal Energy Regulatory Commission (FERC [5]) also organizes several meetings, workshops and conferences throughout the year, focused on dam safety and their hydropower security program.

Other regulators usually resort to national committees on large dams, academic institutions or national engineering associations for the sake of providing professionals with dam related training opportunities. For example, the authors are involved with SPANCOLD's "International Master's Program on Dam and Small Dam Operation and Safety" (SPANCOLD [13]), which is aimed at university graduates and professionals with experience in the field of dams. It is a nine-month program jointly organized by SPANCOLD and Madrid's Polytechnic University (UPM), and it focuses on operation and maintenance of dams but also addresses the dam as a structure and the factors that influence safety levels. The eighth edition of this master's program is currently being held, and more than 200 students from Spain, Central and South America have already obtained their Master's Degree.

Finally, at the dam owner level many examples of dam safety training can also be found worldwide, and the authors can attest to the many initiatives taken by private and state-owned companies to implement dam safety training courses for their workforce.

4. Some practical thoughts on dam safety training and learning

Lastly, a number of considerations on dam safety training and learning is included herein, based on practical experience gained throughout the years in the implementation of courses, seminars and workshops for dam owners, regulators, academic institutions and engineering associations.

4.1. Training and learning with dam engineers and dam tenders

To be effective in teaching dam engineers and dam tenders, it is important to bear in mind that we are dealing with an adult audience that is usually no longer used to an academic environment. The material presented must have immediate usefulness and be relevant to the trainees. In addition, it is always vital to make sure that the training audience feels safe to actively participate, hence the importance of presenting the training in a respectful manner, so that attendees have an opportunity to share their experiences. It is always advisable to recognize the unique background and experience of people attending the course and to engage them by using real examples or anecdotes, showing how the material is relevant (Herrán [8]).

Fig. 3. Workshop on dam visual inspections carried out in Costa Rica.

There are many ways to develop any kind of training, but one practical approach that works well is actually focusing on what the attendees need to learn, rather than thinking about what we will teach. A needs assessment is also a useful way of identifying gaps in learning and further targeting the training for the participants. It is convenient to

know the names and titles of the attendees as well as their background, and determine if there are big differences in skill levels, so that some people may need specific attention. This helps to set out learning objectives that can put the purpose of our training in measurable terms, focusing on the desired outcomes and tailoring the content to the audience.

Other issues that must be addressed when developing any kind of training are the type of resources that will be available or needed; for instance, audiovisual means, rooms, materials, transportation, accommodation, need for special gear, security, safety certificates, etc. (see Figures 3 and 4). In addition, class-size is another key issue, because when dealing with face-to-face teaching, the best class size estimate is approximately 15 trainees per classroom, though smaller class sizes make it easier to use other learning methods besides lecture, such as break into groups or work on practicums and activities. When facing larger groups, it is still possible to make the learning more interactive by means of breaking up the lecture sessions and having attendees discuss several concepts or break into small groups to work on specific activities.

Fig. 4. Adaptation to the available audio-visual resources during a 4-day seminar on dam safety.

In summary, it is appropriate to make sure that the following elements are considered when setting up a training course, if applicable:

- A course outline with the learning objectives and the time allotted.
- A list of professional competencies, capabilities or standards that the course addresses.
- An evaluation tool, such as a quiz, test or final project.
- A syllabus denoting what the course will cover.
- A warm-up or ice-breaking exercise, depending on the group type and setting.
- A plan for open questions and ways to foster discussion throughout the course.
- Activities that ensure participation from all attendees.
- Follow-up resources, references, books, contact names, websites, etc. in order to reinforce learning.
- And finally, flexibility to adjust to the circumstances.

4.2. Dam safety training programs and methods of instruction

In the realm on dam safety, several topics are recurrent and can be found one way or another in most training programs, including the following:

- Regulatory requirements

- Legal obligations of dam owners/operators
- Types of dams and their design
- Historical incidents involving dams
- Dam construction
- Potential Failure Modes Analysis and Risk Assessment
- Safety Reviews: geology, geotechnics, structure, hydrology, hydraulics, etc.
- Monitoring and surveillance inspection of embankment and concrete dams
- Monitoring and surveillance inspection of spillways, outlet works
- Monitoring and surveillance inspection after earthquakes, floods or extraordinary events
- Reporting on inspections
- Operation and Maintenance of dams: operation rules
- Emergency Action Plans and Preparedness
- Asset management: renewal and upgrade of dams and appurtenances
- Occupational Health and Safety issues
- Dam Security

Fig. 5. Practical class on dam monitoring during SPANCOLD's International Master's Program (SPANCOLD [13]).

The length and scope of training courses related to dam safety are also quite diverse, but based on the authors' experience, any of the following types might be found:

- *A training program spanning several years*, for example, focusing on dam operation and maintenance with one particular dam owner, and including a hands-on transfer of knowledge to the owner's workforce. This type o training involves a few people in the making, and it usually needs a combination of lectures, workshops, seminars and specific activities on site, carried out for several weeks every year.
- *A master's course that is developed throughout one academic year*, like the aforementioned SPANCOLD's international program (see Figure 5). In this case, for each module of the course a number of teachers are involved, and both face-to-face and distance formats are possible, because all lectures are recorded and live-streamed (for one and half days per week). The course includes lectures, field trips, seminars and practicums, plus an assessment carried out by means of exams, practical assignments and a final project/dissertation.
- *A specialization course that only lasts a few months*, usually in a face-to-face manner, including classes for one or two days per week. This type of courses typically put an emphasis on one specific topic, for example,

risk assessment or dam surveillance, and they are usually developed for engineers with previous background.

- *A thematic short course that lasts a few days*, which is probably the most common type of training on dam safety related topics, always on the basis of the authors' experience. This course format also focuses on one specific topic and usually implies a hands-on approach, with practical relevance. It generally lasts from 2 to 4 days, and it encompasses introductory lectures with specific on-site activities (see Figure 6), which can be perfectly tailored for dam engineers and dam tenders alike.
- *A one-day training course* that commonly includes several talks or lectures by one or more experts. In this case, the classroom format is almost always used, although nowadays it can be held face-to-face or online. In this regard, virtual webinars are lately becoming very popular, and they entail a meeting of a group of people under the supervision of an expert who leads a discussion or study on a particular subject, even for only an hour or so.

Fig. 6. Use of problem-based learning during a workshop on dam monitoring.

In any of the aforementioned formats, developing proper dam safety training materials is the most time-consuming phase, but it is essential for any successful course because it helps to drive the training process and reinforces the learning objectives. This also includes choosing an instructional method as a means to accomplish those goals, namely:

- *Classroom training and lectures* get information across when interaction or discussion is not possible, or desired. However, they are best used to convey information in a short time, to communicate the same information to a large group of people, or to provide basic information. This is typically used in short courses and seminars.
- *Case studies and small group discussions* are the best way help participants discover learning points themselves and practice skills, perfect to apply new knowledge to a specific situation. It can be used whenever possible, but they are very suited to 2-4 day courses.
- *Experiential learning*, through supervised coaching, practicum, or internship, which lets trainees try new concepts or processes in a controlled environment. This is best used in long-term training and allows an actual knowledge transfer.
- *Simulations and games*, which provide a soft way of presenting course materials that want to recreate a process, event or set of complex circumstances, so that attendees can experience and manipulate the situation without risk and then analyze what happened. This is best used to integrate and apply complex skills, as well as to provide a realistic job-related experience, and the authors have used this type of method when dealing with risk assessment and, specifically, emergency action plan and preparedness training.
- *Projects and writing tasks*, which let trainees reflect on their understanding of concepts, information, and ideas, and allow them to work individually or in small groups on the content. This method is usually restricted to training with dam engineers, and it usually requires a medium or long-term course duration.

- *Self-study* allows trainees to acquire skills and knowledge through self-learning, guided by structured materials. This method is best used with dam engineers as computer-based modules or web-based virtual labs.

As discussed earlier, the instructional method and the training scope must be tailored to the needs and objectives of the participants. However, when dealing with dam safety related topics a hands-on approach is always advisable. As the classic "learning pyramid" shows in Figure 7, people often retain and remember more when they practice and use their learning, compared to when they just read or hear information. The strategies represented at the bottom of the pyramid produce much greater retention rates, and they always involve active learner participation.

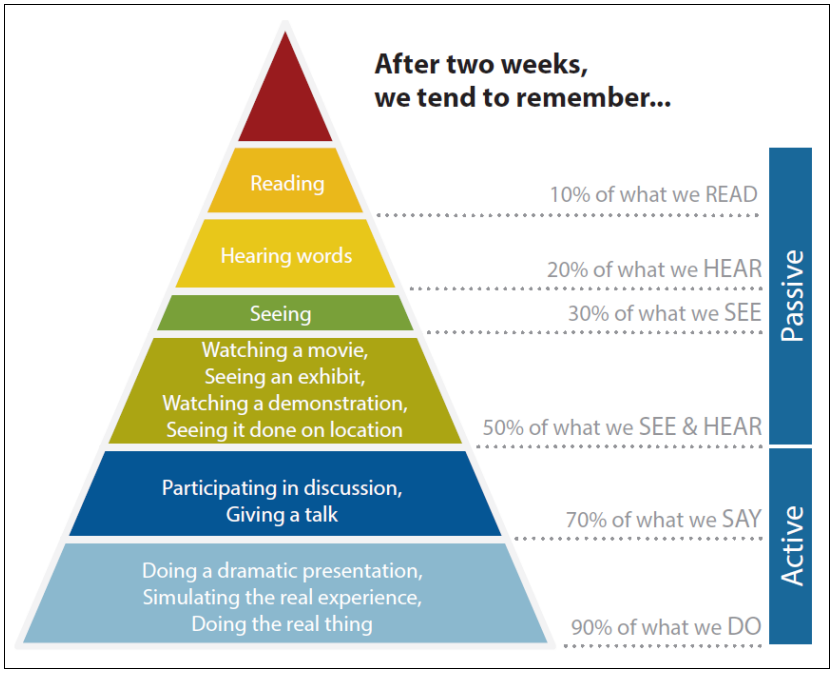

Fig. 7. The learning pyramid and teaching strategies. Source: University of Washington [12].

4.3. Delivering training for dam engineers and dam tenders

How effectively our course is received by the trainees depends largely on the learning atmosphere that we are able to set up and model. It is essential to build an environment of trust with the participants and have a positive attitude, so that constructive and supportive feedback can be delivered. In this regard, facilitation skills such as asking open-ended questions and rephrasing trainees' comments accurately for clarity are recommended. Another tip has to do with arranging for a separate time to tackle additional topics that may come up during the course, as well as always respecting every person's perspectives and contributions. Furthermore, making sure that the entire course content is covered is important, as well as sticking to a schedule.

As a complement to the different details and recommendations put forward in this paper, we can conclude it with the following final thoughts:

- Involve dam engineers and dam tenders in their own training.
- Encourage positive group dynamics (see Figure 8).
- Allow participants to discover facts and concepts for themselves.
- Ask trainees to keep an action list, so that they can revisit it throughout the sessions.
- Design training material that is as entertaining as possible.
- Be dynamic during the training implementation and "change the pace" if need be.

- Allow dam engineers and dam tenders to use their expertise by leaving time to share experiences.
- Try to convey the learning material in different ways and consider trainees' background.
- Teach with passion.

Fig. 8. Positive group dynamics is a key element for effective dam safety training and learning.

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