WATER-RELATED EDUCATION, TRAINING, AND TECHNOLOGY TRANSFER

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Contents

UNESCO – EOLSS SAMPLE CHAPTERS

Summary

Learning processes offer knowledge, skills, and competencies to the individual through different methods of education and training. The learning society and the concept of lifelong learning form the basis for the so-called "knowledge-based" economy. Since water resources development and management are an essential part of this economy, education, training, and transfer of technology for water resources should be seen as important aspects of societal policies for a sustainable future.

This theme article starts with a little history, and introduces several issues related to water resources in the learning environment. What does the water profession expect from education? We must consider the methods and tools used, the need to match demand and supply, and quality assessment of education and training. Transfer of technology to close the technology gap between countries can only be effective if an enabling learning environment exists. Capacity building must ensure that this environment is sustainable.

The concept of Integrated Water Resources Management (IWRM) is a globalization topic, because IWRM requires a thorough restructuring of local and regional water-management at the scale of the river basin, often at transnational level. This affects the workings of democracy, through its principle of public participation, and has profound consequences for the water economy. Thus it depends upon future education, training, and transfer of technology, as much as other aspects of globalization affecting the internationalization of education and civilization in general. An international vision and strategy for Water-Education-Training (W-E-T) is on the way.

1. Introduction: Learning for Everyone

Nobody is born "learned," and Article 26 of the Universal Declaration of Human Rights proclaims that education is everyone's right. Knowledge and skills must be acquired in order that individuals may act competently in society. This reality has been recognized in many ways since complex human societies began to develop. History offers numerous examples of organized learning and teaching systems in different civilizations. Over the last two centuries, educational systems gradually became an essential tool of governments wishing to ensure that the whole of the population of a country participates in its socio-economic and cultural development.

Learning involves asking "what, why, who, where, when, and how?" A non-exhaustive list of key factors in effective education includes:

- Information and communication
- knowledge and skills
- competencies
- methods of education and training
- tools for learning
- target groups for education and training
- motivation of learners
- cost-benefit analysis of education and training methods

UNESCO – EOLSS SAMPLE CHAPTERS

- demand articulation: matching supply and demand of education and training
- quality assessment/assurance
- certification, qualification, and accreditation.

Many of these issues will be introduced below, and in-depth discussion will follow in specific contributions to the theme.

It is said that the world economy is now knowledge-based more than ever, and that societies are becoming “learning societies” where everybody needs lifelong learning. Let’s face it: in reality learning is hard work, and people will always prefer to do something more pleasurable. The Internet will not change this human characteristic. Therefore, informal, formal, and non-formal education will all remain necessary. Figure 1, from UNESCO’s *World Education Report*, describes very well the different types of education necessary for creating a healthy “learning environment,” allowing for continuing education and training, and for effective transfer of technology adapted to the absorption capacity of a given society. Indeed, transfer of technology cannot be effective if the learning environment cannot be adapted. A whole series of educational and training systems must lead towards the development of competent individuals, able to accept, apply, and maintain the transferred technology and, eventually, to adapt the technology in a “wise” manner to address local requirements or problems.

“Competent” people are those who have the right knowledge and skills, abilities, attitudes, and ethical perceptions to undertake a given job. Whatever the level of a society’s sophistication, these people are essential: no buzzword such as “knowledge management” can be a substitute for individuals whose knowledge and skills are not easily transferable. Knowledge and skills can only be acquired through a “learning process”: this is often painstaking, and always individual. Hence the utmost importance must be given to efficient, effective education and training systems, and to the learning environment in general. Methods and tools for improving learning processes must be investigated, and institutions providing the appropriate education and training must be empowered. Motivating the learners is equally important.

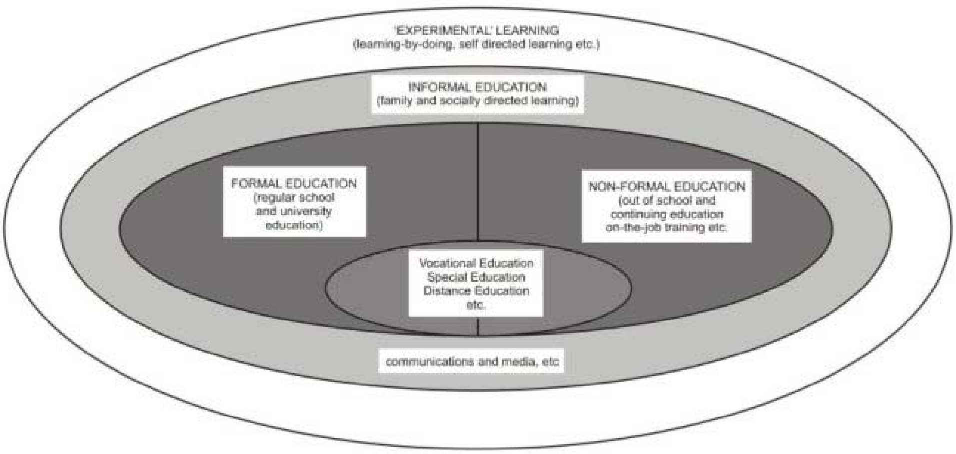

Figure 1. Education and the learning environment
Source: UNESCO (1991).

Quality assurance of education and training activities is essential, as well as the organizational and institutional framework within which education and transfer of technology occurs. Let us not forget the existing link between education and research. Education and research always go together, research being the generator of new knowledge. Capacity building is not complete if research capacity is not also developed through training of researchers. Universities play an essential role here because they introduce young people to science and research. But universities should be also very open, and invite as many practitioners into the educational processes as possible.

These general thoughts about education and transfer of technology apply, of course, to all domains of human activity, and not only to the use of water resources by humankind. Water is a natural resource *par excellence,* however: it is vital for all life on our planet. Water is everyone's property, and must be protected. Citizens should be involved in the decision-making processes. Not only do they have a right to be informed; they also need proper "water literacy," and thus should know "what's going on in the water business." Water resources deserve maximum attention when defining relevant policies concerning education and methods of technology transfer.

2. Education and Technology Transfer for Water Resources

2.1. About Education

Philosophers have always given thought to education, since it is such an important part of every human being's development. These thoughts are also reflected in the world's many mythological and religious systems.

The ancient river in Northern India, the Vedic *Sarasvati*, mentioned in the Rigveda, the oldest text available to humankind, has been considered mythological. By combining archaeological and historical research with paleohydrology, however, it was possible to rediscover this "lost" river beneath the sands of the Rajasthan desert. Within the context of this theme, it is an interesting coincidence that Sarasvati is still revered as the goddess of Arts, Science and Education in the present-day Hindu religion.

The Greek philosopher Plato (*c.* 428–348 B.C.) is considered the embodiment of the search for truth, through discussion and the exchange of ideas. Though he regarded mathematics as a valuable mental discipline, he took little interest in science. His vision of the physical world was an idealistic one, symbolized in his famous "perfect bodies" of geometry described in the Dialogue *Timaeus*: the CUBE associated with earth; the TETRAHEDRON associated with fire; the OCTAHEDRON associated with air; and the ICOSAHEDRON associated with water (see Figure 2). The latter was considered the most complex element in the universe.

UNESCO – EOLSS SAMPLE CHAPTERS

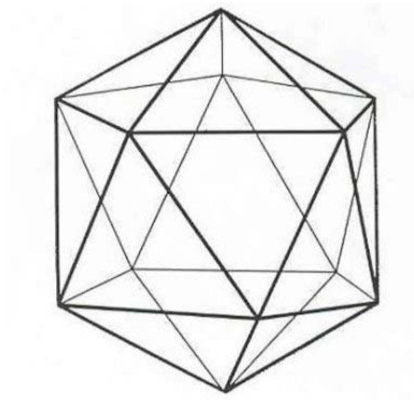

Figure 2. The icosahedron is a geometric body of twenty equilateral triangles with twelve angular points and thirty edges. It is a "perfect body" associated with water, considered as the most complex element in nature by Plato.

Plato's pupil, the philosopher Aristotle (374–322 B.C.), known to have been the tutor of Alexander the Great, did not follow Plato's idealism, and became increasingly concerned with science and the phenomena of the world. He may be considered the founder of the scientific method: critical analysis based on observations of natural phenomena. This scientific thinking resulted in many important water-related discoveries by Archimedes (287–212 B.C.), and by several other scientists, mainly from Alexandria.

Aristotle's thoughts on educating the young are reflected in his *Ethics*, where he stresses the value of "practical wisdom" and introduces the concept of the "kalon": beauty/balance/proportion/ harmony. But Aristotle also says that ethics does not offer a decision-making procedure appropriate to every practical problem. Ethical considerations are more important than ever for the "water business" of today, and thus for educational matters concerning water resources.

Ancient engineering approaches to water resources are well represented in archaeological finds from all over the world. Scientific or technical written records, or treaties, relating to these works are scarce, however, because these works were by "practitioners," and not by intellectuals. The first Roman author who wrote extensively about technical matters is Vitruvius (first century B.C.). His ten books on architecture include a book on water: on how to find it; on different waters; on tests of good water; on aqueducts, wells, and cisterns. Engines for raising water are described in Book Ten. These books had great influence at the time of the Renaissance. Frontinus (A.D. 40–106), principal water-manager of Rome and later governor of Britain, wrote *De aquaductibus*, a very detailed account on the aqueducts and water supply system of the City of Rome. Most of the Roman aqueducts—of which famous examples still exist, notably the Pont du Gard in Southern France—and their related urban water supply and sanitation systems remain undocumented, however. Thus the transfer of this technology primarily took place orally, and by training on-the-job. Hence, it is not surprising that this body of knowledge and skills was lost for more than a thousand years after the Roman Empire collapsed.

UNESCO – EOLSS SAMPLE CHAPTERS

Loss of knowledge and skills gathered in earlier civilizations has, of course, occurred many times in history, but in this instance it is surprising that it happened on such a scale, and that its loss persisted for such a long time. The more sophisticated technology becomes, the greater the risk of failure to maintain peoples' competence with it, unless the society of the time cares for education and training in an enabling learning environment.

The father of the "public school" was Antoine de Condorcet (1743–1794), a French nobleman, mathematician, and expert in hydraulics, a friend of d'Alembert, and a prominent participant in the French Revolution. He drew up a scheme for universal education, and was sincerely convinced about the progress possible to humanity through education. He put into application the ideas of Locke (1631–1704) concerning human understanding and education, rejecting "innate" knowledge but basing knowledge on the experience of the senses, and on inner reflection.

It is that which makes the great difference in mankind: the little, and almost insensible impression on our tender infancies, have very important lasting consequences. It is as in the fountains of some rivers, where a gentle application of the hand turns the flexible waters into channels, that makes them quite contrary courses and by this little direction given them at first in the source, they receive different tendencies and arrive at very remote distant places.

(John Locke, *Some Thoughts Concerning Education*)

2.2. Technology Transfer

The development of land drainage techniques in the nineteenth century offers an interesting case study. Although underground land drainage was well known to the Romans, and probably practiced throughout later centuries, it was applied only on a very limited scale. Mechanized production processes, starting in the late eighteenth century, made it possible to mass-produce clay tiles of standardized sizes, thus facilitating underground drainage of large areas. The European famine of 1830–1840, caused by potato diseases spread from Ireland, was needed before the technique was adopted, however, with the aid of major financial support from governments. France and Belgium sent their engineers to England to study the best land drainage practices. A truly European "training course" was held in 1850 in Brussels. From this time onwards, land drainage was considered an important technique for improving agricultural production all over Europe. Many well-trained practitioners published extensively about their newly found business. This was also an incentive (or a reason) for establishing "land drainage service" administrations, parallel to public works administrations, in many European countries. Thus a "capacity building" development, based on a new technology, took place over a period of about fifty years. These early administrations, in many European countries, were the ancestors of present-day water resources management institutions.

This particular history of technology transfer offers another interesting reflection. The physics of underground water flow were not yet well understood in the nineteenth century. The famous hydraulic expert B. de Saint-Venant, well known for his equation of surface flow, also attempted an equation for subsurface flow applied to land drainage

UNESCO – EOLSS SAMPLE CHAPTERS

but failed. Darcy formulated his empirical relationship for one-dimensional flow in porous media in 1856, as a result of a water supply problem. But it was only in 1904 that Boussinesq finally presented a correct equation for any fluid flow in porous media. Furthermore, it was almost another fifty years before land drainage design was scientifically well established.

This example shows how technological development can often run years ahead of scientific knowledge, and that "training for skills" is not necessarily a parallel activity to "education for knowledge." Present-day life tells us the same story: training for computer skills is essential for many people, but little or no knowledge about electronics is expected of them. One can only speculate about our present scientific knowledge of cybernetics, or systems science, while the technological control of systems—both biological and man-made—is important everywhere in our daily lives.

3. Profession and Education in Water Resources

3.1. Relevant Professions and their Activities

Water-related professions encompass scientists, technologists, engineers, and managers at all levels. They also include planners, consultants, organizers, and operators. More globally, they include:

- professionals
- technicians
- auxiliary workers.

Activities or jobs can be grouped into tasks to be entrusted to a group of people, or to just one person. The ability to perform such a task adequately can be described as a *competency*. Competencies identify measurable and developable human characteristics that permit superior job performance, quality assurance, and professional satisfaction. Competencies should be based on education and training, and formulated with a view to career development among participants. For an organization to be sustainable, it is of the utmost importance that its members acquire new competencies—including team competencies—in order to deal effectively with changing environmental conditions. Professionals must pay continual active attention to their own individual competencies.
It is possible to distinguish between five main types of activities, which might lead to involvement by different professions or jobs at given levels of responsibility:

1. Operation and maintenance of water works (for example reservoirs, navigation and irrigation canals, and related structures, dykes and levees, extraction wells, water supply and waste water treatment plants, and related distribution and collection systems);
2. Management of natural water resources (including lakes, rivers, soil and water conservation);
3. Monitoring (for example, measuring, data handling and analysis) and regulation (setting criteria, legislation, delivery of licenses, oversight and control);
4. Planning, design, and evaluation of the above works or actions;

UNESCO – EOLSS SAMPLE CHAPTERS

5. Research and teaching.

Engineers often work cyclically according to the following scheme:

- assessment
- research
- planning
- screening
- design
- decision-making
- financing
- implementation/construction
- use, operation, and exploitation
- maintenance
- evaluation of performance
- removal of object/decommissioning
- (sometimes also) crisis management.

3.2. Types of Education

Now the professional “target groups” have been defined, can we identify what types of education are needed for each of them?
Formal education itself is characterized by a clear sequence of events. Although there are great divergences in level and extent, the following groups and “steps” can be found in education systems in almost all countries:

- pre-school training
- primary education (in schools)
- secondary education (in higher institutions)
- tertiary education (postgraduate education and doctorates).

In addition, there are many forms of non-formal education and training. These include vocational education and training for technicians; continuing education and training; continuing professional development and individual learning programs; and adult education.

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UNESCO – EOLSS SAMPLE CHAPTERS

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UNESCO – EOLSS SAMPLE CHAPTERS

presently under revision for the 4th edition, gives a classification of personnel, their main activities, and basic instruction packages for professionals and technicians. It discusses continuing education and training, and gives examples of job requirements. WMO has an Education and Training Programme (ETP) with a Virtual Training Library (VTL), as well as a Hydrology and Water Resources Programme (HWRP) with a Programme on Capacity Building for Hydrology and Water Resources. Information on the Internet at http://www.wmo.ch/index-en.html.]

Biographical Sketch

Andre Van der Beken was born in Ghent (Belgium) and received an agricultural engineer's degree (M.Sc. level) in 1962, and a Ph.D. degree in 1969, at the State University of his home town. After a post-doctoral fellowship at the Iowa Institute of Hydraulic Research (Iowa City, USA), he became an appointed researcher of the National Fund for Scientific Research, working at the Laboratory of Hydraulics of the University of Ghent. In 1973 he moved to the newly-established Faculty of Applied Sciences of the Vrije Universiteit Brussels (VUB/Free University Brussels). Here he developed hydrology as a discipline in its own right, within the Civil Engineering curriculum. He became professor ordinarius in 1979, and was head of the Laboratory of Hydrology (later renamed Department of Hydrology and Hydraulic Engineering) from 1975–2000.

In 1979 he developed an M.Sc. postgraduate program in hydrology, under the auspices of the Belgian National Committee of the International Hydrological Programme (IHP) of UNESCO. In 1981 this became the Interuniversity Programme in Hydrology (IUPHY), sponsored by the Belgian Government Department of Co-operation for Development. He was director of IUPHY till 1994, and promoted its merger with a similar program in irrigation engineering at the Katholieke Universiteit Leuven (KU Leuven/Catholic University Leuven), to form the current Interuniversity Programme in Water Resources Engineering (IUPWARE).

Besides leading education programs and research projects in Belgium, the author has taught in Bolivia, Kenya, Italy, Tanzania, and Tunisia, and has helped to develop projects in Indonesia and Zambia. He was chairman of the Planning Group for UNESCO's International Hydrological Programme Phase V (1996–2001), and served at several Working Groups on education and training of IHP. In 1998 he was team-leader of the UNESCO-WMO-DWAF mission on the "Assessment of the Education and Training Needs of the Water Resources Management Services of the Republic of South Africa." He is a member of the WMO Executive Council Panel of Experts on Education and Training.

Since 1988 he has been promoter, partner, and co-ordinator of numerous education/training projects and networks funded by the European Commission. He was a founder and co-ordinator (1990–2000) of the University Enterprise Training Partnership TECHnology for WAter REsources (TECHWARE). The latest network is the European Thematic Network of Education and Training (ETNET) for ENVIRONMENT-WATER (see Bibliography).

UNESCO – EOLSS
SAMPLE CHAPTERS