Teaching and Education Commentary

Contemporary Adjustments Needed to Teaching Water Economics in Light of Changes Facing the Water Sector and Its Users: Introduction to the Special Issue

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Abstract
Water resources management in many countries faces challenges that stem from a combination of impacts of climate change, population growth, and globalization. This introductory note argues that contemporary adjustments are needed to the curriculum of teaching water economics in light of these changes. The note reviews the contribution of each of the thirteen papers in the special issue to the question posed in the title of that special issue. The note concludes that while efforts and new ideas embedded in the papers reviewed, are effective, there is still room and need for additional aspects to be considered in the new water economics curriculum.

1 Motivation for the Special Issue

The water sector has been experiencing increased levels of climate change-induced water scarcity, frequent and longer droughts, water quality deterioration, human health implications, infrastructure fatigue, increased competition over dwindling resources, conflicts, and globalization, among other issues. These issues have various impacts on water managers and users across different sectors (e.g., agricultural, industrial, hydropower, environmental, and urban). In addition, new water sources, such as desalinated ocean and brackish groundwater, treated wastewater, and flood water, have been introduced in recent years for more substantial use by these subsectors. Furthermore, several management practices have been introduced, including joint (cooperative) management of various types of open-access water sources. These changes and challenges require skills that incorporate physical, institutional, and economic expertise on the part of water resource planners, managers, and policy makers.

Does the water (resource) economics curriculum used in our classes address such challenges and skill needs? Does it allow proper education and training of the next generation of water economists, planners, and managers?

Water economics has been taught for many decades at undergraduate and graduate levels. Teaching approaches included the traditional profit/utility-maximizing agents' behavior (e.g., farmers, households), where individuals decide to allocate a given amount of water among consuming activities. Main issues such as availability, allocation, pricing, investment, technology, and management of water resources have been at the forefront of the field of water economics. In recent decades, water resources worldwide have seen many transformations both locally and globally, making the challenges facing water-using agents much more complicated and, as a result, requiring a broader set of more advanced skills for the tools and methods they employ.

This AETR Special Issue (https://www.aetrjournal.org/) addresses whether the water economics curriculum is ready to cope with the increased level of challenges regarding water quantity, quality,

security, and derived complications. Papers in the special issue that are summarized and synthesized in this introductory note also provide examples of how to introduce tools and class activities that address such new challenges to the water economics curriculum. The following section consists of a short description of the various papers in the special issue. All in all, there are thirteen papers describing proposed courses and educational activities, as well as those that were already taught more than once in previous years. Papers describe courses that target graduate as well as undergraduate students. Some courses are designed for economics students, and some can accommodate non-economics students. Most papers provide (either in the paper or in a supplementary appendix to the paper) information about the syllabus, homework, or class assignments, students' feedback, and learning assessment at the end of the course.

The general message from this special issue is that our profession has stepped forward to prepare learning material that could help train the next generation of water economists and water managers to successfully meet the challenges faced by the water sector in the years to come. Is that effort sufficient and effective? After realizing what each of the thirteen published papers in the special issue offers, we will try to answer these questions in the remaining introductory note.

2 Highlights of the Various Papers in the Special Issue

Zilberman et al. (2023) present a new development for a water economics course that analyzes water allocation in a dynamic context. Not like traditional courses that focus on the microeconomics of water (e.g., water use at the levels of producers and consumers), this course examines water use and allocation in the context of evolving systems and institutions, similar to what Dinar and Tsur (2021) coined a "comprehensive approach." The paper by Zilberman et al. (2023) elaborates on the components of the course, the key aim of which is to provide students with a historical, global perspective and build on the role of political economy and public policy in the development of water systems. The paper presents the six elements of the course: an introduction to basic facts and features of the evolution of water systems; the political economy of water systems and their evolution over time; a cost-benefit analysis of developing water supply chains; regulatory interventions such as pricing, allocation, and management of water; negative externalities and environmental implications of water use; and global water issues. The paper also includes a set of assignments for the students in the course.

Brouwer (2023) describes the objective, methods, and structure of a graduate-level course offered to students in the Department of Economics and other schools and departments on the University of Waterloo, Ontario, Canada campus. The course introduces real-world challenges by linking theory and practical examples. The course aims to help students realize the role economic theory plays in real-world practical water management. The course's theoretical component is based on several water economics textbooks and concepts used in the context of water. The practical part consists of four main components: (1) a multi-source water allocation game; (2) a group assignment related to dam building and the subsequent monetary impacts on different sectors; (3) a survey data collection and analysis assignment, where students experience how different market and non-market valuation methods perform in practice; and (4) a field trip visiting local water facilities to realize practical managerial needs and ways to address them.

Nemati and Dinar (2023) observed that the share of agency staff involved in water decision making with a background in water economics in California and local water agencies is less than four percent. To address such a gap, they developed a general water economics and policy course that focuses on strengthening undergraduate non-economic students' understanding of water economics principles and how they can be used to provide insights into the implications of various water policy options and decisions. The course is targeted toward university upper-level non-economics students. The paper describes the objectives of the course, its building blocks and content, and its achievements in terms of learning outcomes. The paper also presents course achievement results from a learning

assessment survey, comparing the knowledge and understanding gained between the first and last week of the course. While the course is specific to California water issues, the pedagogical principles can still be applied to any other state or country and adjusted to the specific water issues and challenges in that state or country.

Ward (2023) calls for introducing innovations in the water resource economics curriculum due to several climate-related challenges faced by those who would become water managers. Some of those challenges include addressing population stress, food security, water security, energy security, environmental protection, peace, economic development, health, climate, and poverty. Few examples exist despite the need for innovations in the water economics curriculum. The paper addresses several curriculum innovations suggested for use in a water economics course. The article presents economic principles needed to form a foundation for curriculum reform in water economics so that students will better understand today's water challenges. In addition, the paper identifies adjustments required to ensure a solid education and training of the future generation of water economists. These two aspects are addressed by describing the range of water-related issues using international contexts. The paper incorporates several innovations to the syllabus, such that they can prepare water economics students to understand better and address emerging water science and policy challenges. A mathematical programming model is implemented as a homework assignment to demonstrate the various concepts used in the class.

Colby (2023) describes the principles of a water resource economics course, which provides a new focus, given global water crises and innovations in effective water management and governance. Among the aspects described are a new generation of water policy tools and an explanation of the role of benefit-cost analyses in the policy process. The paper suggests a more comprehensive approach, emphasizing the role of water in energy, food, and development economics; social justice and cross-cultural considerations; up-to-date understanding of neurobehavior in economic water-related decision making; and the importance of non-market valuation and regional economic methods. Several new aspects provided in the course include geospatial data in water resource economics econometric analyses and more sophisticated treatment of risks related to extreme events such as floods and droughts. The article offers several other practical recommendations for designing upper-level undergraduate and graduate water resource economics courses and includes a list of key topics and sources for class readings.

Whittington and Duncan (2023) describe their experience with developing and teaching a multidisciplinary graduate course from 2010 to 2018. The motivation for the course (like in the case of Nemati and Dinar) was an observation by the authors of a need to train Water Sanitation and Hygiene (WASH) sector practitioners at universities to understand current WASH conditions and to assess possible and actual policy interventions in the sector. The course was designed to be accessible to non-economics and undergraduate students. The course was taught synchronously online at two universities in the United States and United Kingdom. The paper describes the learning objectives and the conceptual framework for policy analysis on which the course was based. In addition, the problem-based learning approach composed of case studies and policy memo assignments that are uniquely developed for this course is described. Because the course has been taught for nine years, the authors were able to extract and share eleven key messages that students are expected to think about when reflecting on the course assignments. The course uses advanced technology, enabling more active participation on the part of the students, and allowing them to watch recorded lectures outside of the class.

Zetland (2023) develops a course that places economic experiences in local institutional and physical contexts and with insights from other disciplines, such as planning and cost-benefit analysis, if they may affect policy consequences. The paper argues that case studies offer a useful way to demonstrate how theory is interpolated for the real world. During this course, students research, write, and present a case study paper on water scarcity affecting a major city and its political and hydrological surroundings. Via the presentation in class, the case helps everyone understand water issues at different

scales, local and regional; the scopes associated with water management, such as issues for irrigators and for urban users; and disciplinary perspectives aspects, such as engineering and politics. The use of case studies in the course helps students explore real-world local and disciplinary complexities. It also helps contextualize economics and reveal other factors affecting water management and use. This paper provides a framework for teaching water economics centered on problem-based case studies.

Zekri (2023) introduces a course designed to teach water economics in desert environments. Looking at a map of the world, desert regions cover quite large areas of the globe, and with the desertification of lands, these desert regions could expand over time. Desert regions rely mainly on groundwater aquifers for the supply of water. In contrast, the physical supply systems are less complex than in other environments where surface water prevails and interacts with groundwater. The course highlights the interactions between groundwater and urban water demand in desert regions. Therefore, the course focuses on demand-side policies such as water quantity restrictions, water rate setting, and promoting technology adoption to save water, to name a few policies. In addition to the effectiveness of the policy interventions on water conservation, the paper emphasizes the environmental impacts and energy requirements of desalination technology as a limit to supply. Another important alternative water source for cities is improved efficiency from agricultural water markets. Such water-related policies are demonstrated and taught in the course. In addition, desert cities are located in proximity to irrigated agricultural regions, and thus, the course also addresses the social barriers to using treated wastewater in irrigated agriculture, which can be a significant water source. The course has been taught since 2011 to undergraduate students through lectures and lab work with the support of videos and flipped classrooms. During the last weeks of the course, each student presents a paper on a pre-assigned main issue to the class.

Wada et al. (2023) introduce in their paper the important question of groundwater sustainability, which has been at the center of economic discourse in recent years. Using a specific aquifer—the Pearl Harbor Aquifer, they apply water economic principles to teach students the linkage between welfare maximizing management of coastal groundwater and hydrological principles. Using an Excel model, the authors find the optimal transition paths of groundwater pumping, price, and groundwater head level and the corresponding solutions in the long run. The paper describes very diligently the entire process of reaching a solution, including setting parameter values and modifying objectives, variables, and constraint cells in Excel to facilitate the successful replication of the results. The course expands the nature of the economic framework by extending the economic issues to be optimized. These include watershed conservation, protection of groundwater-dependent ecosystems, and management of multiple connected aquifers. Through a useful tool that demonstrates the consequences of different management options of an aquifer, the authors were able to engage students in data collection, modifications of the algorithm, the introduction of extensions to management issues, and the ability to compare various policy interventions.

Wilson (2023) presents a course on the water markets in practice. Water markets are a public policy tool that can help allocate water to its highest value uses, creating more efficient outcomes. However, many undergraduate students, especially non-economics majors, face difficulty understanding the equi-marginal principle in markets with a relatively large number of agents. This paper presents a classroom simulation that exposes students to the practical complications of establishing and operating a water market and its outcomes. The activity is part of a larger module about teaching market allocations, where students are requested to role-play as managers/agents of businesses that need water for operation once the initial water endowments are assigned to some of the agents. Students have to buy and sell water on the market to maximize their welfare. The paper shares the results of an assessment showing that students gained a deeper understanding of relative welfare gains from water trades and realize how a lack of information and negotiating power may lead to inefficiency.

Rahman et al. (2023) develop a course that integrates water resources into the economics curriculum such that it helps students understand water-related issues, water distribution, and the

implications of current water management policies on future water sustainability. The paper argues that teaching water economics in most countries is mainly limited to basic economic theories and applications. The authors examine the current state of water issues covered in undergraduate and graduate courses across various institutions in the United States. Using text analysis of the water economics syllabus, they inquired whether states facing different levels of water stress (four levels of water stress) would respond by different coverage of water issues in the water economics curriculum. Findings suggest that water economics programs in different water stress zones are characterized by different water issues in the syllabus of the courses taught in these states. The paper also surveyed different water economics programs to identify three teaching approaches—active learning, experiential or community-based learning, and inquiry-based learning incorporating water topics into existing economics curricula, enhancing students' understanding of basic economic theory, analysis, and real-world implications.

Kunwar et al. (2023) share their undergraduate experiential learning course on water resources. The course combines learning experience in the classroom with community outreach and international research experience via a study abroad program. The course development closely follows the principles of experiential learning theory and consists of four learning components: (1) field-based data collection, problem identification, and setting a conceptual framework; (2) data analysis, problem identification, and development of potential policy interventions; (3) implementation in the field in a study abroad program; and (4) sharing the findings among classmates and community outreach. The course included a unique feature, benefitting from having graduate students mentor undergraduate students and helping them with empirical analysis, as well as leading discussions in developing policy tools and solutions. The broader impacts of these experiential learning courses were evident in the expanded student learning experience, impact on the community, gaining undergraduate research experience, and showing potential for the course to serve as a model for other teaching institutions.

Edwards et al. (2023) present a paper that focuses on training students to calculate price elasticity of demand for policy purposes. This paper builds on recent developments in understanding consumer responses to water pricing, including equity issues and water utility interest in adopting innovative pricing approaches. Instructors of water economics courses can use the tools developed in this paper to teach urban water pricing to both undergraduate and graduate audiences. The paper includes a set of activities and resources to integrate concepts of price elasticity of demand, conservation pricing, utility considerations, and equity issues. Following the use of such materials, students are expected to know how to calculate prices (average and marginal) and elasticities and explain these values in the broader context of conservation and equity.

3 Discussion

All thirteen papers in this special issue add separately and jointly to our understanding of possible advancements in teaching water economics at the undergraduate and graduate levels of economics and non-economics courses on water economics and policy. Several papers provide information on specific courses or parts of courses that can be adopted and adjusted by instructors teaching water economics at the undergraduate and graduate levels. Several papers provide components that can be incorporated into existing courses. Several papers develop algorithms to address specific issues using Excel and GAMS. Different pedagogical models, such as active, experiential, and inquiry-based learning, are explored as well.

Our suggested take-home from this special issue is that the water economics discipline, while making significant progress and innovation in the water curriculum, still needs to keep investing resources to improve the coverage of courses and monitor their effectiveness on the students in the classes. We have not seen interdisciplinary collaboration in preparing the courses. As we move into the uncertain future, the water economics curriculum should reflect multidisciplinary considerations and

collaborations to make the courses more comprehensive and inclusive of various approaches, priorities, and methods. The papers in this special issue provide valuable insights for incorporating multidisciplinary approaches in the water economics curriculum. These approaches can potentially enhance the scholarship of teaching and learning by shedding light on their impacts on student learning, post-graduation outcomes, and the generation and distribution of water economics knowledge. By exploring these impacts, educators and researchers can better understand the effectiveness of these approaches, improve teaching practices, and contribute to the advancement of water economics education.

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