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EDITED BY
Carlos Saito,
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Federal University of Rio Grande do Sul, Brazil

*CORRESPONDENCE
Tom Marcinkowski
✉ marcinko@fit.edu

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Education about, in, and for wetlands: practices, premises, possibilities, and challenges

Tom Marcinkowski*

STEM Education Programs, Department of Mathematics and Systems Engineering, Florida Institute of Technology, Melbourne, FL, United States

The purpose of this paper is to review areas of educational theory, research, and practice relevant to wetlands education, notably education about, in, and for wetlands. Five key areas are reviewed: (a) from the *Report of the Intergovernmental Conference on Environmental Education*, goals and objectives for wetlands education; (b) from the literature, major curricular and instructional approaches in and elements of wetlands education; (c) from the literature, broad instructional strategies available to and commonly used in wetlands education; (d) from websites of federal agencies in the U.S., education, outreach, and training programs that focus on education about, in, and for inland and coastal wetlands; and (e) from print and electronic sources, a sample of curricular and instructional materials that pertain to education about, in, and for inland and coastal wetlands. Each area is summarized in the form of a list or table. The paper concludes with a series of challenges which hold implications for education policy makers, program developers and providers, instructional staff, assessment and evaluation specialists, scientists, and others who collaborate on and work to advance wetlands education at the local, national, regional, and global levels.

KEYWORDS

wetlands, wetlands education, environmental education, marine education, curricular and instructional approaches, educational programs, education materials, educational research

1 Introduction

Wetlands is now a vast topic, having received increasing attention since the 1950s. Education is an equally vast topic, although it extends further back in time. At least within the U.S., linkages between wetlands and education extend back to at least the early 1900s. Given the breadth and depth of work in and relevant to wetlands education (e.g., Otte and Fang, 2014; Park et al., 2020; Roy et al., 2015; Wildfowl and Wetlands Trust [WWT], n.d.), it is both fair and appropriate to begin this paper by clarifying that the purpose of this paper is not to prepare a scholarly historical review of wetlands, education, or even wetlands education. For any number of reasons, each of those would be far beyond the scope of this paper.

Nonetheless, this paper falls squarely within the area of overlap at the center of this Venn diagram: wetlands education (Figure 1). As reflected in this figure, this paper places wetlands education under the wider umbrella of sustainability goals, with wetlands, education, and wetlands education each having vital points of intersection with science, policy, economics, and society. As will become apparent, substantial attention is given to theory, research, and practice in wetlands education, both directly as well as through the application of work in related fields, as is so often the case in education. Thus, as reflected in the title, the purpose of this paper is to explore aspects of theory, research, and practice relevant to education about, in, and for wetlands, with particular attention to the latter.

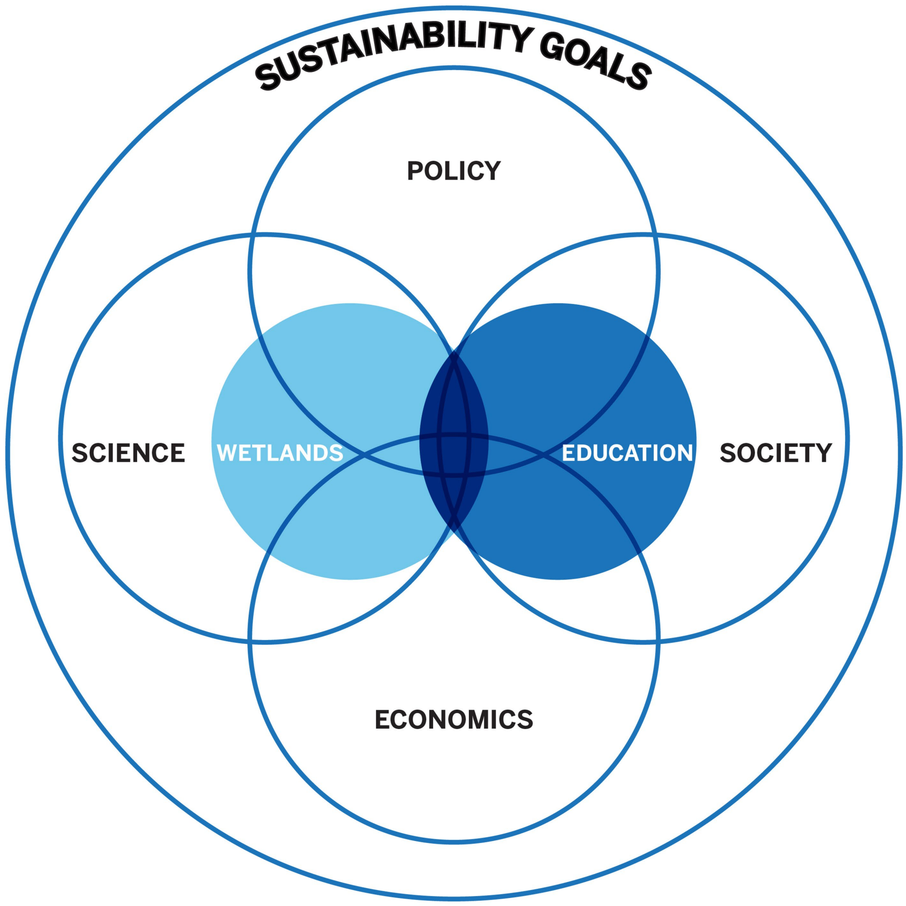

FIGURE 1
Venn diagram reflecting the primary fields of study relevant to this paper.

To provide some framing for the aspects of wetlands education to be addressed in this paper, some background must be provided on wetlands and on education. Although the former will receive substantial attention in the other papers in this collection, some attention will be given to wetland topics relevant to this paper in the *first section*, as wetlands serve as the impetus for, setting of, and subject matter featured in educational programs. Some attention will be given to education topics relevant to this paper in the *second section*. At least within the U.S., wetlands education has evolved within and been influenced by Environmental Education (EE) (e.g., Tabiraki and Allen, 2021), but also by Science Education, Aquatic Education, Marine Education, and Education for Sustainable Development. Although each will receive some attention in this paper, the *third section* of this paper situates wetlands education within the field of EE, including the historical roots of EE, which date back to the 1890s. The historical, definitional, aspirational, and programmatic contexts of EE, both unto themselves and as each relates to wetlands education, are highly relevant to this paper because this is where the phrase "education about, in, and for" was expanded and popularized.

After this background, the focus shifts to selected practices in EE and in wetlands education as these can and do address education about, in, and for wetlands. The *first subsection* summarizes major curricular and instructional approaches available for use in wetlands education. The *second subsection* briefly reviews four areas of pedagogy and practice which underly and support this: place-based education (or learning), problem-based learning, and project-based learning, and skill-based learning. The *third and fourth* subsections presents a review of a sample of educational programs and of educational materials which reflect those curricular and instructional approaches, all of which focus on aspects of wetlands education.

The Discussion section reviews several limitations inherent in and questions raised in this paper, as well as six common challenges facing wetlands education and wetlands educators that follow from points made in various sections and subsections of this paper.

I would like recognize and affirm the work of hundreds of colleagues whose ideas and work are reflected in this paper, and by inviting educators and others who may read this paper to explore, adapt, implement, and extend this work in support of education about, in, and for wetlands, as the need for this extends into our common future.

2 Wetlands as the impetus for, setting of, and subject matter of wetlands education

2.1 Terminology and perceptions

It seems proper to open this section with a quote which attempted to place human perceptions of wetlands in an historical perspective:

> The term "wetland" was not commonly used in the American vernacular until quite recently. It appears to have been adopted as a

> euphemistic substitute for the term "swamp" (Wright, 1907). Nineteenth-century scientists used terms such as mire, bog, and fen to describe the lands that are now called wetlands, and these terms are still used by scientists to describe specific kinds of wetland (Mitsch and Gosselink, 1986; Dennison and Berry, 1993). The term wetland has come gradually into common scientific usage only in the second half of the twentieth century (Committee on Characterization of Wetlands, National Research Council, 1995, p. 43).

Although this reflects an American perspective, it also reflects a scientific perspective which may transcend geographic and national boundaries. These and other authors suggest that prior to the emergence of the ecosystem concept in ecology (ca. 1930s), human perceptions of wetlands tended to be limited in depth and across societies, often shaped by human-centered experiences and concerns such as migration and settlement, insect and disease control, and agriculture (e.g., Marsh, 1864). Interested readers may wish to explore the extent to which this historical perspective and these perceptions are applicable to other regions and societies.

2.2 Definitions and definitional characteristics

From a more contemporary perspective, there now exist numerous definitions of wetlands (e.g., Tiner, 1997, Table 2):

> "Wetland" is a generic term for all the different kinds of wet habitats—implying that it is land that is wet for some period of time, but not necessarily permanently wet. Wetlands. have numerous definitions and classifications in the United States as a result of their diversity, the need for their inventory, and the regulation of their uses … Before the beginning of wetland-protection laws in the 1960's, wetlands were broadly defined by *scientists* working in specialized fields (Lefor and Kennard, 1977; cited in Tiner, 1997).

One of the simplest definitions is contained in the opening sentence in this quote. Essential to that is the phrase "period of time," which implies that *hydroperiod*, the relative length of time in which an area of land is covered by water, is an important characteristic of wetlands. As pointed out by the Ramsar Convention and others, a second important characteristic of some wetlands is the level of *salinity* of that water, which may range from fresh to brackish to saltwater. From an ecological perspective, some wetlands are characterized as transitional zones between inland freshwater, coastal estuarine, and marine ecosystems.

As noted by the U.S. Fish and Wildlife Service (FWS), two additional characteristics of wetlands include the *soil or rock (substrate)* in inundated lands, and the types of *vegetation* commonly found there:

> The FWS developed a nonregulatory, technical definition … [which] emphasizes three important attributes of wetlands: (1) hydrology—the degree of flooding or soil saturation; (2) vegetation—plants adapted to grow in water or in a soil or substrate that is occasionally oxygen deficient due to saturation (hydrophytes); and (3) soils—those saturated long enough during the growing season to produce oxygen-deficient conditions in the upper part of the soil, which commonly includes the major part of the root zone of plants (hydric soils) (Cowardin et al., 1979; Tiner, 1991). (Tiner, 1997).

The Committee on Characterization of Wetlands, National Research Council (1995) included the attributes identified by the FWS in their definition:

> A wetland is an ecosystem that depends on constant or recurrent *shallow inundation or saturation at or near the surface of the substrate*. The minimum essential characteristics of a wetland are recurrent, sustained inundation or saturation at or near the surface and the presence of physical, chemical, and biological features reflective of the recurrent, sustained inundation or saturation. Common diagnostic features of wetlands are *hydric soils* and *hydrophytic vegetation*. These features will be present except where specific physicochemical, biotic, or anthropogenic factors have removed them or prevented their development (p. 59; *emphasis added*).

Regardless of the date, source, purpose, and level of specificity of any definition of wetlands, there appears to be widespread agreement that these are among the most prominent defining characteristics of wetlands.

2.3 Classification of wetlands

The presence of multiple defining characteristics implies that there are many types of wetlands, which in turn implies that there are different ways to classify them. Like definitions, classification schemes for wetlands vary by date, source, purpose, and level of specificity. For example, the U.S. Environmental Protection Agency (U.S. EPA) presented this as a basic classification scheme: "Two general categories of wetlands are recognized: coastal or tidal wetlands and inland or non-tidal wetlands" (U.S. Environmental Protection Agency [U.S. EPA], n.d.-b).

Although not intended as a classification scheme per se, Tiner (1997) used features of landscapes in which inland wetlands occur to identify different types of wetlands. Wetlands typically occur in *topographic settings* where surface water collects and (or) ground water discharges, making the area wet for extended periods of time. Examples of some of these topographic settings, and some common names for wetland types associated with them are:

- *Depressions* (swales, sloughs, prairie potholes, Carolina bays, playas, vernal pools, oxbows, and glacial kettles)
- Relatively *flat depositional areas* that are subject to flooding (intertidal flats and marshes, coastal lowlands, sheltered embayments, shorelines, deltas, and flood plains)
- *Broad, flat areas that lack drainage outlets* (interstream divides and permafrost muskegs)
- *Sloping terrain* associated with springs, seeps, and drainageways; and relatively flat or sloping areas adjacent to bogs and subject to expansion by accumulation of peat.

One of the more comprehensive and detailed classification schemes was developed by the U.S. Fish and Wildlife Service (FWS; Cowardin et al., 1979). This multi-level classification scheme begins with *Systems* (1st level), shifts to the *Subsystems* or *Classes* within each (2nd level), divides those into *Subclasses* based on the substrate or dominant vegetation (3rd level), and divides these into *Dominance Types* based on specific dominant plants and animals in each (4th level). To illustrate the breadth of this scheme, here are the five types of Systems within it:

- *Marine*—open ocean and its associated coastline;
- *Estuarine*—tidal waters of coastal rivers and embayments, salty tidal marshes, mangrove swamps, and tidal flats;
- *Riverine*—rivers and streams;
- *Lacustrine*—lakes, reservoirs, and large ponds; and
- *Palustrine*—marshes, wet meadows, fens, playas, potholes, pocosins, bogs, swamps, and small shallow ponds (Cowardin et al., 1979, pp. 12-18).

Tiner (1997) commented on the significance of the FWS scheme within the U.S. as follows:

> The FWS wetland classification system places ecologically similar habitats into a hierarchal system that permits wetland classification down to dominance types … the system can be used to identify units for inventory and mapping for Federal and State wetland inventories. It also has provided a uniformity of wetland terminology. The FWS uses this classification to determine wetland status and trends—information useful to resource managers and planners at all levels of government.

It is noteworthy that that one widely available EE material, *WOW: The Wonders of Wetlands* (Environmental Concern, Inc. and Project WET International Foundation, 2003), reflects features of the FWS scheme by including lessons/activities in which learners: (a) use characteristics to classify 13 different types of wetlands in the FWS scheme (*Wetland Habitats*), and (b) identify common or dominant plants found in them (e.g., *The Plan Key is All Wet*; *Wetland Wheel*).

2.4 Geographic extent and distribution of wetlands

There are several ways to characterize the geographic distribution and spatial extent of wetlands. From a planetary and marine science perspective, Earth is a water planet. Water covers approximately 71% of the Earth's surface. Of this, about 97% of the water on the planet is found in the ocean(s). Any look at a globe or map of the Earth points out the obvious: coastal wetlands (U.S. Environmental Protection Agency [U.S. EPA], n.d.-b), which include two types found in the FWS Systems, Marine and Estuarine wetlands (Cowardin et al., 1979), are found along the coastlines of nearly all landmasses on the planet.

From a geologic and hydrologic perspective, only about 3% of water on planet Earth is found in the form of fresh water. Until recently, about 80% of this was found in polar ice caps and glaciers (i.e., about 2.4% of that 3%), although this has been declining due to climate change. This means that although waters found in inland wetlands seem plentiful, collectively this represents less than 1% of the water on Earth. Through the hydrologic cycle, precipitation falls on landmasses exhibiting diverse geological and topographical features. As indicated by the list presented by Tiner (1997), precipitation accumulates on or runs off of these landmasses in patterns which form various types of inland wetlands (U.S. Environmental Protection Agency [U.S. EPA], n.d.-b), notably three types found in the FWS Systems of wetlands: Riverine, Lacustrine, and Palustrine wetlands (Cowardin et al., 1979). Using a slightly broader geographic frame of reference, all of these inland wetlands are found in and are part of *watersheds* which, in turn, are part of larger *drainage basins*. It is noteworthy that watershed studies have been part of EE and related fields since the early 1970s.

From the perspective of climate zones, "Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation and other factors, including human disturbance. Indeed, *wetlands are found from the tundra to the tropics and on every continent except Antarctica*" (U.S. Environmental Protection Agency [U.S. EPA], n.d.-b; *emphasis added*). Despite the relatively small percentage of water available to and found in inland wetlands, wetlands are found on all but one continent and in all climate zones.

From a spatial perspective, in their *Global Wetland Outlook*, the Ramsar Convention on Wetlands of International Importance (2018) offered an estimate of the spatial extent of wetlands: "Accuracy of global wetland area data is increasing. Global inland and coastal wetlands cover over 12.1 million km^2, an area almost as large as Greenland, with 54% permanently inundated and 46% seasonally inundated" (p. 4). Among the largest of these wetlands are: "The West Siberian Lowland, Amazon River Basin, and Hudson Bay Lowland … The world's largest protected wetland is Llanos de Moxos, located in Bolivia. It is more than 17 million acres—roughly equal in size to North Dakota" (World Wildlife Fund, n.d.). Other sources list the Pantanal in Brazil, Bolivia, and Paraguay (140,000–220,000 km^2), the Rio Negro in Brazil, a Ramsar site on the north side of the Amazon Basin (120,000 km^2), and the Ngiri-Tumba-Maindombe in the Democratic Republic of the Congo, a wetland around Lake Tumba (66,000 km^2) as three of the largest wetlands on the planet.

2.5 Disturbance and loss of wetlands

Estimates of the loss of wetlands over the past several hundred years, on both national and global scales, have raised serious concerns. In a report entitled *Threats to Wetlands*, the U.S. Environmental Protection Agency [U.S. EPA] (2001) indicated the following:

> More than 220 million acres of wetlands are thought to have existed in the lower 48 states in the 1600s. Since then, extensive losses have occurred, and more than half of the original wetlands have been drained and converted to other uses. The mid-1950s to the mid-1970s were a time of major national wetland loss. Since then the rate of loss has slowed (p. 1).

Unfortunately, this trend has not been limited to the U.S., and appears to be applicable to both inland and coastal wetlands, as suggested in the following estimates of wetland loss:

> As much as 87% of the world's wetlands has been lost over the past 300 years, with much of this loss happening after 1900, despite their value to the human population (World Wildlife Fund, n.d.).

> Scientific estimates show that 64% of the world's wetlands have disappeared since 1900. In some regions, notably Asia, the loss is even higher. Inland wetlands are disappearing at a faster pace than coastal ones but the overall trend is clear (Ramsar Convention on Wetlands, n.d.-f).

> Wetlands, amongst the world's most economically valuable ecosystems and essential regulators of the global climate, are disappearing three times faster than forests (U.N. Framework Convention on Climate Change [UNFCCC], n.d.).

> [T]he world lost 13,700 square kilometers (approximately 5,290 square miles) of tidal wetlands between 1999 and 2019, Science reported. At the same time, however, we gained 9,700 square kilometers (approximately 3,745 square miles) … The "net change" of tidal wetlands (−4,000 km^2) is overwhelmingly still in the negative (EcoWatch, 2022).

Prior to the 1970s, much of the loss of wetlands occurred without scientific monitoring or study. Thus, from a scientific perspective, it has been difficult to pinpoint the cause(s) of such losses (e.g., Morton, 2003). Nonetheless, numerous sources have identified the kinds of disturbances which have contributed to the loss of inland and coastal wetlands over time (e.g., Marsh, 1864). According to technical reviews (e.g., Adamus et al., 2001; Office of Research and Development, 2018), major or dominant disturbances have included, but are not limited to:

- Nutrient enrichment and eutrophication;
- Organic loading and reduced dissolved oxygen;
- Contamination by toxins;
- Acidification;
- Salinization;
- Sedimentation;
- Reduced sunlight availability (e.g., PAR) or penetration (e.g., turbidity);
- Vegetation removal;
- Thermal alteration;
- Major reductions in precipitation and surface flow, including aridification;
- Major increases in precipitation and surface flow, including flooding and inundation;
- Landscape and habitat alteration, including fragmentation and conversion.

Many of these types of disturbance are anthropogenic in nature, and can be traced back to broader demographic patterns in human migration, settlement, development, and land use.

2.6 The importance of wetlands

The rate of loss of inland and coastal wetlands is cause for concern. However, when the contributions of wetlands to life on the planet are analyzed more carefully, this rate of loss become more tangible and significant. Numerous sources have described the wide range of benefits of wetlands, often under the heading of *ecosystem services* (e.g., Barbier, 2019; Park et al., 2020; U.S. Environmental Protection Agency [U.S. EPA], n.d.-a), including national agencies (e.g., U.S. EPA, FWS, Geological Survey [USGS], National Park Service [NPS], and National Oceanic and Atmospheric Administration [NOAA]); and non-governmental organizations (e.g., the Ramsar Convention on Wetlands of International Importance [Ramsar], Conservation International, The Nature Conservancy, the European Wilderness Society, and Ducks Unlimited). The Ramsar Convention on Wetlands (n.d.-d) offered this overview:

> Wetlands are vital for human survival. They are among the world's most productive environments; cradles of biological diversity that provide the water and productivity upon which countless species of plants and animals depend for survival. Wetlands are indispensable for the countless benefits or "ecosystem services" that they provide humanity, ranging from freshwater supply, food and building materials, and biodiversity, to flood control, groundwater recharge, and climate change mitigation.

These and other sources often describe ecological benefits of wetlands (e.g., their role in biogeochemical cycles, as habitats for juvenile and adult species, and in regional ecosystems in which these occur). For example, the World Wildlife Fund (n.d.) offered the following regarding the ecological significance of inland wetlands:

> Freshwater habitats, like lakes, rivers, streams, and wetlands, house more than 10% of all known animal species and about 50% of all known fish species, despite covering less than 1% of the earth's surface.

The International Union for the Conservation of Nature and Natural Resources (IUCN) was created in 1948 as a membership union composed of both governmental and non-governmental organizations. It may be best known for its global monitoring of species. Its *Red List of Threatened Species*, now numbering more than 44,000, includes more than 39,500 species found in inland wetlands and 2,700 species found in coastal wetlands (International Union for the Conservation of Nature and Natural Resources [IUCN], n.d.-c). In addition, IUCN also monitors ecosystems, which serve as habitats for wetland species.

> Freshwater ecosystems and species are a key feature of nature in Asia. Asia hosts some of the world's greatest rivers; the Salween river is the seventh longest free-flowing river in the world; and the Meghna is one of the last remaining, long, free-flowing rivers globally … The Mekong basin is the third most biodiverse river basin in the world. Freshwater ecosystems in Asia host a large number of globally important species (International Union for the Conservation of Nature and Natural Resources [IUCN], n.d.-d).

National Oceanic and Atmospheric Administration [NOAA] (n.d.-b) offered the following to illustrate the ecological, as well as human (or socio-ecological), significance of coastal wetlands:

> Many kinds of fish—from salmon to striped bass, as well as lobster, shrimp, oysters and crabs—depend on coastal wetlands for places to live, feed, or reproduce. Coastal wetlands are some of the most productive ecosystems on Earth. They are crucial for healthy estuaries, which generate approximately half of commercially harvested seafood in the United States.

The ecological importance of coastal and inland wetlands has led them to be featured prominently in the 36 *biodiversity hotspots* identified by the Critical Ecosystem Partnership Fund (n.d.), and its partners, which include Conservation International (n.d.), and recognized by others (e.g., the World Economic Forum, 2023).

From a more human-centered perspective on the importance of wetlands, World Wildlife Fund (n.d.) also offered the following:

> Between 300 million and 400 million people live close to and depend on wetlands. They support the cultivation of rice, a staple in the diet of half the world's population. They also provide flood control, clean water, shoreline and storm protection, materials, medicines, and vital habitat.

Descriptions of additional benefits of wetlands to humans often include: water storage and supply (e.g., Baker, 1960), water purification (e.g., Carter, 1996), wastewater treatment (e.g., Verhoeven and Meuleman, 1999), groundwater recharge (Ramsar Convention on Wetlands, n.d.-b), and recreation and education (U.S. National Park Service [NPS], n.d.).

Finally, any discussion of the importance of wetlands would be incomplete without noting the relationships between wetlands and climate change. These include the relationship of wetlands to storm protection, sea level rise, and carbon capture. Wetlands are increasingly vulnerable to the effects of sea level rise and therefore to climate change.

> Sea level rise is the result of two primary biophysical factors. First, as the oceans absorb excess CO2 from the atmosphere, it causes ocean temperatures to rise which expands the volume of water in the ocean. Second, as average global temperatures increase, arctic glaciers and ice caps melt, adding additional volume to ocean water levels. As a result, and in combination with other drivers of change … coastal wetlands have been lost at an alarming rate. In fact, between the years 2004 to 2009, the rate of loss was 25% greater than from the previous reporting period of 1998–2004. Annually that adds up to 80,160 acres of coastal wetlands being lost each year ([U.S.] National Association of Wetland Managers, n.d.).

However, wetlands have been found to play a vital role in carbon capture (e.g., Were et al., 2019).

> Wetlands can capture large quantities of carbon dioxide and other greenhouse gasses from the atmosphere and store it in their soil and plants—a process known as carbon sequestration. In fact, they are such powerful carbon sinks that they can store carbon that has accumulated over hundreds to thousands of years. The carbon stored in coastal and ocean ecosystems is called blue carbon (Woods Hole Coastal and Marine Science Center, 2023).

2.7 Protection of wetlands

As awareness of the diversity, loss, functions, and benefits of wetlands has grown since the 1970s, so have efforts to protect, maintain, and restore them. Five global advocates for wetlands are described here to illustrate the nature and extent of these efforts to offer hope, and to identify potential partners in wetlands education.

2.7.1 UNEP

One global advocate has been the United Nations Environmental Program (UNEP), founded in 1972. UNEP's work on Fresh Water (inland wetlands) helps countries protect and restore freshwater ecosystems and to sustain their services for generations to come (U.N. Environmental Programme [UNEP], n.d.-a). Its work on Oceans, Seas, and Coasts (coastal wetlands) promotes the protection, conservation, restoration, and sustainable management of the world's marine and coastal areas (U.N. Environmental Programme [UNEP], n.d.-b).

2.7.2 IUCN

A second global advocate has been IUCN, founded in 1948. IUCN's Commission on Ecosystem Management (CEM) hosts and supports a variety of Specialist Groups. The mission of IUCN's CEM Wetland Ecosystem Specialist Group "is to develop a global network of experts dedicated to promoting the preservation and restoration of wetlands and sustainable use of their resources by maintaining ecosystem services, enhancing their biodiversity, ecological processes, resilience, livelihoods and water, [and] food and health security for local communities" (International Union for the Conservation of Nature and Natural Resources [IUCN], n.d.-b). Due to the relevance of water across CEM Specialist Groups, the objectives of the Wetlands Ecosystem Specialist Group are linked with those of other CEM Specialist Groups (e.g., Coastal Ecosystem, Ecosystem Services, Climate Change Adaptation, Resilience, Ecosystem Restoration, and Business and Ecosystem Management). IUCN also hosts a Commission on Education and Communications (International Union for the Conservation of Nature and Natural Resources [IUCN], n.d.-a), and therefore not surprising that one of the CEM Wetland Ecosystem Specialist Group's objectives focuses on education.

2.7.3 Ramsar

A third global advocate has been the Ramsar Convention on Wetlands of International Importance, which was adopted in 1971 and went into force in 1975. This is "the intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources. Almost 90% of UN member states, from all the world's geographic regions have acceded to become 'Contracting Parties'" (Ramsar Convention on Wetlands, n.d.-a). To become a contracting party, each nation is required to identify and place suitable wetlands on the *List of Wetlands of International Importance*, also known as the Ramsar List (Ramsar Convention on Wetlands, n.d.-c).

> Contracting Parties confirmed in 2005 that their vision for the Ramsar List is "to develop and maintain an international network of wetlands which are important for the conservation of global biological diversity and for sustaining human life through the maintenance of their ecosystem components, processes and benefits/services." … Today, the Ramsar List is the world's largest network of protected areas. There are over 2,400 Ramsar Sites on the territories of 172 Convention Contracting Parties across the world, covering more than 2.5 million square kilometres … and includes coastal and inland wetlands of all types in all six Convention on Wetlands regions (Ramsar Convention on Wetlands, n.d.-c).

The largest sites on the Ramsar List are some of the largest wetlands on the planet: the Rio Negro in Brazil, and Ngiri-Tumba-Maindombe in the Democratic Republic of Congo, and Queen Maud Gulf in Canada. "The countries with the most Sites are the United Kingdom with 175 and Mexico with 142. Bolivia has the largest area with 148,000 square km under the Convention protection; Canada, Chad, Congo and the Russian Federation have also each designated over 100,000 square km" (Ramsar Convention on Wetlands, n.d.-c). In addition, portions of one of the world's largest wetlands, the Pantanal, which covers between 140,000–220,000 square km in Brazil, Bolivia, and Paraguay, contains several smaller Ramsar sites.

Ramsar's involvement in and support for education has grown over time. "In 2002, 18 Contracting Parties of the Ramsar Convention had adopted wetland education in the formal school curriculum. As of August 2020, the number has increased up to 42 countries" (Park et al., 2020, p. 257). Further, in 2014, the Ramsar Secretariat oversaw the preparation of a handbook to support the planning, design, and operation of wetland education centres (Ramsar Convention on Wetlands, n.d.-e; Ramsar Secretariat, 2014). Later, under its CEPA Programme, Ramsar formally recognized Wetland Link International (WLI), a global network of such centres which is open to all. The WLI "is a support network for wetland education centres that deliver engaging activities on site. This project is led by the WWT [Waterfowl and Wetlands Trust] has 350 members over six continents" (Wildfowl and Wetlands Trust [WWT], n.d.).

2.7.4 Wetlands International

A fourth global advocate has been Wetlands International (WI), a network of national governments and NGOs. It was founded in 1937 as the International Waterfowl Inquiry, morphed several times, and eventually became WI in 1996 following the merging of three NGOs (Wetlands International [WI], n.d.-a). Today, it has offices in Europe, Latin America and the Caribbean, Africa, and Asia, as well as a network of more than 2,000 Associate Experts and people in Specialist Groups who provide advice on WI programmes and projects. WI is …

> a science-based organisation working with civil society, government and the private sector to enable wetland conservation and restoration. By working together and stepping up actions to safeguard and restore wetlands across whole landscapes, we can boost the resilience society needs to deal with climate emergency and provide the basis for sustainable development … Our public and private donors, which include government and multilateral institutions, private foundations, and corporations, finance projects, usually with a specific geographic and thematic focus and deliverables that contribute to our mission." (Wetlands International [WI], n.d.-b).

Their approach is similar in that they focus on vital wetland ecosystems, and rely on technical knowledge, policy dialogue, and strategic partnerships to "connect the local to the global." WI's impacts include work with land users and resource managers, partnerships (e.g., the Swedish International Development Agency), reports (e.g., the *2022 State of the World's Mangroves*), and wetland conservation (e.g., a Ramsar protected peatland in Argentina) (Wetlands International [WI], n.d.-c).

2.7.5 CEPF

A fifth global advocate has been the Critical Ecosystem Partnership Fund (CEPF), which was founded in 2000. It is a "joint program of l'Agence Française de Développement, Conservation International, the European Union, the Global Environment Facility, the Government of Japan and the World Bank" (Critical Ecosystem Partnership Fund [CEPF], n.d.-a) which works to protect and restore 36 areas designated as biodiversity hotspots, many of which include inland and coastal wetlands. CEPF has summarized it work and impact this way:

> Through grants totaling more than US$277 million and technical assistance to over 2,600 civil society organizations and individuals, we have taken action to conserve more than 1,000 species in the IUCN Red List of Threatened Species, and strengthened the management and protection of 51.6 million hectares of Key Biodiversity Areas. Our grantees have also contributed to the establishment of 16.2 million hectares of new protected areas, and the improved management of 10.5 million hectares of production landscape—areas where agriculture, forestry or natural product harvesting occur. And more than 4,900 communities in the biodiversity hotspots have benefited directly from CEPF-funded projects through improved access to clean water, improved land tenure and increased representation in decision-making processes (Critical Ecosystem Partnership Fund [CEPF], n.d.-b).

For reasons of longevity, stability, reach, impact, and recognition, these five entities have been included here. Nonetheless, as significant as they are, they represent only the tip of the iceberg. Each, in its own way, relies on a vast network of governmental officials, scientists and other technical experts, partners, donors, and committed individuals working at all levels, from local to international, to protect, maintain, and restore inland and coastal wetlands across the globe. The efforts of all of these collaborators are needed, and the contributions of all of them are vital.

3 Education

3.1 Terminology and perspectives

Education can be and has been defined in many ways. All too often, dictionaries and encyclopedias define it narrowly to reflect only the transmission of knowledge, skills, and character traits. Others have expanded this to include processes involving not only transmission (e.g., teaching), but acquisition (e.g., learning). On a broad scale, UNESCO recognized that "Education—the way we organize teaching and learning throughout life—has long played a foundational role in the transformation of human societies" (U.N. Educational, Scientific, and Cultural Organization [UNESCO], 2021, p. 6). Thus, it is not surprising that one of UNESCO's *foundational principles* was "Strengthening education as a public endeavor and a common good" (p. 7). More concretely, the recognition that learners can and do play an active role in the learning process reflects the rise and influence of *individual and group constructivism* as a prominent school of thought in education (e.g., Commission on Behavioral and Social Sciences in Education, National Research Council, 2000; Ormrod, 2012). This school of thought not only allows, but actively encourages, learning throughout the four stages of Kolb's experiential learning cycle: concrete experience, observation and reflection, abstract conceptualization, and active experimentation (Kolb, 1984).

However, to discuss education only in terms of teaching and learning might suggest that the primary place where this occurs is in schools. Today, many recognize that this too is narrow, because teaching and learning is not limited to schools and is not limited to those who attend school. Rather, the settings in which education can and does take place, and the people involved in the teaching and learning process, are far broader (e.g., Committee on Learning Science in Informal Environments, National Research Council, 2009). Consistent with these perspectives, and reflecting the rise and influence of Bandura's ideas about *personal agency* (e.g., Bandura, 1977, 2006) and *self-regulation* in the form of self-directed learning (e.g., Bandura, 1991; Zimmerman, 1989), advocates of "free-choice learning" have pointed out that learners, particularly in non-compulsory settings, can have considerable influence over the what, when, where, and how of what they learn (e.g., Falk and Dierking, 2000).

3.2 Common features

This broader conception of education reflects at least five common features. These are: (a) those who are teaching or communicating (providers); (b) those who are learning or attending (participants); (c) the subject matter involved in (a) and (b); (d) the context in which this takes place, including the sponsor, the physical setting, and the medium; and (e) the purposes associated with each (e.g., for any education program, the purposes of the sponsoring institution or organization, the instructor, and individual learners may differ).

3.3 Major sectors

It is important to describe the major sectors included under this broad education umbrella. To begin, the Science Education (SE) community tends to organize education into two sectors: *Formal Education*, which subsumes education for learners in grades K–16 in school settings, and *Informal Education*, which subsumes education for non-school audiences in non-school settings (e.g., Committee on Learning Science in Informal Environments, National Research Council, 2009). However, since the late 1990s, the EE community has tended to divide the latter into three relatively distinct sectors: *Non-Formal education*, *Informal Education*, and *Community-Based Education*. Of these, non-formal education refers to education designed to take place at resource- and collection-rich educational sites other than schools (e.g., museums, zoos, aquaria, botanical gardens, parks, wetlands, and marine sanctuaries) for diverse audiences including school groups, non-school group, and walk-in visitors (e.g., North American Association for Environmental Education [NAAEE], 2004b, 2009b). The second, informal education, does not require a specific site, as it can take place almost anywhere and anytime, as it relies on traditional, electronic, and social media to communicate ideas, information, and perspectives. Finally, community-based education includes the variety of other educational opportunities available in communities. It can refer to opportunities for school groups that extend into the community such as projects and internships (e.g., Villani and Atkins, 2000), as well as the wide range of community events which anyone can attend and learn from, such as lectures, meetings, forums, hearings, conferences, and trade shows. Individually and collectively, these Major Sectors provide rich and varied opportunities to support learning.

4 Environmental education as a context and support for wetlands education

> In recent years, *outdoor education* has come to mean an emphasis in education, encompassing the use of the outdoors as a laboratory to supplement classroom learnings and the acquisition of knowledge, attitudes, and skills, for a wiser use of the outdoors and natural resources. The term "outdoor education" is currently described as education *in* and *for* the outdoors (Smith, 1960, p. 156; *emphasis added*).

This quote from Smith, once a prominent leader in outdoor education in the U.S., indicates that by the early 1960s, outdoor and conservation education had, at least in part, become integrated and foreshadowed the development of environmental education.

This is more apparent in the work by Disinger (1983) and Lucas (1981):

> Uses of the term environmental education can be classified into education about the environment, education for the environment, [and] education in the environment … education about the environment, which is concerned providing cognitive understanding including the skills … education for the environment which is directed to environmental preservation or improvement … education in the environment, which is sometime called education from the environment … is characterized by a technique of instruction … [and] usually means the world outside the classroom (Lucas, 1981, p. 33).

Lucas went on to suggest that "science courses that use an environmentally organizing theme will not necessarily contribute to the attainment of the aim of the Belgrade Charter (U.N. Educational, Scientific, and Cultural Organization [UNESCO], 1975), usually because they focus on education *about* the environment" (p. 34). Two points are worth noting. First, Lucas' ideas remain as relevant today as they were in 1981 (e.g., OECD, 2023). Second, his ideas are as applicable to wetlands education as to EE. In an analysis of global trends in wetlands education between 1991 and 2020, Park et al. (2020) reported an early focus on awareness and attitudes, which Lucas associated with education *about*. Further, much of the work of the WLI network supported by WWT and Ramsar focus on educational experiences *in* wetlands. Finally, in a review of literature on wetlands education in the U.S., Tabiraki and Allen (2021) reported programs which emphasize education *about*, *in*, and/or *for* wetlands (pp. 14–16).

4.1 Goals and objectives

Following the UN Conference on the Human Environment in 1972, UNEP provided UNESCO with the support it needed to initiate the development of an International Environmental Education Programme (Stapp, 1979). A series of steps taken to develop that programs (Stapp, 1979) led up to UNESCO's Intergovernmental Conference on Environmental Education in Tbilisi in 1977, with official delegations from 66 UNESCO Member States (U.N. Educational, Scientific, and Cultural Organization [UNESCO], 1978). At the Tbilisi Conference, the following categories of environmental education objectives were endorsed:

> Awareness: to help social groups and individuals acquire an awareness of and sensitivity to the total environment and its allied problems.
>
> Knowledge: to help social groups and individuals gain a variety of experiences in, and acquire a basic understanding of the environment and its associated problems.
>
> Attitudes: to help social groups and individuals acquire a set of values and feelings of concern for the environment, and the motivation for actively participating in environmental improvement and protection.
>
> Skills: to help social groups and individuals acquire the skills for identifying and solving environmental problems.
>
> Participation: to provide social groups and individuals with an opportunity to be actively involved at all levels in working toward resolution of environmental problems (1978, pp. 26–27).

Several points about these categories of objectives are appropriate. First, they were reaffirmed at subsequent global meetings sponsored by UNESCO, including Tbilisi+10 in Moscow in 1987, the Earth Summit in Rio de Janeiro in 1992, Tbilisi+20 in Thessaloniki in 1997, Rio + 10 in Johannesburg in 2002, and Tbilisi+30 in Ahmedabad in 2007 (e.g., ESD Happenings, 2007; Gorana, 2007; Knapp, 2000). Thus, these categories of objectives represent the most widely recognized and accepted definition of EE around the world. Second, it is relevant to point out that each category is intended to be broad. For example, *Knowledge* encompasses factual, conceptual, and procedural knowledge (Anderson and Krathwohl, 2001) in different thematic areas (e.g., Hollweg et al., 2011; Simmons, 1995). Similarly, *Attitudes* encompasses a variety of theory- and research-based affective dispositions and associated psychological constructs, many of which are unrelated to attitude (e.g., environmental sensitivity, concern and optimism/pessimism, self-efficacy, personal responsibility or norms, and willingness or intention). Further, *Skills* encompasses different sets of skills, including systems thinking, critical thinking, inquiry and investigation, decision-making, and problem-solving skills (e.g., Hollweg et al., 2011; National Environmental Education Advisory Council [NEEAC], 2005; Simmons, 1995). Third, in part, these goals and objectives were widely accepted due to their breadth and flexibility, as this allowed them to be interpreted and adapted to meet the educational needs of different countries/regions and of different educational sectors, as well as to accommodate emerging global educational needs such as those posed by sustainable development and climate change. As a case in point, within the U.S., EE leaders recommended that the Tbilisi goals, objectives, and guiding principles be further clarified for use by teachers and youth leaders (Gustafson, 1983, p. 112; Stapp, 1978, p. 71). In summary, by intent and design, these categories of objectives reflect the major domains of objectives and outcomes implied by Lucas' education about, in, and for the environment.

Returning to the quote by Lucas (1981), developments over the past 50 years have made it clear that different educational approaches, programs, resources, and teaching methods in EE are *better designed* to help accomplish one or another of the Tbilisi Objectives (e.g., Hungerford et al., 1988). Further, research evidence indicates that these are *more likely to accomplish* certain Tbilisi Objectives than others (e.g., Volk and McBeth, 1997).

5 Wetlands education

Although wetlands education is rarely listed as a distinct *educational movement*, it has a clear relationship to other educational movements which emerged over the last 150 years, including Outdoor, Conservation, Ecological, Environmental, Pollution, Biodiversity, Sustainability, and Climate Education (e.g., Disinger, 1983; Marcinkowski, 2019; McCrea, n.d.; Stapp, 1974; Swan, 1984). In specific, in their bibliometric analysis, Tabiraki and Allen (2021) found the influence of environmental education on wetlands education in the U.S. between 1970 and 2020 to be extensive.

Nonetheless, wetlands education is an important and growing area of practice which, given recent political, environmental, and educational trends, is emerging as a recognizable global educational movement, both within the literature (e.g., Otte and Fang, 2014; Roy et al., 2015; Tabiraki and Allen, 2021) and in education practice (e.g., formal: Park et al., 2020; non-formal: Wildfowl and Wetlands Trust [WWT], n.d.). As was true of these other movements, wetlands education can: (a) adapt and build on the purposes and infrastructure of what came before, which could help to accelerate its growth and development, successes, and impacts as an educational movement; and (b) contribute new insights and practices based on attention to contemporary societal, environmental, sustainability, and educational needs and opportunities.

5.1 Major curricular and instructional elements of environmental and wetlands education

Since the early 1970s, various EE *approaches* and *programs* were developed, implemented, refined, and championed by professionals in different institutions. At one time, each tended to be viewed as a stand-alone approach or program (e.g., *Issue and Action Instruction* by Hungerford and his colleagues, and *Action Research: Community Problem Solving* by Stapp and his colleagues, as discussed in Bardwell et al., 1994 and in Ramsey, 1998). More recently, approaches/programs in areas such as citizen science and service-learning have established new and unique curricular and instructional niches. From a pragmatic perspective, the field of EE has matured to the point where the experiential and evidentiary base of many approaches/programs is sufficient to allow the merits of each to be recognized, and for each to be treated as a distinct curricular and instructional *element* within the larger mosaic of EE and Wetlands Education programming (e.g., building blocks for K–12 scope-and-sequence plans). Eight prominent curricular and instructional elements are outlined in Table 1.

TABLE 1 Selected curricular and instructional elements of environmental and wetlands education.

Elements	Suggested Attention, by Age/Grade Level												
	Lucas' Purposes (Lucas, 1981)[1]			Tbilisi Objectives (U.N. Educational, Scientific, and Cultural Organization [UNESCO], 1978)[2]					Early/ Primary (PreK–2)	Intermediate (3–5)	Middle (6–8)	Secondary (9–12)	College (13–16) and Adult
	In	About	For	Aw	Kn	Dsp	Sk	Par					
1. Science Foundations: Ecological, Earth, and Earth Systems Sciences	N	X		P	P	S	S		Introduce	Expand	Expand, Analyze, and Apply	Deepen, Analyze, and Apply	Deepen, Analyze and Apply
2. Social Foundations: History, Geography, Govt., Economics, Sociology, Psychology	C	X		P	P	S	S		Introduce	Expand	Expand, Analyze, and Apply	Deepen, Analyze, and Apply	Deepen, Analyze and Apply
3. Conceptual Awareness of Problems, Issues and Solutions: Earth and Environmental Sciences, Natural Resources and Natural Disasters	N	X		P	P	S	S			Introduce (e.g., local, regional)	Expand (e.g., state, national)	Expand, Analyze, and Apply	Deepen, Analyze, and Apply
4. Analyze and Evaluate Environmental Conditions: Data Science and Modeling		X		P	P	S	P				Introduce	Expand, Analyze, and Apply	Deepen, Analyze, and Apply
5. Monitor and Evaluate Local Environmental Conditions and Problems: Citizen Science	N	X		P	P	S	P				Introduce	Expand, Analyze, and Apply	Deepen, Analyze, and Apply
6. Investigate and Evaluate Local Problems and Issues: Issue Analysis and Investigation	C	X		P	P	P	P				Introduce	Expand, Analyze, and Apply	Deepen, Analyze, and Apply
7. Investigate and Evaluate Local Community Needs, Options, and Partners: Service-Learning and Action Research	N and C	X		P	P	P	P	P		Introduce	Expand, Analyze, and Apply	Deepen, Analyze, and Apply	Deepen, Analyze and Apply
8. Plan, Conduct, Report, and Reflect on Local Service and Action Projects: Action Instruction, Service-Learning, and Action Research	N and C		X	P	P	P	P	P		Introduce	Expand, Analyze, and Apply	Deepen, Analyze, and Apply	Deepen, Analyze and Apply

[1]For Lucas' Purpose, under the column for In, N = Fieldwork in Natural Areas, C = Fieldwork in Human Communities.
[2]For Tbilisi Objectives, Aw = Awareness, Kn = Knowledge, Dsp = Dispositions, Sk = Skills, Par = Participation. Also: P = Primary Obj., S = Secondary Obj.

Several points may help clarify material presented in Table 1. First, these are referred to as *curricular elements* because they reflect different educational objectives and contribute to different learning outcomes. Further, each can be treated as a relatively distinct component of, or strand in, K–12 scope-and-sequence plans, each lasting one or more semesters. In addition, they are referred to as *instructional elements* because each tends to require different instructional designs, teaching methods, and instructional technologies and resources. Second, even though these are presented as elements of schooling, each may be offered in partnership with and/or by various agencies, institutions, and NGOs. Third, as suggested in Table 1, these eight elements reflect the full range of the Tbilisi Objectives.

Fourth, each element is apparent in literature of and practices in Environmental and Wetlands Education. In the U.S., Element 1 is addressed in national standards for science education (National Research Council, 1996; NGSS Lead States, 2013), and Element 2 in national standards for social studies education (McKeown-Ice and Dendinger, 2000; National Council for the Social Studies [NCSS], 1994, 2010). Element 4 has been promoted by the National Oceanic and Atmospheric Administration (NOAA), which makes its extensive databases on atmospheric, climate, oceanic, and estuarine conditions available for educational use (National Oceanic and Atmospheric Administration [NOAA], n.d.-c). Element 5, citizen science and related forms of environmental monitoring, has received increased attention since the 1990s (e.g., Association for Advancing Participatory Sciences [AAPS], n.d.; Ballard et al., 2024; Kaucheck and Marcinkowski, 2010; National Oceanic and Atmospheric Administration [NOAA], n.d.-a; Pandya and Dibner, 2018; The GLOBE Program, n.d.; U.S. Environmental Protection Agency [U.S. EPA], 1996). Element 6 includes issue analysis and investigation, which have been featured in curricula and teacher education (e.g., Hungerford et al., 2003; Marcinkowski, 2004; Ramsey and Hungerford, 1989; Ramsey et al., 1989), as well as related forms of human dimensions research (e.g., Bennett et al., 2017; Ewert, 1996). Elements 7 and 8 have received substantial attention in the service-learning community (e.g., Berger Kaye and Cousteau, 2023; National Youth Leadership Council [NYLC], 2008), as well as in action research (e.g., Posch, 1993; Bull et al., 1988; Wals, 1994). Element 8 also received attention in other programs (e.g., Hungerford et al., 2003). In summary, substantial attention has been given to each of these elements.

5.2 Selected instructional strategies for wetlands education

Of the Curricular and Instructional Elements in Table 1, the design and implementation of Elements 4 through 8 often rely on several common instructional features or strategies (e.g., Ramsey, 1993: local, issue-based, and skill-based). Three of those strategies can be abbreviated as *PBL*: place-based education (or learning), problem-based learning, and project-based learning. The fourth is skill development. Although projects associated with Elements 4 through 8 also often rely on cooperative learning strategies, those will not be discussed here, in part because information about them is so widely available.

5.2.1 Place-based education (PBE)

This family of instructional approaches includes field and community studies, as well as service-learning (e.g., Elements 3, 5, 7, and 8 in Table 1). PBE emphasizes the role of teachers in providing real-world experiences which connect learners with local human and natural environments and, more generally, in building and strengthening connections among schools, communities, and environments (e.g., Sobol, 2004). Learners interact with, study in and about, investigate, and engage in service projects in and for their communities and environments (e.g., Tabiraki and Allen, 2021, pp. 16–17). There are a number of benefits to PBE. First, the emphasis on local allows for greater attention to the developmental, experiential, and educational needs of learners. Second, this emphasis also avoids undue attention to environmental conditions and problems which are remote and abstract (e.g., in other countries or global), but about which learners can do little, thereby fostering unhealthy psychological/emotional perceptions of and reactions to those conditions and problems. Third, the development of connections to local community and environments supports learners' affective development, including developing their sense of connection to, caring for, and responsibility for their community and local environments (e.g., Duffin et al., 2008). Finally, by affirming that schools exist within human and natural communities, PBE can support community development and environmental protection. These characteristics and benefits of PBE have allowed it spread beyond its roots in New England across the U.S. (Vander Ark, 2016), with recognition and support from U.S. EPA and NOAA (e.g., Goal 2 in NOAA's 2021–40 Education Strategic Plan: National Oceanic and Atmospheric Administration [NOAA], 2021).

5.2.2 Problem-based learning

This also encompasses a family of instructional approaches. In her review, Hmelo-Silver (2004) provided the following overview:

> Problem-based approaches to learning have a long history of advocating experience-based education. Psychological research and theory suggest that by having students learn through the experience of solving problems, they can learn both content and thinking strategies. In PBL, student learning centers on a complex problem that does not have a single correct answer. Students work in collaborative groups to identify what they need to learn in order to solve a problem. They engage in self-directed learning (SDL) and then apply their new knowledge to the problem and reflect on what they learned and [on] the effectiveness of the strategies employed … The teacher acts to facilitate the learning process rather than to provide knowledge. The goals of PBL include helping students develop (1) flexible knowledge, (2) effective problem-solving skills, (3) SDL skills, (4) effective collaboration skills, and (5) intrinsic motivation … The evidence suggests that PBL is an instructional approach that offers the potential to help students develop flexible understanding and lifelong learning skills (p. 235).

Hmelo-Silver (2004) described major features of problem-based learning, including features of the problem, the role of the teacher, and the role of student collaboration (Table 1, p. 238), as well as the problem-based process or cycle, which begins with learners formulating and analyzing the problem and proceeds to them applying new knowledge as they formulate solutions (Figure 1, p. 237). Further, she suggested that there are at least two core principles and practices which lie at the heart of problem-based learning and related approaches to learning through problem solving, both of which require a shift away from traditional or direct instruction and therefore can serve as obstacles or barriers for some teachers.

> First, all the approaches emphasize that learners are actively constructing knowledge in collaborative groups. Second, the roles of student and teacher are transformed. The teacher is no longer considered the main repository of knowledge; she is the facilitator of collaborative learning (p. 239).

Hmelo-Silver (2004) also reviewed evidence related to the goals of problem-based learning. She began by pointing out "There are many innovative descriptions of using PBL in various settings … but there is less empirical evidence as to what students are learning and how" (p. 249). For Goal (1) developing flexible knowledge, she found that "The results on what students learn from PBL are mixed" (p. 249), but cited more favorable results in studies of knowledge application and in studies of problem-solving tasks. For Goal (2) she found that "[a]lthough research on the influence of PBL on strategy transfer is limited, it does provide some evidence that students in PBL learn problem-solving and reasoning strategies that are transferable to new problems" (p. 253). For Goal (3) she concluded that research on SDL in PBL also was limited. "For students who are poor self-regulated learners, PBL is likely to pose difficulties without appropriate scaffolding for students trying to develop SDL skills … Becoming self-directed learners is not a given … [and] It is not at all certain how to structure PBL for less mature learners" (p. 258). For Goal (4) she concluded that "There is evidence that students do work together to provide collaborative explanations … [but] There is not yet evidence that supports the hypothesis that PBL helps students become better collaborators" (p. 259). Finally, for Goal (5), she concluded that "Motivation in PBL [is] a complex issue … There is little empirical data about motivation in undergraduate or K–12 education making it difficult to draw conclusions" (p. 259).

In general, problem-based learning is a family of instructional approaches used in all levels of education by teachers who engage in the messy process of working with learners to identify, explore, and synthesize information about a complex, real-world problem and possible solutions to it. In EE, four problem-solving approaches were described by Bardwell et al. (1994) and by Ramsey (1998), although other approaches have emerged since then, including service-learning. Frequently, these EE approaches extend beyond problem-based learning to include the *implementation of solutions* in the form of service and action projects (Table 1, Element 8).

5.2.3 Project-based learning

This term is sometimes used interchangeably with problem-based learning, in part due to a shared acronym (PBL) and to shared psychological principles and teaching/learning practices (e.g., student autonomy, constructive investigations, goal-setting, collaboration, communication, and reflection). Project-based learning has been used in various levels of schooling, in different school subjects, and on a wide range of topics. In their review of the literature on PBL, Kokotsaki et al. (2016) offered the following overview:

> Project-based learning (PBL) is an active student-centered form of instruction which is based on three constructivist principles: learning in a specific context, learners are actively involved in the learning process, and they achieve their goals through social interaction and the sharing of knowledge and understanding (Cocco, 2006). It is considered a particular type of inquiry-based learning where the context of learning is provided through authentic questions and problems within real-world practices … that lead to meaningful experiences … PBL … has clear connections with other pedagogical approaches, such as problem-based learning among others (pp. 267–268).

The Buck Institute for Education described concrete teaching practices and design elements of student projects in PBL (Table 2). Collectively, these sets of features characterize project-based learning, and may be used to differentiate it from problem-based learning.

When a project begins with a real-world problem and ends with a solution, problem-and project-based learning are likely to closely resemble each other. However, when this is not the case, there are likely to be several differences between them, including the starting point, process, and end point of each. First, problem-based learning is

TABLE 2 Buck Institute for Education PBL teaching practices and design features.

Order[1]	Teaching practices[2]	Project design elements[3]
1	Design and Plan (i.e., from project launch to culmination)	Challenging Question or Problem (i.e., a meaningful, but challenging, starting point)
2	Align with Standards	Sustained Inquiry
3	Build a Culture (i.e., promote independence, growth, open-ended inquiry, team spirit, and attention to quality)	Authenticity (i.e., ties to real-world context, tasks and tools, and/or to personal concerns, interests, and issues)
4	Manage Activities (e.g., organize tasks, schedules, checkpoints, and deadlines)	Student Voice and Choice (i.e., student decisions about what and how)
5	Scaffold Student Learning	Reflection (e.g., on self, process, and quality)
6	Assess Student Learning (i.e., use formative and summative assessments)	Critique and Revision (i.e., students offer, receive, and apply feedback on the project process and product)
7	Engage and Coach (e.g., learn with students, identify skill-building needs, offer guidance and encouragement, redirect as needed)	A Public Product (i.e., a presentation to other people beyond the classroom)

[1]Although the Buck Institute presented these features in this order, and some features reflect a sequence, this is not true of all features presented in either column.
[2]Source: https://www.pblworks.org/what-is-pbl/gold-standard-teaching-practices.
[3]Source: https://www.pblworks.org/what-is-pbl/gold-standard-project-design.

problem centered, starting with a real-world problem. Although the starting point in any project may be a problem or may be framed as a problem, not all projects have real-world problems as their starting point. Second, in problem-based learning, the path taken to develop a solution may not resemble the sequence commonly found or used in projects. Third, in problem-based learning, the end point is a solution to the problem, while in project-based learning the end point is a product of some kind, not necessarily a solution (e.g., the report of an investigation, analysis, or evaluation, as in Elements 4 through 7 in Table 1).

As readers are likely to know from experience, projects can vary considerably (e.g., from a week to two semesters). In addition, the nature and scope of the projects undertaken, the learners who undertake them, and the contexts and purposes of those projects also can vary considerably. In (a) a more structured, teacher-driven, and deductive approach to PBL, the teacher develops the specifications for the final product (i.e., the end in mind, such as an outline for a research paper or report) which they can use that to: develop a sequence, timetables, and checkpoints; communicate those to learners; and guide learners. In (b) a less structured, more student-driven, inductive approach to PBL, learners take more active roles in making unfolding decisions about: the nature, scope, and purpose of their project; the sequence of project activities they plan to follow and the procedures they plan to use; and when to seek review and comment from teachers. Each approach to PBL has relative advantages and limitations. For example, a more structured approach (a) is likely to work better for younger, less experienced, less knowledgeable, less capable, and/or less motivated learners (e.g., it provides greater opportunities for scaffolding and monitoring), while a less structured approach (b) is likely to work better for older, more experienced, more knowledgeable, more capable, and/or more intrinsically motivated learners (e.g., it provides greater opportunities for SDL and creativity). In summary, teachers should make strategic decisions about which PBL approach to use based on what they know about the learners, the subject matter, the project to be undertaken, the context or setting in which the project is undertaken, and themselves. Taken together, the features in Table 2 and practices noted above closely reflect practical recommendations that followed from Kokotsaki et al.'s (2016) review of the literature on PBL (pp. 273–274), and which are applicable to K–16 student projects associated with Elements 4–8 in Table 1.

5.2.4 Skill development

This is one of the more important (e.g., U.N. Educational, Scientific, and Cultural Organization [UNESCO], 1978; North American Association for Environmental Education [NAAEE], 2004a, 2009a), more complex, more difficult to achieve, and more misunderstood, areas of instructional planning and practice. To begin, "a skill [may be] defined as the ability to do something proficiently in repeated performances" (National Council for the Social Studies [NCSS], 1989, p. 378). In Anderson and Krathwohl's (2001) revision of Bloom's Taxonomy, this definition reflects the intersection of: (a) the *procedural knowledge* associated with a skilled performance; and (b) the *cognitive process* of application and, quite possibly, higher level processes (e.g., analysis and evaluation). Although skills and abilities can be viewed this way, OECD prefers *competencies*, and routinely includes them in the domain for PISA assessments (e.g., Hollweg et al., 2011). Competencies may be viewed as the combination of subject-area knowledge plus skills (e.g., a student's ability to apply *X* skills when working with *Y* subject matter), a perspective supported by Anderson and Krathwohl (2001) and Willingham (2007). These ideas about skills and competencies suggest that cognitive process are not developed and applied in a vacuum, but rather in the context of specific fields (i.e., a disciplinary perspective) and/or in the context of real-world conditions, problems, and issues (i.e., a multidisciplinary perspective). The place of skills and skill development in wetlands education was affirmed by Tabiraki and Allen (2021, Figure 4, p. 13).

Relevant curriculum questions which follow from this are: (a) which skills and competencies are relevant to EE and wetlands education; and (b) how have those skills and competencies been described and operationally defined? For example, National Environmental Education Advisory Council [NEEAC] (2005) identified four clusters or sets of relevant skills and competencies: collaboration, critical thinking, decision-making, and problem-solving skills. Further, in her EL framework, Simmons (1995) included issue and action skills reflected in this Tbilisi Category of Objectives and in the higher levels of Bloom's Taxonomy (Bloom et al., 1956). As an extension of Simmons' work, the NAAEE guidelines for PreK–12 Education (NAAEE, 2004a,b) included prominent attention to skills associated with problem-and project-based learning under *Strand 1: Questioning and Analysis Skills* (i.e., starting with *Questioning* and ending with *Developing Explanations*), and issue and action skills under *Strand 3: Skills for Understanding and Addressing Environmental Issues* (i.e., including *3.1: Skills for Analyzing and Investigating Environmental Issues*, and *3.2: Decision-Making and Citizenship Skills*). These and other efforts have identified and described relevant skills and competencies, as well as developed measures for them (e.g., Cheak, 2000).

Several instructional questions also follow from this: (c) when and how can learners and others develop these skills and competencies; and (d) how can they learn to transfer them to new subject matter and new settings? Within EE, a variety of responses have been offered to these questions (e.g., Bardwell et al., 1994; Ramsey, 1998). First, different responses have been offered as to *when* to develop skills and competencies, such as those noted above. From a curriculum scope-and-sequence perspective, the *Suggested Attention* to Elements 4 through 8 in Table 1 was intended to reflect developmental, experiential, and educational factors, and included suggested ages/grades when the teaching and learning of skills and competencies may be most appropriate and fruitful. However, those suggestions are general guidelines which can and should be modified on the basis of learners' prior learning, experience, and readiness. From the perspective of problem- and project-based learning, four of the more common responses to the *when* question are summarized in Table 3.

Second, different responses have been offered as to *how* to help learners develop skills and competencies, as is apparent in Table 3. Some approaches are more curriculum-based, although these require capable teachers to lead learners through skill development (which is more teacher-centered), and then skill application (which is more student-centered). Others rely more on the background and experience of a capable facilitator (e.g., to lead learners through the stages of service-learning or action research). Regardless, in these approaches, the process of skill development requires dedicated and capable teachers/facilitators who are ready and able to: (a) use some type of assessment to determine learners' skill-related needs (e.g., pre and/or formative); (b) provide learners with instruction on and modeling of the skills needed; (c) offer guidance and constructive feedback to learners as they practice those new skills; and (d) help

TABLE 3 A general comparison of four approaches to the timing of skills and competency development for student environmental issue and action projects (adapted from Bardwell et al., 1994 and Ramsey, 1998).

General approach	Example	Guidance for skill development	Relationship between skill development and application	Timing of skill application
Develop nearly all skills before a project begins	Hungerford et al. (2003)	Curricular and instructional scaffolding	Skills developed and practiced prior to project application	After all skills are developed
Develop skills needed before each segment of a multi-segment project	Marcinkowski et al. (2000)	Curricular and instructional scaffolding	Skills developed and practiced prior to project application	After skills needed for each segment are developed
Develop skills when learners are likely to need them in a project	Bull et al. (1988); Hammond (1994)	Facilitated by a capable leader/ mentor/coach	Skills developed and practiced shortly before project application	As called for in each stage, phase, or cycle of a project
Develop skills on an as-needed/just-in-time basis during a project	Bull et al. (1988); Hammond (1994)	Facilitated by a capable leader/ mentor/coach	Skills developed and practiced during an unfolding project	As called for given the unique, unfolding nature of a project

learners integrate newly developed skills into the fabric of their projects. Most of these features are apparent in the skill development approaches presented in Figure 2.

Third, different responses have been offered regarding the *purpose* for helping learners further develop certain skills. For example, skills needed for environmental monitoring (Table 1, Element 5) often vary from one environmental condition or problem to another (e.g., those used to monitor water quality, air quality, or threatened/endangered species). However, skills involved in issue analysis and investigation (Element 6) can be applied to a wide range of environmental issues. Thus, program designers and teachers/leaders are encouraged to consider the extent to which the skills developed for/in a given project need to be and will be transferable.

In summary, these questions, notably (a) how we describe/define skills and competencies, (b) which are to be taught and learned, (c) how they are to be taught and learned, (d) how the teaching and learning of skills is related to their integration and use in student projects, and (e) whether transferability of skills is important, are strategic questions for those working with learners on any of the types of projects reflected in Elements 4 through 8 in Table 1.

5.3 Selected wetlands education programs in the U.S

A number of sources have searched for and reported on wetlands education programs, both internationally (e.g., Otte and Fang, 2014, Table 2, pp. 40–42) and in the U.S. (e.g., Tabiraki and Allen, 2021, pp. 14–17). However, for the purposes of this paper, a search for and review of wetlands education programs in the U.S. was conducted to illustrate how the Curricular and Instructional Elements, and Instructional Strategies presented in previous sections are apparent in and can be applied to wetlands education. This search included federal agencies associated with the Preservation, Conservation, and Environmental Quality waves of the Conservation movement in the U.S. which continue to play vital roles in wetlands protection, management, and restoration, although some have not had a prominent role in wetlands education (e.g., Army Corp of Engineers, U.S. Forest Service). In the U.S., agencies which provide education, outreach, and/or training in, about, and for inland and coastal wetlands include the following.

- NOAA's Bay Watershed Education and Training (B-WET) Program: This grant program is dedicated to supporting place-based experiential learning for K–12 students and professional development for teachers.[1]
- NOAA's National Marine Sanctuary System: This is a network of national marine sanctuaries (16) and monuments (2) that includes coastal and inland wetlands (e.g., the Great Lakes), and is dedicated to conservation, research and monitoring, education and outreach, and community engagement.[2]
- NOAA's National Estuarine Reserve System: This is a network of 30 coastal estuaries across the U.S. dedicated to long-term research, education, and stewardship in partnership with coastal states.[3]
- NOAA's SeaGrant College Program: This program supports coastal, marine, and Great Lakes communities through research, extension, and education.[4] EPA's National Estuary Program: This is a collaborative, ecosystem-based network of organizations dedicated to the protection and restoration of 28 coastal estuaries of national significance which develop and implement Comprehensive Conservation and Management Plans (CCMPs), and which often support education and outreach activities (e.g., professional development for teachers, community participation.[5]
- Fish and Wildlife Service's National Wildlife Refuge System: This is a network of more than 570 refuges (e.g., wildlife refuges, marine national monuments, waterfowl production areas) dedicated to developing community-driven conservation solutions that have ecological and economic benefits for fish, wildlife (i.e., including wetland species), and people.[6] The FWS provides education programs beyond those available through refuges.[7]

1 https://www.noaa.gov/office-education/bwet
2 https://sanctuaries.noaa.gov/
3 https://oceanservice.noaa.gov/ecosystems/nerrs/
4 https://seagrant.noaa.gov/
5 https://www.epa.gov/nep
6 https://www.fws.gov/program/national-wildlife-refuge-system
7 https://www.fws.gov/education-programs

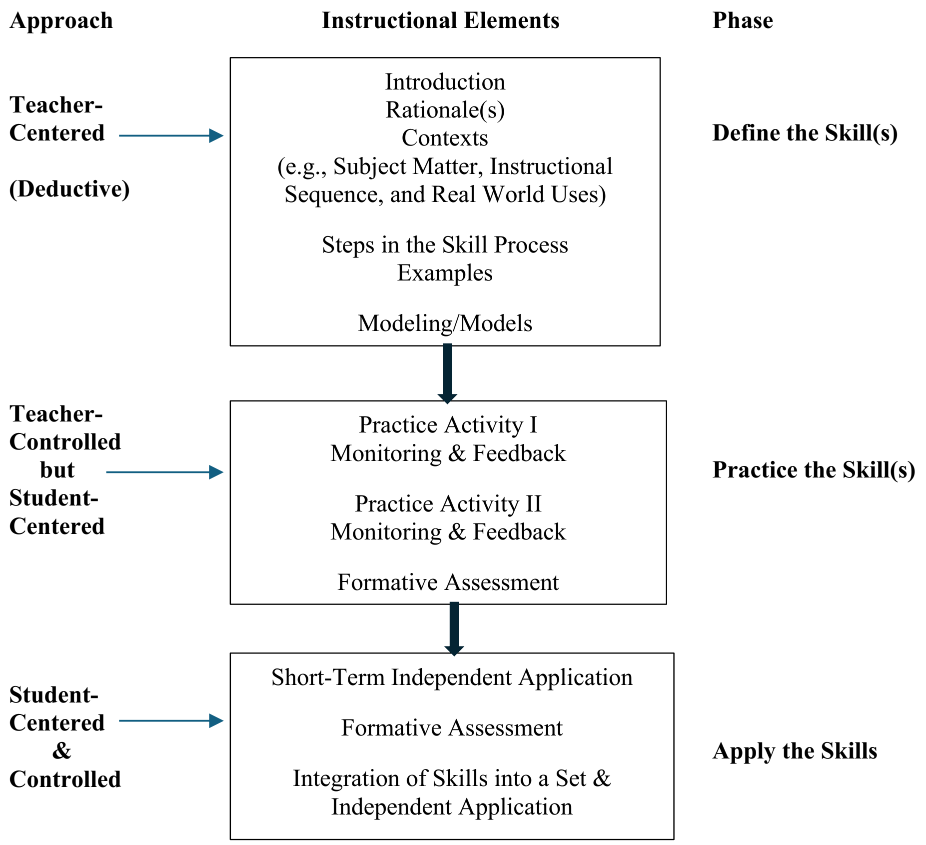

FIGURE 2
Model of skill development.

- U.S. Geological Survey: This agency provides data on surface and groundwater for K–12 education, as well as educational materials and support services.[8]
- The National Wild and Scenic Rivers System: This is an interagency program supported by agencies in the Departments of Interior and Agriculture dedicated to the preservation of certain rivers with "outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generation" and which provides training for professional.[9]
- USDA's Natural Resource Conservation Service: This agency is dedicated to providing conservation solutions to soil, waters, and other resources needed to support agricultural producers, including farmers, ranchers, and forest landowners.[10]

In addition, The National Association of Conservation Districts is a nationwide network of almost 3,000 conservation districts in nearly all counties across the U.S. which works directly with landowners to conserve and promote health soils, water, forests, and wildlife, and which provides outreach and training.[11] These Districts have been involved in conservation and environmental education for decades. Beyond this, there are numerous regional programs designed to address education in, about, and for inland and coastal wetlands. Many are affiliated with one or more of the federal and national programs listed above (e.g., Gulf of Mexico and Great Lakes education programs affiliated with B-WET and Sea Grant). One additional noteworthy regional supporter of wetlands education is the Chesapeake Bay Foundation, which is dedicated to saving Chesapeake Bay through education, advocacy, litigation, and restoration.[12] Both NOAA's B-WET Program and Chesapeake Bay programs focus on *Meaningful Watershed Education Experiences (MWEEs)* which are place-based and which feature several Elements in Table 1, including Elements 3, 5, 6, and 8 (Frungillo et al., 2022).

5.4 Selected wetlands education curricular and instructional materials

This search and review included materials focused on prominent inland and coastal wetlands in the U.S. For practical reasons, no attention was given to secondary and post-secondary textbooks, or to more localized and smaller collections of lesson plans and activities, as there are many of each. To begin, there are different kinds of materials.

8 https://www.usgs.gov/search?keywords=Education
9 https://www.rivers.gov/
10 https://www.nrcs.usda.gov/
11 https://www.nacdnet.org/about-nacd/about-districts/
12 https://www.cbf.org/about-cbf/our-mission/educate/

Within the context of K–16 education, at the most general level, materials can be classified as: (a) *supplemental materials*; and (b) *sequential materials*. The former refers to collections of lessons, activities, and supporting materials which teachers may select from and modify to enrich their classroom instruction as they wish. As EE is not recognized as a school subject in most states within the U.S., (a) reflects the long-standing tradition of *infusing* EE into school programs and instruction. The latter, (b), refers to materials which are designed to be used in some sequential manner (e.g., to support the teaching/learning of breadth and depth of content, and/or to support skills development and student projects). In general, these include textbooks, which have been developed for EE courses in some countries, typically those with an education system overseen by a National Ministry of Education (e.g., South Korea: Noh and Marcinkowski, 2004). Although there are numerous textbook on wetlands for use in undergraduate and graduate education, I was unable to find any for use in K–12 education. However, there are prominent secondary school textbooks which include sections on inland and/or coastal wetlands (e.g., Alexander et al., 2005; Biological Science Curriculum Study [BSCS], 1998). In addition, there are sequential materials that are not textbooks and that are not designed for use over an entire school year (e.g., those that require one school term). In EE, these are sometimes referred to as a curriculum *insert*. Returning to the Elements in Table 1, in very broad and general terms supplemental materials and an infusion approach are often used to enrich instruction for Elements 1–3, while sequential materials and an insertion approach are often used to support instruction and student projects associated with Elements 4–8.

This search was for nationally available materials, as well as those focused on prominent regional inland and coastal wetland areas in the U.S. (e.g., Chesapeake Bay, the Everglades, the Gulf of Mexico, and the Great Lakes). The ten materials located in this search are reviewed in Table 4. First, attention has been given to the design and development of materials for wetlands education since the late 1980s. Second, this sample includes nationally available materials, as well as materials pertaining to several regions, notably the Everglades and Gulf of Mexico, although a recent curriculum focused on the Gulf of Mexico was not yet available at the time of this review (*Deep Sea to Coastal Connectivity*: https://deep-c.coaps.fsu.edu/education-and-outreach/gom-curriculum). Third, in Table 4, the type of material is identified (e.g., whether it was designed for supplemental or sequential use), and it is noted if unit plans were or were not included (i.e., as a step toward encouraging some type of sequential use). Of those, four were Supplemental materials for K–12 use (two included unit plans), five were Sequential materials (two for middle school, two for secondary school, and one for middle-secondary use), and one, a lecture series for adults, could not be classified this way. Fourth, of these materials, one focused on inland wetlands, three on coastal wetlands, and six addressed both. Fifth, while all of these materials emphasized education *about* wetlands, only three emphasized education *in* wetlands, and four emphasized education *for* wetlands (i.e., in the form of service or action projects). Sixth, all ten materials addressed Tbilisi Objectives pertaining to Awareness, Knowledge, and Affective Dispositions, although only five gave explicit attention to Skill Development and four to Participation in service and action projects. Sixth, attention to Curriculum and Instructional Elements in Table 1 also varied. All but one of these materials gave attention to Elements 1 and 3, although only two gave some attention to Element 2 (i.e., Lucas's *about*). One of these materials gave attention to Element 5 and three to Element 6, all of which involved learners in either field-or community-based investigations, respectively. Finally, four of these material gave attention to Element 8, some type of service or action project (i.e., Lucas' *for*), although only two included attention to Element 7, involving learners in planning for such projects.

When viewed as whole, there are at least two points that follow from this brief review of programs and of materials in Table 4. First, there are wetlands education programs and materials available for use, for modification and adaptation to meet local/regional educational needs, and for curricular and instructional integration in schools (i.e., within or across grades). Second, there is ample room for the design and development of new programs and materials focused on wetlands, notably those that would address Elements 4 through 8 (Table 1), and particularly those that involve the use of place-based education, problem-based learning, project-based learning, skill development, and collaboration as instructional strategies.

6 Discussion

These comments have been organized into four subsections. The first, *Purposes* reviews the purposes inherent in the major sections of this paper. These reflect the manner in which this paper has been delimited and, in a few instances, its limitations. The second, *Premises and Possibilities*, reflects an attempt to summarize key points drawn from earlier sections (premises) and to point out how they have been applied and can be applied in wetlands education (possibilities). The third, *Challenges*, draws upon prior work by Hungerford and Volk (1984) in attempting to articulate major challenges for wetlands education which follow from those premises and possibilities, notably challenges that those responsible for wetlands education are likely to face when attempting to put those into practice. The last section, *Final Remarks*, contains some closing thoughts about the future of wetlands education.

6.1 Purposes

The first purpose of this paper was addressed in the Background section on Wetlands: to provide basic information on the nature and distribution wetlands, factors associated with their disturbance and loss, and initiatives to protect and restore them. This was done in an attempt to establish the importance of wetlands and the need for protection and restoration efforts on local-to-global scales. For this paper, this background also helped to establish the broader context of and impetus for, as well as content of, wetlands education. Like prior educational movements, wetlands education arose and continues to evolve in the context of and as part of *wider environmental and social movements*, notably those associated with the disturbance and loss of wetlands, as well as with their protection and restoration. Five international leaders deeply involved in the protection and restoration of wetlands were identified and described. Around the world, wetlands education initiatives and programs have been *about*, have *supported*, and have been *part of* many of those protection and restoration efforts (e.g., as case studies, public media campaigns, and service/action projects, respectively) (e.g., Otte and Fang, 2014; Park et al., 2020; Roy et al., 2015; Tabiraki and Allen, 2021; Wildfowl and Wetlands Trust [WWT], n.d.).

However, unlike the international leadership in wetland protection and restoration, there appear to be few international agencies,

TABLE 4 Selected features of a sample of wetland-related curricular and instructional materials.

Title of material	Authors or publisher (Date)	Type of Curr. and Instr. Material[1]	Targeted Age/Grade Levels	U.S. Environmental Protection Agency [U.S. EPA], (n.d.-a)		Wetlands Education Emphases (Lucas, 1981)			Tbilisi Objectives Emphasized[2] (U.N. Educational, Scientific, and Cultural Organization [UNESCO], 1978)					Curr. and Inst. Elements (Table 2)
				Inland	Coastal	About	In	For	A	K	A	S	P	
Aquatic Project WILD	Western Regional Environmental Education Council [WREEC] (1987)	Activity Manual (Supplemental)	Grs. 1–12	X	X	X	X		P	P	P	S		1, 3
Exploring the Everglades	The Everglades Foundation (n.d.)	Activity Manual with Lesson Plans (Supplemental)	Grs. 4–5	X	X	X			P	P	S			1, 3
Project WET	The Watercourse and The Council for Environmental Education (1995)	Activity Manual with Unit Plans (Supplemental)	Grs. K-12	X		X			P	P	P	S		1, 3
WOW! The Wonders of Wetlands	Environmental Concern, Inc. and Project WET International Foundation (2003)	Activity Manual with Unit Plans (Supplemental)	Grs. K-12	X	X	X	X		P	P	P	S		1, 3
Wetlands	Wang-Mandaca (1991)	1 Unit (Sequential: 1)	Grs. 9–12		X	X	X		P	P	S	P		1, 3, 5
Wetlands Education Curriculum	Virginia Institute of Marine Science [VIMS] (1991)	13 Units (Lecture Series)	Adult Professionals		X	X			P	P		S		1, 2, 3
Wetlands: A Major North American Issue	Culen (1992)	Extend. Case Study (Sequential: 1)	Grs. 6–9	X	X	X		X	P	P	S	P	P	1, 3, 6, 8
Coastal Marine Environmental Issues	Culen et al. (1998)	Extend. Case Study (Sequential: 1)	Grs. 6–9		X	X		X	P	P	S	P	P	1, 3, 6. 8
The Everglades Case Study	Marcinkowski et al. (2000)	Extend. Case Study (Sequential: 1–2)	Grs. 9–12	X	X	X		X	P	P	S	P	P	1, 2, 3, 6, 7, 8
Going Blue	Berger Kaye and Cousteau (2023)	Service-Learning (Sequential: 1)	Teens	X	X	X		X	P	S	P	P	P	7 and 8

[1]Type of Curricular and Instructional Material: for Sequential Materials, the number in parentheses refers to the number of school terms this is likely to require.
[2]Abbreviations for the Tbilisi Objectives should be interpreted as follows (in order, left to right): A = Awareness, K = Knowledge, A = Affective Dispositions, S = Skills, and P = Participation. Abbreviations for "Objectives Emphasized": P = Primary (direct), S = Secondary (indirect).

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institutions, associations, or consortia with a *primary focus* on wetlands education; i.e., to advance theory, research, and practice in wetlands education in a coordinated and coherent manner. One such initiative is WWT's network of wetlands education centres (Wildfowl and Wetlands Trust [WWT], n.d.). A second more recent initiative that may fulfill at least a part of this leadership role is the U.N. Ocean Decade (n.d.), which runs from 2021 to 2030. The Ocean Decade Alliance was formed to advance the vision, mission, and activities of the U.N. Ocean Decade, which includes advancing ocean literacy on national and international scales. On the one hand, this Decade, Alliance, and associated Ocean Literacy Campaigns focus on the global ocean(s), which include *coastal wetlands* and associated wetlands education efforts. However, this Decade and Alliance, and these Campaigns do not focus on *inland wetlands*, and therefore may not support and advance wetlands education about, in, and for these types of wetlands.

It is unfortunate that the literature contains few, if any, comprehensive descriptions of the scale and scope of wetlands education programming around the world (e.g., annual surveys or databases of providers and programs, information about consortia or networks), with some exceptions [e.g., the WLI supported by WWT and Ramsar; Park et al.'s (2020) review]. Further, although recent bibliometric analyses of trends report a growing body of peer-reviewed literature in wetlands education (e.g., Otte and Fang, 2014; Roy et al., 2015; Tabiraki and Allen, 2021), searches for systematic reviews of existing research studies in wetlands education revealed little (i.e., no narrative reviews such as Rickinson, 2001, vote counts such as Volk and McBeth, 1997, or meta-analyses such as Hines et al. 1986/87). Thus, as this stage in evolution of wetlands education, the literature reveals as little about patterns of outcomes and impacts as it does about the scale and scope of programming.

Given the attention to wetlands education programs at the local, regional, national, and international scales, and this apparent absence of a comprehensive understanding of wetlands education on an international or global scale, what was once said about environmental education may be applicable to wetlands education today.

> There is clearly "a lot of it" though it is ill-defined—conservation education, energy education, [aquatic education], marine education, outdoor education, population education, urban environmental education, in various mixes; fragmentation, and continuing fuzziness of definition, are apparent (Disinger, 1981, p. 154).

To paraphrase Disinger's missive of more than 40 years ago, what is known about how much of wetlands education has reflected or currently reflects Lucas' (1981) education *about*, *in*, and *for* wetlands appears to decrease as programming expands from the local to the international level.

The purpose of the section on Education was to provide a fairly broad and inclusive, but general, view of the nature, sectors, providers, and purposes of education. This was done to recognize: (a) that *education*, includes not only formal education, but non-formal, informal, and community-based education; and (b) that all of these sectors and providers are relevant to, available to, and often part of wetlands education (e.g., formal: Park et al., 2020; Tabiraki and Allen, 2021; non-formal: Ramsar Secretariat, 2014; Wildfowl and Wetlands Trust [WWT], n.d.; and community-based: Roy et al., 2015).

The purpose of the section on Environmental Education was to briefly review literature on the historical evolution of, the purposes of and goals for, and selected aspects of theory, research, and practice in, EE and related fields that are relevant to wetlands education.

The final purpose of this paper was addressed in the section of this paper on wetlands education: to review selected instructional practices, programs, and materials in order to illustrate what has been, what is being, and what can be done in wetlands education. Although these samples were drawn from U.S. sources, this is solely due to resources available to the author for the purposes of this paper. The author is acutely aware that comparable programs and materials have been developed for and exist in numerous other countries around the world.

6.2 Premises and possibilities

Wetlands education can and does takes many forms. *First*, as suggested by Lucas (1981), and found by Park et al. (2020) and Tabiraki and Allen (2021), in very general terms, education *about* wetlands is more common in K–16 education (e.g., due to its fit to school standards and to teacher background), non-formal programs (e.g., due to limited visitation time and visitor interest), and informal programming (e.g., due to media coverage). This is apparent in the sample of materials in Table 4.

Second, as the educational benefits of education *in* wetlands have become clearer (e.g., Chawla, 1998; Committee on Learning Science in Informal Environments, National Research Council, 2009; Pastor, 2023; Sward and Marcinkowski, 2001), this has become more common in K–16 education (e.g., field study programs in watersheds and wetlands), as well as some non-formal programs (e.g., WLI wetlands education centers, as well as camps, nature centers, national scenic rivers, estuaries, and marine sanctuaries, and entities involved in NOAA's B-WET Program).

Third, although research in EE has indicated that education *about* and education *in* wetlands contributes to and even paves the way for education *for* wetlands (e.g., by supporting the development of knowledge and affective dispositions), it also indicates that educational programming *for* wetlands is fundamentally different and requires more. This is apparent in *Participation* as a category of the Tbilisi Objectives (U.N. Educational, Scientific, and Cultural Organization [UNESCO], 1978). There is no single best way to go about this, although Curricular and Instructional Elements 7 and 8 (Table 1) and the associated instructional strategies (i.e., place-based, problem-based, project-based, and skill development) offer research-based practical guidance for this.

Finally, education programming *for* wetlands can be designed to engage learners in one or more types of participation, often in the form of service/action projects planned and carried out by learners. These projects often make tangible contributions to wetland protection and restoration and therefore both to local communities and to environmental quality (e.g., removal of exotic invasives and replanting/restocking native species; reduced sedimentation, turbidity, and nutrient loading). As challenging as this kind of programming can be in formal, non-formal, and community-based settings (e.g., expertise, time, cost, transportation, and parental permission), the activities, learning outcomes, and improvements in environmental quality often make these significant life experiences for participants, providers, and partners (e.g., Chawla, 1998; Pastor, 2023).

6.3 Challenges

Although attention to these purposes, premises, and possibilities may be of scholarly interest to some, this paper was prepared with policy makers, leaders of education associations, those responsible for the design and development of educational programs, educators in all sectors, and those involved in educational assessment, research and evaluation in mind. What follow are prominent challenges for and to them, along with some thoughts and questions pertinent these intended audiences.

6.3.1 Major challenges

In 1984, Hungerford and Volk prepared an invited paper entitled *Challenges for K–12 Environmental Education*. In that paper, they presented challenges that seem to be as relevant to wetlands education today as they were (and continue to be) for EE. Six major challenges for wetlands education have been adapted for this paper and are described here, although these are far from the only challenges facing those responsible for wetlands education. For the sake of clarity, these challenges are numbered, and begin with a question and a statement intended to clarify the nature of each challenge. Although, as the numbering implies, there is some relative sequence to these challenges (e.g., Challenge 1 leads into Challenges 2 and 3, and Challenge 5 may come last), there is no fixed order in which they can or should be addressed. Rather, as is apparent in the descriptions, below, these challenges are inextricably interrelated. Collectively, these challenges are intended to encourage reflection, analysis and exploration, decision making, and action for the benefit of both of the major themes of this paper: education (within and across sectors) and wetlands (within and across types).

6.3.1.1 Challenge 1: what should our focus be?

This challenge is about making deliberate decisions to address education about, in, and for wetlands in your educational programs. The first major challenge is to expand wetlands education beyond education *about* wetlands, and to find ways to design, support, and sustain programs that provide opportunities for learners of all ages to engage in education *in* wetlands and, whenever possible, to extend that to education *for* wetlands. This challenge is reflected in the Tbilisi Objectives, specifically those which call for the development of Skills and forms of Participation associated with education *for* wetlands. Otte and Fang (2014) and Park et al. (2020) found that policy decisions such as this (e.g., as national legislation, and as modifications to the school curriculum, respectively) serve as one of the primary mechanisms to support and enable wetlands education.

6.3.1.2 Challenge 2: how can we translate those decisions into programs?

This challenge is about operationalizing education about, in, and for wetlands in the form of curricular and instructional plans for your program(s). As noted by Hungerford and Volk (1984), once decisions have been made to address the range of objectives associated with education about, in, and for wetlands, the next challenge is to develop plans that allow educators and learners to accomplish those objectives. Depending on the education sector(s), provider(s), and target audience(s) involved, this can include:

- development of scope-and-sequence plans for a set of wetlands education programs (e.g., using Elements outlined in Table 1), including where educational experiences *in* wetlands offered by local non-formal partners can fit in those plans (e.g., pre-visit, on-site, post-visit teaching and learning sequences);
- developing and/or adapting specific wetlands education programs and projects (e.g., using instructional strategies described in the section on Wetlands Education);
- developing, selecting, and/or adapting curricular and instructional materials (e.g., such as those in Table 4) and other resources; and
- integrating these into plans for teaching and learning (e.g., unit and lesson/activity plans, as well as projects, as described in Tables 2, 3, and Figure 2).

After addressing Challenge 1, one common pitfall is to fall short of developing coherent curricular and instructional plans, as well as the materials, resources, sites, and partners that will provide learners with realistic opportunities (a) to accomplish that range of educational objectives and (b) to make a difference in their communities and in local wetlands.

6.3.1.3 Challenge 3: will we be able to provide the program we envisioned and planned?

This challenge is about your capacity and readiness to implement those curricular and instructional plans for wetlands education. As an extension of Challenge 2, the best laid educational plans are for naught if they are not implemented in a manner that reflects those plans and their intent. To ensure this can and does happen, a necessary ingredient is the clarity of the plans themselves, but plans alone are insufficient. It also takes creative, dedicated, knowledgeable, and skilled educators to bring those plans to life, whether in classroom, online, lab, field, or community settings. Thus, there are two distinct aspects to this challenge. As discussed by Joyce and Calhoun (2010), the first is ensuring there have been adequate opportunities for the preparation and professional development of the educators who will be responsible for bringing those plans to life (e.g., *in* wetlands: experience with content and methods appropriate to local wetlands; *for* wetlands: experience with the kinds of projects in which learners will engage). The second is involving educators in the preparation of those plans, materials, and resources, as well as in final implementation planning. Although there can be practical challenges associated with each (e.g., time and resources), research in EE has indicated the benefits of addressing these challenges are considerable (e.g., Hungerford et al., 2000; Rickinson, 2001; Volk and McBeth, 1997).

6.3.1.4 Challenge 4: how can we determine what participants are getting out of our program?

This included challenges inherent in designing and conducting assessments of participant learning and growth consistent with your decisions, plans, and programming. Challenge 4 is, essentially, an extension of Challenges 2 and 3. The development and implementation of curricular and instructional plans for wetlands education can work well, engaging educators and learners fruitfully in lessons, activities, and projects. As vital as this is, this may be incomplete in some educational sectors and settings. In formal education and many non-formal education programs, whether for internal reasons and/or for external ones (e.g., sponsoring agencies and foundations), it is likely that someone will be interested in evidence of participant learning, growth, and development in, and other accomplishments of a given wetlands education program. Such evidence can be collected fairly easily during a program (formative) and/or after a program (summative) using phenomenological methods (e.g., learner responses to open-ended questions or prompts, and to individual or group interviews), although analyzing, summarizing, and reporting that evidence can be challenging and time-consuming. Beyond that, the use of more involved instruments and procedures for formative and summative assessment often requires greater planning and preparation. Although most K–16 educators have had some preparation to gather, summarize, and interpret evidence of participant learning, this is less often the case among non-formal educators (e.g., Chenery and Hammerman, 1984/85; Disinger, 1981). With these points in mind, the planning suggested under Challenge 2, and both challenges discussed under Challenge 3, are as relevant to planning and carrying out assessments of participant learning in wetlands education programs as they are to planning and implementing curricular and instructional plans. The needs inherent in Challenge 4 can be met in various ways. For example, the development of assessment plans, materials, and procedures, and support for professional development can be accomplished by: peer educators (e.g., educators in that program and/or in related programs); in university courses on and by faculty versed in assessment and research methods; and by other qualified professionals in the field (e.g., graduate students at nearby universities, outside consultants).

6.3.1.5 Challenge 5: what kinds of longer-term and broader impacts could our program have?

This includes challenge inherent in your designing and conducting an evaluation of the longer-term and wider impacts of your wetlands education programs. Challenge 5 is, essentially, an extension of Challenge 4. For example, the assessment of participant learning is often included as part of program evaluation (e.g., as in logic models) as well as in support of program evaluation (e.g., weak assessment findings can raise evaluation questions such as: Which features of that program may have influenced those assessment results?). However, program evaluation is not limited to the assessment of participant learning following participation in a wetlands education program. Program evaluation also can explore questions about the impacts of a program on the host institution, program partners, and the wider community (e.g., impacts on the educators in the program; the capacity to offer or partner with this program in the future; impacts on parents as active or passive supporters; the impacts of participant presentations of projects to community leaders). *These program evaluation questions explore the contributions of wetlands education to organizational and community development.* Further, program evaluation can explore questions about the impacts of projects on wetlands and surrounding environments (e.g., using scientific monitoring methods and/or methods developed by Duffin et al., 2008, Johnson, 2013, and Short, 2007, 2010). *These program evaluation questions explore the direct contributions of wetlands education to wetland protection and restoration.* With this in mind, the planning suggested under Challenge 2, and both challenges discussed under Challenge 4 are as relevant to planning and carrying out program impact evaluations as they are to planning and carrying out assessments. Finally, despite differences in the nature, purpose, scope, and procedures of participant assessment and program evaluation, many of the needs inherent in Challenge 5 can be met in the same ways as suggested in Challenge 4.

6.3.1.6 Challenge 6: where can we find the resources we need to address these challenges?

This challenge is about your fostering collaboration and developing partnerships to address Challenges 1 through 5. The design, development, and implementation of plans for, the assessment of participant learning, and the evaluation of longer-term and wider impacts of wetlands education programs can range from simple (e.g., one-time projects) to quite complex (e.g., sizable, ongoing restoration initiatives which involve monitoring and follow-up). Regardless, even simple programs require resources (e.g., financial, material, and human). Of these, some resources can be provided by the host institution, and some will require other kinds of external support and assistance (e.g., food, transportation, field equipment and supplies, scientific and educational materials, various kinds of expertise). From the perspective of host institutions, many administrators and educators are good at finding ways to acquire needed resources (e.g., grants, donations, in-kind services, volunteers, and through other requests). Nonetheless, the more involved these wetlands education programs and projects become, the more likely it is that those resource needs will expand. It is at times such as these that regional and national partners (e.g., agencies listed earlier in this section) and international partners (e.g., wetland protection and restoration leaders described in the section on Wetlands; members of the Ocean Decade Alliance) can be sought out. Regardless of scale, collaborators and partners are vital, and underscore why the (U.S.) K–12 Service-Learning Standards for Quality Practice (NYLC, 2008) included Partnerships as one of its eight standards. In that standard, NYLC emphasized that partnerships are best when they are mutually beneficial, i.e., when partners establish a shared vision and goals, maintain regular communication, support program development and implementation, value each other's contributions, and each gain some tangible benefit(s) from their involvement in that partnership and program.

6.3.2 Addressing these challenges

Many have sought to draw attention to and to address these and other, related challenges to wetlands education: this paper would not have been possible without your vision, leadership, and efforts. Others have thought about, even struggled with, these challenges: this paper was designed to encourage your further thought, plans, and efforts. Lastly, some are relatively new to wetlands education and have only begin to consider these challenges: this paper was designed to offer some assistance as you take up that path.

Some of these challenges may be easier to address than others, particularly in the context of *local* wetlands education programs and projects. However, as the nature and scope of wetlands education programs expand, these challenges can become more complex and difficult to address. For this reason, some wetland educators may prefer to stay local and keep it simple, limiting their attention to local wetland needs that are more immediate and pressing. On the other hand, wetland educators working at the national and international levels may prefer to work with leaders, policy makers, and partners in an attempt to remove barriers, create conditions, and develop tools that support/facilitate the involvement of many in well-established, ongoing wetlands education programs (e.g., standards and scope-and-sequence plans for K–12 education; competencies for the preparation and professional development of educators).

Regardless of the scale of your wetlands education program, and of the past efforts of those who helped nurture its development, when efforts are made to address challenges such as these, it can be helpful to begin with an internal review (e.g., What are the strengths and limitations within your program to address these challenges?) and an external review (e.g., What are the supporting and constraining forces in your educational, social, and resource environment relative to these challenges?). The results of these reviews can and should be used to inform program decision making and planning.

6.4 Final remarks

> A paper such as this, by its very nature usually raises more questions than it answers. Unfortunately, some of the unanswered questions are used or can be used as excuses for not acting on the challenges facing EE [and wetlands education]. In this particular instance it appears as though meeting the challenges should transcend both the questions and the excuses (Hungerford and Volk, 1984, p. 27).

Hungerford and Volk were concerned that challenges such as these were formidable and therefore could be ignored for any number of reasons. However, underlying their concern was their recognition that, as a professional community, the field of EE was learning how to address these challenges in ways that were both educationally and environmentally sound, meaningful, and effective. This theme has been apparent in the writing of hundreds of educators over time, from the first issue of (*The Journal of*) *Environmental Education* in 1969 to the working papers prepared for UNESCO's Belgrade Workshop in 1975 to Disinger's admonition that "the groundwork has been laid for dialogue, early agreement and 'getting on with it'" (Disinger, 1983, p. 7).

With Disinger's comments in mind, the key points addressed in this paper and inherent in these challenges, can be summarized as follows:

- the significance of wetlands for ecological, resource, economic, and sustainability reasons;
- the significance of the ongoing destruction and loss of wetlands, as well as of the international initiatives to protect and restore them;
- by comparison, the limited attention that has been given to the coordination and support of international initiatives with a primary focus on wetlands education;
- despite this, the role that education has played, continues to play, and is capable of playing in local efforts and large-scale initiatives to protect and restore wetlands;
- major challenges that face those involved in wetlands education at all levels, notably those inherent in efforts to deliberately link wetlands education to participant learning outcomes that reflect the Tbilisi Objectives, as well as to community development and environmental quality;
- the evolving bodies of theory, research, and practice that have evolved and are now available to help advance education about, in, and for wetlands;
- advances in outdoor, conservation, environmental, and sustainability education (e.g., those summarized in Tables 1–3 and Figure 2) that can be adapted by those involved in wetlands education to sustain, enhance, expand, document, and share the results of their efforts, as they to work to shift beyond education *about* wetlands to include education *in* and, eventually, education *for* wetlands;
- the presence of educational objectives, programs, materials, and other resources as sources of guidance and support for wetland educators and education (e.g., wetlands education materials reviewed in Table 4; the list of national agencies involved in wetlands education in the U.S.; the list of international leaders in wetlands protection and restoration affiliated with WWT's WLI and in the Ocean Decade Alliance as potential supporters and partners); and, lastly,
- the growing importance, necessity, and value of fostering collaboration and partnerships to help make these things possible, both for the improvement of education and for the protection and restoration of wetlands.

These points and these challenges are intended to encourage and support educators in all sectors and at all levels in their efforts to develop, offer, expand, improve, and document the outcomes and impacts of educational programs about, in, and for wetlands, anticipating that wetland protection and restoration efforts will become more vital in the future and that education has major contributions to make to those efforts. Arguably, attention to these challenges would allow wetlands education to more readily and effectively address what Lucas (1981) had in mind when he envisioned and wrote about education about, in, and for the environment.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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