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Teaching and Educational Methods

Water and Economics: Why We Need and Ought to Teach Water Economics in the Modern Economics Curriculum

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Abstract

Water scarcity and the availability of good quality water are major challenges facing many regions globally, and these topics warrant attention in economics; a discipline that studies the allocation of scarce resources. Integrating water resources into the economics curriculum is essential for students to understand water-related issues, water distribution, and the implications of current water management policies on the future. Although water economics is covered by some institutions in the United States and around the world, the coverage is mostly limited to basic economic theories and applications, with little attention paid to the broader issues pertaining to water. We provide an examination of the current state of water issues coverage in undergraduate and graduate courses across various institutions in the United States. A novelty of our investigation lies in analyzing how water topics are addressed at institutions located in different water-stressed regions. Additionally, we present several pedagogical approaches that are currently being applied to water economics teaching. This study also proposes innovative teaching interventions that incorporate water topics into the economics curriculum and, in doing so, enhance students' understanding of basic economic theory, analysis, and real-world implications.

1 Water and Economics

Many regions around the world are facing challenges related to both water scarcity and water quality, and the impacts of these challenges are increasing as climate change and population density issues worsen. The World Resource Institute estimates that a quarter of the world's population face extreme water stress (Hofste et al. 2019). Major cities around the world are encountering water crises known as "Day Zero" (the day when there was no water available to deliver through a system) or are at risk of running out of water (BBC News 2017; Chapman 2019; Sengupta 2019). The growing global trend of urbanization, coupled with worsening climate change issues, is likely to result in more water stress and exacerbate water-related challenges.

The severity of water shortage is especially apparent in the agricultural sector (Connor 2015; Campbell et al. 2017). The resulting consequences are crop yield reductions and threatened global food security (Cook, Ault, and Smerdon 2015; Zhao and Running 2010). Further, water scarcity and degradation of water quality have an enormous impact on public health. A World Health Organization (WHO) report estimates that improved water supply alone could reduce diarrhea-related morbidity incidence by 6 percent to 25 percent (World Health Organization 2004). The burgeoning problem of water scarcity also has implications regarding human rights and international laws and conflicts. Drought and depleting water detected by satellite imagery in and around Iraq and Syria have been attributed as contributing factors in inciting wars and human displacements (Madani, AghaKouchak, and Mirchi 2016; Eklund and Thompson 2017; Selby 2019). The tension over transboundary water resources among countries in the Himalayan region and disputes over the Nile River are also a consequence of increasing water shortages (Ranjan 2019; Pemunta et al. 2021). The water crisis issue

has, therefore, garnered much public and political attention, influencing many policies globally. The United States Clean Water Act of 1977 and the Water Quality Act of 1987 are examples of such efforts. The socio-ecological nature of water issues around the world requires multidimensional approaches to confront an inevitable crisis, and as such, water is a critical topic that needs to be covered in economics curricula.

The inclusion of water in the economics curriculum can have a multifaceted approach. In his book The Wealth of Nations (1776), Adam Smith described his observation of the Diamond-Water Paradox: "Nothing is more useful than water: but it will purchase scarce anything; scarce anything can be had in exchange for it. A diamond, on the contrary, has scarce any value in use; but a very great quantity of other goods may frequently be had in exchange for it." As the topic of scarcity is at the heart of the traditional economics curriculum, water economics is presented to students in introductory courses, often through Smith's Diamond-Water Paradox, to lead the discussion on scarcity. Similarly, the example of water can be applied when introducing marginal analysis to identify optimal water pricing, consumption, and distribution. Water scarcity can also be used to introduce topics in public health economics. For example, using water quality as an input of health in the Grossman framework (Grossman 1972) can help demonstrate the relationship between water quality and health status theoretically and empirically. Subsequently, students can perform the economic analysis of calculating the health cost associated with water quality reduction. Moreover, this opens the door for policy implication discussions such as subsidies within infrastructures, cleanliness practices, and taxation at the producer level to account for the negative externality.

Given the magnitude of the water crisis problem and its far-reaching impacts on various sectors, there is a dire need for courses (and programs) focused on water economics. Although teaching applications of microeconomic theory on water allocation could help students understand the basic framework of water resources management, the importance of broaching the broader significance of water resources must also be considered in these courses. Furthermore, considering the interdisciplinary nature of the subject, it is essential for students pursuing water economics to develop a deeper understanding of water resources and approach problems concerning water resources not just from an economic perspective, but also from other disciplinary perspectives.

The objective of this article is to assess (1) the current state of how water issues are covered in undergraduate and graduate courses across different institutions in the United States and (2) how modern pedagogical approaches are being applied to water economics teaching. To achieve the objective, we take three steps: (1) conduct a web examination of water economics courses in the United States with a text analysis of course syllabi, (2) review and categorize novel teaching methods and strategies pertinent to water economics and present evidence-based examples, and (3) detail novel teaching strategies on multiple course examples across different institutions and disciplines. Our contributions are twofold. First, we provide a comprehensive review of water economics courses taught across different U.S. institutions dictated by regional necessity. We present concrete examples of the courses from U.S. research and liberal arts institutions that cover water topics both at the undergraduate and graduate levels. A novelty of our presentation includes using text analyses to analyze how water topics are covered at institutions located in different water stress regions in the United States. Second, we provide teaching methods and strategies pertaining to water economics and how it could be integrated into the modern economics curriculum. We also provide a set of suggested sample course syllabi which vary by regional water stress levels.

2 Investigation of Water Economics Courses in the United States: A Text Analysis

To obtain a comprehensive view of water economics courses taught in the United States, we begin by conducting an online examination of such courses. Considering the potentially vast number of institutions that offer courses in water economics in the United States, along with data availability constraints, we limit our sample to syllabi that can be obtained online by searching for the phrase "water economics courses" (see Appendix A1 for details).[1] We anticipate the identified courses and institutions to encompass a wide range of U.S. universities and colleges due to this broader online examination approach for sample institutions. We also expect the identified institutions to span over U.S. regions with different levels of water stress. Following the Water Resource Institute (Hofste et al. 2019), Figure 1 shows the map of U.S. states classified into five levels of baseline water stress, including extreme stress, high stress, medium-high stress, low-medium stress, and low stress. Generally, the U.S. Southwest faces much higher water stress compared to the rest of the country, with New Mexico experiencing extremely high water stress.

The online examination identified 25 water economics courses taught by 24 institutions across 19 states in the United States. Table 1 provides a summary of all the courses concerning the course level (graduate vs. undergraduate), the department in which the course is cataloged (economics vs. non-economics), and the institution and state where the course is offered. In terms of teaching levels, there are 17 undergraduate courses, 6 graduate courses, and 2 cross-listed between graduate and

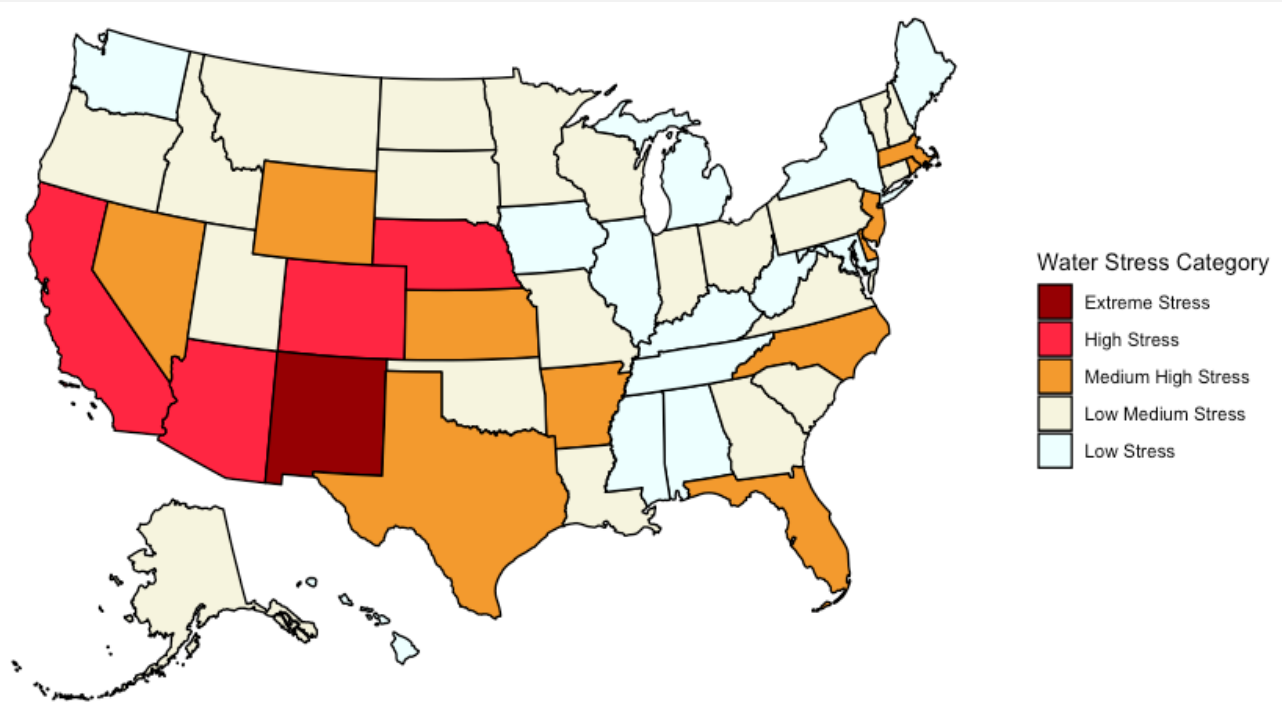


Figure 1: Regions Characterized by Different Levels of Water Stress in the United States

Data Source: Water Resource Institute (Hofste et al. 2019).

[1] Our online examination of water economics courses taught in the United States is not necessarily encompassing and does not include all types of courses and institutions because a course can be offered at an institution but cannot be identified via search engines.

Table 1: List of Water Economics Courses from an Online Survey across Regions with Four Levels of Water Stress (High, Medium High, Low Medium, and Low)

Course	Undergraduate/ Graduate	Department	Institution	State
		High-Stress Regions		
EES 270: Water Economics	Graduate	Environmental Studies	California State University	CA
Econ 267: Economics of Water	Graduate	Economics*	UC San Diego	CA
EEP 162: Economics of Water Resources	Undergraduate	Agricultural Economics*	UC Berkeley	CA
AREC 479: Economic Analysis of Water, Food, and Environmental Policy	Undergraduate	Agricultural Economics*	The University of Arizona	AZ
ENVS 129-01: Water Policy in the Western United States	Undergraduate	Environmental Studies	San Jose State University	CA
AREC 342: Water Law, Policy, and Institutions	Undergraduate	Agricultural and Resource Economics*	Colorado State University	CO
AEEC 575: Economics of Water Resource Management and Policy	Graduate	Water Science and Management	New Mexico State University	NM
CEE 173: Urban Water	Undergraduate	Civil Engineering	Stanford University	CA
		Medium-High-Stress Regions		
ECON 615: Water Resource Economics and Policy	Graduate	Economics*	University of Nevada, Reno	NV
397W: The Economics of Water Policy	Undergraduate	Resource Economics*	University of Massachusetts Amherst	MA
AGEC4720: Water Resource Economics	Undergraduate	Agricultural and Applied Economics*	University of Wyoming	WY
WATR 2350: Topics in Water Resources	Undergraduate	Department of Mathematical, Physical, and Engineering Sciences	Texas A&M university	TX

Table 1 continued.

Course	Undergraduate/ Graduate	Department	Institution	State
GEO/NRS/EEC 234: Introduction to Water Resources	Undergraduate	Environmental and Natural Resource Economics*	The University of Rhode Island	RI
EEC430: Water Resource Economics	Undergraduate	Environmental and Natural Resource Economics*	The University of Rhode Island	RI
AEB 2451: Economics of Natural Resource Use	Undergraduate	Food and Resource Economics*	University of Florida	FL
Low-Medium-Stress Regions				
AAEC/FREC 4464: Water Resources Policy and Economics	Undergraduate/ Graduate	Environmental and Natural Resources	Virginia Tech	VA
Econ 3466E: Environmental Economics	Undergraduate	Economics*	University of Connecticut	CT
GEOG 467/567: International Water Policy	Undergraduate/ Graduate	Geology	University of Oregon	OR
ENV 865: Water Resources Institutions and Policies	Graduate	Environmental Studies	University of Wisconsin–Madison	WI
Econ 322: Environmental/Natural Resource Economics	Undergraduate	Economics*	College of William and Mary	VA
Low-Stress Regions				
EAS 501: Water Resource Economics	Graduate	Environmental and Sustainability	University of Michigan	MI
ESWS 325: Principles of Water	Undergraduate	Environmental, Soil, and Water Science	West Virginia University	WV
Econ 349: Environmental and Natural Resource Economics	Undergraduate	Economics*	Rhodes College	TN
CEE 433: Water Technology and Policy	Undergraduate	Civil Engineering	University of Illinois at Urbana–Champaign	IL

Table 1 continued.

Course	Undergraduate/ Graduate	Department	Institution	State
Envr 322: Water Policy	Undergraduate	Environmental Studies	University of Puget Sound	WA

* Indicates courses offered by Economics or Applied Economics departments.

undergraduate. For departments, any courses offered by the Departments of Economics, Agricultural Economics, Environmental and Natural Resource Economics, and Food and Resource Economics are categorized in the economics category. All other courses, including those offered by the departments of Environmental Studies, Civil Engineering, Sustainability, Water Science, and Geology, are classified in the non-economics category. Among the 25 courses, 13 are cataloged in economics departments while 12 are in non-economics departments, indicating that departments other than economics also teach water topics with an emphasis on economic aspects.

The information on the institution and the state in which a course is offered, combined with Figure 1, allows us to group these courses into four subgroups based on water stress levels. While Figure 1 shows five levels of water stress, we combine both extreme stress and high-stress levels into one category "high stress" to balance the data sample, as New Mexico is the only state experiencing extremely high water stress. Consequently, we use four levels of water stress for our analysis: high stress, medium-high stress, low-medium stress, and low stress, as illustrated in Figure 2. According to Table 1, there are eight courses listed in the high-stress regions, seven courses in medium-high, five courses in low-medium, and five courses under the low-stress regions. Furthermore, these courses span both graduate and undergraduate levels across various departments. For instance, there are four courses listed by economics departments in high-stress regions, six courses in medium-high-stress regions, two in low-medium-stress regions, and one in the low-stress regions. The fact that these identified courses cover a wide range of U.S. universities and colleges and span different departments and water stress regions justifies our inclusive online examination approach.

To explore whether courses taught in different water stress regions focus on local water issues and how they do so, we conduct text analyses of the syllabi for all courses listed in Table 1. While a comprehensive course syllabus (that includes the course objective, description, topics, grading, schedule, etc.) was not available for each course, we were able to extract the course objective, course description, and learning outcomes from each identified syllabus. Using the extracted course objectives, course descriptions, and learning outcomes, we perform several text analyses to gain insights into qualitative patterns from the words in different groups of syllabi. The analyses are carried out in two categories: (i) analysis of the course syllabi based on the water stress regions, and (ii) analysis of the course syllabi based on economics and non-economics disciplines (see Appendix A1 for detailed steps of the text cleaning and analysis). We present our results using word clouds, which are commonly used for visualizing unstructured text data to gather new insights on trends and patterns from the words used.

Figure 3 displays the word clouds of the top forty words used in the course objective and description sections of the syllabi across the different water stress regions. A cursory glance at the word clouds in Figure 3 suggests that the coverage of topics in high-stress regions differs from low-stress regions. It appears that courses in high-stress regions emphasize words like "urban," "groundwater," "rights," and "law" when teaching water-related topics (Figure 3a and 3b). In contrast, in low-stress areas, words such as "river," "management," and "human" appear more frequently (Figure 3c and 3d).

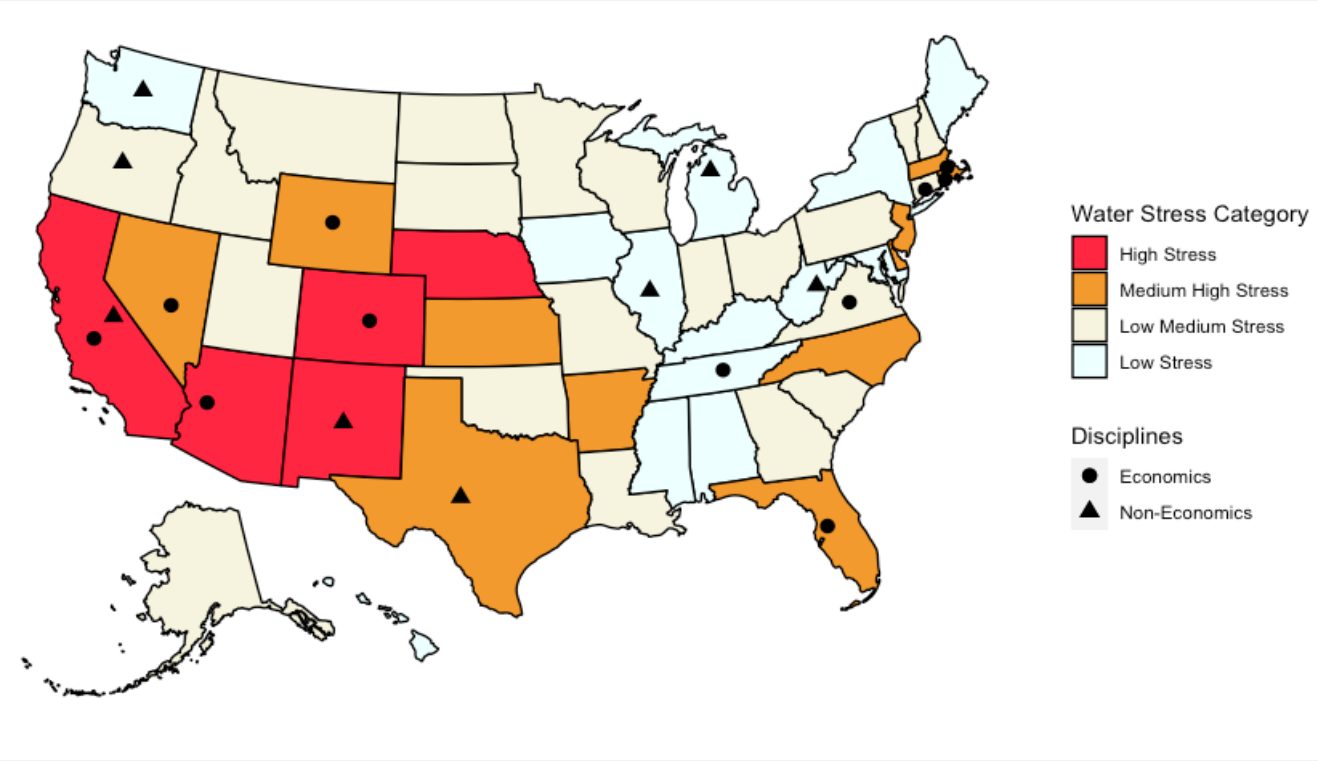


Figure 2: Regions and Disciplines Characterized by Different Levels of Water Stress in the United States

We obtain further insights on word usage by combining the information from the word clouds with the distribution of specific words. Table 2 shows the percentage count of select words used in the syllabi across the four water stress regions. The values of each word in Table 2 were normalized by using the count of that word over the total count of all words in the syllabi (i.e., course objectives and the learning outcomes) in each water stress region. If we look at the word frequency in Table 2 alongside the results of the word cloud in Figure 3, the emerging pattern becomes more evident.

Higher occurrences of words like "water" and "management" in both high- and low-stress regions are evident from the U-shaped relationship in Figure 4. This relationship suggests that courses in both high- and low-stress regions place a bigger focus on understanding water management issues. However, the topic of water management is likely to differ significantly between the two regions. The occurrence of words such as "urban," "groundwater," "management," "law," and "rights" in the high-stress region (Table 2) could indicate an interest in understanding and investigating the management of urban water scarcity within the context of water rights and water laws. On the other hand, words such as "river," "human," and "market" are more prevalent in the low-stress region (Table 2). Examining these words alongside the graph in Figure 4 suggests a focus on water management from water quality, flood management, and market perspective.

When we look at the course list in Table 1, it is apparent that the number of water-focused courses offered by economics departments is higher in the high-stress region, and this number gradually decreases as we move toward the low-stress regions. While there are fewer water-related topics taught by economics departments in the low-stress regions, the number of water economics courses taught in non-economics disciplines is higher in these areas. Similar to the earlier text analysis carried out on the four water stress regions, we also explore the common words used in the syllabi on economics vs. non-economics disciplines. Figure 5 displays word clouds of the top forty words used in the economics and

(a) High Water Stress Region

(b) Medium-High Water Stress Region

(c) Low-Medium Water Stress Region

(d) Low Water Stress Region

Figure 3: Word Cloud of the Top Forty Words in Syllabi in Each of the Four Water Stress Regions

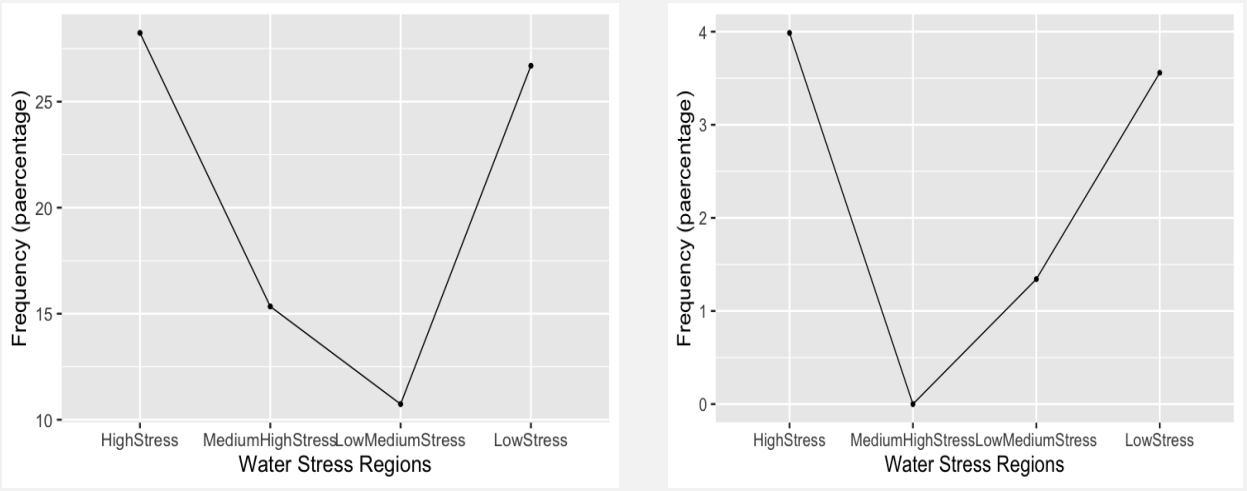
Note: The size of each word indicates the frequency—large-sized words occurred more frequently than small-sized words.

non-economics disciplines. While words such as "water," "economics," "resources," "policy," and "management" are used somewhat equally in both economics and non-economics disciplines, there are certain words more pronounced in either the economics or non-economics disciplines. For instance, words like "allocation," "supply," "valuation," and "markets" are entirely missing from non-economics disciplines. Likewise, words such as "governance," "agricultural," "social," "urban," "river," and "federal" seem to be used more in the non-economics disciplines.

To summarize, the text analyses reveal consistent patterns of differing content taught in the different water stress regions, as well as variations in content between economics and non-economics disciplines. These findings suggest a need for the economics discipline to provide a more holistic understanding of water-related issues by incorporating not only the economic dimension of water, but also the policy, governance, sociological, and anthropological aspects of water use. One way this could be possible is by instructors from different disciplines (e.g., economics and environmental studies) co-

Table 2: Percentage Count of Select Words Used in the Syllabi across Different Water Stress Regions

Word	Word Frequency			
	High-Stress Regions	Medium-High-Stress Regions	Low-Medium-Stress Regions	Low-Stress Regions
Water	28.23%	15.34%	10.73%	26.69%
Economics	8.30%	10.22%	8.05%	4.98%
Urban	4.31%	0.00%	0.00%	0.00%
Management	3.98%	0.00%	1.34%	3.55%
Rights	2.32%	1.13%	0.00%	0.00%
Law	1.99%	0.00%	0.00%	0.00%
Quality	1.99%	1.13%	0.00%	3.55%
Supply	1.65%	1.70%	0.00%	0.00%
Allocation	1.66%	2.84%	0.00%	0.00%
Pollution	0.00%	2.27%	1.34%	0.00%
Demand	0.00%	1.70%	0.00%	0.00%
Market	0.00%	0.00%	4.02%	2.13%
Governance	0.00%	0.00%	4.02%	0.00%
Public	0.00%	0.00%	2.01%	0.00%
Human	0.00%	0.00%	0.00%	1.77%



(a) Percentage of the Word "Water" **(b) Percentage of the Word "Management"**

Figure 4: Percentage of the Word "Water" and "Management" across Water Stress Regions

(a) Economics **(b) Non-economics**

Figure 5: Word Cloud of the Top Forty Words in the Economics and Non-Economics Disciplines

teaching a course on water-related topics. While the differences in content between economics and non-economics disciplines are interesting to observe, our other findings are more intuitive and seem to arise from relevant water issues and needs in these regions. If we look at the actual syllabus of the courses, topics like "water law and water rights," "groundwater," "agricultural water and water pricing," "property rights," "water markets," "water supply and demand," "urban water use," "water quality," "water conservation," "investment analysis," "optimal groundwater management," "river basin management," and "interjurisdictional conflicts," etc. are dominant in the high-stress area. These contents occur less frequently as we move from high- to the low-stress areas. Topics like "water quality," "managing freshwater resources," "environmental impact of water use," "non-market valuation of water quality," and "exploring the importance of water to biological processes" are common in low-stress areas. Based on these observations, we provide in Appendix A2 a set of suggested sample course syllabi for teaching water economics in economics departments that varies by water stress levels.

3 Review of Teaching Methods and Strategies in Water Economics

Next, we review novel teaching methods and strategies used in water economics classes, including those listed in Table 1 and additional courses from a general literature review. Economics teaching has been improving from the traditional "chalk and talk" pedagogical approach to a more interactive environment approach. Educators are now exploring alternative teaching methods and strategies in the discipline of economics to offer a diverse learning environment to the students and engage them in real-world economic issues (Truscott, Rustogi, and Young 2000; Becker, Becker, and Watts 2006; Roach 2014). We have reviewed and categorized these novel teaching methods as they relate to water economics, with pertinent examples in three pedagogical approaches: active learning, experiential or community-based learning, and inquiry-based learning. Focusing on water economics, while it is not as widely formally taught in class, we find a few examples of teaching water economics using one or more of these three approaches.

3.1 Active Learning

Using case studies as a teaching and learning methods has been proven to be an efficient method in improving academic performance in economics courses (Habasisa and Hlalele 2014). Student performance is further enhanced when case studies are combined with opportunities for students to collaborate and engage in small group discussions with their peers (Smith and MacGregor 1992; Monaco 2018; Liverpool-Tasie, Adjognon, and McKim 2019). In the subfield of water economics, with

interdisciplinarity as one of its major characteristics, active and collaborative learning can be a practical approach to foster group activities and enhance students' communication and outreach skills. An example of such an approach is evident in the Water Resource Economics (AAE 4800/6800) offered at the University of Georgia, where students worked on the tri-state water dispute case and participated in a three-day "mock negotiation" session with students from Florida and Alabama on the A.C.F. (Apalachicola-Chattahoochee-Flint)/A.C.T. (Alabama-Coosa-Tallapoosa) tri-state water dispute case (Jordan 1999). In these mock negotiation sessions, students represent different interest groups to negotiate a water allocation formula between the states of Georgia, Florida, and Alabama. With this active learning practice, students have the advantage of both theoretical and applied methodologies.

Collaborative learning is a common type of active learning in which students exchange opinions and new information by relating prior knowledge (Smith and MacGregor 1992; Monaco 2018; Liverpool-Tasie et al. 2019). In addition to case studies, visual aids such as TV shows and movies also support teaching economics and fostering collaborative learning (Al-Bahrani et al. 2016). Leung and Nakagawa (2021) provide an example of showing the movie Lord of the Flies for an introductory microeconomic course. The learning objective is to guide students in identifying the economic concepts that have been applied in the movie. Educational videos on Youtube about water market rights can also be instrumental in the classroom while teaching water rights and water conflicts. In the subfield of water economics, with interdisciplinarity as one of its major characteristics, collaborative learning can be a practical approach to foster group activities and enhance students' communication and outreach skills.

3.2 Experiential or Community-Based Learning

Experiential learning is a pedagogical approach that provides students an opportunity to understand classroom-acquired knowledge better through the experience of real-world situations. This learning approach also aims to engage higher education students in the community. An illustration of this point is the Water Resources Economics (ECON 484/673) course offered at the University of Waterloo, which includes a trip to the region of Waterloo's wastewater treatment plant located in Kitchener, Ontario. During the trip, students learn the details of the treatment plant's construction, operation, and maintenance, helping students connect the theory on water management learned in the classroom to the real-world case of Waterloo's wastewater treatment plant. Furthermore, the University of Wisconsin–Parkside started university-community partnership in the mid-1990s. Their economics community-based learning brownfield project provided the information for environmental economics and econometrics courses to examine the economic impacts from the neighborhood park and the two brownfields (former industrial sites). In this way, economics students taking relevant courses learned firsthand that abstract economic theories and models can be applied to real-world problems, and can yield results that affect people's lives (Kaufman and Cloutier 2004). Furthermore, specific to water economics, the study of the relationship between water quality and health issues can benefit communities and enhance the learning experiences of students.

Another such case is the research agenda around "participatory action research" and "experiential learning" developed by the American University of Kuwait for students to develop their knowledge and skills by working on water challenges in Kuwait (Aljamal, Speece, and Bagnied 2016). The program includes economics students' direct participation in projects on assessing the cost structure of water production, pricing strategies, and water demand management.

In economics teaching, community-based learning is applied in various regions, aiming to engage higher education students in the community. Community-based learning can also provide an efficient learning experience for sustaining economic development in disadvantaged communities. The potential for positive impacts by virtue of community-based learning, especially among disadvantaged groups, has important implications for issues related to water. According to an article in Forbes (Ewing-Chow 2021), there exists a racial divide in access to clean tap water in the United States. This experiential and

community-based learning technique, which is interdisciplinary in nature, could allow students to engage in their local communities and promote development efforts.

3.3 Inquiry-Based Learning

Inquiry-based learning is a teaching method that encourages students to ask questions and investigate real-world problems, and by doing so attempts to elicit curiosity among students. By developing a problem-solving environment in the classroom, students are actively engaged in the learning process and are given the opportunity to explore their natural curiosities. At the undergraduate level, Course-Based Undergraduate Research Experiences (CURE) programs can be highly successful in promoting engagement in water economics research. Students learn several foundational skills necessary for research within the context of water economics research. With a research question given, students can, either individually or in a group, work on their own to find and prepare data, perform analysis, and find the answer. This "hands-on" experience can feed curiosity and enhance the learning experiences of students. For instance, Water Economics (EES 270) at California State University utilizes the inquiry-based approach for understanding water economics concepts and encourages the ability to analytically apply these concepts to real-world problems. This is accomplished through various instruments such as written exercises (e.g., reading responses), quantitative exercises (e.g., problem sets), and holistic analyses (e.g., case studies).

Figure 6 summarizes the topics of water economics courses, the course levels at which water economics needs to be taught, and the teaching methods that can be applied in teaching water economics. With our online survey of the term "water economics course" and the text analysis of the syllabi, we recommend that topics such as water scarcity and water quality are important topics in economics courses. Water topics can be taught interactively as our examples show, and should be taught at all levels of higher education. For general economics courses, raising questions about water scarcity and quality can lead students to develop their interests in and attention to this daily natural resource. The following section presents examples of how water can be taught in different economics courses and levels.

4 Innovative Examples of Teaching Water Economics

While section 3 gives the essence of different strategies and teaching methods at different levels, the authors detail strategies in this section on multiple course examples across different institutions and disciplines that the authors have taught where water economics has been embedded. Along with the detailed strategy of each course we have taken, we also delineate them with the teaching methods described in Figure 6. Table 3 presents a brief overview of the courses, and later we explain in detail the courses and teaching strategies.

Although the contents of economics classes at the undergraduate and graduate levels are different, the objective of educating students at both levels is the same, which is to enhance their learning and developing capabilities. While a graduate-level course is more complex and technical, both graduate and undergraduate courses aim to prepare students to work independently and conduct effective research. That being said, we also observe the difference in educating undergraduate students versus graduate students. One of the differences between undergraduate students and graduate students is learning motivation. More undergraduate students are still exploring their interests. Providing more guidance and triggering their interest in economics, especially water economics, can be the main goals when we integrate the topic of water into economics education. Meanwhile, undergrad courses need to be more structured, while grad courses can allow more autonomy and flexibility. Undergraduate and graduate students also differ based on their career goals. However, economics educators should still prepare both undergraduate and graduate students to achieve their own career

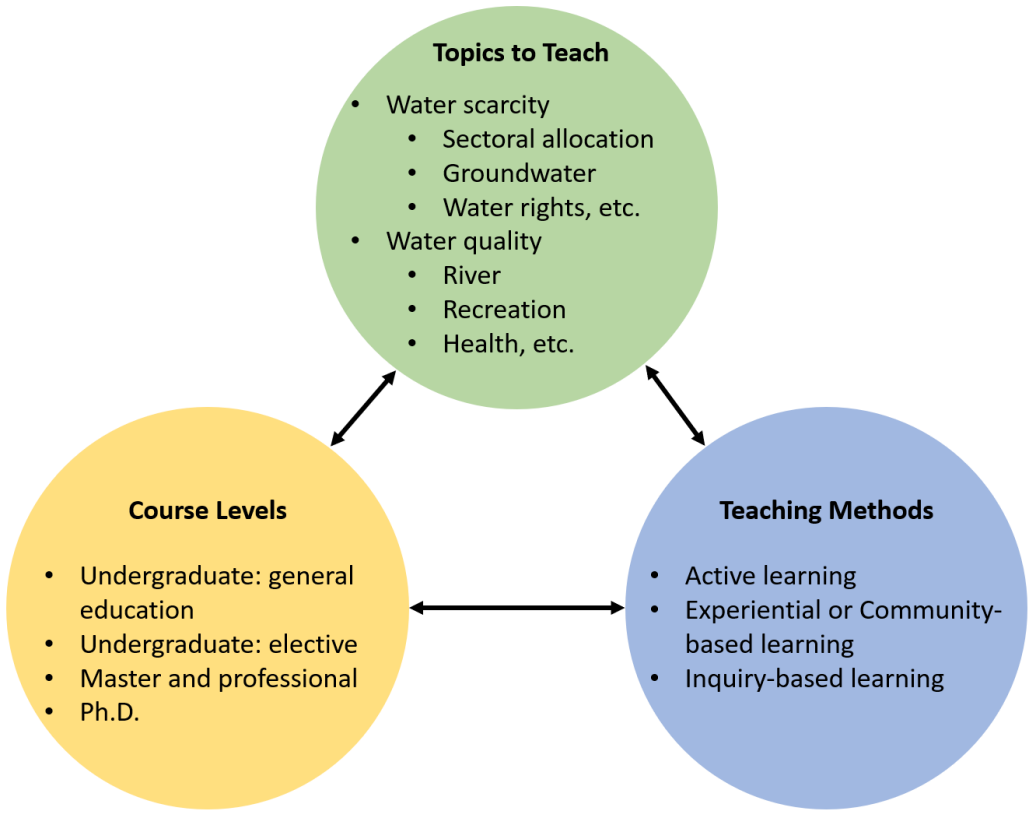


Figure 6: Potential Topics to Teach, Course Levels, and Teaching Methods in Water Economics

goals. Some undergraduate courses, like at the University of Arizona[2], adopt seminar-type classes to encourage students to learn deeper and practice their knowledge, while some graduate water courses welcome undergraduate students to participate for credit, like several courses of the Water Resources Program at the University of New Mexico (UNM).

In the following sections, we present cases showing interactive learning examples at both the undergraduate and graduate levels. Though there are some dissimilarities in terms of the content and structural design between undergraduate and graduate courses, the inherent objective is the same.

4.1 Examples of Undergraduate Teaching

We begin by looking at the introductory economics course (ECON 2120 Microeconomic Principles) at UNM, which focuses on sustainable water resources to facilitate active and inquiry-based learning in an inclusive environment. Why water? Because economics is the study of the allocation of scarce resources and New Mexico is the only U.S. state identified by the World Resource Institute as facing extreme water stress (Hofste et al. 2019), incorporating a teaching module on how to optimally manage scarce water resources in New Mexico and the Southwest is a natural fit. For UNM, with nearly 40 percent of the incoming students being the first in their family to go to college, adding a module on water that relates to their everyday life significantly helps with their learning. The course design consists of three parts. The first part of the course is dedicated to understanding the foundational tools of economics including the demand and supply framework and efficiency. The second part of the course focuses on firms' pricing, production decisions, and the role of antitrust authorities. The final part of the course examines the social issue of water scarcity and water resources management within the framework of economic

[2] https://economics.arizona.edu/undergraduate/bs-environmental-water-resource-economics

Table 3: Courses across Institutions with Different Teaching Methods Used by the Authors

Course Level	Course Name	Institution	Teaching Methods
Undergraduate (General education)	Microeconomic Principles (Econ 2120)	University of New Mexico (UNM)	Active and Inquiry-Based Learning
Undergraduate (Upper level)	Natural Resource Economics (Econ 433)	State University of New York (SUNY), Binghamton	Active Learning
	Environmental Economics and Policy (Econ 359C)	College of Saint Benedict and Saint John's University	Active Learning
	Environmental and Natural Resource Economics (Econ 335)	Fort Lewis College	Active Learning
	Problem-Based Learning Using Data Analytics (Econ 369*)	University of New Mexico (UNM)	Experiential/Community-Based Learning
	Economic Development (ECB305)	Gordon College	Active Learning
Graduate Level	Water Resources II (ECON545)	University of New Mexico (UNM)	Active and Experiential Learning
	Applied Environmental Economics (ECO 526)	Northern Arizona University	Active and Inquiry-Based Learning

Note: * Indicates that the course is also available for graduate credit.

analysis in the geographical Southwest. In this last section students apply the economic models they have learned in the first two parts. Specifically, they examine how our economic and political institutions have allocated water in the past (focusing on sources of inefficiency) and how they might improve on its allocation in the future (focusing on potential remedies and opportunities for institutional reform). Students also share their personal experience with water scarcity, learn about why sustainable water resources is one of UNM's Grand Challenges, and discuss how water management in New Mexico and the Southwest can be improved in the future. A unique component of the course is to offer students entry-level water economics research engagement as a part of the UNM Expanding Course-Based Undergraduate Research Experiences (ECURE) program. After water pricing is introduced as a source of water allocation inefficiency, students are guided to participate in two types of inquiry-based ECURE activities. First, they research and collect data on the historical and current tap water rates in their cities and communities. Then, they read and critically review relevant peer-reviewed journal articles. Examples of these ECURE activities as well as a performance-based assessment are provided in Appendix A3. Through these ECURE activities, students learn several necessary foundational skills.

Moving to upper-level courses, we introduced the topic of water resource allocation in environmental and resource economics at different institutions (Econ 433: Natural Resource Economics at SUNY Binghamton; Econ 359C: Environmental Economics and Policy at the College of Saint Benedict and Saint John's University; and Econ 335: Environmental and Natural Resource Economics at Fort Lewis College). We adopted a combination of active and inquiry-based learning in these courses, and the content of water resources is typically covered in five class periods. The water resource module began with discussions of background information on the hydrological cycle and water scarcity issues in the United States and around the world. A larger portion of the focus was then devoted to understanding the theoretical and empirical analysis of surface and groundwater sources. The theoretical analysis of water allocations was carried out using graphical and basic mathematical analysis (algebra and calculus), where students first learned the statically efficient allocation of surface water use with multiple competing user groups. Then, the course moved to the dynamic allocation of groundwater resources. Once students were taught the theoretical nature of water allocation, the next two class sections were dedicated to carrying out an empirical analysis of a static and dynamic scenario using Microsoft Excel. In Excel, students worked with a solver to determine and graph the optimal allocation of groundwater sources under various constraints such as constant versus increasing marginal extraction costs and under the assumption of availability of a substitute resource versus when substitute resources are not available.

While the theoretical and empirical analysis on the water resources topic focused only on the static and dynamic allocations, students were also separately introduced to the concepts of non-market valuation approaches using contingent valuation, hedonic valuation, and travel-cost approaches, all of which could also be employed to investigate water resource issues when students worked on their final projects. After completing the theoretical and empirical analysis, students were introduced to potential sources of inefficiencies in water resource allocation around the world, as well as different water pricing structures. The class section ended with discussions on potential remedial policies, and case studies were used to aid these discussions. For example, the coping mechanism of water security for Tucson, Arizona (Tietenberg and Lewis 2018) was discussed to highlight the supply of water in the face of severe scarcity. Another example was the mechanism of water rights trading among different parties, which was shown on the Water Colorado website (Water Colorado 2019). These case studies increased students' understanding of the water markets, current water crises, and the future of water supplies in the United States. Finally, students were introduced to the empirical application of theoretical understanding and presented what they had learned. By doing a group presentation on their assigned group project, students also experienced the phase of disseminating their project outcomes to the public.

One surprising outcome of these courses has been that each year at least a few students choose to continue working on their class topics even after the completion of the course, and sometimes these topics get converted into the students' capstone projects or honors theses. At the College of Saint Benedict and Saint John's University, during the Econ 359C course in Spring 2021, one student used a hedonic valuation approach to estimate the economic value of Mille Lacs Lake in Minnesota as their final project for the course. The student showed interest in continuing to expand on this topic even after the course was completed. Although the original class paper evolved to a different topic, the student was able to write a research paper that became the student's honors thesis, titled "Effect of the Mississippi River on Property Values in Anoka County: A Hedonic Price Analysis" (Parisi 2021). Overall, the approach of introducing students to a natural resource topic such as water by integrating theoretical models with empirical exercises in Excel, and ending with discussions on policies, has allowed the students not only to develop an appreciation of the role of economics in understanding environmental issues, but has also given them the tools and ideas necessary to complete capstone courses and theses.

Along with the theoretical approach in the above-mentioned courses, we have used empirical techniques to teach water economics to undergraduate students in a set of courses at UNM. These courses,

all named "Problem-Based Learning Using Data Analytics" but with different course numbers in different semesters, use primary survey data to communicate real-world challenges pertaining to water resources, particularly in the context of a developing country. The overarching objectives of these undergraduate courses have been to teach the importance of water resources by showing the linkages between water, public health, and behavior through real-world data and rigorous empirical tools. The first course in this series, Econ 451: Problem-Based Learning Using Data Analytics, which was an upper-level undergraduate course offered in Fall 2016, exemplifies this. In the class, undergraduate students analyzed primary household survey data on the Danda River in Nepal collected in Summer 2016 by the graduate students. We used a graduate-undergraduate research mentorship model for the course, where five PhD students worked closely with the undergraduate students to analyze and interpret the data. Designed and coordinated by the Nepal Study Center of UNM, a similar teaching approach was adopted in our two other Problem-Based Learning Using Data Analytics courses: Econ 395 (Fall 2017) and Econ 369*[3] (Fall 2018). An important aspect in these two courses was the development of ten to twelve learning modules that were used to teach the theory of basic statistics and econometric models and then practically execute them in the software STATA, using variables from our Danda River survey data. The final research outcomes of these courses were group posters that students presented in class and at the UNM UROC conference. For example, a group of students from Econ 395 developed a research poster on linkages between water quality risk perception and water treatment actions. Another example is a research poster, developed in Econ 369, that examined the relationship between the presence of E. coli in drinking water, handwashing behavior, and the occurrence of diarrhea. The health impact of water quality is also discussed in an ECB305: Economic Development class at Gordon College. This class has a multidisciplinary design, incorporating students focusing on economics, biology, environmental science, and international affairs. The students are assigned a research paper to read (for example, "The Interconnection Between Water Quality Level and Health Status: An Analysis of Escherichia Coli Contamination and Drinking Water from Nepal" (Kunwar and Bohara 2020; Rahman, Kunwar, and Bohara 2021). After that, students participate in an online discussion forum to share what they have learned from the reading. Embedding a discussion portion in this type of interdisciplinary development economics course can be effective in teaching water-related issues.

These courses are designed not only to teach real-world problems with data analysis, but to expose the students to the implementation and dissemination of their classroom findings. An important extension to these courses took the form of two Himalayan Study Abroad Programs offered at UNM through its Nepal Study Center in Winters 2017 and 2018. Around eighteen students from Econ 395 and Econ 369 traveled to Nepal to implement the solutions developed in the classes, which included installing a water quality monitoring device in the Danda River and designing a sanitation awareness bulletin board for public viewing. Students from the Econ 395 class had the opportunity to further enhance their learning by presenting their research to the wider research audience at the Undergraduate Research Opportunity Conference, UNM (2018), and the Annual Meeting of the Southwestern Society of Economists (2018). Students had hands-on experience on projects in solving community-based problems by applying what they had learned in the classroom. This classroom-to-field approach, which teaches a combination of theoretical and practical knowledge, has far-reaching impacts on students, institutions, and communities.

The teaching approach that we have adopted to enhance students' understanding of water-related challenges and potential solutions using real-world data has been enriching on several fronts. Undergraduate students who have completed these courses have a deeper understanding of the importance of water resources through their research and learning experiences, and have a deeper understanding of statistics and data analytical tools. The graduate-undergraduate mentorship model that we used in our courses was helpful for the undergraduate students and provided the undergraduate mentoring experience to the graduate students. Students who took part in the study abroad programs had

[3] *Indicates that the course is also available for graduate credit.

the opportunity to witness water-related problems and implement solution projects in the field. Moreover, the study abroad programs helped students better understand the social, economic, and cultural significance of water resources like rivers in local communities in developing countries. The field component of this innovative program was facilitated and inspired by a team of interdisciplinary UNM faculty, an economist, a hydrologist, and a climate scientist. Their trip to Nepal in 2015 was supported by a small National Science Foundation travel grant.

4.2 Examples of Graduate Teaching

At the graduate level, the approach tends to be research-oriented. In an interdisciplinary graduate course ECON545 (AOA WR 572) Water Resources II at UNM, which is co-taught by an economist, a hydrologist, and a journalist, students spend six weeks on a team modeling project that focuses on developing an integrated hydro-economic dynamic model for the local Middle Rio Grande Basin. Students look into different water-using sectors in the basin (agriculture, cities, environment, etc.), talk to stakeholders, identify their research questions, search data sources, explore future scenarios (climate change, population growth, etc.), build models (using system dynamics modeling software such as Powersim or GoldSim), obtain results, write reports, and present to a policy audience at the end of the course. The research questions are typically identified via discussion with local stakeholders such as the Bureau of Reclamation, irrigation districts, farmer associations, and environmental organizations. Student teams have different yet closely related research questions, which aids in student interaction and group problem-solving. This type of cooperative and active learning has proved to be very effective as evidenced by skills acquired by the students and their successful placement at various sectors, including top national research labs and consulting firms.

A similar approach is taken for the Applied Environmental Economics (ECO 526) course at Northern Arizona University. The negative externality of water pollution and how to incorporate that into market outcomes are taught as a subtopic in this course. A simulation scenario is created involving water pollution where students learn to identify optimal pollution reduction activities. Students learned why the individual level of effort to reduce pollution varies from the social outcome. Students also completed a class paper as a requirement of the course, and several students selected water pollution as their class project. The class paper is designed to review the current policies related to water pollution, and the students need to propose better policies than the status quo to account for the marginal social cost. For this paper, students identify water pollution point sources such as agriculture, dairy production, industrial run-off, etc. Then, they must propose policy tools to reduce water pollution, such as cap and trade, pollution tax, etc., for both point and nonpoint sources of water pollution. At the end of the semester, students present their research, generating discussion in the classroom. Along with the skill development, students receive significant exposure to the public policy aspect of water economics from this inquiry-based learning approach.

The teaching approach we have adopted at the graduate level has higher research exposure in terms of technical knowledge and research implementation compared to undergraduate teaching. From the identification of research questions to methodology to the policy implication of results, students experience different components of research and actively engage in class projects. Along with quantitative research skills in water economics, students also gain practical knowledge from a comprehensive research experience.

5 Discussions and Further Thoughts

Water resource management is an ideal topic for use in exploring scarcity, crisis, pollution, health impacts, and international disputes, especially in its usability in the innovative teaching approaches described previously. The need for such an intervention arises from the fact that, in most economics courses, analysis is limited to pricing mechanisms and marginal analysis, and without an opportunity for

real-world exploration and application of these analyses, the scope of learning outcomes may be diminished or incomplete. This paper proposes innovative teaching interventions and frameworks at the graduate and undergraduate levels that we believe are lacking in the broader economics curriculum. In this article, we first provide an overview of water economics teaching in different U.S. institutions. Then we introduce different types of teaching methods in which water economics can be embedded, delineated by undergraduate and graduate applications.

Most standard water resource economics courses use basic applied microeconomic theory and principles, supply and demand, pricing, welfare optimization, and cost-benefit analysis. Students also get exposure to water markets and water rights, and some game theory as a tool for conflict resolution. Econometric tools are also used to perform forecasting of the supply and demand models of water usage. This standard curriculum practiced in economics departments seems to fall behind when it comes to underscoring the importance of regulatory mechanisms, which influence a wide range of water-related issues. For example, the public-private partnership in water and sanitation infrastructure projects can have far-reaching implications for public health and safety. There are laws regarding the recharging of groundwater with treated water, and it is not uncommon to have "fights and rights" debates and litigations over it. Regulations governing surface water quality can also affect water usage activities in the residential and commercial sectors, especially in the use of products with certain chemical compositions. It is worth noting that the Clean Water Act of 1972, which was designed to ensure the safety of drinking water, was extended by the Obama Administration's Clean Water Rule to protect the U.S. rivers and streams. The recent repeal of this regulation by the Trump administration further highlights how regulations surrounding water resources can have far-reaching consequences when it comes to usage, public health, and the environment. Likewise, climate change and its impact on freshwater bodies have forced many countries around the world to devise various institutional mechanisms to deal with their respective water crises. Thus, it would be important to incorporate these legal aspects into the modern curriculum of water economics.

Economics departments could take an inclusive approach to help address water challenges by collaborating with other departments within and beyond their institution. Water cannot be taught by simply looking at allocation and pricing issues as is traditionally done in economics courses. Economics students, especially those who are interested in environmental and resource economics, need and ought to be exposed to holistic dimensions of water resources. In addition to faculty and departments' initiatives, institutional support and assistance from external sources such as institutional benchmarking can be effective in moving toward a modern economics curriculum pertinent to water. An example is the Sustainable Water Resources Grand Challenge launched at UNM in Spring 2019, which is one of the university's three Grand Challenges. This challenge requires high levels of interdisciplinary research, scholarly innovation, and community connection. By using the size and strength of its interdisciplinary programs in natural sciences, social sciences, engineering, law, and policy, the UNM Sustainable Water Resources Grand Challenge is seeing great success in its first three years of establishment. A reason for this is the cultivation of collaborative partnerships across campus, which increases the visibility of research (Whitt 2021). These collaborative partnerships among colleges, centers, and departments (including the Department of Economics, and with an economics faculty member on the Grand Challenge leadership team) also significantly improve the training of the next generation of water managers and leaders needed to solve local and global water problems. For example, more courses have been cross-listed across programs, and several departments, including economics, are considering co-taught interdisciplinary water-focused courses. An Academic Affairs General Education Teaching Fellowship that targets Grand Challenge course enrichment was also established via the UNM Office of the Provost to recruit faculty interested in transforming how undergraduates are educated in the general education program. Specifically, teaching fellows collaborate to leverage the UNM Grand Challenges to further enrich an existing general education course or to develop a new general education course. The corresponding author of the article was awarded the

fellowship with funding support to develop a water-focused module for an introductory microeconomics course and has successfully implemented it in both face-to-face and online classes with excellent feedback from the students. The course was further enhanced in subsequent semesters to use a set of research-based interventions to build equitable learning environments via the UNM Student Experience Project program, which is part of a national program with six university partners, and to offer students entry-level water economics research engagement via the UNM ECURE program. Institutional support like the Grand Challenge initiatives and teaching fellowship programs provides great opportunities for instructors to share ideas across disciplines and connect teaching and learning with global challenges like water issues.

External funding and resources can be sought from various funding agencies and foundations to support such efforts within and across institutions. For example, the UNM Sustainable Water Resources Grand Challenge led a $3 million, five-year proposal to the National Science Foundation Research Traineeship Program focusing on big data for multi-scale hydrologic systems. The proposal had an economist as a co-PI and, although not funded, has laid a foundation for future collaboration of similar training proposals. A successful training grant example is the PATHWAYS (Partnerships Along the Headwaters of the Americas for Young Scientists) program, co-hosted by UNM and Washington State University as part of the National Science Foundation's International Research Experience for Students, where students conduct research and receive training on headwater dependent systems along the Transect of the Americas in Central and South America (Washington State University 2022). Improved availability and securement of these external resources will assist in moving toward a modern water economics curriculum where students are introduced to the practical implementation and analysis of local and global water issues. In summary, we call for a dynamic economics curriculum to help address challenges and workforce demands related to water resources. We also call for better education and training of the next generation of water economists and, more generally, water citizens.

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Appendix

A1. Details of Text Analysis

The generation of word clouds for text analysis is detailed in this section. We started by searching the phrase "water economics course" on Google (https://www.google.com/). From the resulting pages, we collected the names of the courses and institutions. We browsed all the pages until the course listings ended. After identifying the course names, we collected the syllabus of those courses. However, some course syllabi were not available on the institution's website. In those cases, we collected the course description and other related content information from the website of that department.

Next, we moved to the text-gathering part. First, we gathered all the course descriptions and course content from the syllabi and websites by each water stress area and by economics vs. non-economics disciplines. Second, we cleaned the text to carry out the text analysis. We removed any punctuation, numbers, and stop words (i.e., common terms like "a," "an," "the," "was," "from," "for," etc.). Additionally, any words in the syllabi that captured classroom decorum, but were not relevant to understanding water-related topics were also removed. These are "assignment," "students," "university," "attendance," "description," "class," "topics," "related," "particular," "course," "work," "techniques," "change," "options," "united," "role," "based," "explain," "include," "with," "introduction," "such," "part," "their," "how," "each," "assigned," "learning," "these," "syllabus," "help," "also," "particular," "covering," "instructor," "apply," "focusing," "based," "take," "meet," "draft," "objectives," "due," "audience," "used," "week," "discussion," "review," "brief," and "tools." We have also combined a few similar words: "resource" and "resources" to "resources"; "policy" and "policies" to "policy"; "economic," "econ," "economists," "economist," and "economics" to "economics"; and "environment" and "environmental" to "environmental." After cleaning the text, we created the word clouds and frequency tables of words.

A2. Suggested Course Syllabi in Different Water Stress Regions

1. High Water Stress Region
https://are.berkeley.edu/sites/are.berkeley.edu/files/job-candidates/pdfs/EEP162_Syllabus_2019.pdf

2. Medium-High Water Stress Region
http://www.uwyo.edu/agecon/about-us/facultystaff/faculty-pages/McLeod/AGEC%204720%20Syllabus%20Water%20Resource%20Economics.pdf

3. Low-Medium Water Stress Region
https://cpb-us-e1.wpmucdn.com/blogs.uoregon.edu/dist/3/5358/files/2014/01/467_intnl-water-policy-192a76h.pdf

4. Low Water Stress Region
https://seas.umich.edu/sites/default/files/2022-04/EAS_501.086_Fall_2021.pdf

A3. Expanding Course-Based Undergraduate Research Experiences (ECURE)

Activities in an Introductory Microeconomics Course

ECURE Activity 1: Your Water Price

1. Do you know the current price you (or your landlord) pay for a gallon of water from your tap? If so, what's your current water price? If not, can you try to find it out? (If you receive water bills, you may calculate it from your last bill; if you don't receive water bills, ask a family member or a friend who does receive bills.)
2. Do you think your current water price reflects water abundance/scarcity in your region?

ECURE Activity 2: U.S. Urban Water Prices: Cheaper When Drier?

Read the following two papers (published in a top water journal but easy to read):

1. Luby, I.H., Polasky, S., and Swackhamer, D.L. 2018. "U.S. Urban Water Prices: Cheaper When Drier." *Water Resources Research* 54(9):6126–6132.
2. Switzer, D., and Teodoro, M.P. 2019. "Comment on 'US Urban Water Prices: Cheaper When Drier' by Ian H. Luby, Stephen Polasky, and Deborah L. Swackhamer." *Water Resources Research* 55(7):6316–6321.

After you read Paper 1:

1. What is the purpose of the research (aka, what is the research question)?
2. What data is collected in order to investigate the research question?
3. What is the finding of the research?

After you read Paper 2:

1. According to Paper 2, what are potential flaws in the research in Paper 1? Do you agree?

An ECURE Performance-Based Assessment

Here we provide an example of a performance-based assessment designed for an introductory microeconomics course that offers students entry-level water economics research engagement. The research project described in the assessment is adapted from Luby et al. (2018).

Your partner on a research project drafts results for a poster you will both present at a regional conference. They share a draft with a research question, figure, and bullet points below, which relate to data you collected and analyzed.

The purpose of your research project is to examine how municipal water rate structures align with the issue of water scarcity in the United States (US). Specifically, the project investigates whether water prices are higher in water-stressed regions like the Desert Southwest than in water-rich areas like the Northeast. You collected data on water pricing in the largest city within the 35 most populous metropolitan areas in the US and analyzed the pattern in the data. You found that cities facing greater water scarcity tend to have lower water prices. In fact, the least expensive water in the country was found in the cities with high water scarcity (Sacramento, Las Vegas, and Phoenix). Below is the poster:

a. *Write a three- or four-sentence summary of the research project that communicates the main findings to an interested friend or family member who isn't familiar with the project.*
b. *In addition, write constructive criticism of the draft for your partner. Be specific about what changes or additions you would make to overcome any problems you notice, and why you would make those changes/additions. Make sure to provide feedback about the (1) research question, (2) figure, and (3) bullet points.*

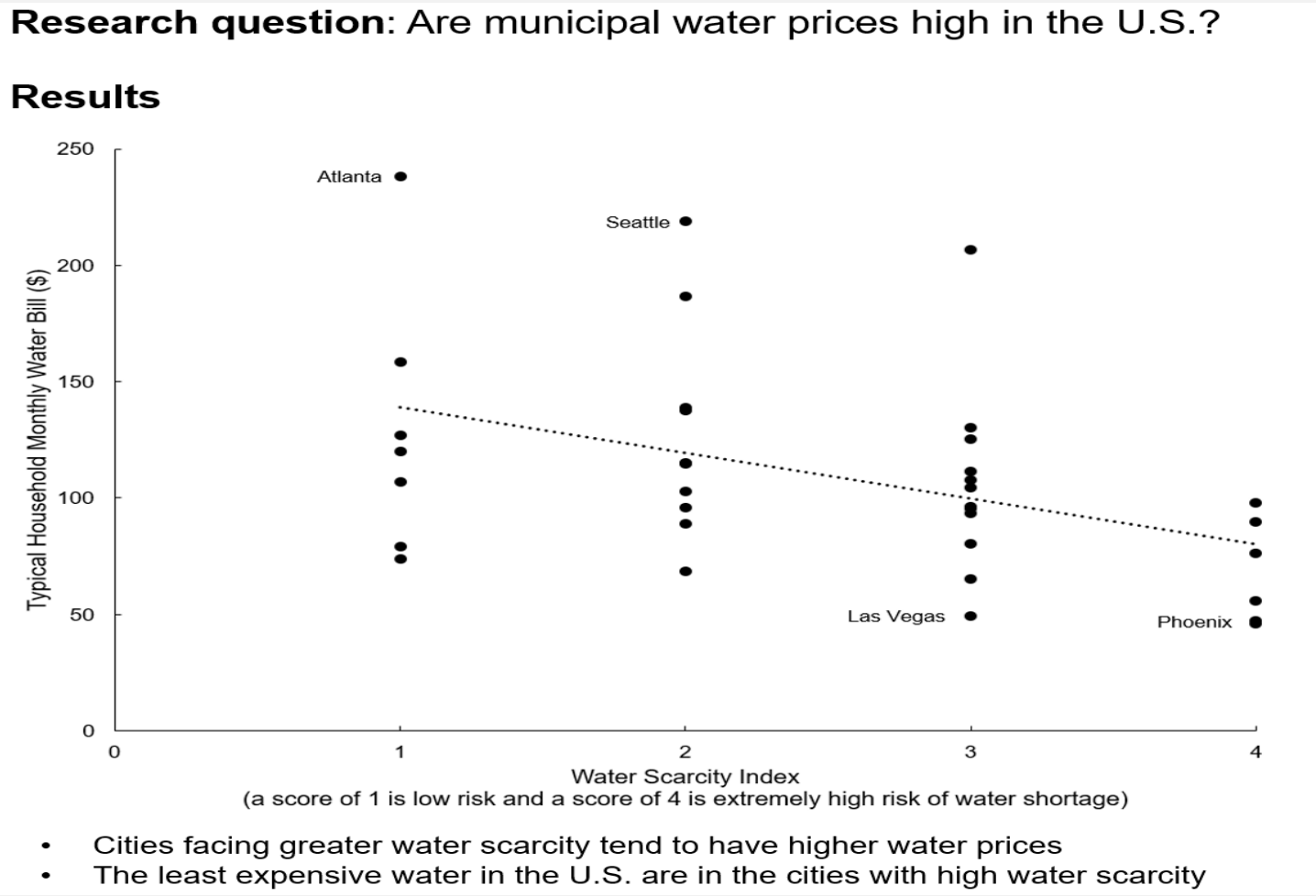

Figure A1: An Example Poster from a Performance-Based Assessment Designed for an Introductory Microeconomics Course

Data source: Luby, Polasky, and Swackhamer (2018).

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