J Environ Stud Sci (2016) 6:336–343
DOI 10.1007/s13412-015-0339-4

Environmental Science: the interdisciplinary STEM field

Gwendelyn Geidel[1] · **William E. Winner**[2]

Abstract The recognition of Environmental Science (ES) academic programs as science, technology, engineering, and mathematics (STEM) is important to the role ES will play in scholarship and in socio-economic development. The National Science Foundation, other federal agencies, and many academic leaders recognize ES as a STEM discipline. However, some state agencies and academic colleagues do not. This article builds the case that ES is a STEM discipline, is a "rigorous science," and provides in-depth treatments of science disciplines. In general, ES qualifies as STEM education for four reasons: ES is grounded in the scientific method and the process of discovery, ES is empirical and predictive, ES is rigorous in its provision of specific skills for analytical analysis, and ES provides students with critical thinking skills. We develop viewpoints that the interdisciplinary field of ES is a mature science that appeals to students and prepares them for meaningful careers. Recognition and classification of ES as a STEM discipline provides a crucial link for their funding, provides career opportunities and research initiatives for students and faculty members, and gives those from ES academic programs standing in the science-based discussions for advancing sustainability in a rapidly changing world.

Keywords STEM · Environmental Science · Curriculum · Quantitative · Rigor · Complex models · Systems

Importance of STEM classification for Environmental Science academic programs

Rationale for discussing ES and STEM

Recognizing that the academic field of Environmental Science (ES) is a science, technology, engineering, and mathematics (STEM) discipline is controversial. On the one hand, ES is recognized as a STEM discipline by the National Science Board (NSB 2014) and by the Department of Labor (US Bureau of Labor, 2010). On the other hand, ES is not uniformly treated as a STEM discipline in other circles (NSB 2015). For example, state education systems do not uniformly put ES academic programs in the same funding category as STEM fields (see, e.g., South Carolina Commission on Higher Education, 2011).

Even within colleges and universities, ES academic programs are considered by some to be "soft science" and therefore not with the same standing as STEM disciplines. The idea that ES academic programs are academically weak is decades old and much discussed in the past. For example, the idea that both environmental science and environmental studies academic programs lack rigor and depth was summarized and rebutted by Maniates and Whissel (2000). Even though the rigor and depth of ES programs are not currently a topic for formal study, those engaged in environmental science still hear colleagues in engineering and traditional science departments, and those in academic administration make comments that clearly identify ES programs as "Low in science content and lacking both rigor and depth."

✉ Gwendelyn Geidel
geidel@environ.sc.edu

[1] Environment & Sustainability Program, School of the Earth, Ocean and Environment, University of South Carolina, EWS 603, Columbia, SC 29208, USA

[2] Environmental Sciences Academic Program, Department of Forestry and Environmental Resources, North Carolina State University, Campus Box 8008, Raleigh, NC 27695, USA

The issue of whether ES academic programs are considered STEM programs is important and involves funding for environmental science. Also at stake is the academic stature of ES programs and those engaged with them. More importantly, the denigration of ES, and efforts to separate it from STEM disciplines, weakens the environmental agenda. Since the issues explored in ES, such as climate change, are often controversial, the efforts to distance ES academic programs from STEM disciplines can result in discussions of environmental controversies descending into the world of myths and beliefs.

Here, we use a range of approaches to develop the idea that ES academic programs are STEM programs that embrace critical thinking, rigor, and depth. Our approach includes looking at the origins of ES academic programs, identifying the factors that led the National Science Foundation and the U.S. Department of Labor to consider ES as STEM scholarship, comparing approaches in ES practice to those of other STEM fields, and comparing the STEM course content in ES academic programs to the STEM content of academic programs in traditional science disciplines.

Defining STEM, critical thinking, academic rigor, and depth

The discussion of STEM disciplines and degrees is important, but STEM is difficult to define (Gonzalez and Kuenzi 2012; Kuenzi 2008). The National Science Foundation uses a “liberal” interpretation of STEM and includes psychology and social sciences. But the Department of Homeland Security and the Immigration and U.S. Citizenship and Immigration Services uses a more “conservative” definition of STEM that excludes psychology and social sciences. Similarly, the American Competitiveness Council uses a broad interpretation of STEM education programs in their survey while the National Science and Technology Council uses more strict criteria for listing STEM programs (National Science and Technology Council 2011).

Elements of STEM disciplines include critical thinking skills, rigor, and depth of study, but these terms are also difficult to define and measure (Wyatt et al. 2011). Although a more careful discussion of ES rigor and depth occurs later in this paper, the goal of this paper is not to review definitions of terms such as STEM, critical thinking, rigor, and depth. Rather, the goal is to work with common understandings of these terms and show that ES has all the hallmarks of commonly recognized STEM disciplines and degrees.

The focus is exclusively on environmental science (ES) academic programs. Environmental Studies academic programs are beyond the scope of this discussion. In general, environmental studies curricula contain fewer basic science courses and more policy and humanities courses than do ES curricula (e.g., Emmett and Zelko 2014; Stevenson et al. 2014).

Origins of ES academic programs

Emergence of ES in higher education

Academic programs leading to B.S. degrees in Environmental Sciences (ES) began emerging in the 1960s in parallel with the increased public interest in environmental issues. There are now several hundred environmental science academic programs at colleges and universities across the nation (Romero and Silveri 2006).

The convergence of Rachel Carson’s book, *Silent Spring*, (1962) with a fleet of new federal laws, stimulated colleges and universities to create academic programs to help prepare students for new careers and personal lives where environmental issues would be increasingly important. Although attacked by some for her views on the impacts of DDT on environmental resources, few can seriously doubt the level of rigor and depth Rachel Carson demonstrated as a foundational piece of environmental science as a discipline.

ES academic programs in colleges and universities formed to explore the changing relationships between humans and nature. A suite of federal laws emerged in the 1970s that set standards for air, water, and soil pollutants designed to protect human health and the environment. An initial area of ES study included the effectiveness of existing and proposed state and federal environmental regulations, and creating a workforce to monitor environmental risks, compliance with federal laws, and preparing required environmental impact statements. ES academic programs matured and are now finding new ways of thinking about the increasingly complex issues of water quality and quantity, air pollution, population growth, food production, and energy that go far beyond regional and national borders (Winner and Champion 2012).

Connecting ES to other disciplines within academic institutions

Important to the discussion about the origins of interdisciplinary ES academic programs is the inherent conflict with existing disciplines. Some chemists, biologists, physicists, geologists, oceanographers, and engineers suggested that their disciplines could manage the need for environmental curricula and programming within their separate departments and would simply need new resources. Others suggested that the traditional science and engineering departments, however well financed, would never be capable of integrating concepts across academic disciplines, including the social sciences (e.g., political science, sociology, anthropology, behavioral psychology, business, economics, communication). Ultimately, the resource flow into new, interdisciplinary ES academic programs created tensions, especially in large universities.

There were many infrastructure issues for emerging ES programs (Winner and Champion 2013). In some cases, ES curricula began as interdisciplinary academic programs embedded in existing departments or university colleges. In other cases, ES academic programs began as new departments staffed with space, faculty members, staff members, and reporting lines to executive officers. In some institutions, ES academic programs formed as "virtual" academic units managed by an ES faculty comprised of faculty members from diverse academic units across the campus. Over time, some ES academic programs moved into institutional organizational charts, shifting from independent programs into university colleges or merging into other academic units.

STEM programs and Environmental Science

Much of the emphasis on STEM education over the last decade comes from a report, *Rising Above the Gathering Storm* (Committee on Prospering in the Global Economy of the 21st Century 2007 and 2010) that shows that US student enrollments and skill levels in science and mathematics are below those of other nations. There is now widespread understanding that improving STEM education in the USA is essential for reclaiming a leading, global role in innovation of new technologies essential for socio-economic growth (e.g., National Academy of Sciences 2012; Gonzalez and Kuenzi 2014; and National Science Foundation Budget 2015).

Academic institutional investment in STEM academic programs, including ES, drives innovation and socio-economic development and stimulates acquisition of new resources that further develop STEM disciplines. Examples include providing "Matching" funds for ES grant proposals and hiring new ES faculty members who generate comprehensive resource bases for their academic programs.

The connection with STEM proficiency and socio-economic growth is driving interest to better understand STEM education and to think critically about which disciplines are STEM and which disciplines are not. The umbrella covering STEM disciplines is expanding beyond the traditional disciplines of chemistry, physics, biology, geology, engineering, and mathematics. New areas now under the NSF STEM label include agriculture, forestry, natural resources, soil science, social sciences, and environmental sciences. The interest in expanding the STEM umbrella comes in part because innovation often results from combining aspects of several disciplines. In addition, disciplines initially not classified as STEM sought inclusion in order to be eligible for resources dedicated to improving STEM education.

The National Science Foundation and STEM

In about 2000, the National Science Foundation (NSF) started using the acronym STEM to refer to academic programs in science, technology, engineering, and mathematics (Sanders, 2009). The NSF created large numbers of research programs to discover the values of STEM academic programs, how to develop STEM activities at all grade levels and in higher education, and set about listing those areas of study that would qualify for NSF STEM programs.

The main categories of NSF STEM disciplines include: Agricultural Sciences, Chemistry, Computer Science, Engineering, Environmental Science, Geosciences, Life/Biological Sciences, Mathematics, and Physics/Astronomy. The National Science Board of the NSF now provides the *Science and Engineering Indicators* report (most recent annual report is, NSB 2014) to document trends in STEM activities including pre-kindergarten, K–12, higher education, and the migration of students from STEM disciplines into the workforce. (See also, NSB 2015).

Foreign students, immigration, and STEM

The Immigration and Customs Enforcement (ICE) agency is responsible for listing academic degrees that qualify as STEM for the Department of Homeland Security (DHS) (Wasem 2012). The list of ICE Stem degrees includes environmental science.

The DHS uses the list of STEM degrees in managing the length of stay for foreign students. Foreign students who graduate have the opportunity gain further skills with Optional Practical Training (OPT). The OPT status can extend student stays that allow work for an additional 12 months, following graduation. The extension can be for 17 months if the student's academic program is classified by DHS as a STEM degree.

The goal of the ICE and the DHS is to use the STEM degrees as a way to extend opportunities for highly educated and skilled students to contribute to socio-economic development in the USA. The connection between earning a STEM degree and immigration is not clear.

Environmental Science is a STEM discipline

The NSF and ICE recognize ES as a STEM discipline because it requires similar thought processes required by engineering and the traditional science disciplines. In general, ES qualifies as an element of STEM education because (1) ES involves the process of discovery, (2) ES is empirical and predictive, and (3) ES provides students with critical, analytical thinking skills.

A number of outstanding college-level environmental science textbooks demonstrate that ES is a true science and provide core knowledge that explain the scope and scale of ES scholarship (e.g., Enger and Smith 2012; Cunningham and Cunningham 2014; Christensen and Legge 2015). The ES core knowledge includes topics such as biogeochemistry; the physical, chemical, and biological mechanisms that account for climate change; the changes in biodiversity that include extinctions, invasions, and speciation; toxicology and impacts of pollutants on humans, other species, and ecosystem functions; population growth and the increasing needs for sustaining human endeavor; and much more.

The core knowledge required to understand ES topics are by nature interdisciplinary and would not neatly fit into courses in engineering or traditional science departments. More specifically, ES is a STEM field that is more than just piecing together loose concepts from engineering and the traditional sciences. ES has a distinct intellectual challenge that requires integration of life science, physical science, and social science disciplines that assemble in complex case studies.

The process of science and discovery

The process of scientific thinking begins with forming a question as a testable hypothesis, gathering relevant information, interpreting results, drawing conclusions, and communicating results in a peer reviewed format. ES is fully engaged in all aspects of the process of discovery-based science across a broad range of topics that span the issues of energy, environment, and sustainability.

Perhaps nowhere is the full force of the process of science more evident than in the field of ES. There are many discoveries in ES that require the process of the scientific method. To provide just three of countless examples, ES research has revealed the connections between air and water quality and public health, the trajectories of trends in energy use and climate change, and the impacts of a rapidly changing environment on both known and unknown species.

ES is empirical

The empirical use of data is fundamental to all sciences that resolve hypotheses of the material world. Since thinking in the realm of ES originates from thinking in traditional science disciplines, those in ES rely on metrics as the principle way to test ideas and resolve questions. ES creates a new framework of scholarship by integrating empirical and conceptual elements of STEM disciplines and, therefore, also assumes the role of a STEM discipline.

The use of metrics includes the careful design of experiments for evaluation with statistical tools (Winner et al. 2015). Scientists in ES commonly use statistical tools, analytics, and big data approaches to attack questions that range in scope from toxicology at an oil spill site to projections of climate change. Research in ES must take into account the statistically important issues of sample size, replication, defining an experimental unit, blocking, the choice of which statistical tools to use in advance of the experiment, and many other aspects of experimental design.

Replication of experimentation and observational data is central to traditional sciences and to ES. Failure to replicate an experiment or observation indicates features of the system not yet understood. Such misunderstood features often provide fertile ground for refining experiments and clarifying thinking.

ES builds system views with predictive models

Many of the systems involved in ES research are too complex to understand through traditional statistical tools. In addition, some experiments simply cannot be done. For example, there is no control treatment for earth, i.e., a second earth in space, but without people and their impacts. Similarly, there can be no research experiments that expose humans to health risks such as controlled doses of carcinogens that would reveal thresholds for cancer.

Some of the best approaches to further understanding of complex systems are through the use of modeling. One modeling approach starts with assumptions about how a system works and creating mathematical expressions that reflect system functions. The mathematical expressions can be a single regression equation or a complex set of equations that interact in ways to simulate a system. Models can be applied to many complex systems, such as simulating satellite orbits and estimating photosynthesis and primary productivity on a global scale. Modeling in ES can also include techniques for managing “Big data” and super computers.

Models in ES not only simulate our understanding of complex systems but such models can also make predictions of how complex systems will likely change in the future. For example, climate change models are predictive. A sound approach for using climate change models is to not rely on a single model but to rely on the outputs of a suite of climate change models that were derived independently. A suite of process-based, simulation models can be run to test an assumption about a specific climate change scenario or greenhouse gas emission control strategy. If all the models give a similar result, there is confidence that the prediction has a high degree of certainty. Disagreement among models is also important as it leads to understanding the difference between models and the way they predict future conditions.

Issues of ES rigor and depth of study

Concerns about the lack of rigor and depth of study threaten to reduce the impacts of those engaged in ES academic programs. Unchecked, these concerns limit faculty member engagement in ES academic programs and professional career options for those graduating from ES academic programs. In addition, considering ES academic programs as second-tier science programs reduces the ability of ES faculty members to contribute to the science discussions about environmental issues or to connect ES to the policies essential for environmental protection.

Environmental Science programs are rigorous academic science programs

No unified method for appraising academic rigor for courses and curricula exists. Still, there is value in comparing the curricula for STEM science content for traditional STEM science disciplines and ES programs. If the science content in ES programs is equal to or greater than in traditional STEM, there is evidence that ES curricula have important elements of rigor. To make the comparison, we used a simple count of traditional STEM courses in the curricula for ES and the curricula for the traditional disciplines of biology, chemistry, physics, mathematics and computer sciences, and geology and earth sciences.

The survey is limited to two large, public universities: the University of South Carolina (USC) and North Carolina State University (NCSU). USC and NCSU are Carnegie Tier 1 institutions, and NCSU is a land-grant and forestry-grant institution. The goal is not to complete a thorough survey of STEM courses for ES programs at all academic institutions but rather to get an initial view of how STEM course content might differ between ES and other STEM disciplines. Although the survey is limited to two universities, they are likely typical of other large, public universities which have environmental science degrees (Romero & Silveri 2006).

Counting STEM courses in science curricula is only an initial gauge to compare rigor and may not account for an array of criteria important for STEM classification, such as critical thinking skills. Since the NSF considers ES as a STEM discipline, ES courses are counted as STEM courses in the survey. In addition, engineering curricula are not included in the analysis because ES is more closely aligned with science and mathematics curricula.

Evidence from the ES Academic Programs at USC and NCSU show these programs contain as many, or more, STEM courses than curricula from traditional science disciplines (Table 1). At USC and NCSU, ES majors take at least 17 STEM courses for up to 80 Cr of the 120 or 128 credit hours required to graduate. STEM credit hours for NCSU students in traditional science degree range from about 54 in earth sciences to about 68 in biology. USC students in traditional science disciplines take about 60 STEM credit hours.

The comparison also shows that ES requires as many mathematics and computer science courses (both introductory and advanced) as other STEM degrees. At both universities, ES students are well founded in quantitative skills that require two semesters of calculus, along with extensive course work in courses that emphasize quantitative skills such as statistics, economics, and higher-level courses in chemistry, physics, and earth and atmospheric sciences.

The curricula comparisons also show that ES students take courses in all the basic sciences, including biology, chemistry, physics, and mathematics. Students in many of the traditional STEM disciplines are in curricula that lack one or more basic science field. For example, students with majors in chemistry, physics, and geology are not required to take a biology course.

The number of STEM credit hours for ES students varies within and between each university. All students, in addition to the required STEM courses, develop a unique focal area that can differ in STEM content. For example, an ES major at NCSU might choose a focal area in biology that requires 15 credit hours of STEM courses while an ES major at USC with a focal area in sustainability might take 18 credit hours of STEM courses. Still, the total STEM content of ES curricula at both universities is higher than for traditional STEM majors at these same universities. Students in the NCSU ES curriculum also have 19 credit hours of advised and free electives, many of which are from STEM disciplines.

In addition, the ES curricula at both USC and NCSU require project-based, writing intensive courses that engage students in critical thinking skills, skills in integrating concepts across STEM disciplines, and communications skills. Such project-based, writing intensive courses may or may not exist for students in traditional STEM curricula.

The credit hour survey indicates that ES students have well-developed backgrounds in the sciences. Although the comparison of science curricula at these two universities is limited, such a comparison at other large, public universities may give similar results. In addition, information from USC and NCSU provide important examples of ES programs that provide curricula rich in STEM course content, and the result may justify a more complete survey of STEM courses in ES academic programs across a broad range of colleges and universities.

Students emerging from environmental science programs acquire focused, interdisciplinary skills

A concern of ES academic programs is that the students lack depth of study and become a “Jack of all Trades, and Master of None.” Yet, the ES curricula at many colleges and

Table 1 Comparison of six degrees from North Carolina State University and the University of South Carolina that are traditionally considered SM degrees, including Biology, Chemistry, Mathematics, Physics, Geology/Earth Science and ES

	Biology # Courses/Cr hr*	Chemistry # Courses/ Cr hr	Analytical reasoning[a] # Courses/ Cr hr	Physics # Courses/ Cr hr	Geo/Earth Sci # Courses/ Cr hr	Env. Sci. # Courses/ Cr hr	Total # Courses/ Cr hr
B.S. degree							
NCSU							
Env. Sci	2/8	3/8	4/12	2/8	2/8	4/12 + 24[d]	17/56 + 24 (80 hrs total)
Biology	15/45	8/16	3/9	2/8	NA	NA	28/78
Chemistry	NA	20/54	3/11	2/8	NA	NA	25/69
Mathematics	NA	2/4	18/57	4/8	NA	NA	24/69
Physics	NA	2/4	7/19	12/34	NA	NA	21/57
Geology	NA	4/8	4/12	3/7	10/27	NA	18/54
UnivSC							
Env. Sci	6/12	4/8	3/11	2/4	2/8	3/11 + 8/25[d]	20/54 + 8/25 (79 total)
Biology, Gen.	13/36	8/16	3/9	NA	NA	NA	24/61 to 63
Chemistry, Gen.	NA	14/35	4/16	4/8	NA	NA	22/59
Mathematics	4/8[b]	N/A	12/41	N/A	NA	NA	17/52
Physics	NA	4/8	6/22	13/43	NA	NA	23/63
Geology	NA	4/8[c]	3/9	4/8[c]	8/34	NA	19/59

NA not applicable

* Number of courses required to be taken and number of credit hours for required courses

[a] Includes Mathematics and Computer Science

[b] Required to take 8 h of science (any)

[c] Either 4 chemistry courses and 4 physics courses or 2 each and 4 biology courses

[d] At NCSU ES, majors typically take additional STEM courses to complete their focal area (15 hrs) and advised elective (9 hrs) requirements. Total hours in "()." At USC, 11 hrs are required ES hours, 7 hrs are STEM but not SM, and the remaining 18 hrs may be either ES, SM, or selected from certain STEM courses. The "+" indicates those that could be STEM

universities evolved to ensure that each ES student develops a focused set of studies within the domain of environmental science. The focused area of study gives each student a specific academic skill set and a sense of academic identity within ES.

Each academic institution takes its own approaches to developing ES curricula that ensure both academic rigor and depth, and common approaches are to develop formally identified concentrations, tracks, or focal areas. From this framework, ES students drill down in a specific area of ES and develop focused skills that give them a sense of academic identity within the broad field of environmental science. The concentration, track, or focal area chosen by ES students forces depth of study and provides a pathway to post-graduate education, careers, and adds value to their personal lives.

In general, ES focal areas, concentrations, or tracks are well established and defined. To acquire depth of study typically requires at least 15 Cr of coursework that forms a cohesive body of study with related courses. Such packages for depth of study may be structured around existing minors, informal lists of required and elective courses, or course lists decided by the student and advisor. Importantly, focus areas will continue to change over time as the community deals with unfolding environmental issues.

Focal areas at USC

One example of a focal area at USC is Environmetrics in which students learn to use mathematical and statistical methods to design environmental monitoring and to analyze measurements necessary for modeling environmental problems (Piegorsch 2014). Students interested in Environmetrics select their courses from GIS, modeling, applied statistics, data analysis, remote sensing, or mathematics. The nature of modern measurement technology which links environmental applications with statistical and quantitative science often produces multivariate measurement signals that are complex and require an understanding of analytics and Big Data. Environmetrics is an example of a focus area that requires a depth of science understanding across disciplines.

Water Resources is another USC focus area and students with this interest select from Chemistry, Geology, and/or Geography courses. While water is an important resource, this and other focal areas are rapidly changing and ES students must have a depth of science across fields to keep abreast of emerging topics. For example, the new National Science Foundation focus on the links between food, energy, and water systems (NSF budget 2015) demonstrates how the diversity of rigorous science courses is important in understanding the challenges that must be addressed from a comprehensive, systems approach that integrates massive amounts of new data.

Focal areas at NCSU

At NCSU, ES students can complete their focal area requirement by completing any of nearly 80 existing minors relevant to environmental sciences. Each minor is a minimum of 15 credit hours (Cr), but courses are carefully selected so students build a focused area of study within the minor. In addition, ES students can propose 15 Cr of coursework that form a focal area in themes where the University does not offer a minor.

The focal area is generally much more than the minimum of 15 Cr of coursework to satisfy a degree requirement. For example, many advanced courses within a minor have a prerequisite of an upper level STEM course. Students use their 19 Cr of electives to meet prerequisite requirements.

For each student, the focal area becomes the center point for the program of study. The focal area affects the selection of advised and free electives, the goals for study abroad programs, and internship and research choices. In short, the focal area becomes the bridge to post-graduate education and career development. Importantly, the 15 Cr required for the focal area is embedded within, not added on to, the 120 Cr needed for graduation. Many ES students appreciate getting both a B.S. degree in Environmental Sciences and a minor within the 120 Cr of their academic program.

Discussion

Students enrolled in current ES programs are engaged in programs that provide a range of science as well as a breath of knowledge. The ES degree has matured to a science that not only appeals to students for its promise of discovery, but that is rigorous, predictive, and requires analytical and critical thinking skills. The recognition and classification of ES as a STEM curriculum and discipline provide a crucial link between funding, early career opportunities, and research initiatives.

As students in ES programs are recognized as a STEM field, the faculty members and students now understand the level of effort needed to prepare for careers and personal lives in a rapidly changing world. Many faculty members and students recognize that ES is the most difficult science, requiring some level of mastery in mathematics and all the sciences. In addition, those in ES learn to couple the ability to think across the scientific disciplines, to integrate concepts and principles from social sciences and humanities, and to consider multiple environmental consequences and solutions across a range of spatial boundaries and time frames.

ES students face challenges and can be at a disadvantage compared to traditional STEM students. For example, fellowships and scholarships at some colleges and universities are reserved only for traditional STEM students, excluding ES students. Such exclusions may be the result of ES academic programs that are relatively young or lack of ES academic programs being featured in colleges and departments. ES academic programs may play minor roles in institutional advancement campaigns or face limited budgets at the state level.

In addition to student support, recognition of ES as STEM will increase opportunities for programs seeking internal funds for enhancement of programs as well as increase opportunities for programs, faculty, and students seeking resources from agencies in the public sector and with partners in the private sector. These funds increase the ability of both faculty and students to advance research initiatives that build on the critical ES elements of rigor, discovery, prediction, and analysis.

Recognizing that ES students are STEM students increases their career opportunities. Such recognition also provides those engaged with ES academic programs important standing in the science-based discussions that are critical in a rapidly changing world.

References

Carson R (1962) Silent spring. Houghton Mifflin, Boston

Christensen, N. and L. Legge (2015) Environment and you, 2nd Edition. Benjamin Cummings Pub., 704 p.

Committee on Prospering in the Global Economy of the 21st Century: an agenda for American science and technology. Rising above the gathering storm. National Academy of Science, National Academy of Engineering, Institute of Medicine (2007) National Academies Press, 562 p.

Committee on Prospering in the Global Economy of the 21st Century: an agenda for American science and technology. Rising above the gathering storm, revisited: rapidly approaching category 5. National Academy of Science, National Academy of Engineering, Institute of Medicine. (2010). National Academies Press, 562 p.

Cunningham, W. and M. Cunningham (2014) Environmental science: a human concern, 13th Edition. McGraw-Hill Pub., 640 p.

Emmett R, Zelko F (eds) (2014) Minding the gap: working across disciplines in environmental studies. Rachel Carson Center Perspectives. Ludwig-Maximilinas-Universitat, Munich

Enger, E. and B. Smith (2012) Environmental science: a study of interrelationships, 13th Edition. McGraw-Hill Pub., 512 p.

Gonzalez, H. B. and J. J. Kuenzi (2012) Science, Technology, Engineering, and Mathematics (STEM) Education: a primer. Congressional Research Service Pub., 34 p. https://www.fas.org/sgp/crs/misc/R42642.pdf

Kuenzi, J.J. 2008. Science, Technology, Engineering, and Mathematics (STEM) Education: background, federal policy, and legislative action. Congressional Research Service Pub., Report to US Congress, Order Code RL33434. http://fas.org/sgp/crs/misc/RL33434.pdf.

Maniates MF, Whissel JC (2000) Environmental studies: the sky is not falling. BioScience 50:509–517

National Academy of Sciences (2012) Research universities and the future of America: ten breakthrough actions vital to our nation's prosperity and security. National Academy Press, 24 p.

National Science Foundation Budget (2015). Innovations at the Nexus Of Food, Energy, And Water Systems (INFEWS) $74,960,000. www.nsf.gov/about/budget/fy2016/pdf/37_fy2016.pdf. Accessed 3 May 2015.

National Science Board (2014) Science & engineering indicators 2014. National Science Foundation Pub. NSB, Arlington, pp. 14–01

National Science Board (2015) Revisiting the STEM workforce: a companion to science and engineering indicators 2014. Pub. NSB-2015-10, 38 p.

National Science and Technology Council, Committee on STEM Education (2011) The Federal Science, Technology, Engineering, and Mathematics (STEM) Education portfolio. Pub. L. No. 111, 358, 102 p.

Piegorsch, W.W. (2014). Twenty five years of environmetrics. Environmetrics 2014: 25:1. http://onlinelibrary.wiley.com/doi/10.1002/env.2260/epdf.

Romero A, Silveri P (2006) Not all are created equal: an analysis of the environmental programs/departments in U.S. academic institutions from 1900 until May 2005. J. Integrative Biol 1:1–15

Sanders, M. 2009. STEM, STEM Education, STEMmania. The technology teacher, p. 20–26. South Carolina Commission on Higher Education (2011) http://www.che.sc.gov/InstitutionsEducators.aspx, accessed August 2015 and http://www.che.sc.gov/CHE_Docs/StudentServices/LIFE/Directives/PolicyGuidelineforthePalmettoFellowsandLIFEScholarshipEnhancements.pdf

Stevenson, R. B., Brody, M., Dillon, J., & Wals, A. E. (Eds.) (2014) International handbook of research on environmental education. Routledge Pub., 592 p.

US Bureau of Labor (2010) USBL Statistics Standard Occupational Classification under the category of Physical Science described as code 19-2041. See: http://www.bls.gov/soc/2010/soc192041.htm.

Wasem, R. E. (2012) Immigration of Foreign Nationals with Science, Technology, Engineering, and Mathematics (STEM) Degree. Congressional Research Service, Report 7-5700; R42530, 26 p.

Winner WE, Champion E (2012) Environmental academic programs: advancing sustainability with a new environmental agenda. Sustainability, The Journal of Record 5:248–254

Winner WE, Champion E (2013) Embedding environmental academic programs in higher education: rebuilding environmental sciences at North Carolina State University. Sustainability, The Journal of Record 6:327–332

Winner WE, Dickey D, Showalter DS (2015) Sustainability and metrics: use of statistics and independent auditing. Sustainability, The Journal of Record 8:54–60

Wyatt, J.M., A. Wiley, W. J. Camara, and N. Proestler, 2011. The development of an index of academic rigor for college readiness. College Board Pub., 43 p.