Teaching and Educational Methods

Teaching Water and Sanitation Economics and Policy with a Focus on Low- and Middle-Income Countries

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Abstract
This paper describes our experience from 2010 to 2018 developing and delivering a multidisciplinary graduate course on "Water and Sanitation Policy and Planning in Developing Countries." This course was synchronously taught at the University of North Carolina at Chapel Hill and the University of Manchester, UK. We describe both our learning objectives and the conceptual framework for policy analysis that were used to structure the course. We discuss our problem-based learning approach to case studies and policy memo format assignments. We summarize eleven key messages that we want students to think hard about when reflecting on the course materials. This aligns with our aim to prepare students to address key challenges of water and sanitation access and provision that they could encounter in careers in the global Water Sanitation and Hygiene (WASH) sector. We discuss how our teaching was improved from 2012 after we converted our in-person class for parallel delivery as two massive open online courses (MOOCs) on Coursera. This afforded more class time to use a "flipped" classroom format, enabling more active participation because students could watch recorded lectures outside class.

1 Introduction

Low to middle income countries face a range of challenges to provide appropriate water supply and sanitation services to their growing populations. We believe there is a need to train Water Sanitation and Hygiene (WASH) sector practitioners at universities to understand current WASH conditions and to critically assess policy interventions in the sector. This paper describes our experience developing and delivering such a course. Our reflections on the course will hopefully assist readers who may wish to develop material on WASH policy and planning for use in their own contexts.

The policy model our course adopts stresses that students should understand current "status quo" conditions and be able to critically assess existing policy interventions. We also engage students with eleven high-level "key messages" across the course material. These address how "ancient instincts" affect water and sanitation behaviors (1), the relationship between raw water supplies and infrastructure (2), path dependency (3), how the state views WASH services (4), the difference between economic and financial analysis of water investments (5), corruption in the WASH sector (6), important attributes of piped WASH services (water is heavy and piped networks are expensive) (7), and how this affects water problems and solutions (8), the difference between optimal and minimal water use (9), uncertainty about the magnitude of the health benefits of WASH interventions in different locations (10), and the multilevel nature of water policy debates (11).

The paper is structured as follows. First, we present an overview of the course development and its approach, which has involved synchronous U.S./UK in-class teaching and parallel development of two massive open online courses (MOOCs). Second, we detail the eleven key messages that we want students to think hard about over the semester (term). Third, we list some case studies that we have found most useful and with which we believe students should be familiar with as they organize their thinking about

potential professional work in the WASH sector. Fourth, we discuss some of the participatory exercises we use in our "flipped" classroom (including class debates, the calculation of intervention costs), and the use of formative and summative problem-based learning assessments. Fifth, we offer brief reflections on our experiences with designing and offering the two MOOCs and how this enriched classroom practice. We then conclude with final thoughts.

2 Course Overview and Approach

From 2010 to 2018 we simultaneously taught a graduate course entitled "Water and Sanitation Policy and Planning in Developing Countries" at the University of North Carolina at Chapel Hill and the University of Manchester, UK.[1] The audience for this course included students from several different disciplines (e.g., business and management, environmental sciences and engineering, city and regional planning, innovation studies, pollution control, public policy, public health, sociology, geography, political science) who were interested in problems of poor water and sanitation in low- and middle-income countries.

We set overall learning objectives for students for this course to be as follows:

- To develop the knowledge and understanding of status quo (baseline) conditions in the water and sanitation sector in low- and middle-income countries; and how problems are defined.
- To understand current trends in water and sanitation conditions and where current programs, economic growth, population growth, and demographic changes are headed (dynamic baseline).
- To understand and think critically about the different types of policy interventions (instruments) that can be used to improve water and sanitation conditions in low- and middle-income countries.
- To understand the policy objectives (criteria) that governments and donors use to assess the outcomes of policy interventions in the water and sanitation sector.
- To understand the causal links between policy interventions and outcomes and to critically assess the available evidence about how effective different policy instruments are in improving conditions in the water and sanitation sector.
- To think critically about implementation issues and the lessons learned about implementation, monitoring, and evaluation.
- To develop critical writing and communication skills to better explain policy recommendations in the water and sanitation sector to decision makers.
- To learn how to read and synthesize professional and scientific literature on a policy issue in the water and sanitation sector.

This period beginning in 2010 was in the relatively early days of this kind of remote teaching. We had a video link between a classroom in Chapel Hill and a classroom at the University of Manchester. At both ends this required dedicated camera technology and operators, so we needed more planning than when using current platforms like Zoom and Teams that have since become commonplace. Sometimes Professor Whittington was in Chapel Hill and would broadcast the lecture to students in Manchester, and Dr. Thomas would moderate a discussion of the materials with students in Manchester after the broadcast ended. Sometimes Professor Whittington was in Manchester broadcasting to students in Chapel Hill. Sometimes Dr. Thomas would lecture from Manchester to students in Chapel Hill with the

[1] Beginning in 1996, Dale Whittington taught an earlier version of this course for students at University of North Carolina at Chapel Hill, Duke University, and North Carolina State University. The majority of students were in Masters degree programs, but PhD students and upper division undergraduates were also permitted to enroll. In 1998 and 1999, Professor Whittington simultaneously taught this course in the Department of Urban Studies and Planning at the Massachusetts Institute of Technology and the University of North Carolina at Chapel Hill. No video technology was used; he flew back and forth between Chapel Hill to Boston once per week throughout the semester.

Manchester students present in person. Students at both Chapel Hill and Manchester could participate in discussions and pose questions to their instructors and each other in real time. Around 40 to 60 students took the class in person each year.

In 2012 the University of Manchester put out a call for proposals to faculty who wanted to work with Coursera[2] and create a MOOC under the University of Manchester brand. The winning teams received funding of around US$18,000 to work with the University of Manchester Media Production Unit to record their lectures for the MOOC. The University of Manchester was dipping its toes into the new world of MOOCs and hoped to learn lessons for a broader, more comprehensive initiative. We wrote a proposal, and our course was selected as one of five MOOCs to be launched by the University of Manchester on the Coursera platform. We converted the classroom-based course into an online version in two parts. We recorded our lectures for part one in 2013 and 2014. Part one launched in May 2014, with endorsement from the Global Water Partnership[3], and was taken by 17,500 students from more than 190 countries before it closed later that year. Lectures for part two were recorded from 2015 to 2017 with additional funding support. Part two launched in January 2017, and part one was re-launched, with no set closure date.[4] By November 2022, an additional 25,000 students had taken the courses, bringing total enrollment to 42,500. This currently continues to increase by around 75 students per week.

The class already had a pedagogic approach of placing emphasis on class participation and treating policy challenges in the WASH sector as "wicked problems." This guided how the material was taught. Our assignments required students to compose "policy memos" that responded to realistic, real-world problem scenarios. However, building a library of recorded MOOC lectures created a new opportunity for us to take this approach farther by adding various "flipped class" approaches. We could have students listen to the lectures before class and use class time for other, more interactive, participatory activities. For example, we used class time to answer student questions about the recorded lectures, for guest lectures, to hold class debates on current topics of special interest, and to give students the opportunity to present and discuss new literature in the field. Often, we would read a new article or paper and then have the author join by video link into the live class session to answer student questions about the author's research.

The course (and the MOOCs) is organized in two main parts across fourteen taught sessions (for syllabus see Annex 1). The first describes current and evolving conditions in the water and sanitation sector. We want students to have a nuanced understanding of the kinds of situations that they will find in low- and middle-income countries if they chose to enter into professional work in the Water Sanitation and Hygiene (WASH) sector. Topics in part one include infrastructure coverage in the Global South; the provision of water by informal providers (water vendors); costs of service provision; different forms of corruption; water and food relationships; the determinants of demand for improved services; and WASH water development paths and the associated technical, financial, and political disequilibria that occur in different phases (Whittington et al. 2023). The second part of the course covers the different types of policy interventions that have been used to improve poor water and sanitation conditions and what we know about their effectiveness. Policy interventions discussed include government investments, new planning protocols, tariff reforms, subsidy schemes, information provision, privatization, and regulation. We believe this two-part "status quo" and "interventions" structure has broad application to many such courses on water economics topics.

As the course format evolved over the years, we gravitated to the use of more case materials. There are now many excellent cases in the WASH field that illustrate well different aspects of the challenges of improving water and sanitation conditions in the low- and middle-income countries and

[2] https://www.coursera.org/.
[3] https://www.gwp.org/.
[4] The course links are https://www.coursera.org/learn/water and https://www.coursera.org/learn/water-part-2.

the policy interventions that planners and policy makers can deploy. We use these case studies to illustrate a set of eleven key, overarching messages. One can thus conceptualize the organization of the course as a matrix with, for example, ten case studies and eleven key messages. We use each of the case studies to call attention to and re-enforce one or more of the eleven key messages. We will not use a single case study to try to discuss all of the key messages, but typically more than one message can be discussed in each case study.

3 Eleven Key Messages

3.1 Message No. 1: Ancient Instincts

Economic theory has important insights to offer water and sanitation planners, especially in the areas of investment planning and pricing and tariff design. However, students need to appreciate that water policy interventions may evoke powerful emotional responses in the *homo sapiens* that can play an important role in their responses to policy interventions. John Maynard Keynes described the role played by "animal spirits" in the financial markets, and that the decision to undertake an investment was not simply the result of "cold calculation."[5] In the course we call Keynes's animal spirits "ancient instincts" and stress to students their importance in understanding water policy debates and designing interventions in the WASH sector. We argue that water has played a crucial role in the evolution of *homo sapiens*, and that this history has left us with four ancient instincts related to water and sanitation that continue to influence our behavior in the WASH sector (Whittington 2016).

The first ancient instinct is our primal fear of losing access to water. When our ancestors on the African savannah went to water holes to drink, they faced the risk of attack by predators. They had to be especially vigilant; the risk of losing access to water was very real and could be life threatening. Finlayson (2014) contends that the *homo sapiens* body evolved for long distance running in part to be able to reach distant water sources, especially if nearby sources dried up or access was denied.

The second ancient instinct is our love of water for relaxation and recreation. Not only did our ancestors need water for drinking to survive, but they also enjoyed water for bathing, cooling off, and the aesthetic beauty of light reflections on water surfaces. We discuss with students their own preferences for swimming, walking on the beach, and camping near scenic bodies of water. These preferences are reflected in the housing premiums that people today pay for waterfront properties where they can see and experience water.

The third ancient instinct is *homo sapiens*' universal repulsion of the smell of feces. On the African savannah, this ancient instinct served an important purpose, i.e., to encourage people to defecate away from communal living sites. In the course we refer to this ancient instinct in our discussion of the challenge of ending open defecation in South Asia and Sub-Saharan Africa, noting that many people still like to defecate in the open. Understanding *homo sapiens*' universal repulsion of the smell of feces also helps us examine the concept of "triggering" a community response to end open defecation that is a central idea in the policy intervention community-led total sanitation (CLTS).

The fourth ancient instinct is *homo sapiens*' reluctance to assign an exchange value to water. Early humans created complex trading systems, exchanging flint, obsidian, shells, hides, and food over long distances. These trading systems established exchange values for many commodities. However, because water was heavy and hard to carry, *homo sapiens* had to live relatively near a water source. This meant that it was not one of the commodities in such long-distance trading systems. As a result, throughout most of human history, water was never assigned an exchange value. This does not mean that humans treated water as a "low-value" commodity. Indeed, water is deeply embedded in almost all spiritual and

[5] "If human nature felt no temptation to take a chance, no satisfaction (profit apart) in constructing a factory, a railway, a mine, or a farm, there might not be much investment merely as a result of cold calculation." (Keynes 1936, p. 135)

cultural traditions. But because it was not traded, there was no tradition of establishing a monetary value to water.

Throughout the course we discuss the importance of these four behavioral traces from our evolutionary past, especially in the analysis of case studies. Reflecting on these four ancient instincts helps students understand why economists' policy advice is routinely rejected by decision makers and civil society in the water sector and how such resistance to economic advice can sometimes be overcome.

3.2 Message No. 2: WASH Services Require Both Raw Water Supplies and Infrastructure

In the Southwestern United States, water rights lawyers refer to "dry water" and "wet water." "Dry water" means water without the associated infrastructure. "Wet water" refers to having both the water right and the funding to build the infrastructure needed to use the water at the time and location where people want it. In many situations a water right without infrastructure is not worth very much.

This distinction between a water supply with and without infrastructure should be front and center in students' minds as they study water economics and policy—both in low- and middle-income and in high-income countries. A surface or groundwater raw water supply typically must be combined with infrastructure to make it more valuable to users. Infrastructure is used to move water from its existing location to where people want to use it (e.g., water transmission pipelines), to improve the quality of the raw water (e.g., water treatment facilities), and to improve its reliability (e.g., reservoirs, storage tanks). Such water and sanitation infrastructure is very capital intensive, long-lived, and expensive (Whittington et al. 2009). Typically, a community cannot pay for all the water infrastructure it needs out of cash flow. Long-term financing is required to match the benefits of providing water and sanitation services over time with long-lived infrastructure.

The cost structure for raw water supplies is very different than for infrastructure. Both formal and informal property rights determine whether one party can obtain access to a raw water source. Raw water may or may not be tradable depending on the local property rights regime. The state may allocate a raw water supply to one party free of charge, or the price to obtain a water allocation may be high (or obtaining an allocation may not be permissible). The availability of raw water supplies varies greatly by location and over time. Raw water may be available part of the time, but not available at other times, so the price of a raw water supply traded in a water market will have an associated reliability.

The coupling of these two very different goods—raw water and water-related infrastructure—is one of the reasons that water resource economics and policy is such an interesting, complex field of study. Students need to think about the economic value of water with or without the associated infrastructure. For example, the piped water services delivered to households combine a raw water source with infrastructure to produce water and sanitation services that have a high economic value to households and other urban customers. The economic value of these water and sanitation services is much greater than the economic value of a raw water supply in a river that is 100 kilometers from the city.

However, conversely, a modern piped water and sewerage infrastructure system is worth much less without a reliable raw water source. This can occur in extreme drought conditions. For example, in the recent drought in Cape Town, South Africa, the piped infrastructure existed in most parts of the city, but the raw water supply itself was almost exhausted (Visser and Brühl 2019; Muller 2017; Kohlin and Visser 2022). In such a situation, the infrastructure itself cannot deliver the water services people want and the economic value of the infrastructure without the raw water supply is essentially zero until the drought is over and the raw water supply returns.

Students also need to realize that policy discussions about the human right to water may not properly account for this distinction between raw water supplies and water with infrastructure. This is true for discourses in both civil society and high-level policy circles.

3.3 Message No. 3: Path Dependency

Building water infrastructure in cities almost always involves adding on to existing infrastructure. This requires a careful consideration of what is already in place, which in many cases may not be ideal. For example, in many cities wastewater flows from residential customers are combined with stormwater. In extreme (or even normal) precipitation events, the volume of wastewater may be too great for the available wastewater treatment facilities, and raw sewage must be discharged untreated to surface waters (unsatisfactory combined sewer overflows). One can replace combined sewer systems with separate stormwater and wastewater networks, but this requires major capital investments.

Similarly, single-family housing is typically plumbed for only one line to supply potable water throughout the dwelling. Treated potable water is not required for flushing toilets or watering lawns, but residential customers are "locked in" by past investments in indoor plumbing and public piped network investments to housing units. Residential wastewater collection infrastructure does not separate urine and feces, even though both the treatment and disposal issues involved with these two waste streams are very different.

Students need to understand that the capital required to provide water and sanitation services is embedded in both the infrastructure outside the house (typically publicly owned) and the plumbing inside the house (typically privately owned) (Whittington 2020). The problem of path dependency is especially severe in multifamily housing units. For example, if the plumbing within a multifamily apartment or condominium building is not initially designed for metering individual units, it is often prohibitively expensive to later retrofit units with meters. In some cases, installing meters to a single individual unit could require multiple meters, one for each distribution line entering a unit (Davis and Whittington 2004).

WASH students need to appreciate that it can be prohibitively expensive to quickly change the way piped water and sanitation services are delivered in a city, even if this seems desirable, i.e., to make these services more resilient to a changing climate. One possible solution is to require new infrastructure standards on new construction, while existing buildings are allowed to continue with their existing infrastructure.

3.4 Message No. 4: The State Often Considers WASH Services to Be Merit Goods

Many students refer to piped water and sanitation as "public goods." What they typically mean is that the public has a strong interest in having high-quality WASH services provided to its citizens. Often students also have a strong preference that WASH services be provided by the public sector. This is another reason that they refer to WASH services as "public goods." From our perspective, it may or may not make sense for WASH services to be supplied by the public sector. This varies by both time and location.

We want students to understand economists' definitions of (1) "public goods," (2) "merit goods," and "externalities." We consider it is not helpful to define WASH services as "public goods" because consumption by one person *does* reduce the amount of water available to others, and capital used to supply infrastructure to one group of households cannot be used to supply a different group. On the other hand, some water resources (e.g., scenic lakes) may be public goods in the sense that the utility one person derives from viewing its natural beauty *does not* diminish the experience available to another one person (as long as the site is uncongested and unspoiled).

However, WASH services—especially sanitation services—*do* have positive externalities. In our experience many students are familiar with the concept of an "externality," but have difficulty both

defining it and understanding its significance for WASH policy interventions. There are many definitions of "externality" in the literature. In this course we use a simple one:

> *An externality is an effect or consequence of the production or consumption of a good or service on a third party that was not the intention of the consumer or producer of the good or service. This unintentional consequence of consumption or production may be positive (welfare-enhancing) or negative (welfare-reducing) on the third party.*

For WASH students, an important example of a positive externality is the health benefit to others that may result from the safe disposal of a household's feces. A household practicing safe disposal may itself receive a direct health benefit, and a neighbor may also receive a health benefit (a positive externality). The household practicing safe feces disposal may not have intended to provide a health benefit to their neighbor, but this occurred anyway. If a household does not take this positive externality into account, from a social perspective they will make too little investment in safe feces disposal.

In the WASH sector students tend to be unaware of the possibility of negative externalities associated with the provisions of WASH services. However, these can also occur and are location specific. The provision of piped water services inside dwellings and public spaces in very crowded slums may facilitate the spread of diseases (Bennett 2012). Finding the appropriate policy response to both positive and negative externalities requires a quantitative estimate of the magnitude of these externalities, which is typically difficult to obtain and will vary significantly by time and location.

We believe it is helpful for students to think of WASH services as "merit goods," which are defined as goods or services that the state has determined households should receive regardless of their ability to pay (Hanemann and Whittington, 2023). The key idea is that the determination of whether a good or service is a merit good is based on some concept of need, rather than on the basis of a household's ability and willingness to pay. A good example of a merit good is primary education. Almost every state wants all children to have at least a primary education regardless of their family's income. Health care is an example of a service that some but not all states treat as a merit good.

We emphasize to students that designating water and sanitation services as merit goods is not the same as to claim that water and sanitation are *human rights*. What constitutes a merit good is a political judgment made by a state at a particular time and place given competing claims on budget resources. Claims of human rights are not moderated by a state. The state must align its designations of merit goods and its budget resources. This is not how human rights are defined.

We use Table 1 to illustrate the distinctions between a public good, a merit good, and a private good. We start the discussion by pointing out that most goods and services are not either public goods or merit goods. Automobiles, houses, hamburgers, and cosmetic surgery are all goods that the state may regulate but allows the market to determine the prices to be charged. Whether a person has access to such goods depends on their ability and willingness to pay for them.

It is possible that the state could determine that a good or service is both a public good and a merit good. National defense and clean air are public goods because consumption by one person does not reduce the amount available for consumption by others. The state may also determine that national defense and clean air are merit goods that everyone should receive regardless of their income (Case 1). However, as a practical matter, it is not possible to exclude people from a public good like national defense, so some public goods inevitably will be provided regardless of a person's ability and willingness to pay.

Table 1: Public Goods and Merit Goods

	Merit Good	Not a Merit Good
Public Good	Case 1 – National defense, clean air	Case 2 – Television, radio signal
Not a Public Good	Case 3 – Access to health care, primary education, piped water supplies	Case 4 – Automobile, house, hamburger, cosmetic surgery

Television and radio signals are an example of a public good because one person's consumption of the signal does not reduce the amount of the signal available to someone else. However, it is technologically possible to exclude people from receiving such signals. Because most states have not determined that such signals are merit goods, states may allow charging for the signal. Such charges may not be based on a determination of the need or ability to pay of the household. This is an example of a public good that is not a merit good (Case 2).

Access to health care, primary education, and piped water and sanitation services are not classic public goods because consumption by one person *does* reduce the amount available for consumption by others. However, most states have determined that some minimum level of these services should be provided to people regardless of their ability to pay, so these would be merit goods but not public goods (Case 3).

A good class exercise is to break students up into small groups and give each group some examples of WASH-related services (e.g., public handpumps, in-house water treatment technologies, bottled water, tanker truck delivery, septic tank desludging, etc.), and instruct each group to classify these goods or services using this table. Each group can then report back to the class the reasoning they used to make their classifications.

3.5 Message No. 5: Economic Analysis of Water Investments Is Not the Same as Financial Analysis

We want students to understand the difference between an economic analysis and a financial analysis of a WASH investment. In our experience most students without training in economics use the term "economic" and "financial" interchangeably. Students' confusion about the difference is to some extent understandable because monetary units are used to measure changes in both financial and economic criteria, and because increases (or decreases) in people's income due to a WASH intervention may both count as financial benefits (or costs) and as economic benefits (or costs). However, students need to understand that maximizing net economic benefits and maximizing net revenues are not the same criterion. The market (or regulated) price of a good or service is not equivalent to its economic value, although in some cases prices may be good approximations. In practice, WASH projects are often evaluated using both a financial criterion and an economic criterion. For example, it is standard practice at the World Bank to evaluate projects from both perspectives.

Students need to appreciate that the difference between a financial analysis and a benefit-cost analysis lies in the set of protocols and procedures used to transform the physical data on project inputs and outcomes into monetary units. Financial accounting procedures and protocols use market prices to measure the value of inputs and outputs. To conduct an economic (benefit-cost) analysis, a WASH planner may use either market prices or shadow prices to value inputs and outcomes—whichever is appropriate in a specific context or situation.

Another important difference between the use of financial and economic efficiency criteria is that in a financial analysis the analyst typically restricts the focus to a single client or enterprise (e.g., the water utility). A benefit-cost analysis should include the economic gains and losses to all the groups of people (stakeholders) affected by the project or policy intervention.

We use Table 2 to show students that when both a financial criterion and an economic efficiency criterion are used to evaluate a WASH intervention, four outcomes are possible. Cases A and D are straightforward. In Case A, the WASH intervention passes both a financial and an economic efficiency test. This means that the project is both financially feasible (revenues exceed costs), and potentially welfare-enhancing (winners could compensate the losers, and everyone could be better off). In Case D, the project fails both a financial and an economic efficiency test, i.e., revenues cannot cover costs, and the winners cannot compensate the losers and in theory make everyone better off.

Table 2: Four Outcomes of the Use of Both a Financial and an Economic Efficiency Criterion to Assess a WASH Intervention (Project)

	Projects passes an economic efficiency test	Project fails an economic efficiency test
Project passes a financial test	Case A	Case B
Project fails a financial test	Case C	Case D

Cases B and C are the most interesting for students. In Case B the project passes a financial test but fails an economic efficiency test. This could happen if a water utility or government looked only at the financial returns of a project, which were favorable, but did not consider the negative side effects or externalities. For example, an investment in water vending trucks might look financially attractive to a water utility (and perhaps also to a property owner receiving payments from the sale of groundwater abstracted on its land to the tanker truck vendors). The negative externalities of adding a fleet of tanker trucks to the city's transport network and the depletion of local groundwater resources would be ignored in such a financial analysis. However, an economic efficiency analysis that incorporated the negative externalities associated with traffic congestion, increased air pollution, and groundwater depletion could tip the analysis and result in this project failing an economic efficiency test. However, whether this would occur is an empirical question.

In Case C the project or policy intervention passes the economic efficiency test but fails a financial test. Such a project is economically justified but cannot be self-financing. An example might be a wastewater treatment facility with large positive externalities to downstream water users. In this case the economically optimal fee to charge households for wastewater collection and treatment might fail to raise sufficient revenues to pay for these costs. WASH projects designed to provide a variety of services that have been determined to be merit goods may fall into Case C.

3.6 Message No. 6: The Provision of Water and Sanitation Is Especially Prone to Corruption

The issue of corruption in the WASH sector is a reoccurring theme in the case studies students discuss in this course. It can be uncomfortable or surprising for students, but we want them to realize that the countries with poor water and sanitation conditions (where they may want to work) are also countries where corruption is high. Of course, corruption in such economies is not limited to the WASH sector, but we want students to understand six reasons why the WASH sector is especially prone to corruption. First, because the WASH sector is so capital-intensive, there are large flows of funds changing hands. Big construction projects are always opportunities for contractors to pay bribes to obtain contracts. Because financing is required to implement large, capital-intensive projects, bribes may be paid to facilitate deals. Second, because the price elasticity of the demand for piped water services is inelastic in low- and middle-income countries (Nauges and Whittington 2010), a water seller with market power (e.g., a utility, possibility a water vendor) can restrict supply, raise prices, and increase revenues. Students often assume that managers of water utilities operate the utility to serve the public interest, but this may not be the case (Lovei and Whittington 1993; Davis 2004).

Third, because much of the water and sanitation infrastructure is underground, it is difficult for customers to understand the actual physical condition of the infrastructure. It is easy for the providers of water and sanitation services to siphon off financial resources and allow the physical infrastructure to depreciate, or to install inexpensive, low-quality infrastructure but invoice for more expensive, high-quality infrastructure, without the public knowing what is going on. Fiscal malfeasance can be hard to detect until the accumulated liabilities for repairs and replacement of the infrastructure become very large.

Fourth, there is often a lack of transparency in the billing practices of utilities. Utilities typically present customers with a water bill that they do not really understand. In most cases it is difficult for customers to question or challenge how the water tariff structure was used to derive their bill. We have seen cases in which a customer's water bill was not calculated using the official tariff. This can happen when a utility manager needs more revenue and simply requests the accounting department to "tweak" the customer billing software to generate the required increase in revenue.

Fifth, water utilities rarely face the discipline of the market to operate efficiently. Regulators can try to provide incentives for efficient utility operation, but this is a constant struggle. The lack of market discipline means that the costs of corruption can often be hidden from customers and the regulator. Sixth, there are typically many donors and nongovernmental organizations working in the WASH sector, often with different policies and incentives to disburse funds for projects. This means that if one donor objects to a corrupt practice, the government or utility can often obtain the funds from another donor. We want WASH students to understand that opportunities for corruption arise at multiple scales (international, national, regional, city), and it is a multistakeholder practice. Corruption always requires two parties: someone willing to offer a bribe, and someone willing to accept it. Many different stakeholders in the sector may have an incentive to offer a bribe (a contractor, an employee wanting a promotion, a household desiring a lower meter reading), and many different parties may be tempted to accept it (a senior government or donor official with the power to determine who wins a contract, a utility official with the power to deny an applicant a job or decide whether a network expansion will reach a specific neighborhood).

3.7 Message No. 7: Water is Heavy and Expensive to Move, but Grain is Not

The late Tony Allan, Professor at Kings College London and the 2008 winner of the Stockholm Water Prize coined the term "virtual water" to describe his insight that global grain markets can alleviate local water shortages (Allan 2011; Whittington and Thomas 2020a, 2020b). It is typically much easier and cheaper to use water in site A (where water is abundant) to grow grain at site A, and then ship this grain from site A to site B (where water is scarce) than it is to ship water from site A to site B and grow grain in site B.

We believe this insight about the relationship between water and food is important for our students to understand, even though our course is not about regional water resources management. Local water shortages may fail to materialize if peaceful conditions for trade exist and countries have the financial resources to purchase grain from global markets. Egypt is the classic example of a country with limited freshwater supplies that has relied on grain imports to feed its rapidly growing population. Students studying WASH planning and policy need to appreciate the different order of magnitude of water required for irrigation and for domestic use. As a rough approximation, an irrigation scheme requires 1,000 cubic meters of water to grow enough grain for a person to eat for a year. Fifty cubic meters are required to supply an individual with sufficient water for domestic use from a private connection to a piped distribution system (137 liters per capita per day) for a year. Ten cubic meters of water (27 liters per capita per day) are required to meet minimum (basic) requirements for drinking, cooking, and washing for a year.

We use a simple exercise to drive home these relative magnitudes. We ask groups of students to estimate how many cubic meters of water would be required to fill up the entire classroom that we are all in. For purposes of illustration, assume that our classroom has a space of 500 cubic meters (e.g., 10 meters by 10 meters by 5 meters). We then point out that one would need twice the quantity of water of this classroom volume to grow sufficient grain to feed just one of the students in the classroom for one year. However, the water volume of this classroom would be sufficient to supply 10 students in class with water for domestic use from a piped distribution network for a year. The water volume in the classroom would be sufficient to supply 100 students with a minimum supply of water (27 liters per capita per day) for a year.

This exercise illustrates for students the relatively small amounts of water that the WASH sector needs relative to the water needs of irrigated agriculture. And this exercise assumes that there is no recycling of municipal wastewater.

3.8 Key Message No. 8: Water Problems Are Local, Solutions Are Contingent

It is perhaps understandable that both scholars and students seek solutions to water problems that are widely applicable across time and space. But the late Dr. John Briscoe, Global Water Advisor at the World Bank and the 2014 winner of the Stockholm Water Prize, emphasized that "water problems are local, and solutions are contingent" (Briscoe 2014).[6] What Dr. Briscoe meant was that water problems are typically the result of unique local political, social, hydrological, epidemiological, temporal, and cultural circumstances that are unlikely to exist elsewhere in precisely the same configuration. Thus, local decision makers and water planners need to craft their own solutions to fit their specific circumstances in time and place. These solutions may change because they are contingent on a multitude of factors that are themselves evolving and stochastic.

Dr. Briscoe never argued that local policy makers and water resources planners could not learn from the experiences of others in grappling with related problems in their own locations. Indeed, he spent much of his career at the World Bank investigating case studies and describing experiences that he felt would provide useful insights and lessons for others. But the essential point was that local policy makers and water planners would need to find solutions and then adapt them over time. Cookie-cutter applications of solutions transferred from other places were unlikely to work (Briscoe 2011).

Yet this insight that "water problems are local, and solutions are contingent," is not widely accepted in the WASH sector. In the course we give students examples of policy proposals that are framed as "one size fits all" solutions that can be deployed across space and time. One of the reasons that we rely heavily on case materials in this course is that the cases offer students the opportunity to think about local realities outside their existing experience and perhaps taken for granted assumptions. Case studies help students focus on the timing and sequencing of solutions and to move away from simplistic policy advice that is devoid of the local context. We like to tell students that Dr. Briscoe's advice is actually good news for them, i.e., that their skills will be in demand to craft and then adapt local solutions to water and sanitation problems. We also point out that this is a good argument for them not to spend their career working solely in international organizations.

3.9 Message No. 9: Optimal Water Use Is Not the Same as Minimal Water Use

The economist's concept of optimal water use is that the social costs of supplying the marginal unit of water to a customer should equal the social marginal benefits. It is thus possible that a customer's water use is too high (the marginal costs of supply exceed the marginal benefits). But it is also possible that a customer's water use is too low (the marginal costs of supply are less than the marginal benefits). In our experience, this concept of "optimal water use" is not widely understood or shared by WASH professionals and can be conflated with prevailing notions about sustainability.

For households with piped connections, the common assumption is that "water conservation" is always good—the more conservation the better. For example, "water conservation" is often listed as one of the objectives of water tariff design, i.e., that the tariff should promote or incentivize water conservation. If it is clear that the marginal costs of supply exceed the marginal benefits, then reducing customers' water use indeed makes economic sense. However, in many low- and middle-income

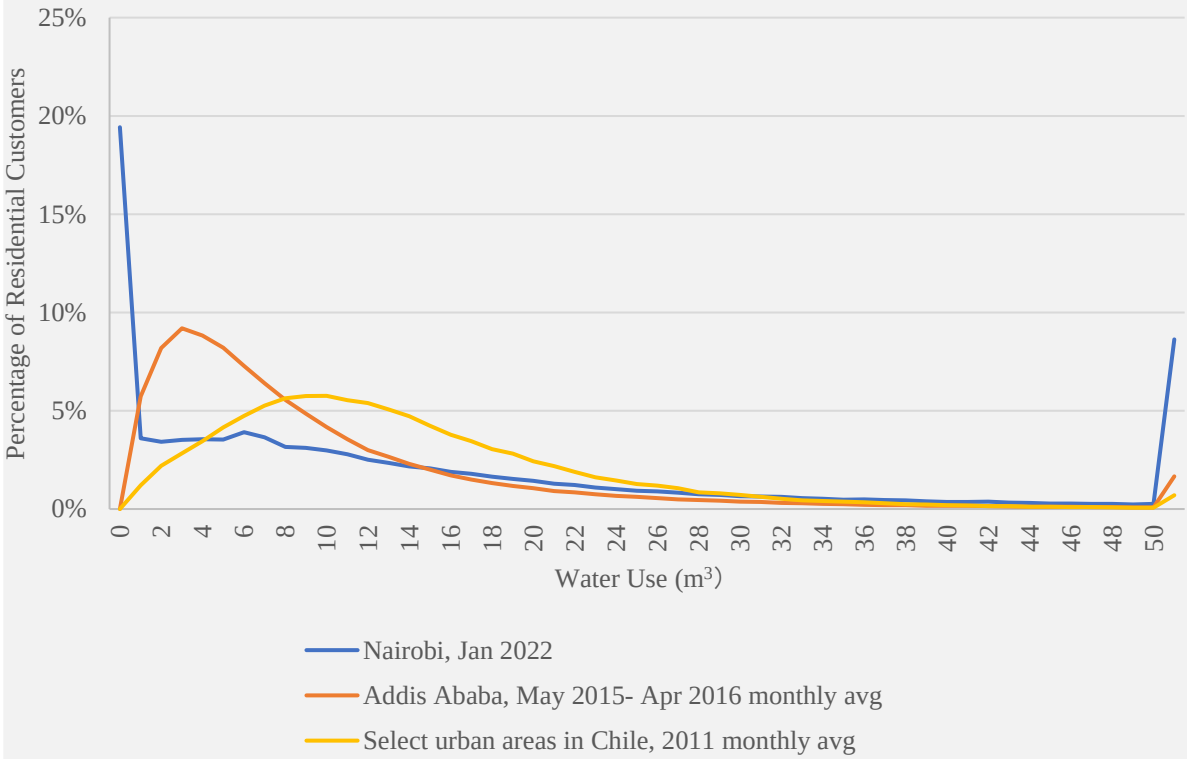
[6] Another formulation of this advice was offered by the economist Joseph Schumpeter in his book *Business Cycles* (1939, p. 412): "[O]ne essential peculiarity of the working of the capitalist system is that it imposes sequences and rules of timing … it is not sufficient to be right [about investment opportunities] in the abstract; one must be right at given dates."

countries, water use by many households already is quite low, and WASH planners need to examine carefully whether they really think households should conserve water.

We stress to students that from our perspective water conservation *per se* does not always make economic sense and should not be an objective of water tariff design. For example, households without piped water connections are typically using very little water. WASH planners should not want them to conserve water.

We thus want students to think carefully about how much water customers are using and its relation to the marginal costs of supply. To do this, it is helpful for students to get in the habit of examining the distribution of residential customers' water use at a specific time and location. The best source for these data are the customer billing records from a water utility. Most such distributions have a long tail of high-water users (see Figure 1).

Figure 1: Frequency Distributions of Water Use in Three Urban Areas



Students who are convinced that households should reduce their water use need to think about two strategies: (1) shifting the entire distribution to the left (i.e., incentivizing everyone to reduce their water use); or (2) reducing the water use of the highest water users (i.e., cutting off the righthand tail of the distribution).[7] The choice between these two strategies focuses students' attention on the question of who these high-water users are and why they are using so much water. Are they "wasting" water? Or do they have a good reason for using more water than other customers?

In industrialized countries, one tends to think of high-water users as high-income households that are using more water for residential lawn irrigation and perhaps swimming pools. Students typically have few reservations about recommending policy interventions that attempt to reduce the water use of such households, who they assume are wealthy. However, especially in low- and middle-income countries, customers with high-water use may be households with many members, such as multigenerational households. Also, customers with high-water use may have a business in their home

[7] We are grateful to Professor Michael Hanemann at Arizona State University for pointing out these two strategies to us.

that explains why their household is using more water than households in their neighborhood without a business. It is less clear that such high-water use households are using "too much" water and that WASH planners should focus on cutting off the right tail of the distribution.

When the average water use of households with piped connections is in the range of 100–150 liters per capita per day, as is the case in many low- and middle-income countries, we like to ask students what household water uses should be reduced. Do they think households are taking too many showers (in what might be hot, tropical, or dusty conditions)? Do they think poor households with large families are flushing their toilets too often? Such an exercise helps students reflect on this balancing of the marginal costs of supply and the marginal benefits of additional water use.

This balancing of costs and benefits necessitates an understanding of the long-run supply curve for raw water. Many students come to our course without an understanding of the economics of water desalinization. They implicitly imagine that there is a fixed supply of freshwater that is becoming increasingly scarce due to increasing population and economic growth or perhaps climate change. However, most of the world's population lives near oceans or has access to brackish groundwater. These populations can use desalinization technologies to convert saltwater to freshwater. Coastal populations essentially can have all the raw water supply they want if they can afford to pay for desalinization. Desalinization is still expensive and energy intensive, but the costs have been falling rapidly over the past several decades due to advances in both desalination technologies and solar energy (Hilal, Goh, and Ismail 2023). The problem for these populations is a shortage of capital and energy—or alternatively a shortage of "cheap" freshwater.

There are issues involved in cities becoming heavily reliant on desalinization as a raw water source. Desalinization plants may be subject to natural disasters or intentional sabotage, but then so are other water infrastructure facilities. Desalinization facilities also require an environmentally acceptable approach for brine disposal. Even though the costs of desalination are falling, desalinized water is still too expensive to be a raw water source for irrigated agriculture.

However, recognizing that the supply curve for water for many cities is ultimately horizontal (not vertical) is an essential insight for WASH students. This insight encourages students to look more carefully not only at one raw water source but at a city's portfolio of sources and to think about the concept of optimal water use as a balancing of the costs of water services with the benefits that customers receive.]

3.10 Key Message No. 10: The Magnitude of the Health Benefits of WASH Interventions Is Uncertain, and, at a Specific Time and Place, May Be Modest

Students are surprised and puzzled to learn that the empirical evidence regarding the health outcomes from different WASH interventions is quite mixed (Brown, Albert, and Whittington 2019). This may be due to the heterogeneity of treatment effects in different settings and across households in the same location, as well as the quality of the design and implementation of an intervention. WASH practitioners need to confront the fact that the health benefits of WASH interventions may be modest in a specific time and location.

In the course students review the findings of fourteen randomized controlled trials (RCTs) of CLTS and recent rural sanitation interventions (Radin et al. 2020; Whittington et al. 2020). The results of this RCT research program to evaluate CLTS and related sanitation interventions suggest that the magnitude of the treatment effects was much smaller and uncertain than CLTS proponents once anticipated. Of the ten studies that reported results for reductions in childhood diarrhea, only three found statistically significant decreases, and the magnitude of the decreases in the three studies with statistically significant results was modest.

We want WASH students to come to grips with the policy implications of such results. Student should realize that if the health benefits of a WASH intervention in a specific time and location are small,

this does not necessarily mean that the intervention is not justified. WASH interventions have other nonhealth outcomes that people value, particularly time savings. The value of the nonhealth benefits may be greater than the health benefits (Cook, Kimuyu, and Whittington 2016). Students should also realize that even if the health benefits are modest, if the costs of the WASH intervention are modest, the intervention may still be attractive.

Another reason that the magnitude of the health outcomes from WASH interventions is uncertain is that WASH interventions are often part of a multisector intervention. Students often think that WASH investments are like medical interventions, and that health outcomes can be improved without complementary investments in housing, other aspects of community infrastructure, and health care. However, in practice the timing and sequencing of WASH investments need to be coordinated with investments in other sectors. Of course, investing in, say, both modern housing and water and sanitation infrastructure is expensive, but the benefits that accrue to households from multisector investments also can be large.

An important lesson for students is that sound economic analysis is needed to improve the timing and sequencing of such multisectoral investments. WASH practitioners cannot "go at it alone." They need to work together with other planning and government officials to design and implement water, sanitation, housing, drainage, and health care solutions that are tailored to local environmental and political realities.

3.11 Key Message No. 11: Water Policy Debates Occur at Multiple Levels and Scales: Global, National, City, and Household

WASH policy is debated at four main scales: global, national, city, and household. Policy change can be difficult or impossible to implement when WASH professionals working at different scales are not in agreement about what needs to be done. Some WASH professionals are engaged in policy discourse at all four scales, but typically people and their associated institutions are primarily focused on policy debates at just one or two scales. Different policy issues are debated at the global, national, and city scales. We want students to understand these differences and that the role played by economic and financial arguments in WASH policy debates differs across these four scales.

At the global level WASH professionals use economic analysis primarily for policy advocacy, not for resource allocation or budgetary decisions. In our experience global WASH professionals use benefit-cost analysis to make the argument that the benefits of WASH investments dwarf the costs, and thus more international donor funding is justified. Global WASH policy debates are currently focused on the fulfillment of the human right to water and the need for additional financial resources to achieve the Sustainable Development Goals (Heller 2022). Global WASH professionals do not often acknowledge the possibility that some WASH investments would fail a benefit-cost test. Global WASH policy debates rarely focus on the issues of water pricing and tariff design, except to emphasize that tariffs must not threaten the affordability of water and sanitation services. Global WASH policy debates either explicitly or implicitly assume that WASH services should be heavily subsidized.

At the national level, funding for WASH investments is determined as part of a country's budget allocation process. We want students to understand the multisectoral nature of the national budgeting process and to look outside a "WASH silo." For example, if the global policy consensus is that WASH services should be heavily subsidized, it is up to the national government to make WASH a budget priority, which inevitably will entail allocating fiscal resources away from other sectors to WASH expenditures. As another example, at the national scale much of policy discourse that most directly affects WASH services actually involves housing policy. National governments are especially attuned to public concerns about access to housing. Since WASH-related costs embedded in housing are typically of comparable size to the infrastructure costs to supply water and sanitation services to the premises, national policies that affect the affordability of housing have a large effect on the affordability of piped

water and sanitation services. A budget reallocation away from housing to the WASH sector may therefore not achieve WASH goals.

We want students to appreciate that when economic analysis is used to help set national budget priorities, WASH investments typically do not figure prominently in the most economically attractive public investments (Lomberg 2012, 2017; National Development Planning Commission 2020). In part this is because in many low- and middle-income countries, WASH funding is captured by middle- and upper-income groups and does little for the poor. It is naturally difficult to mobilize poor households to support policies that do not benefit them.

At the city level, the municipal government and the water utility typically lead WASH policy debates. These officials are concerned about how to meet their service obligations and recover costs. The finances of the water utility are thus a central focus of concern of municipal and utility officials and local stakeholders. Water tariffs are important because they determine customers' water bills and thus the revenues utilities receive. The affordability of water bills often becomes a local political issue.

At the household level, many people lack not only piped water and sanitation network infrastructure, but also modern housing with indoor plumbing. The United Nations Sustainable Development Goal (SDG) 6 for water says that water services should be both "affordable" and available "on the premises." Water and sanitation professionals typically think of the costs of the piped water network to get potable water to the home and the cost of collecting and treating a household's wastewater as the main financial barriers to providing poor households with modern water and sanitation services. However, households also need to make large investments in indoor plumbing, toilets and appliances, and the added floor space needed for showers, toilets, and kitchens to take full advantage of WASH services brought to their premises. Households face tradeoffs between paying for these costs of water and sanitation infrastructure on their property and paying for service providers to deliver water and sanitation services to their property.

Because the provision of high-quality, piped network water and sanitation services is very capital-intensive, how capital investments are financed plays a crucial role in the magnitude of the costs and affordability of WASH services. Such investments will provide services to a water utility's customers for decades, and long-term financing allows these customers to match their payments for services more closely with the time at which services are received. It is not affordable for customers to pay upfront or repay short-term loans for infrastructure that provides services far into the future.

One of the enduring puzzles of the WASH sector is why a simple intertemporal financial deal between lenders and borrowers is so difficult. If the benefits of improved water and sanitation to households are so much greater than the costs, as most WASH professionals argue, why cannot households borrow today to have modern WASH infrastructure installed, and then repay the loan from increased income that results from improved health, time savings from not having to collect water, and cost savings from reductions in a wide range of coping costs (such as purchases from vendors, point-of-use treatment costs, and investments in household water storage)?

Taking a multilevel perspective on WASH sector policy debates can help students better understand this puzzle. During policy debates at each level—international, national, city, household—questions about capital financing for infrastructure hang in the air. Who will be responsible for servicing the debt incurred when large capital expenditures are required to provide improved piped water and sanitation services? At each scale stakeholders may hope to push debt obligations onto someone else, often to someone on another scale. At the international scale, donors push these debt obligations onto national governments. At the national scale, central governments may try to push these debt obligations onto lower levels of government and to utilities. At the city level, questions of where financing will come from and who will incur the debt are especially complex because there are three different groups of stakeholders that need financing for capital investments to improve WASH services.

First, water utilities in low- and middle-income countries—both public and private—need financing to expand network coverage, build water and wastewater treatment facilities, and construct raw water

transmission conveyance systems and other non-network WASH infrastructure. But at the city scale, municipal governments and utilities often lack the expertise to structure, manage, and oversee large financial deals. Moreover, municipal and utility officials know that in most cases, there is no consensus among households on what fair, reasonable water bills would be, nor is there agreement among households as to who should pay the higher tariffs needed for the high-quality piped network services provided by a water utility (Truong, Khanh, and Whittington 2020; Fuente, Mulwa, and Cook 2023). When households have not agreed to pay high tariffs for improved services, even low-cost, long-term financing will be insufficient to enable water utilities to provide piped network services to unserved populations. Households then make the individual decisions to self-supply and to purchase services from private-sector providers. Thus, at the city level the intertemporal financial deal between lenders, municipal and utility officials, and households is very hard to finalize, and city-level officials look to higher levels of government for subsidies.

Second, there are many private entrepreneurs that provide WASH-related services that need access to financing to run and expand their businesses and to hire professional staff with the skills needed to improve the quality of services delivered. Tanker truck vendors and wastewater desludging businesses need finance to purchase their trucks. Firms that drill boreholes need financing to purchase drilling equipment and working capital to operate. Bottled water businesses need financing to purchase reverse osmosis equipment. The economic life of trucks, drilling riggs, and reverse osmosis equipment is much shorter than the life of piped water and sanitation networks, so most private sector actors still need access to medium-term financing to effectively provide WASH services. Loans for private entrepreneurs that provide WASH-related services rarely come from higher-level government or donors. Instead, medium-term financing is typically provided by the extended family, private money lenders, and commercial banks.

Third, households themselves need capital financing to fully utilize water and sanitation services in their dwelling units (Whittington 2020). Financing for households to construct and rehabilitate their housing units so that they can utilize the WASH services provided to their premises is rarely considered as part of WASH financing requirements. Yet if households do not make substantial private capital expenditures on their housing units to bring WASH services for cooking, cleaning, washing, and waste removal inside their house, the health and nonhealth benefits of improved WASH are likely to be limited. Long-term mortgage financing for upper-income households may be available at the national scale but is typically “invisible” to WASH professionals. Financing is rarely available from official financial institutions or donors for poor households for such housing expenditures. Instead, poor households typically access capital from personal savings, extended family, and private moneylenders.

This multilevel perspective encourages students to focus on the influence of financing on the design of WASH infrastructure and who ultimately incurs the debt obligations that long-term financing entails. Alain Bertaud (2018) has argued that cities are built the way they are financed. We want students to recognize that the same is true of water and sanitation infrastructure. We also want students to recognize that broad policy debates are occurring at all four scales and that policy consensus at one scale does not necessarily result in progress at other scales. Change occurs when policies at multiple scales align (Geels 2006, 2010).

4 Case Studies

A central component of our course is discussion of case studies. We want students to be aware of what has happened in the water and sanitation sector in terms of both provision of services and policy interventions. We have used many cases during our years of teaching this course, and we are always looking for new ones. We use case study discussions to illustrate the eleven key messages described above and other issues.

Table 3 presents the main case studies that we have used over the years along with the associated readings and video materials that can accompany each. These are arranged in order of the sequence in which we present them to students across the fourteen sessions, in line with the policy model we use to organize the course. The case studies cover locations all over the Global South. Some describe situations that are now quite old; others are new. We tell students that we believe that there are important lessons to be learned from history, and not to look at "old cases" as out of date. We believe that it is useful for students to know how WASH professionals in the past thought about problems posed by these cases. There are lessons to be learned from both successes and failures, and it is possible and necessary to change our opinions as new practices and evidence emerge.

When selecting cases for a course with such a wide geographic scope and that will run for many years, it is important for instructors to reflect on how contextually independent the chosen cases are, whether learning is transferable to other settings, how much "closure" a case involves, and whether the cases are "finished" or are ongoing events and processes (Whitley 2008). We deal with these issues by including several cases we consider "iconic" (Phnom Penh water sector reform, Chilean subsidy design, Manila water privatization, Orangi low-cost sewers, Brazil condominial sewers, management of the Cape Town Drought, UK price regulation model). We almost always use these cases in the course. In our opinion, WASH students need to know these stories and be able to draw their own lessons from these experiences. We deliberately include here the privatization and regulatory experience of the UK, though not a low- to middle-income country.

The UK water privatization and regulation experience has been discussed and debated throughout the world, including in low- and middle-income countries. We believe that using the UK water privatization and regulation as a case study enables students to develop a nuanced understanding of the UK experience and to reflect on its transferability to a low- or middle-income context. Other cases are more easily substituted with new materials that may better illustrate a "hot" policy issue with which students should be familiar to be up-to-date with the literature.

5 Participation and Assessment: Debates, Cost Calculations, and Policy Memos

5.1 Class Debates

Creating the two MOOCs gave us prerecorded lectures that students could watch outside of class, giving us more class time for discussion, participatory group exercises, and student presentations. One format we used was class debate. The process used to develop these debates was exploratory. In-class debates are known to potentially improve students critical thinking and collaboration skills (Brown 2015). To assess whether this format was including or excluding students and their perspectives, we informally monitored levels of participation and whether students were experiencing any difficulties. For the debate structure, we give students a "proposition" to focus the debate and create a small group (typically 2–3 students) to argue in favor of it ("Pro side") and 2–3 students to argue against it. The majority of the students remain in the audience, but have an important role to ask both the pro and con sides questions after their presentations, and then to judge which side they think "won" the debate.

Table 4 presents the organization of a typical class debate. We ask the pro side to begin with a 15-minute opening statement, following by a 15-minute opening statement from the con side. Then the pro side gets an opportunity for a 5-minute response, followed by a 5-minute response from the con side. We then open the floor to questions from the audience for both sides.

Table 3: Examples of Case Studies

Session	Topic	Location	Readings and Resources	Key Messages Covered
1	Water vending	Onitsha, Nigeria	Whittington, Lauria, and Mu 1991	3, 6, 11
2	Water vending, affordability	Coastal Bangladesh	Hoque and Hope 2019	2, 5, 8
3	Water vending, coping costs, household demand for improved services	Kathmandu, Nepal	Whittington et al. 2002; Pattanayak et al. 2005; Raina et al. 2019	3, 6, 7, 10
4	Corruption, water vending	Port au Prince, Haiti	Fass 1988; PBS Frontline "Battle for Haiti," http://video.pbs.org/video/1737171448	2, 6, 8
5	Water development paths	Netherlands	Geels 2006; Whittington et al. 2023	2, 3, 5
6	Condominial sewers	Brasilia and Salvador, Brazil	Melo 2005; Nance 2012; multiple videos from the Appropriate Sanitation Institute: https://www.appropriatesanitation.org/	1, 3, 8
7	Low-cost sewers, participation	Orangi, Pakistan	Hasan 2023; video interview of Arif Hasan conducted by Diana Mitlin https://youtu.be/WBubv3VvUm0; "Orangi City of Hope" video documentary	1, 3, 8
8	Drought management, selection of policy interventions	Cape Town, South Africa	Muller 2017; City of Cape Town 2019; Leonie and Ziervogel 2019; Visser and Brühl 2019; Ziervogel 2019; Kohlin and Visser 2023	5, 7, 8, 9
9	Water tariffs	Nairobi, Kenya	Fuente et al. 2016	1, 4, 9, 10
10	Design of subsidies	Chile	Gómez-Lobo and Contreras 2003; Contreras, Gómez-Lobo, and Palma 2018	4, 10
11	Privatization	Manila, Philippines	Beer and Weldon 2000a, 2000b; Dumol 2000; Wu and Malaluan 2008; Wu, Jensen, and House undated; Video: Manila Water Company Philippines, https://youtu.be/6bJr-aeOsNk	1, 4, 11
12	Privatization	Cartagena, Colombia	Lee 1998	1, 10, 11
13	Sector reform	Phnom Penh, Cambodia	Ching 2009; Biswas and Tortajada 2010; The Connection: https://youtu.be/HBaSjmxXg0w	5, 8, 11
14	UK utility economic regulation model	United Kingdom	Littlechild 1988; Beesley and Littlechild 1989; Gassner and Pushak 2014; video interview with Stephen Littlechild: https://youtu.be/cKv68aRxIM4	1, 9, 11

Table 4: Class Debate Format
• Pro – Opening Statement (15 minutes)
• Con – Opening Statement (15 minutes)
• Pro – Response (5 minutes)
• Con – Response (5 minutes)
• Audience can ask questions of either the pro or con side
• Audience judges the outcome

When there are no more questions from the audience, we judge the outcome. We ask each student in the audience two questions: (1) Did they support or oppose the proposition before the class debate? and (2) Do they support or oppose the proposition after the debate? Their answers place each student in the audience into one of the following four groups shown in Table 5.

Table 5: Approach for Judging the Outcome of the Debate

Student position	Before the debate I supported the proposition	Before the debate I opposed the proposition
After the debate I supported the proposition	Group 1 Support → Support [no change]	Group 2 Oppose → Support [changed to pro side]
After the debate I opposed the proposition	Group 3 Support → Oppose [changed to con side]	Group 4 Oppose → Oppose [no change]

We tell the students that the "winner" of the debate will be the side that changed the most minds. There are limitations to this approach to judging success. It will be most effective when the audience is initially evenly split between supporting and opposing the proposition. One could also calculate the percentage of the students who changed their minds by the arguments made by the pro and con side. However, this simple approach for judging the outcome of the debate creates a simple, fun classroom exercise.

As all the students in the audience make their marks into this table drawn on a whiteboard, it becomes clearer which side will win the debate. We typically ask the audience members to reflect on why one side won, and on the arguments presented by both sides they found most persuasive. We then ask the members of the pro and con side to offer their reflections on the debate.
Table 6 presents some propositions we have used in these class debates. Often, we select a proposition that is topical or controversial in the WASH sector at the time the course is being offered.

5.2 Class Calculations of Intervention Costs

We have found that students have difficulty appreciating the capital intensity of piped water and sanitation services when they are simply presented with an estimate of the aggregate capital cost of a water and sanitation investment. It is much easier for students to appreciate the magnitude of capital costs when they are expressed in the same units as a household water bill (dollars per household per month). We have thus devised a group exercise to take students through the calculations necessary to translate estimates of total capital costs and annual operating and maintenance costs to equivalent household costs per month.

This requires that we introduce students to the concept of and formula for a capital recovery factor. We show students how the capital recovery factor changes with the assumed life of the capital and the interest rate. We discuss the pros and cons of using a real versus nominal interest rate in this

Table 6: Examples of Debate Propositions

Debate Topic	Propositions (Suggested Readings)
Human right to water	The United Nations Declaration establishing a human right to water and sanitation is a big step forward and will result in many more poor households receiving improved WASH services in the future. (Briscoe 2011; Burgess et al. 2020; Heller 2022; Resolution A/RES/64/292. United Nations General Assembly, July 2010. Available at: http://www.un.org/es/comun/docs/?symbol=A/RES/64/292&lang=E)
Health risks of poor water and sanitation conditions	The health risks from poor water and sanitation are a relatively small, unimportant part of "portfolio" of risks confronting poor households in low-income countries. (Collins et al. 2009; Landrigan et al. 2018; Fuller et al. 2022)
Economic value of water and sanitation infrastructure	The majority of water and sanitation infrastructure in low-income countries is best conceptualized as "dead capital." (De Soto 2003)
Ethics of Randomized Controlled Trial (RCTs)	Any risks associated with RCTs in low- and middle-income countries have been overblown and should not impede WASH-related research. (Coville et al. 2020; Deaton 2020; https://twitter.com/joshbudlender/status/1292170843389386761)
Privatization, regulation	UK private water companies should be returned to public ownership. (Helm and Yarrow 1988; Bartle 2003; Helm 2005; Barraque 2012)

calculation. Then we have students multiply the total capital costs of a project (such as a condominial sewer system,improving rural piped water systems, or the very large UK Thames Tideway Tunnel project), by a capital recovery factor to obtain an estimate of total annual capital cost of the project.

Each student group next adds the annual capital cost and the annual operations and maintenance costs to obtain the total annual cost of the investment. We then discuss how many people will use this investment and how many people who use the project should share the costs. We also discuss whether to use the current population or an estimate of the future population. We have students assume an average household size. Dividing the assumed population by household size gives them the number of households served. We tell them to assume that the investment will only serve residential customers; this thus gives them an annual cost per household. The assumptions about the size of the population served and the household size raise important questions about the trajectory of annual costs over time and intergenerational equity that can be discussed.

Finally, we have student divide the total annual cost per household by twelve to obtain an estimate of the total cost per household per month. This estimate can then be compared to an average household water bill to give students a sense of what proportion of the total costs households are currently paying in their water bill and what they would have to pay to achieve full cost recovery. We encourage students to conduct sensitivity analyses on the uncertain parameters in this sequence of mathematical calculations to test how the results change with different assumptions about the life of the capital, the interest rate, population, and household size.

It is useful for students to do this calculation for both a small rural community and for a large city in order to appreciate the effect of economies of scale in the costs of capital investments on costs per household per month.

5.3 Policy Memo Format Assignments

We wanted students to learn to write in a style and professional format actually used in the WASH sector. We thus require students to write their course assignments as short (3- to 5-page) "policy memos" (for an example assignment see Annex 2, an example final exam using policy memos is shown in Annex 3). Assignment instructions were written as real-world tasks that also introduced the idea to students that WASH problems are often "wicked." There may or may not be sufficient existing evidence, and there may be no obvious policy prescription to offer. Writing in this format helps student learn not only how to mobilize evidence relevant to policy and practitioner needs, and to provide well-argued recommendations, but also to have an acute sense of caveats and limitations of available evidence.

We found that writing policy memos was new to most of our students. For our Manchester students, we therefore issued two assignments for each class. The first was a formative piece, with feedback given but no mark was assessed. The second assignment was summative, and was issued only after each student had received feedback on their formative work. This gave students one opportunity to "get it wrong" and to learn, opening up critical thinking and flexibility. This seemed especially useful for individuals new to the policy memo format and to writing about complex and challenging policy topics. Examples of assignment topics we set are presented in Table 7. We also wrote into our assignment briefs clear guidance about what role we wished students to adopt and the expected tasks. We told students that we would adopt a simulated professional role during the assignment period (indicating to students that if this were a real professional assignment, their supervisor issuing it would probably not want to respond to multiple requests for guidance). We also provided students with both written and video guidance on how to write a policy memo.[8]

Over the years of running the course, we built up a knowledge base of how students had attempted each assignment. This allowed us as instructors to learn what students found challenging about the assignments, which concepts from the course could be most effectively mobilized when attempting the assignments, and how best to help students write in a policy memo format. We provide students with not only feedback on their individual assignment, but also feedback on how the class had performed with the assignment overall that year and in previous years.

For several years, we invited actual WASH sector professionals to provide part of the formative feedback to students. Selected students would present their policy memos in class and argue for their proposed solutions. The WASH professional then evaluated the student's work, drawing upon their own professional experience. We found students really enjoyed and valued this close-to-practice approach, and we believe it provided students with realistic preparation for working in WASH sector.

6 Reflections on Teaching with MOOCs

Finally we offer short reflections on teaching this course online on Coursera as two MOOCs. During 2010 to 2018, teaching across U.S. and UK classrooms, we reached around 300 students. By contrast for the six years the material has been online to date, around 42,500 students have enrolled with a 7.5-percent average completion rate, meaning around 3,200 students have finished these MOOCs.[9]

[8] https://www.youtube.com/watch?v=_Y1Kuq5NK_8.

[9] A highlight of running the MOOCs was that diverse learners from multiple countries enrolled. For the 2013 to 2014 run, students from 191 countries took part, with 42 percent from emerging economies and 40 percent female. Advertising the course via WASH sector networks and mailing lists, and having Global Water Partnership endorsement helped this uptake, and to reach emerging economies and learners outside major cities. From 2017 until late 2022, the courses still have 40 percent female students, ranging from 18 to 65+ years old. More than half the MOOC learners are from India, and 20 percent are from Africa, contrasting with Coursera typically having most learners from the United States and 5 percent from Africa. Around 57 percent of MOOC students are not currently in education, with 45 percent employed full-time and 40 percent already having a Masters degree. This suggests we reached educated professionals, perhaps some re-training while already in WASH-related roles.

Table 7: Examples of Policy Memo Assignments

Assignment Topic	Role Adopted by Student	Associated Learning Outcomes
Performance indicators to evaluate UNICEF's rural water supply and sanitation programs in Africa	Policy analyst in the office of the Chief of Water, Sanitation and Hygiene at UNICEF, leading an ex-post evaluation using at most four indicators.	Students think of simple indicators that work without baseline data and within a modest cost evaluation.
Reforming water tariffs in Egypt	Policy analyst advising Egyptian government on whether reforms are needed to current water tariff arrangements.	Students explore information treatments to convey to customers and policy makers whether current tariff structures need to be changed.
A sanitation policy for India	Policy analyst for a World Bank Water and Sanitation Program field office, proposing policy instruments to achieve the "Clean India" campaign.	Students assess previous experiences in India and other countries, and think about how different policy instruments interact in a given context.
Monitoring global WASH affordability	Policy analysts taking a fresh look at how the UNICEF/WHO Joint Monitoring Program monitors global WASH affordability.	Students critically reflect on costs of providing WASH in a context of climate change, and rising standards found in the Sustainable Development Goals (SDGs).
Re-nationalizing the England and Wales water industry	Policy analyst for the UK Regulatory Policy Institute reporting on possible benefits and costs of water sector re-nationalization to an All Party Parliamentary Water Group session.	Students assess evidence about the effects of ownership on economic and environmental performance of water utilities.
	Parliamentary Water Group session.	

While the throughput from enrollment to completion is obviously lower than for a classroom setting, the MOOCs enabled us to reach an order of magnitude of more students. The MOOC format forced us to improve our class materials. Visuals needed to be clearer, and insights need to be presented in concise, easy-to-follow ways. We were also able to re-use the produced video materials in the classroom, and for students to watch before or after classes.[10]

Downsides are that the design of Coursera, like most MOOC platforms, limits control over the learning conditions of students. Greater numbers of learners also means significantly reduced contact with them compared to a classroom, on-campus course. For the first run of part one in 2014, it was a one-off course, and we had a team of 12 people (including ourselves), with five part-time teaching

[10] We were also able to meet other course instructors at two Coursera conferences in 2015 and 2016, to share ideas about re-using MOOC materials in the classroom.

assistants. These teaching assistants were former students from the Manchester classroom version of the course. The classroom experience enabled the teaching assistant to engage productively with students via message boards and forums inside Coursera. We also had some direct interaction with MOOC learners through email contacts. For the MOOC runs since 2017, these were opened for separate enrollment each week, and similar resources were not available to support them. We did not have teaching assistants, material could not be updated or revised, and we have had far less hands-on involvement over time.[11]

Similarly, producing the two MOOCs turned out to be much more work than we expected, involving a significantly expanded workflow compared to a typical classroom course. We also did not have the resources to update our MOOCs with newly recorded materials. Running MOOCs with consistently high levels of interactions with students would also cost more. We have no regrets about the work involved in producing these MOOCs, but instructors contemplating launching a MOOC should go in with "eyes wide open."

7 Concluding Remarks

While running this course across a U.S./UK classroom and as MOOCs with a global reach, we tried to teach water economics and policy in ways that exemplified and embedded attitudes and working practices we wished students to take forward into their potential future careers in the WASH sector. We have also been able to distill eleven key messages that are present across the course materials, which we believe are relevant and useful for students to engage with. We aimed to teach water economics and policy in ways that encouraged active class participation with materials and exercises that were informed by practice. We also brought in WASH practitioners to take part in formative assessment of student assignments, to increase the quality and relevance of feedback they received, and to afford students insights into the future challenges of working in this sector.

Through the cases, videos, recorded lectures, debates, class cost calculations, policy memo assignments, and guest lecturers, we tried to stress the importance of not learning in the abstract, but through studying successes and failures of policy interventions around the world. We highly recommend considering these aspects when designing and running courses of this kind in the future. From the evidence of our classroom course, MOOC appraisals, and indications that the MOOCs were reaching working professionals, we believe these elements were also well received by learners. However, it should be noted that developing courses in this way involves mobilizing contributions from a diverse range of people and countries, and materials that may lie outside the scope of traditional university department organizations. It also requires cultivating over the years guest participants who become familiar with learning aims and intended outcomes of such a course.

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[11] Considering how to resource MOOCs long-term is therefore an important consideration. This includes planning what happens if instructors, as we both did, later change university positions. Our strategy here was to also upload our course materials to YouTube so they remain free to access. Part one is available here: https://www.youtube.com/playlist?list=PLO0Q0P_Y4YulwSmXupshcwVR798iNvdJ1; part two is here: https://www.youtube.com/playlist?list=PLO0Q0P_Y4Yunpl0i551N5zPQGgyX0BdQl. Some MOOC platforms, and university faculties, might not allow this, depending on their strategies (Thomas and Nedeva 2018).

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Annex 1: Course Syllabus

The following is an overview of the 2022/2023 academic year syllabus for the Chapel Hill in-person class (a full syllabus is available upon request from the corresponding author). The course uses a two-part policy model, where in Sessions 1 to 6, typically taught over six weeks, students are introduced to key status quo conditions for water and sanitation access and provision in low- to middle-income countries. Sessions 7 to 14, taught over the following eight weeks, next invite students to critically reflect on a series of cases of actual policy interventions, using the understanding they have developed in the first part of the course.

Part 1: Understanding Status Quo Conditions

Session 1 – Introduction, Conceptual Framework, Ancient Instincts

- Introduction, Course Organization
- Student WASH experiences
- Conceptual Framework Discussion of course requirements
- Key Messages

Session 2 – Infrastructure Coverage, Dynamic Baseline, Climate Change

- Class discussion—questions about videos (MOOC materials watched outside class)
- Lecture: Forecasts of coverage, WASH SGDs: discussion of new targets and affordability
- Student-led discussion of two papers on economics of water affordability, with cases on Bangladesh and the United States

Session 3 – Water Vending, Corruption

- Class discussion—questions about videos
- Lecturer-led discussion of paper on the structure of water vending markets in Kathmandu, Nepal
- Class Debate No. 1 (USAID Aid to Haiti – Proposition: USAID should not invest in water and sanitation projects in Haiti at this time)

Session 4 – Understanding the Supply Side, Costs, and Technologies

- Class discussion—questions about videos (MOOC materials watched outside class)
- Lecturer-led discussion of paper who pays for water, based on life-cycle costs of water services among low-, medium-, and high-income utilities; also discussion of costs of water and sanitation services embedded in housing
- Discussion on condominial sewers

Session 5 – Understanding Demand for Improved Water and Sanitation Services

- Class discussion—questions about videos (MOOC materials watched outside class)
- Student-led discussion of paper on piped water adoption in urban Morocco
- Assignment No. 1 due: Student presentations of their assignments

Session 6 – Water Development Paths

- Class discussion—questions about videos (MOOC materials watched outside class)
- Student-led discussion of a paper on a multilevel perspective transition from cesspools to sewer systems (1840–1930) in the Netherlands
- Teaching Case No. 1 (Orangi pilot project)

Part 2: Policy Interventions

Session 7 – Planning Protocols, Sustainability of Rural Water Supply Projects

- Class discussion—questions about videos (MOOC materials watched outside class)
- Discussion of papers on evaluating waterpoint sustainability and revenue collection in rural Kenya, on handpump sustainability in Ghana, and demand-driven community managed rural water supply systems in Bolivia, Peru, and Ghana

Session 8 – Information Treatments

- Class discussion—questions about videos (MOOC materials watched outside class)
- Discussion of community-led total sanitation
- Class Debate No. 2 (The Human Right to Water – Proposition: The United Nations Declaration establishing a human right to water and sanitation is a big step forward and will result in many more poor households receiving improved WASH services in the future.)

Session 9 – Water Pricing and Tariff Design

- Class discussion—questions about videos (MOOC materials watched outside class)
- Discussion of papers on water and sanitation service delivery, pricing, and the poor in Nairobi, Kenya, and on the development path of water and sanitation tariffs and subsidies in China

Session 10 – Designing Subsidy Schemes to Reach the Poor

- Class discussion—questions about videos (MOOC materials watched outside class)
- Questions about a paper on choosing among pro-poor policy options in water supply and sanitation
- Student-led discussions of a paper on, and on water subsidy policies in Chile and Colombia, and on distributional impacts of water subsidy policy in Chile from 1998 to 2015

Session 11 – Changing Institutions: Privatization

- Class discussion—questions about videos (MOOC materials watched outside class)
- Assignment No. 2 due: Student presentations of their assignments
- Teaching Case No. 2 (Manila Privatization)

Session 12 – UK Privatization: the Regulation of Water Utilities

- Class discussion—questions about videos (MOOC materials watched outside class)
- Student-led discussion of a paper on the impact of the privatization of water services on child mortality

- Class debate No. 3 (Return to Public Ownership – Proposition: The private water utilities in England and Wales should be returned to public ownership.)

Session 13 – Case Study: Phnom Penh Water Supply Authority

- Class discussion—questions about videos (MOOC materials watched outside class)
- Teaching Case No. 3 (Ek Son Chan and the Transformation of the Phnom Penh Water Supply Authority)

Session 14 – Wrapping Up, Student Presentations of Assignment No. 3

- Class discussion—questions about videos (MOOC materials watched outside class)
- Assignment No. 3 due: Student presentations of their assignment
- Preparation for final assignment/exam

Annex 2: Example Policy Memo Assignment: Propose Four Performance Indicators to Evaluate UNICEF's Water Supply and Sanitation Programs in Africa

What role do you want me to adopt?

We want you to imagine that you are working as a policy analyst in the Office of the Chief of Water, Sanitation, and Hygiene at UNICEF.

What type of task do you want me to undertake?

The Chief wants you, in your role as policy analyst, to lead an upcoming ex-post (after the fact) evaluation of UNICEF's water supply and sanitation programs in Africa. She informs you that the forthcoming evaluation should use at most four performance indicators (criteria). She also explains that you should not assume that you have access to any reliable, accurate baseline data from households or communities before UNICEF started working in the African countries concerned.

What does my specific task involve?

Before the evaluation is done, the Chief wants you to write a four-page "policy memo" that you will submit to her. In your policy memo, you should propose the four performance indicators that you intend to use. Before you depart, the Chief wants to discuss with you the four performance indicators that you propose in your policy memo. The Chief wants you to be sure that your four proposed performance indicators (criteria) are both practical and measurable. She also explains that you need not be overly concerned with the resources required actually to conduct the upcoming evaluation. At the same time, the Chief is clear that the cost of the evaluation should be reasonable, and certainly the evaluation should not cost more than 5–10 percent of the total program cost. She emphasizes to you that this is not a research effort. This means it should be feasible to measure your four proposed performance indicators without needing teams of research scientists with PhDs.

What else should I consider?

Your four performance indicators should consider the fact that UNICEF water, sanitation, and hygiene programs are implemented in partnership with government departments, which UNICEF seeks to strengthen. Ideally your proposed performance indicators should be applicable to different levels of rural water and sanitation services (by which we mean public taps, hand-pumps, protected springs, yard taps, and connections inside the home for the exclusive use of household members, and improved pit latrines). If you believe that this is not practicable, then you should make this argument in your memo, and explain how the performance indicators you propose would change for different levels of service.

Please make sure to identify clearly each of your four performance indicators (criteria) and specify how you plan to measure them. Bear in mind that your suggestions will aid in the design of an evaluation effort to compile quantitative measures for comparisons across programs.

Annex 3: Example Final Exam

Instructions

Your task in this exam is to select one of the four "clusters" of questions below and have a short dialogue with ChatGPT ("Chat") about these questions. You are not limited to the specific questions listed in an option below that you choose. You can ask a follow-up question depending on ChatGPT's answer to your previous question, but you should not initiate more than 5 queries or requests. You can use any version of ChatGPT that you wish. You should then write a policy memo (maximum 2000 words) that critiques the answers you have received from ChatGPT. If for some reason you are unable to access ChatGPT, you should explain the circumstances that prevented you from accessing ChatGPT, and then simply answer the questions in one of the four options below.

Your critique should be based on your study of the materials in this course (readings, lectures, teaching cases, guest lecturers, assignments, etc.). Your policy memo should explain what you agree with, what you disagree with, and the reasons for your answers. You can also conceptualize your policy memo as a way to tell your supervisor "what ChatGPT should have said" i.e., what would have been a better ChatGPT answer given your own knowledge of water and sanitation problems in developing countries.

This exam is an "open-book", take-home exam. You can work anywhere you like and use any written sources you like, including course notes, case studies, publications, the internet, etc. However, no help may be received or given from other students (or anyone else) on this exam.
No questions will be entertained during the exam, nor will any clarification of the instructions or questions be offered. If you feel the instructions or any of the questions are ambiguous or unclear, please state how you choose to interpret the question and answer the question as best you can.

Select one and only one of the following four question clusters for your chat with ChatGPT:

Option 1: Household Water Use Behavior

- Write a 10,000-word essay on the main determinants of the quantity of water that household uses.
- How does the technology a household uses the affect the quantity of water a household uses?
- How do emotions affect household water use?

Option 2: Systematic racism and colonialism

- Is systematic racism a major reason that poor households in developing countries have poor water and sanitation infrastructure?
- Is colonialism a major reason that poor households in developing countries have poor water and sanitation infrastructure?
- Are system racism and colonialism the most important reasons that poor households in developing countries have poor water and sanitation infrastructure?
- What is the best approach to reducing system racism and colonialism in the WASH sector?

Option 3: Privatization

- Is privatizing a public water utility a good way to improve water and sanitation services?
- Can a water privatization help poor households obtain better water and sanitation services?
- What are the main problems that result from privatizing a public water utility?

Option 4: Water Tariff Design

- Is an increasing block tariff a good way to price residential water supplies?
- Are there any situations where an increasing block tariff might be inappropriate?
- Is an increasing block tariff a good way to charge businesses and industrial water users?

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