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Restructuring a hydropower engineering course to address international professional needs

Efrossini C. Kalkani†, Leda G. Boussiakou‡ & Iris K. Boussiakou*

San José State University, San José, United States of America†
University of York, York, England, United Kingdom‡
University of Kent, Canterbury, England, United Kingdom*

ABSTRACT: The primary objective of this research is to restructure a course in hydropower engineering for an international audience. The principal research questions examine which engineering issues in hydropower and related areas should be addressed, what elements of effective teaching according to learning types and learning cycle should be considered, and what educational objectives should be pursued for the international professional needs. The research design and methods consider investigation of the international publications in hydropower, the published research on Kolb's Learning Styles, and Bloom's Educational Taxonomy. The scholarly contribution, beyond the application of the learning cycle sequence of *why*, *what, how* and *what if*, describes the educational procedures designed to transfer students from the knowledge-comprehension-application cognitive domains to the analysis-synthesis-evaluation domains. Opportunities for further research include considerations on adding subjects to the course that are related to the hydraulic-machinery industry, environmental issues, entrepreneurial know-how, legal frameworks and licensing requirements.

INTRODUCTION

The main objective of this article is to restructure and enhance a higher-level course in hydropower engineering. The course is presently taught to senior civil engineering students who specialise in hydraulics at the School of Civil Engineering at the National Technical University of Athens, Athens, Greece. The first author has taught the course for the last 22 years and, although the course has undergone enhancements and developments over the years, a major restructuring of the course is still necessary in order to address the needs of the international professional.

The following questions are associated with the primary objectives of this article and the hypotheses that guide the authors towards a satisfactory restructuring of the course:

- What engineering issues in hydropower and related areas should be covered in order to address the needs of the international professional?
- What are the elements of effective teaching in the classroom?
- What are the maximum educational objectives that should be pursued?

The author's research design includes investigation of the international publications in educational journals, books and the Internet. This research primarily covers areas such as teaching hydropower in the international arena, research on hydropower by international organisations, learning styles of students and classroom techniques, learning cycles for lower level skills and educational objectives for higher level skills.

The main outcomes and results of this research are included in the course restructuring. The course content includes the issues on hydropower to be taught, along with the necessary items of effective teaching in the classroom, as well as a list of course requirements in obtaining higher-level educational objectives for interested students.

Future research may include a continuation of the research presented here, with the goal of the continuous restructuring of the course according to international trends in hydropower teaching, global developments in engineering education and professional needs.

INTERNATIONAL HYDROPOWER TEACHING

A prime research question of this article covers the knowledge regarding the teaching of hydropower in an international setting. The authors' research indicates there to be three main educational centres engaged in hydropower teaching and preparing students for the profession, namely in Norway, China and India. The programmes in those centres differ regarding the content of the programme and the audience to which the programme is addressed. A short description of the existing programmes in hydropower education is presented below.

The Experience from Norway

At the School of Engineering and Technology, Department of Hydraulic and Environmental Engineering at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway, the programme, the course, *Hydropower Development*, is taught as a typical interdisciplinary course [1]. The programme provides education for future project managers in hydropower development and planners in the hydropower sector, and requires two years of study. The titles of courses and the content of general courses are included here, along with the areas of group projects:

- Hydropower Planning I, Hydropower Planning II, Hydropower Planning III, Hydropower Project, River System Analysis, Rock Engineering, Head-works and

Sedimentation Engineering, MSc Thesis in Hydropower Development;
- Geo subjects: Engineering geology, rock-blasting and tunnelling, soil mechanics, embankment dams, concrete dams and structures, concrete production;
- Hydro subjects: Basic and applied hydrology, hydraulics, hydraulic design, scour, basic sediment transport, turbines, stability, hydraulic steelworks, powerhouse design;
- Non-technical subjects: Environmental impact studies, basic economics, economic and socio-economic analysis, planning, management and implementation of hydro projects, tenders and contracts, small hydro;
- Group projects on pre-feasibility studies, hydropower development of river basins.

The Experience from China

The Hohai University in Nanjing, China, includes the College of Water Conservancy and Hydropower Engineering, which consists of the Department of Hydropower Engineering, the Department of Irrigation and Drainage Engineering, and the Institute of Water Conservancy and Hydropower Engineering [2]. Both the Department of Hydropower Engineering and the Department of Irrigation and Drainage Engineering are pioneering departments in science and engineering at Hohai University. The programme, which is a four-semester long programme, includes courses in the areas of hydropower, irrigation and drainage, plus auxiliary areas, as follows:

- Hydro Structure Engineering, Hydropower Engineering, Hydraulic and River Dynamics;
- Hydrology and Water Resources, Irrigation and Drainage Engineering;
- Fluid Machinery and Fluids Engineering;
- Computational fluid mechanics, and research on sediment motion;
- System analysis and optimisation;
- Irrigation and drainage engineering, pump station modelling;
- Structure, stability and seismic design of high concrete dams;
- Structure, materials and construction techniques of high embankment dams;
- Dam safety inspection and monitoring, seepage control;
- Inspection and monitoring of sluice gates and other metal structures;
- Structures of hydropower and pumped-storage development, numerical analysis and model tests of transients in water conveying systems;
- Design and test of hydro turbines and pumps, simulation of transients of machinery, modelling of governed hydro turbines and microcomputer-based governors.

The Experience from India

The Indian Institute of Technology at Roorkee, India, formerly University of Roorky, and its Alternate Hydro Energy Center organises an international training course on *Technology Selection for Small Hydropower Development* [3]. The course is sponsored by the Government of India for the development of Small Hydropower Plants (SHP) up to 25 MW and is taught to national and international students, mainly engineering professionals. The programme, part of a larger four-semester long programme in hydropower that leads to an MS of Technology degree, includes the following courses and activities:

- An overview of SHP project components;
- Use of modern technology, such as a Global Positioning System (GPS);
- Remote sensing and Geographical Information System (GIS) to conduct surveys, investigations and planning;
- Selection of technology for civil structures;
- Selection of hydraulic turbines;
- Selection of gates and valves;
- Selection of hydroelectric generators;
- Conventional and digital governors and controls;
- Power evacuation systems;
- Auto and remote operation of SHP;
- Economic and financial aspects related to technology selection for various components of SHP;
- Case studies, site excursion and tours.

INTERNATIONAL RESEARCH

One other research question of this article is the assessment of activities of international organisations, which collect data and perform research in hydropower issues and hydropower education. The main agency on energy statistics and research is the International Energy Agency (IEA), based in Paris, France. The IEA is an autonomous agency linked with the Organisation for Economic Cooperation and Development (OECD) and is the energy forum for 26 countries. The IEA sponsored the IEA Hydropower Agreement, with the title *IEA Implementing Agreement for Hydropower Technology and Programmes*, which completed its first phase in 1995-2000 [4]. The taskforces during the first phase considered the following major issues:

- Upgrading of hydropower installations;
- Small-scale hydropower;
- Environmental and social impacts of hydropower;
- Education and training in hydropower.

The taskforces have produced 19 technical reports and databases intended for professionals in their respective fields, and a report on sustainable energy with the title *Hydropower and the Environment: Present Context and Guidelines for Future Action*. The main items in each task include the production of guidelines, procedures, manuals, surveys and recommendations, as follows:

- Upgrading of existing installations (participating countries are Canada, Finland, France, Norway and Sweden):
    - Guidelines on Methodology for Hydroelectric Turbine Upgrading by Runner Replacement;
    - Guidelines on Methodology for the Upgrading of Hydroelectric Generators;
    - Guidelines on Methodology for the Upgrading of Hydropower Control Systems.
- Small Hydro, reduction in manufacturing costs:
    - Small Scale Hydro Assessment Methodologies;
    - Research and Development Priorities for Small Scale Hydro Projects;
    - Financing Options for Small-Scale Hydro Projects;
    - Global database on small hydro sites available on the Internet at: www.small-hydro.com
- Environmental and social issues (participating countries Canada, Finland, Japan, Norway, Spain and Sweden):

  - Hydropower and the environment: a survey of environmental and social impacts and the effectiveness of mitigation measures in hydropower development;
  - A comparison of the environmental impacts of hydropower with those of other generation technologies;
  - Legal Frameworks, Licensing Procedures, and Guidelines for Environmental Impact Assessments of Hydropower Developments;
  - Hydropower and the Environment: Present Context and Guidelines for Future Action;
  - Guidelines for the Impact Management of Hydropower and Water Resources Projects.

- Education and training, the needs of well-trained personnel in the operation, maintenance and planning of hydropower projects, as follows:

  - Summary of Results of the Survey of Current Education and Training Practices in Operation and Maintenance;
  - Development of Recommendations and Methods for Education and Training in Hydropower;
  - Operation and Maintenance;
  - Survey of Current Education and Training Practice in Hydropower Planning;
  - Structuring of Education and Training Programmes in Hydropower Planning, and Recommendations on Teaching Material and Reference Literature;
  - Guidelines for the Creation of Digital Lectures;
  - Evaluation of tests: Internet-based distance learning.

RESEARCH ON LEARNING STYLES

One of the main theories of learning is the theory on experiential learning, or experience as the source of learning and development [5]. Learning theories such as knowledge structure, Piaget's concrete and formal operational stages, Myers-Briggs intuitive versus sensing, Perry's model of college student development, as well as deep versus shallow approaches to learning, have been used by researchers to analyse student learning [6].

The Kolb model considers the thinking (abstract conceptualisation and concrete experience) and the processing (reflective observation and active experimentation) as essential elements of learning [5]. The concept of the four types of learners refers to people who can think and process along the axes between the four extremes defined by Kolb. A simplification of the Kolb's axes and the concepts of thinking, watching, sensing-feeling and doing are introduced later [7][8].

Researchers found that observations of their students in teaching an engineering course were consistent with the prediction of the type theory. Hence, the Myers-Briggs type indicator is a useful tool for helping engineering instructors and advisors understand their students and to design instruction in a way to benefit them [9].

The four elements of learning procedure and learning styles according to Kolb are graphically visualised in Figure 1 [5]. The abstract conceptualisation considers the theory and refers to thinking from the part of the student. Reflective observation involves watching and observations (lists, charts, diagrams, cross sections), concrete experience includes sensing and feeling (know material, dimensions, properties), while active experimentation covers doing (creating, designing, performing). Although Kolb identified four types of learners, newer research considers more categories, along with a scale for the degrees of intensity for each style [10].

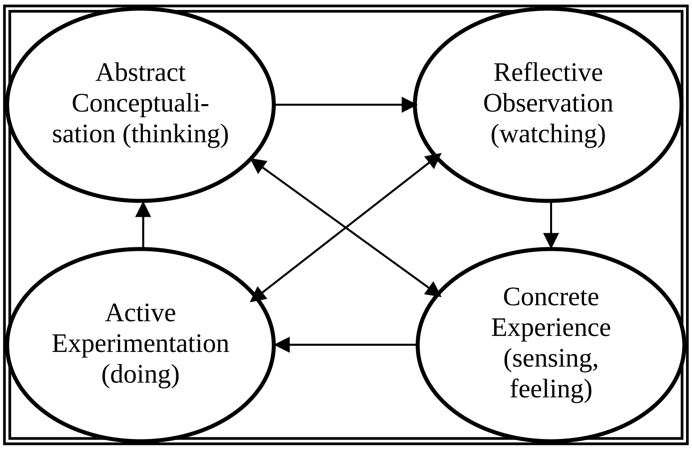

Figure 1: Graphical representation of the elements of learning and learning styles [5].

The main elements in addressing students' learning styles are those elements of thinking, watching, sensing/feeling and doing that should be included in the course. These elements are incorporated in lectures, demonstrations, videos and field trips, class quizzes and homework, as well as individual and group projects.

RESEARCH ON LEARNING CYCLES

The authors of this article based the main outcomes and results of their research on the restructuring of the course by using the Learning Cycle Theory by McCarthy, who developed his 4Mat theory as an extension of the basic elements of the work by Kolb [7]. Faculty can apply the Learning Cycle, independent of their disciplines, to improve and enhance engineering education [11]. Harb et al present the application of learning style theory to engineering education and include sample lessons [11].

The main features of the Learning Cycle can be represented in the four quadrants of the Cartesian coordinate system. The axes of the coordinate system have directions to the four elements of learning by Kolb [5]. This system is graphically visualised in Figure 2.

Considering a clockwise direction of the quadrants in Figure 2, one can model the cognitive sequence of the main questions of the students: why → what → how → what if. This sequence mandates certain activities from the part of the professor or instructor and from the part of students. These are the in-classroom activities summarised in the main outcomes and results section.

Furthermore, research in education regarding homework and group projects has indicated that the individual effort in cooperative learning of teamworking is unknown in the case of doing homework, unless team members confidentially rate how well they and their team-mates fulfil their responsibilities. By using individual weighting factors, individual project grades are computed as the product of the team project grade and the weighting factor, categorised in ratings received and given by men, women, ethnic minorities and non-minorities [12].

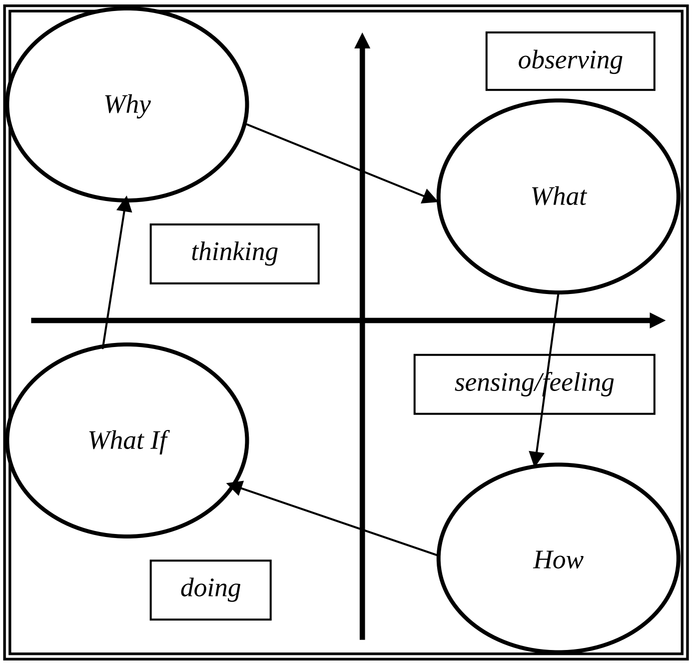

Figure 2: Graphical representation of the Learning Cycle according to McCarthy and Harb et al [7][12].

Students are encouraged to develop creative, independent thinking and to cultivate a deeper level of understanding through journal writing exercises. This means that students are asked to develop analogies or think of experiments before discussing them in class, where several analogies are presented, and the class then decide on the best analogy to be applied [13].

Engineering students tend to learn through active experimentation. It was found that students in interdisciplinary projects develop their engineering abilities better and enhance their interest in multidisciplinary curricula [14]. In order to understand dynamic systems, the modelling and control of an innovative approach to provide a physical demonstration was used by researchers according to the saying *feeling is believing* [15].

Regarding modern techniques, the researchers have considered *theme-course-structure* in order to improve students' mastery of course material by helping them to relate different course topics to one another via real equipment and processes. A comparison has been made to students who took the course given in the traditional manner of a *lecture-homework-examination* format. It was found that *theme-course-structure* students developed higher level skills, such as analysis, synthesis and evaluation [16]. Alternatively, a research tool that can be used to assess student learning is the Verbal Protocol Analysis, with which the student design process is evaluated along with the final design product [17].

As a result of the above-mentioned research of other researchers, the course restructuring will incorporate homework and group projects with the sequence: why → what → how → what if. Students in groups will grade their peers for performance. Also, students will develop analogies and models, use active experimentation, record their thinking procedures, and relate issues taught through group projects.

RESEARCH ON EDUCATIONAL OBJECTIVES

There are six levels of educational objectives according to Bloom's Taxonomy, namely three lower levels and three higher levels [18]. Usually, the undergraduate education deals almost exclusively with levels one to three, which refer to the knowledge, comprehension and application. Further, graduate education mainly covers levels four to six, which refer to analysis, synthesis and evaluation [19].

A graphical representation of the Bloom's taxonomy of educational objectives in the cognitive domain is presented in Figure 3, where the sequence of objectives is indicated with arrows. The sequence in educational objectives is usually knowledge → comprehension → application → analysis → synthesis → evaluation. In problem solving in higher-level education, the sequence of objectives may change and a return to the first step may be possible, thereby restarting the objectives sequence again. The authors consider a more free approach in moving between these steps and returning to knowledge, as indicated by the arrows in Figure 3.

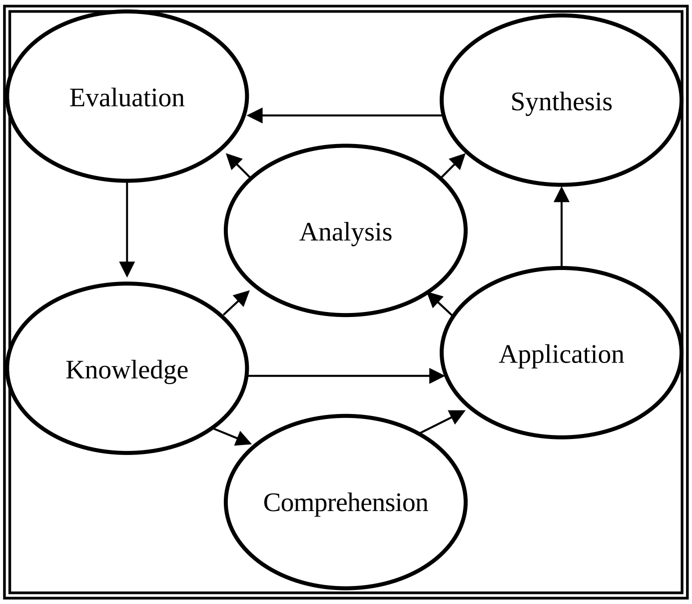

Figure 3: Graphical representation of the Bloom's Taxonomy of Educational Objectives [18].

The first step to achieving educational objectives is knowledge, which refers to the material that one can repeat from memory, or knows where to find it and how to reproduce it. The second step refers to comprehension, which means that the student understands the material and procedures, and is able to associate that information with other information. The third step refers to application, which means that the student can apply the knowledge and the understanding to a product or process using knowledge and comprehension. The fourth step refers to analysis, which comes in cases of word problems to solve, and the student has to classify, categorise, model, simulate, compare, and contrast his/her knowledge on products and procedures. The fifth step involves synthesis, where the student has to create, design and produce the product and procedures, as well as imagine, forecast, predict, invent and propose a solution. The sixth step involves evaluation, where the student has to decide, select, justify, recommend the product or the procedure, as well as to verify, debate, defend, judge and argue his/her solution.

The course in hydropower engineering that the authors are restructuring is a higher-level course in the civil engineering curriculum. The educational objectives of knowledge, comprehension and applications are covered in the lectures, homework, class discussions and group projects. The upper level educational objectives of analysis, synthesis and evaluation are covered with simulations, role-playing, Socratic lectures and group projects involving several issues from the lectures.

MAIN OUTCOMES AND RESULTS

The main outcomes and results of this article are associated with the research performed and previous experiences in the course. At this point, the major objectives of this article on which the outcomes and results are based are reiterated:

- Issues in hydropower and related areas;
- Elements of effective teaching in the classroom;
- Maximum educational objectives.

The main issues in hydropower and related areas that the course covers are societal needs regarding renewable energy, environmental possibilities and constraints, available hydropower machinery, types of layouts with main and auxiliary structures, construction management issues, and the economics and finances of hydropower. The course is taught in Greek and English. The English version is an intensive course, which is part of the curriculum of the European Engineering Graduate School Environment Water (IAHR-EGW), at the University of Stuttgart, Stuttgart, Germany.

The restructured course is a four-credit-hour course, consisting of two-hour lectures and two hours of practice, and is taught once a week with the practice session following the lecture session. The teaching subjects are distributed over 14 weeks and are placed in sequence according to content. Each weekly session has a separate subject delivered in class with descriptions and demonstrations to generate thinking and observing, followed by a sensing and feeling stage, and then by a doing stage. The overall weekly schedule of class time for the restructured course is presented in Table 1. Several teaching and communication techniques for the instructors to achieve their educational objectives are listed in Table 2.

The restructuring of the course will take into consideration the sequence of the main questions of the learning cycle shown in Figure 2, namely: why → what → how → what if. This sequence contains certain activities from the part of the professor or instructor and students individually, as group members and as a whole class. These activities, which are summarised in Table 2, give answers to the educational objectives discussed earlier, since these activities refer to the acquisition of knowledge (why, what, how), comprehension (why, what), application (how), as well as analysis (why, what), synthesis (how), and evaluation (what if).

Both Tables 1 and 2 include the main activities for the restructuring of the course. The authors believe that the information in both tables gives the body of knowledge in hydropower and develops students' skills in the higher educational levels of analysis, synthesis and evaluation.

IMPLICATIONS FOR FURTHER RESEARCH

The restructuring of the course was based on the previous experiences of the authors and the outcome of the research presented in this article.

Regarding the research on international hydropower teaching, compared to the experience from Norway, issues such as rock mechanics and geology, extended issues on dams, management and socio-economic issues are not included in the restructured course, since students studying hydropower may attend separate elective courses on those subjects. Compared to the experience from China, the course does not include hydrology, computational fluid mechanics, sedimentation, system analysis and optimisation, irrigation and drainage, structural design of structures and design of hydro-machinery, since there are separate courses on those topics available in the curriculum. Regarding the experience from India, although the Indian programme is designed for small hydro power plants, issues on GIS and GPS, as well as the automatic and remote operations of hydropower plants, are not included in this course.

Regarding IEA research, the upgrading of installations, runners, generators and control systems are not included in the restructuring of the course. Also not included are issues concerning the manufacturing industry in hydraulic machinery. Such matters like legal frameworks, licensing, creating electronic lectures and Internet-based distance learning are not included in the present restructuring, but may be included in a future course restructure.

Regarding learning styles in this research, in case students are not formally tested, assumptions can be made based on long experience with students in the classroom that most of the characteristics of the learning styles are present to varying degrees, such as active and reflective, visual and verbal learners, sensing and intuitive, and sequential and global. The prevailing personality type is that of the guardian, considering the attitudes of students towards learning issues, as well as the concerns and interest in their studies and their engineering work.

Concerning learning styles, the learning cycle and the educational objectives, the course was restructured so as to consider all learning types, and the actual sequence of the learning cycle. Also the educational objectives for lower and higher levels of learning were incorporated in the restructuring of the course.

Regarding environmental issues, the authors consider that these issues are already covered adequately in the course. The practices of civil, environmental and geological engineers share many common ethical and behavioural dilemmas, due to extensive interactions with clients, corporate cultures and regulatory agencies, while also dealing with unpredictable earth materials with uncertain design parameters [20]. A series of exercises had been developed for use in the classroom to incorporate a variety of active learning styles, individual and group writing, group design and role-playing [20]. However, this type of extended consideration of environmental issues is not included in the reorganisation of the course.

Regarding environmental education, other researchers consider that although the spectrum of environmental education approaches is broad, two main directions are proposed: learning to scientifically define how environmental processes work, and learning how to value and feel concern for the environment [21]. The importance of environmental and sustainable development considerations, as well as the need to be included in engineering education, has been discussed along with the requirements of the ABET Engineering Criteria [22]. Researchers have found that environmental literacy is an important part of undergraduate engineering education and that an environmental course enables students to make informed

Table 1: Overall schedule of teaching/learning activities in class per teaching week.

Wk	Theme Subject	Abstract Conceptualisation, Reflective Observation	Concrete Experience	Active Experimentation
		Thinking, Observing	*Sensing and Feeling*	*Doing*
1	Societal needs	Needs in power (capacity and energy). The physics in electricity theory, production, transport, consumption.	Sketching power capacity and energy consumption curves. Drafting production, transmission and distribution layouts.	Calculating individual and community needs in capacity and energy, and predicting variations of these needs over time.
2	Environmental issues	Availability in power production from water, resources available, capacity and energy possibilities.	Reviewing new developments, use of available resources, opportunities and threats.	Assessment of the availability factors in favour of and against developing hydropower
3	Availability of water	Environmental constraints, main and complementary uses of water, the hydrologic cycle, reservoirs, pumped storage.	Sketching the hydrologic cycle, making lists of known available water bodies, possible exploitation sites.	Listing the environmental constraints, advantages and disadvantages to the environment, and remediation.
4	Equipment, machinery	Available hydro machinery for small and large installations, auxiliary equipment.	Slide and video show of the available machinery in the market (turbines, pump-turbines, pumps).	Field trip to the hydraulic machinery laboratory on campus, and writing a report on the hydro machines.
5	Design of layout	Overall design and layout for small and large capacity hydropower installations.	Slide show of layouts, copying and sketching of the main features of layouts.	Sketching layouts, calculating dimensions of the main features on a given simple topography.
6	Design of layout	Design of access roads, removal of human installations, providing temporary and permanent facilities.	Creating lists of human or natural features at the site to be removed, alternatives of accessing the site, needed facilities.	Evaluate the quantities and cost, develop a time schedule for the removal of installations, and building facilities and accesses roads.
7	Design of waterways	Design of diversion tunnels, channels and alternative layouts.	Sketching the different types of structures in perspective, advantages and disadvantages in different site situations.	Performing preliminary hydraulic calculations, and identifying criteria for structural and foundation design.
8	Design of dam	Design of the dam and the reservoir, the cofferdams, river diversion and reservoir impoundment.	Sketching the different types of dams in perspective, advantages and disadvantages in different site situations, seepage and flow nets.	Performing preliminary stability calculations, identifying criteria for geo-technical and foundation design, grouting and drainage curtains.
9	Design of waterways	Intakes and headrace tunnels and channels.	Sketching the different types of structures in perspective, advantages and disadvantages in different site situations.	Performing preliminary hydraulic calculations, identifying criteria for structural and foundation design, and excavation methods.
10	Design of waterways	Spillways and bottom outlets.	Sketching the different types of structures in perspective, advantages and disadvantages in different site situations.	Performing preliminary hydraulic calculations, identifying criteria for structural and foundation design, excavation methods, and use of rock materials.
11	Design of power plant	Design of the power plant: underground, semi-covered or above ground.	Sketching the different types of power plants in perspective, advantages and disadvantages in different site situations, positioning the electro-mechanical machinery.	Performing preliminary dimensioning of turbines and pumps, criteria for structural and foundation design, listing of auxiliary functions, and switchyard structures.
12	Design of waterways	Design of tailraces in tunnels and channels, reservoir shore development, downstream landscaping.	Sketching the different types of structures in perspective, advantages and disadvantages in different site situations.	Performing preliminary hydraulic calculations, criteria for structural and foundation design, excavation operations, landscaping requirements, plus other uses.
13	Project management	Construction stage, management, resources, schedules, temporary and permanent installations, plus access roads and facilities.	Field trip to a hydropower construction site. Collection of information on resources, schedules, separate contracts, budgets, completion dates.	Report writing on the materials collected in the field trip. Input of items that should be considered in the project management design.
14	Economics	Economics and financing hydropower development.	Lists of cost and benefit items in a hydropower project, sources of financing and payback methods.	Calculating the cost and duration of activities, overall budget and schedule, plus cost-benefit analysis.
15	Final exam	Examination stage in thinking and observing.	Examination stage in sensing and feeling.	Examination stage in active experimentation.

Table 2: Learning cycle activities with reference to educational objectives.

Sequence	Why	What	How	What If
1	Motivational lecture	Formal lecture	Interactive lecture	Socratic lecture
2	Student concerns	Group concerns	Class concerns	Class discussion
3	Individual thinking	Group thinking	Brainstorming	Think tank
4	Instructor examples	Student examples	Internet examples	Guest lecturers, video/ television shows
5	Calculations and graphs by hand	Calculations and charts from *Excel*	Problem solving software	Complex software
6	Rough solutions	Exact solutions	Complex solutions	Simulations and role-playing
7	Individual student input	Student group input	Student oral presentations	Group oral presentations
8	Information from the textbook	Information from the Internet	Information from technical publications	Information from scientific publications
9	Examples from the textbook	Examples from the Internet	Examples from professional journals	Examples using engineering software
10	Examples in class undertaken by students	Examples worked at home (homework)	Laboratory or project reports individual	Complex problems and group projects
11	Class quiz	Class writing	Objective examinations	Subjective examinations
12	Observation	Analysis	Synthesis	Evaluation and revision

decisions within the context of environmental issues. The researchers describe the content of the course and discuss the assessment of the effectiveness of the course in promoting environmental literacy [23]. The authors consider an extension of the course to incorporate environmental issues extensively in a new restructuring of the course. Furthermore, the deregulation of the electric power industry is causing changes in the types of jobs that power engineers take after graduating, and makes necessary the hands-on active learning experience with power systems and machinery, as well the conversion of traditional courses to studio-type courses in the laboratory [24]. Actually, the deregulation of the electric power industry poses a major challenge in the development of many small producers of electricity from renewable energy sources like hydropower, which may prove considerably extensive in the future for students in civil engineering.

Although universities accomplish their primary mission in teaching and research, they do not establish or nurture the tradition of new venture creation, so that many new concepts and ideas are not directed to a commercialised product. The University of Arkansas has already seen this opportunity and has become a centre of entrepreneurial activity over the last decade [25]. The introduction of engineering and science students to entrepreneurship has been applied in at least six American universities. This includes not only championing by the dean, but also promotes collaborative activities, engaging faculty in teaching and research in entrepreneurship, promoting experiential learning, plus national recognition [26]. Issues on entrepreneurship are not included in the restructuring of the course; however, in a future review, those issues may be important in a hydropower course.

From a survey of former students in the workplace, the researchers have detected a direct correlation between the amount of technical communication instruction and career advancement. The study indicates that students should be encouraged to practice and develop their oral and written technical communication skills, and gain feedback while they study at university [27]. Although students' oral and writing skills are not especially considered in the restructuring of the course in this article, an effort will be made to give students appropriate guidelines for their oral and written presentations.

CONCLUSIONS

The primary objective of this article is to restructure a course in hydropower engineering so that it addresses international professional needs. The principal research questions and objectives refer to engineering issues in hydropower and related areas that should be covered, the elements of effective teaching according to learning types and learning cycle that should be considered, and the maximum educational objectives that should be pursued.

The research design and methods consider the international experience of curricula in hydropower from Norway, China and India, the research work and recommendations of the IEA, learning styles and learning cycle theories, plus Bloom's Taxonomy on Educational Objectives. Also, the research investigates results in educational issues from different researchers and the application of new theories in education.

The scholarly contribution of this research is that beyond the application of the learning cycle sequence of *why*, *what*, *how*, *what if* in the course's weekly schedule; the educational procedures recommended in this article will serve to transfer students from the knowledge-comprehension-application cognitive domains to the analysis-synthesis-evaluation domains.

The implications for further research cover the inclusion of international subjects related to hydropower, hydraulic machinery industry, environmental issues, entrepreneurial knowledge, legal frameworks, licensing issues and opportunities in electricity production from hydropower.

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