Interdisciplinary Environmental and Sustainability Education on the Nation's Campuses 2012:

Curriculum Design

A study conducted by
The National Council for Science and the Environment

Shirley Vincent, Stevenson Bunn and Lilah Sloane

August 2013

National Council for Science and the Environment
Improving the scientific basis for environmental decisionmaking

National Council for Science and the Environment

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- Communicating Science to the Public;
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- Climate Solutions Curricula
- Curriculum
- Diversity
- Environment & Human Health
- Interdisciplinary Tenure
- Program Assessment

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Executive Summary

Interdisciplinary environmental and sustainability (IES) programs study coupled human-nature systems using interdisciplinary knowledge and insights gained from systems-based approaches and different epistemological viewpoints.

Working at the science-policy, science-management, and policy-management interfaces, IES programs have a distinctive goal: preparing sustainability-oriented problem solvers through interdisciplinary scholarship, research, practice and informed citizenship.

This report is the first in a series presenting the results of the 2012-13 National Council for Science and the Environment (NCSE) survey of IES baccalaureate and graduate academic program leaders in the United States. Additional reports will focus on administration, structure, learning outcomes and student assessment, program evaluation, alignment with workforce and societal needs, partnerships, and IES centers and institutes.

The data for this report were obtained from 231 IES program administrators, who rated the importance of 41 knowledge areas and 38 skill areas in what they view as the "ideal" curriculum for each IES degree that they administer.[1] The knowledge and skills areas included in the survey were extensively vetted by numerous IES experts.

The study included data on 242 undergraduate and 112 graduate IES degree programs (363 total), which were representative of 1,859 IES degree programs nationally.

Three different statistical analyses were conducted on the undergraduate and graduate data sets. The first investigation was an exploratory factor analysis to reveal the nature and number of the *interdisciplinary* components of knowledge and *integrated* components of skills found in ideal curricula. The correlations between the components reveal how they are related to each other and define illustrative "models" for ideal curriculum design. The results of this analysis include:

- 14 interdisciplinary/integrated knowledge and skills components in ideal curricula for undergraduate programs – 7 each for knowledge and skills
- 16 interdisciplinary/integrated knowledge and skills components in ideal curricula for graduate programs – 8 each for knowledge and skills
- Models that show how the knowledge and skill components are related in ideal curricula

The second investigation used cluster analysis to identify groups of degree programs with similar importance ratings to reveal the number and nature of different approaches to ideal curricula design. The results of this analysis include:

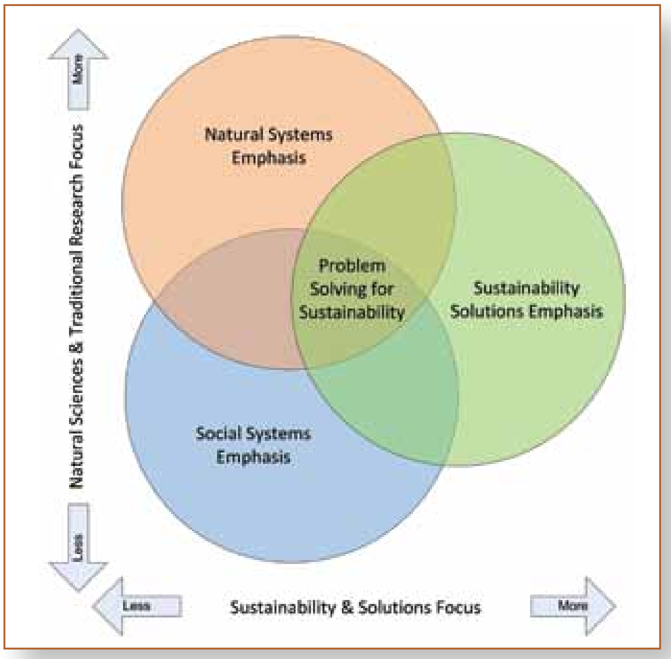
- Three models for ideal IES undergraduate curriculum design
- Two models for ideal IES graduate curriculum design
- Specific characteristics of the degree programs aligned with each model

1. See Appendix A for details on the study methodology and Appendix C for the knowledge and skills survey question.

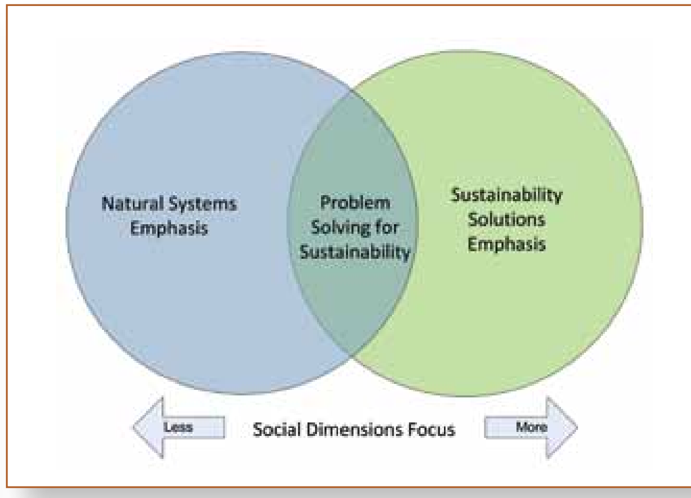
The third investigation used discriminant analysis to confirm the results of the cluster analysis and to identify the functions that distinguish the groups/models from each other. The results of this analysis include:

- A framework for understanding IES undergraduate program curriculum design
- A framework for understanding IES graduate program curriculum design

A framework for understanding undergraduate IES programs in the U. S.



A framework for understanding graduate IES programs in the U. S.



Previous NCSE research studies strengthen the conclusions presented in this report; the varied IES programs fit statistically within the two broad frameworks. A 2006 study investigating program leaders' perspectives on ideal curriculum design revealed a consensus view on the identity of the IES field and three distinct perspectives on ideal curriculum design oriented toward preparing three types of program graduates. These three perspectives align closely with the three ideal approaches for IES education revealed by the analyses of survey data collected in 2008 and again in 2012. The convergence of the findings from the three separate studies with three different samples, using two different methodologies, reinforces the conclusion that there are three primary models for undergraduate IES education. The 2008 data did not reveal a distinction between undergraduate and graduate programs—both groups fell into the same three broad models. Analysis of the 2012 data shows two distinct models for graduate programs as described in this report.

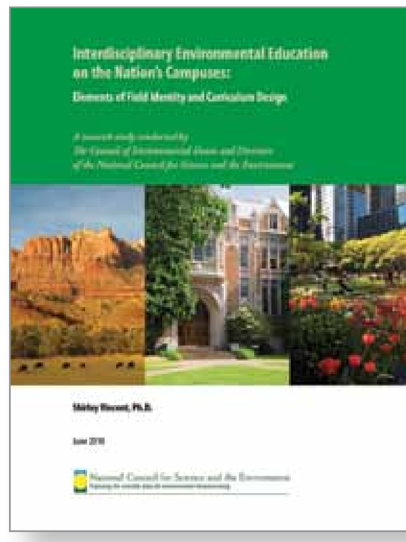
An additional important finding is that sustainability degree programs fit statistically within the IES frameworks. Sustainability programs have emerged since 2006 and now comprise 8% of all IES programs. The 2012 data include a representative proportion of sustainability degree programs.

Although all IES programs in the U.S. fall within the two frameworks, there is tremendous diversity and innovation in curriculum design within each of the model groups. The complexity of environmental and sustainability issues, and the rapid advancements in technologies and knowledge drive the ongoing evolution of IES education.

Background – the NCSE Research Program on Environmental and Sustainability Higher Education

NCSE initiated its extensive research program on IES higher education in 2003. The first study sought to understand the nature and number of academic leaders' perspectives on ideal curriculum design for baccalaureate and graduate IES degree programs.

One of the most important findings from this initial study was a consensus on the identity of the IES field: it is focused on the interfaces and interactions of coupled human-nature systems with the goal of preparing students to be sustainability-oriented problem solvers. Key learning outcomes include disciplinary synthesis, systems-thinking cognitive skills, knowledge of the sociopolitical and natural aspects of environmental problems, understanding the limits of science and technology, and the importance of acknowledging and reporting uncertainty.[2]



IES programs have a distinctive role in higher education in preparing students to understand problems and devise solutions using insights gained from interdisciplinary knowledge and different epistemological viewpoints and a systems approach rather than a traditional reductionist approach.

In 2008 a census was conducted to identify all baccalaureate and graduate IES degree programs offered by universities and colleges in the U.S. The census served to define and characterize the population for ongoing research.

The census was followed by an extensive national survey of IES program leaders. The three related research tasks together comprised the first comprehensive empirical study that sought to identify the defining characteristics of the field and describe the diversity of programs' administrative and curricular structures at U.S. higher education institutions.

The national survey of IES academic program administrators elucidated the characteristics that collectively describe the diversity of programs, including:

- Ideal core interdisciplinary knowledge and integrated skills competencies
- Ideal models for curriculum design
- A framework for understanding the diversity of programs
- The different types of administrative structures for programs

The findings of these studies are summarized in the 2010 NCSE report *Interdisciplinary Environ-*

2. For more information on the perspectives study see Vincent, Shirley and Will Focht. 2010. U.S. Higher Education Environmental Program Managers' Perspectives on Curriculum Design and Core Competencies: Implications for Sustainability as a Guiding Framework. *International Journal of Sustainability in Higher Education*. 10(2): 164-183. For a more thorough discussion on sustainability and its relationship to the consensus view of IES program identity see: Vincent, Shirley and Will Focht, 2010. In Search of Common Ground: Exploring Identity and the Possibility of Core Competencies for Interdisciplinary Environmental Programs. *Environmental Practice* 12(1):76-86.

mental Education on the Nation's Campuses: Elements of Field Identity and Curriculum Design, available on the NCSE website.

The 2012-13 Census and Surveys

The census of IES programs was updated and extended in 2012. A total of 1562 public and not-for-profit and 76 for-profit schools were reviewed. The new census identified baccalaureate and graduate academic programs with an explicit interdisciplinary approach as well as academic programs in disciplines and professional fields with formal specializations in environment and sustainability; minors and certificate programs; and centers and institutes focused on the environment and/or sustainability. A series of three reports from NCSE illustrate the rapid growth in the IES field overall—especially in sustainability academic programs—and the emergence of new types of interdisciplinary energy programs:

- *Interdisciplinary Environmental and Sustainability Education: Results from the 2012 Census of U.S. Four-Year Colleges and Universities.*
- *Sustainability Education: Results from the 2012 Census of U.S. Four-Year Colleges and Universities.*
- *Non-traditional and Broad Energy Education: Results from the 2012 Census of U.S. Four-Year Colleges and Universities.*

A survey of the leaders of IES academic programs was completed in spring 2013. The survey instrument was developed with numerous experts and included questions on degree program attributes and curriculum design, program leadership and faculty, administrative structure and resources, internal and external partnerships, and influences on programs' success. A series of reports will be released throughout 2013-14 combining findings from the survey with case studies and relevant information from other published journal articles and reports. This report represents the first in this series.

A separate survey of IES centers and institutes included questions on mission and goals, administrative structure, and resources. A report on the findings of this study is anticipated for release at the end of 2013.

Rapid Growth in Environmental and Sustainability Higher Education

The number of IES programs continues to expand dramatically. The 2012 census identified 1151 academic units/programs offering 1,859 IES baccalaureate and graduate degrees located at 838 colleges and universities. In the four years following the 2008 census, the number of schools offering IES programs increased by 29%, the number of academic units by 37%, and the number of degree programs by 57%.

Matriculation in IES programs also increased; 64% of baccalaureate programs reported positive growth trends, as did 30% of master's programs, and 23% of doctoral programs. The average number of students enrolled in IES programs increased by 49% for undergraduate programs and 15% for master's programs; the average number of students enrolled in doctoral programs remained steady.

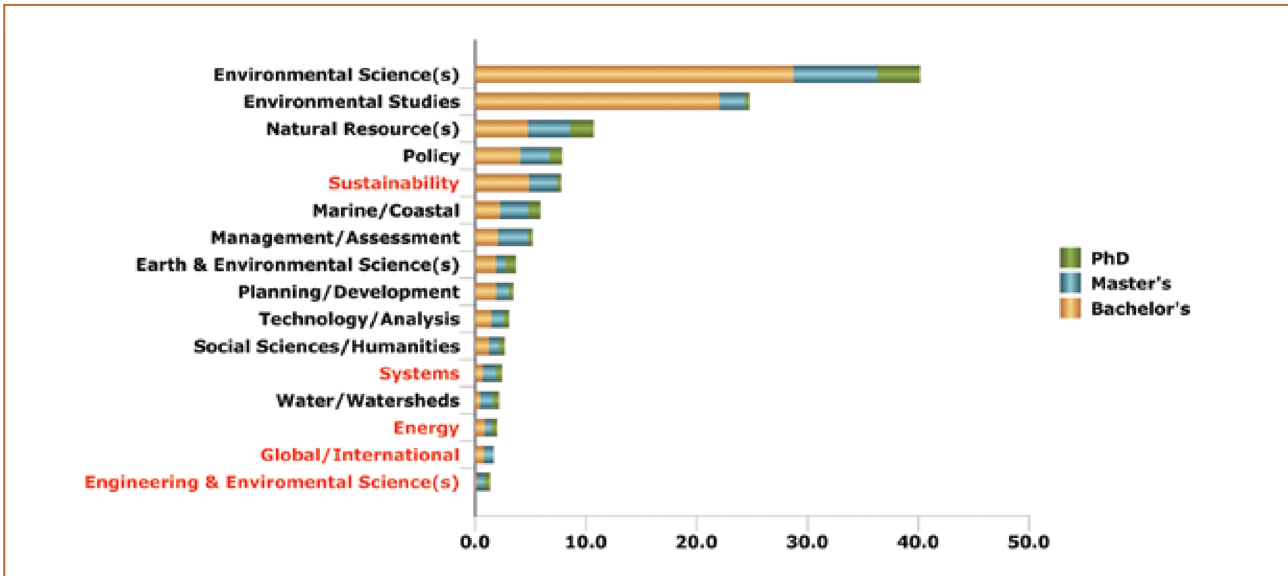
The census findings reveal several trends:

- More degree programs focused on specific themes or problem-solving domains. The numbers of all types of IES degree programs increased, but the proportion of the total named environmental science(s) or environmental studies declined, while programs with other names such as Community, Environment and Development; Environmental Dynamics; or Coastal and Watershed Science and Policy increased.

- Tremendous growth in the number of sustainability academic programs—from 13 in 2008 to 141 in 2012.
- The emergence of new types of IES programs: interdisciplinary energy programs, environmental/sustainability systems programs, programs that combine engineering and environmental science, and programs with an international or global focus.
- More master's programs. The number of master's degrees increased by 68%, compared with 57% for bachelor degrees and 35% for doctoral degrees. A number of the new master's programs—37—have received a Professional Science Master's™ designation.

One of the defining characteristics of IES programs is their diversity; both in the types of programs offered and in their administrative structures. The largest proportion of IES degree program names, 40%, includes the term environmental science or sciences (Figure 1). Another 25% include the term environmental studies. Program names that include natural resource(s) comprise 11%. The growth in sustainability programs brings this category to 8%, tied with the proportion that includes policy in their names.

Figure 1. IES degree program types (titles in red indicate new types of programs)



IES degrees are offered in a variety of administrative locations, including degree programs within a traditional disciplinary department or school; IES departments, schools, and colleges; IES centers and institutes; programs than span multiple departments, one or more colleges, or an entire institution; and degree programs operated by a consortium of campuses or institutions. The administrative homes for the majority of IES degrees are interdisciplinary academic units or programs. Many (41%) are located in interdisciplinary academic units—a department, school, college, or a center or institute. Another 37% are offered through interdisciplinary programs that span units. Only 22% are located in traditional academic departments or schools.

Ideal Curricula for Interdisciplinary Environmental and Sustainability Academic Programs

The NCSE conducted two national surveys of IES program administrators in 2008 and 2012 to address two primary areas of curriculum research: (1) components of knowledge and skills for ideal IES program curricula, and (2) ideal educational models that represent different approaches to IES education. To obtain perspectives on ideal curricula, the surveys asked program leaders to indicate the ideal curricular emphases for a variety of knowledge and skills for each degree offered by their program (see Appendix C for the knowledge and skills question included in the survey). The knowledge and skills areas included were vetted by a number of experts.[3]

The first national survey conducted in 2008 obtained data on 251 undergraduate degrees and 92 graduate degrees (total 343) and found little distinction between undergraduate and graduate programs in terms of ideal curricula components and models—and thus they were analyzed together. The second survey conducted in 2012 obtained data from 242 undergraduate degree programs and 112 graduate degree programs (total 354).

Analyses of the new data discovered distinct dimensions of knowledge and skills and curricular model typologies for undergraduate and graduate degrees. Analysis of the undergraduate program data resulted in findings essentially identical to the findings from 2008—three ideal models for curriculum design. However, analysis of graduate program data revealed a different typology—two distinct models. The dimensions of interdisciplinary knowledge and integrated skills that represent ideal competencies for IES programs and the different models of ideal IES curriculum design are discussed in the remainder of this report.

Competence in higher education is often defined as achieving specified learning outcomes that include theoretical and practical understanding, cognitive abilities, and techniques relevant to a specific field of study. Learning outcomes can also be expressed in terms of core competencies. Core competencies for IES programs serve several purposes:

- Provide a guide for curriculum development as well as for the overall development of the IES field;
- Promote recognition of the IES field and the expertise and qualifications of its graduates;
- Facilitate cooperation and communication among faculty from a wide range of disciplines; and
- Form a potential basis for IES program assessment, professional licensure, and perhaps degree program certification/accreditation.

The dimensions of knowledge and skills that may form core competencies for IES programs were determined from an analysis of IES program administrators' ratings of the importance of 41 knowledge and 38 skills variables in an ideal curriculum for each of their program's degrees. Maximum likelihood factor analysis of these ratings revealed how program leaders group various knowledge areas and skills included in IES program curricula into dimensions (components) of interdisciplinary knowledge and

3. Experts were drawn from the national Council of Environmental Deans and Directors, the American Association for the Advancement of Science, the Association of Environmental Studies and Sciences, the National Association of Environmental Professionals, the Association for the Advancement of Sustainability in Higher Education, and other organizations.

integrated skills.[4] These components represent ideal components of IES knowledge and skills; their composition provides a guide for the creation of interdisciplinary courses and curricula and their interrelationships provide a guide for structuring program curricula. They also provide a broad learning outcomes framework and may be considered as general core competencies for IES programs.

Although the knowledge and skills components are applicable to all IES programs, the importance of each component for IES curricula and the emphasis placed on them in any individual curriculum varies significantly according to the educational approach adopted for each degree program.

Undergraduate Knowledge and Skills Components in Ideal Curricula

Interdisciplinary Knowledge Components

Factor analysis of the ratings of the 41 knowledge areas for undergraduate IES programs revealed seven interdisciplinary knowledge components labeled *Systems, Humanities, Built Environment, Social Sciences, Sustainability, Physical Sciences* and *Life Sciences.*[5] Each component represents a dimension of IES knowledge and is characterized by significant correlations with a subset of the 41 knowledge variables aligned with each component to varying extents. The names of the components are based on the knowledge areas significantly correlated with the component and the magnitude of the correlations. For example, the *Life Sciences* component includes concepts from four knowledge areas—biology, ecology, other life sciences and chemistry—with biology the most highly correlated and therefore contributing most strongly to this component (Table 1).

Tables 1 and 2 illustrate the relationships among the original 41 knowledge variables and the seven interdisciplinary IES knowledge components, and the interrelationships among the seven components. The center column in Table 1 lists the seven interdisciplinary knowledge components. The right column lists the individual knowledge areas significantly correlated with each component and the magnitude of the correlations. The left column illustrates that the *Systems, Humanities, Built Environment, Social Sciences* and *Sustainability* components are highly correlated with each other (≥.4) forming a unified interdisciplinary knowledge group labeled *Sustainable Systems.*

The *Physical Sciences* and *Life Sciences* components are moderately correlated with each other to comprise a unified *Natural Systems Emphasis* knowledge group. These two components are not significantly correlated with the other five components that make up the *Sustainable Systems* knowledge area and therefore form a distinct knowledge focal area.

Table 2 shows the relationships (correlations) between the seven components. Figure 2 illustrates how correlations between the seven components describe a knowledge model for ideal undergraduate IES curricula design (solid lines connecting the components indicate a stronger correlation, dotted lines a weaker but still significant correlation).

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4. Although *factor* is the correct statistical term, the term knowledge and skills *component* is used hereafter as it is more descriptive of what the factors represent for IES program curriculum design.

5. The seven component IES knowledge model is robust; all but one of the 41 knowledge variables—systems analysis—are significantly correlated with at least one knowledge component, the total variance explained was 63%, the goodness-of-fit test of the model was highly significant at $p>0.000$, and Cronbach's alpha scores confirm the reliability of the composition of each component (KMO=.9; Bartlett test sig.=.000).

Table 1. Undergraduate IES interdisciplinary knowledge components

Combined IES knowledge group	IES knowledge component	Knowledge area (correlation with component)
Sustainable Systems	Systems	food systems (.737)
		water systems (.737)
		natural resources management (.628)
		agriculture (.623)
		climate change (.598)
		energy systems (.595)
		geography (.479)
		environmental justice (.438)
		waste (.370)
		research design & ethics (.356)
		education (.343)
	Humanities	literature (.916)
		arts & aesthetics (.766)
		religion (.704)
		language arts (.650)
		history (.640)
		philosophy & ethics (.500)
	Built Environment	green materials design (.772)
		engineering & technology (.680)
		business (.601)
		architecture (.594)
		planning & built environment (.533)
		human health (.511)
		waste (.490)
	Social Sciences	economics (.920)
		political sciences (.777)
		policy & public administration (.667)
		business (.421)
		behavioral social sciences (.396)
		environmental justice (.386)
		business/economic sustainability (.358)
	Sustainability	environmental sustainability (.813)
		sustainability concepts (.761)
		social sustainability (.726)
		sustainability science (.566)
		sustainability governance (.542)
Natural Sciences	Physical Sciences	physics (.650)
		other physical sciences (.548)
		geosciences (.544)
		chemistry (.471)
		engineering & technology (.347)
	Life Sciences	biology (.846)
		ecology (.595)
		other life sciences (.434)
		chemistry (.430)

Table 2. Undergraduate IES interdisciplinary knowledge components correlation matrix

Knowledge component	Systems	Humanities	Built Environment	Social Sciences	Sustainability	Physical Sciences	Life Sciences
Systems	1.000	.463	.483	.437	.548	.063	.128
Humanities		1.000	.420	.540	.364	-.191	.025
Built Environment			1.000	.380	.446	.135	.147
Social Sciences				1.000	.592	-.300	-.214
Sustainability					1.000	-.028	-.098
Physical Sciences						1.000	.310
Life Sciences							1.000

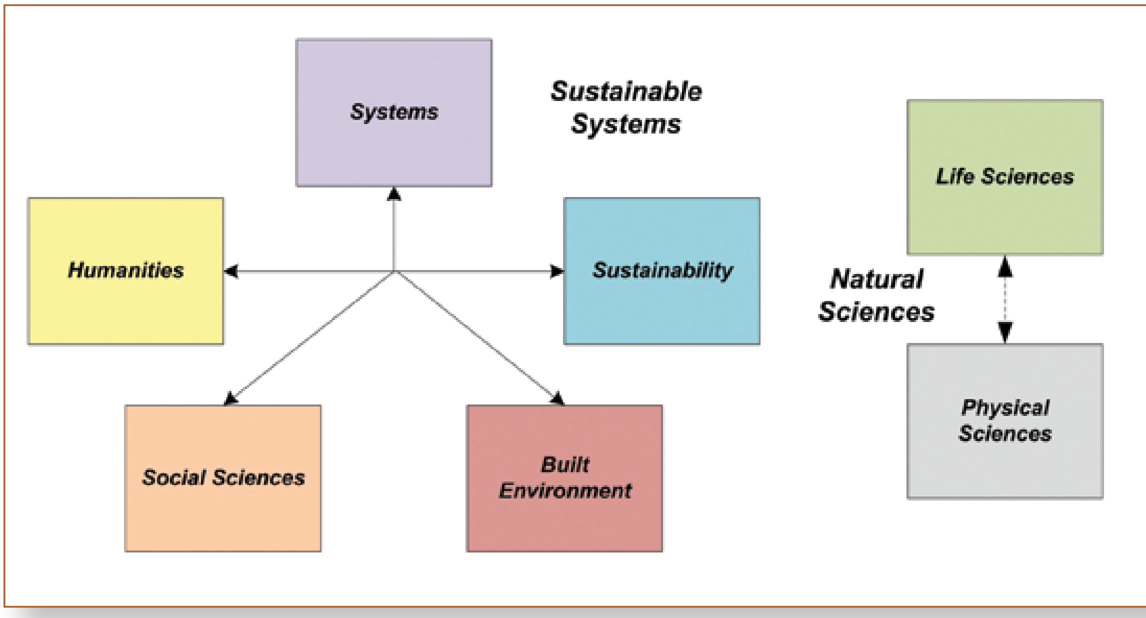
The *Systems* component accounts for 30% of the explained variance in the ratings patterns; this component best explains (predicts/distinguishes) how program administrators' importance ratings fall into the seven components of interdisciplinary IES knowledge. The second component, *Humanities*, accounts for 11%. The other five components account for only small proportions (<10% each) and therefore are less important in distinguishing differences among undergraduate IES degree curricula. One knowledge variable—systems analysis—is not significantly correlated with any of the seven components, indicating it may be cross-cutting across undergraduate IES curricula or is a distinct knowledge focal area.

Although undergraduate IES programs emphasize, combine and incorporate the seven interdisciplinary knowledge components into their courses and curriculum designs in myriad ways, the knowledge model provides a shared framework for understanding how these components are structured in ideal undergraduate IES degree curricula (Figure 2). All the knowledge areas included in the survey had mean ratings of low, moderate or high importance in ideal IES undergraduate curricula (see Appendix D). Averaging the mean ratings of the knowledge areas correlated with each of the interdisciplinary knowledge components indicates that five of the seven are of moderate to high mean importance (*Sustainability, Life Sciences, Systems, Social Sciences* and *Physical Sciences*) and two are of low mean importance (*Built Environment* and *Humanities*) in ideal IES undergraduate curricula overall (but not necessarily in specific degree programs).

The structure of the undergraduate knowledge component correlation model reveals an interconnected set of knowledge components collectively focused on understanding sustainable systems shaped by societies' cultural and behavioral aspects, economic and other polices, technology, business practices and the built environment.

The physical and life sciences components form a distinct *Natural Systems Emphasis* knowledge group separate from the *Sustainable Systems* group. A focus on *Systems* is the most important factor distinguishing undergraduate programs from each other, followed by the *Humanities*. Although the *Natural Sciences* knowledge area is not significantly correlated with the *Sustainable Systems* group, this knowledge is viewed as highly important for undergraduate IES program curricula. Biology, ecology and geosciences—along with policy and public administration, sustainability concepts, environmental sustainability, water systems and climate change—have the highest mean importance knowledge ratings across all undergraduate IES programs. The *Physical* and *Life Sciences* components also explain the least variance or differences between curricula. This is a strong indication that knowledge of the natural sciences is viewed as foundational, as was expressed in the initial NCSE study on the perspectives of IES program administrators.[6]

Figure 2. Undergraduate IES interdisciplinary knowledge model



Integrated Skills Components

Factor analysis of the ratings of the 38 skills areas for undergraduate IES programs discovered seven integrated skills components labeled *Collaborative Engagement, Informatics, Project Management, Systems Thinking, Technical Communication, Laboratory and Field Research,* and *Personnel Management*. Similar to the knowledge components, each IES skills component is also an amalgam of various skills that correlate with the component to various extents. For example, *Systems Thinking* includes six cognitive skills—synthesis, problem solving, analysis, anticipatory thinking, strategic thinking and creativity—with synthesis/systems thinking the most highly correlated with this component (Figure 3).[7]

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6. The comparable 2008 knowledge model centered on sustainable stewardship of natural resources through understanding of coupled human-nature systems informed by knowledge of the natural sciences and economic development. The 2008 survey and analysis included fewer knowledge variables (16 versus 41); when the same set of 16 variables is analyzed using the 2012 data the results are almost identical to the 2008 results. The new model therefore represents a richer understanding of IES undergraduate program curricula versus a shift in ideal knowledge content. Sustainable stewardship of natural resources is still central to the knowledge model as represented by the systems and sustainability components coupled with societal systems represented by the social sciences, humanities and human-built environment.

7. The seven component IE skills model is robust; all but one of the 38 skills variables—literature research—were significantly correlated with at least one skills component, the total variance explained was 64%, the goodness-of-fit test of the model was highly significant at p>0.000, and Cronbach's alpha scores confirm the reliability of the composition of each component (KMO=.9, Bartlett's test sig.=.000).

Tables 3 and 4 illustrate the relationships among the original 38 knowledge variables and the seven integrated IES skills components, and the interrelationships among the seven components. The center column in Table 3 lists the seven integrated skills components. The right column lists the skills areas significantly correlated with each component and the magnitude of the correlations. The left column illustrates that the *Collaborative Engagement, Informatics, Project Management, Systems Thinking, Technical Communication* and *Personnel Management* components are inter-correlated (≥.3 correlation with more than one other component) to create an integrated skills group labeled *Complex Problem Solving*. The *Laboratory and Field Research* component is only moderately correlated with one other component—*Technical Communication*—and therefore is listed as a separate skills group. Table 4 shows the relationships (correlations) between the seven components. Figure 2 illustrates how correlations between the seven components describe a skills model for ideal undergraduate IES curricula design (solid lines connecting the components indicate a stronger correlation, dotted lines a weaker but still significant correlation).

The *Community Engagement* component accounts for 32% of the explained variance in the ratings patterns; this component best explains (predicts/distinguishes) how program administrators' importance ratings fall into the seven components of integrated IES skills. The second component, *Informatics*, accounts for 11%. The other five components each account for only small proportions (<10%) and therefore are less important in distinguishing among undergraduate IES degree curricula. One skills variable—literature research—is not significantly correlated with any of the seven components, indicating it may be cross-cutting across undergraduate IES curricula or is a distinct skill.

Although undergraduate IES programs emphasize, combine and incorporate the seven integrated skills components into their courses and curriculum designs in myriad ways, the skills model provides a shared framework for understanding how these components are structured in ideal undergraduate IES degree curricula (Figure 3). All the skills included in the survey had mean ratings of low, moderate or high importance in ideal IES undergraduate curricula (see Appendix D). Averaging the mean ratings of the skills correlated with each of the integrated skills components indicates that five of the seven are of moderate to high mean importance (*Systems Thinking, Technical Communication, Laboratory and Field Research, Collaborative Engagement* and *Informatics*) and two are of low mean importance (*Project* and *Personnel Management*) in ideal IES undergraduate curricula overall (but not necessarily in specific degree programs).

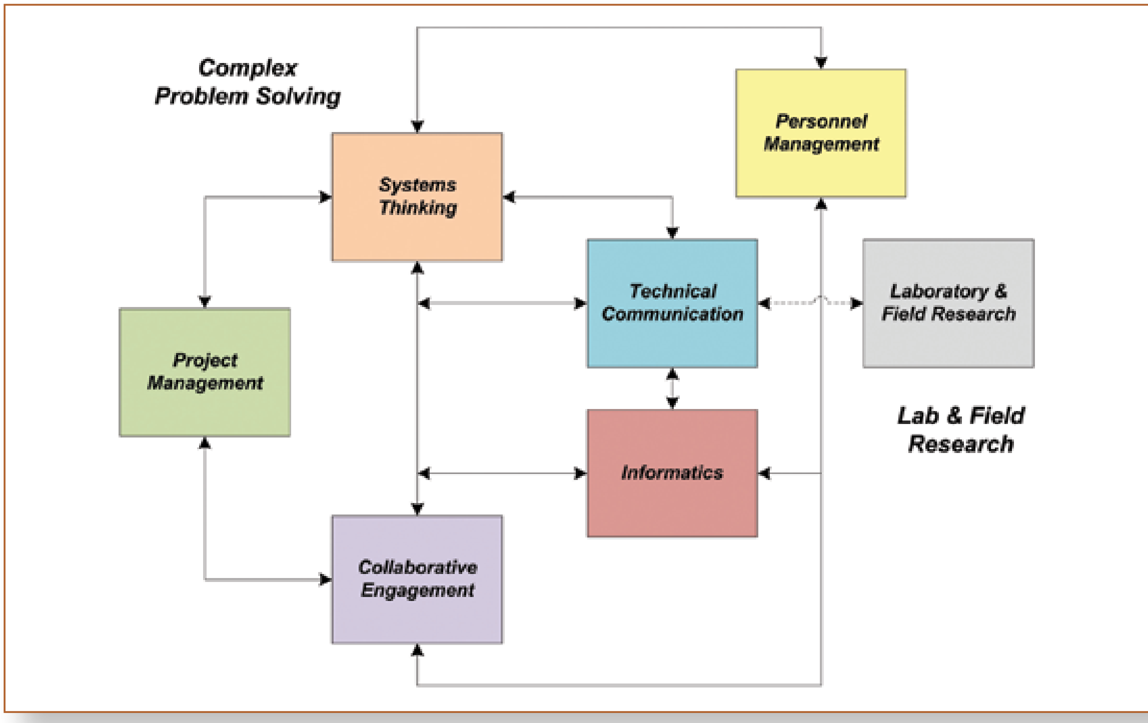
Table 3. Undergraduate IES integrated skills components

Combined IES skills group	IES skills component	Skills (correlation with component)
Complex Problem Solving	Collaborative Engagement	advocacy & outreach (.910) cultural competence (.818) interdisciplinary/intercultural communication (.794) community engagement (.790) organizational learning/development (.737) normative thinking (.685) media communications (.657) conflict resolution (.629) creative & journalistic writing (.604) internet communication (.562) social research (.531) leadership (.430) archival research (.396) strategic thinking (.367) creativity (.360)
	Informatics	computer programming/modeling (.779) decision science (.705) spatial analysis/remote sensing (.603) information management (.603) statistics (.544) mathematics (.493) field research (.350)
	Project Management	project management (.829) assessment & reporting (.732) planning & reporting (.688) personnel management (.639) collaborative decision making (.524)
	Systems Thinking	synthesis (.689) problem solving (.614) analysis (.606) anticipatory thinking (.533) strategic thinking (.490) creativity (.326)
	Technical Communication	technical & academic writing (.776) oral communication (.607) information literacy (.431) critical thinking (.363) teamwork (.343)
	Personnel Management	personnel management (.687) project management (.588) media communication (.343)
Laboratory & Field Research	Laboratory & Field Research	laboratory research (.821) field research (.582)

Table 4. Undergraduate IES skills components correlation matrix

Skills component	Collaborative Engagement	Informatics	Project Management	Systems Thinking	Technical Communi-cation	Laboratory & Field Research	Personnel Management
Collaborative Engagement	1.000	.309	.439	.546	.420	-.170	.324
Informatics		1.000	.182	.314	.480	.240	.409
Project Management			1.000	.288	.089	.024	-.027
Systems Thinking				1.000	.407	.010	.357
Technical Communication					1.000	.248	.244
Laboratory & Field Research						1.000	-.127
Personnel Management							1.000

Figure 3. Undergraduate IES integrated skills model



The structure of the undergraduate skills component correlation model reveals an interconnected set of skills that are focused on complex problem solving, centered on systems thinking and project management skills, informed by research and analysis skills, and include collaborative engagement with public and private stakeholders.[8] Laboratory and field research skills form a somewhat distinct skills area connected to problem solving via analysis and technical communication skills.

8. The comparable 2008 skills model centered on two sets of overlapping skills—problem analysis skills and devising problem solutions and management skills. The 2008 survey and analysis included fewer knowledge variables (23 versus 38); when the same set of 23 variables is analyzed using the 2012 data the results are almost identical to the 2008 results. The new model therefore represents a richer understanding of undergraduate IE program curricula versus a shift in ideal skills content.

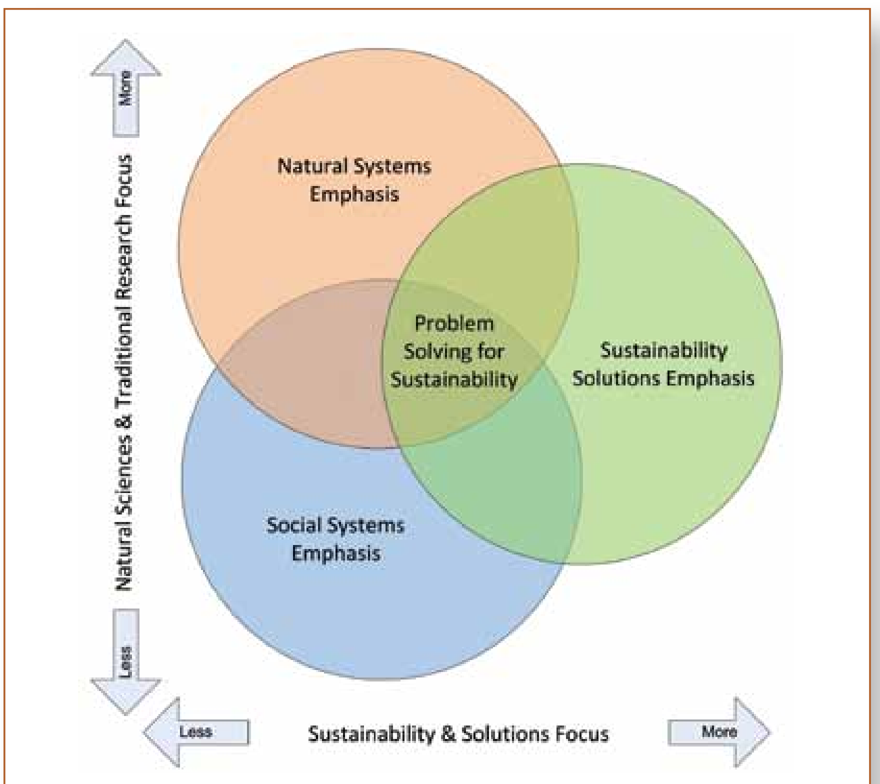
Undergraduate Models for Curriculum Design

The ideal models for IES undergraduate programs were determined from a cluster analysis of the seven knowledge and seven skills component scores for each degree (derived from the ratings of the 41 knowledge and 38 skills areas). The analysis revealed three ideal approaches or models for undergraduate IES education.

The three models are labeled *Natural Systems Emphasis, Social Systems Emphasis* and *Sustainability Solutions Emphasis* based on the knowledge and skills components each emphasizes. Each model emphasizes different knowledge and skills components to prepare graduates for different types of sustainability-oriented problem solving. The models are characterized by their mean component scores (from the factor analyses described above) and by significant differences in the degree programs associated with each group: the proportions of degree types (name and level), and certain degree program requirements.

Figure 4 illustrates a unified framework for understanding undergraduate IES programs in the United States based on the cluster and discriminate analyses discussed below. The three models are not opposed to each other; instead they overlap considerably so that some undergraduate IES programs are situated on the boundaries of two or three models. The three models are oriented on two dimensions: (1) focus on sustainability and solutions, and (2) focus on natural sciences and traditional laboratory and field research.

Figure 4. A framework for understanding undergraduate IES programs in the U. S.



The three approaches represent the views of groups of program administrators that rate the ideal curricular components—the seven interdisciplinary knowledge components and the seven integrated skills components—in similar ways. Figures 5 and 6 illustrate how the mean importance ratings for each of the three ideal approaches—*Sustainability Solutions Emphasis, Social Systems Emphasis* and *Natural Systems Emphasis*—differ from the overall mean for all undergraduate IES programs and from each other.[9]

Figure 5. Undergraduate IES knowledge component means by curriculum model

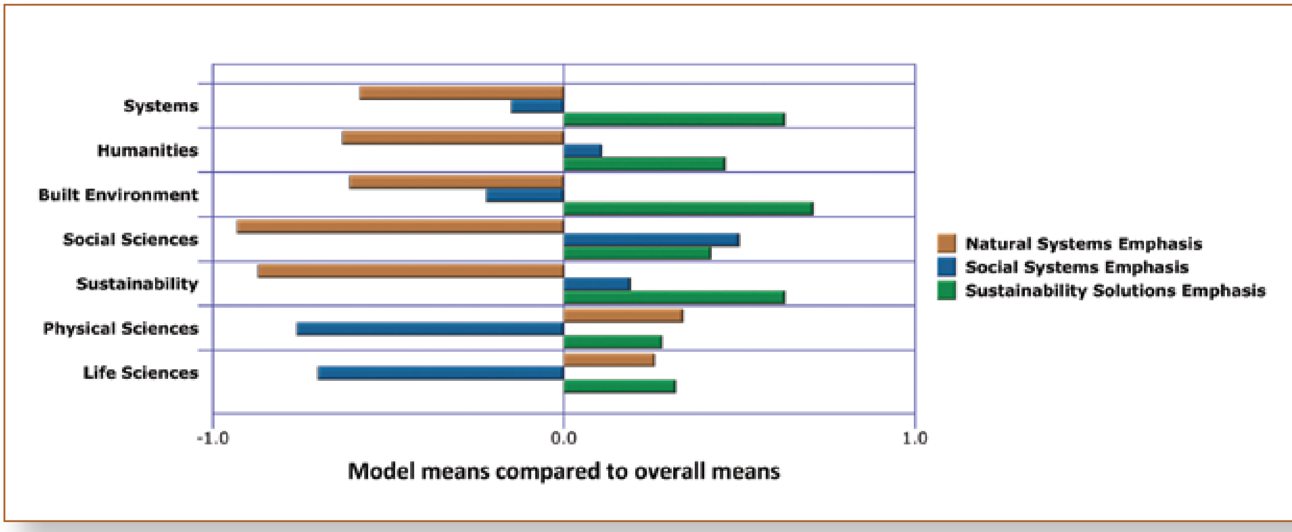
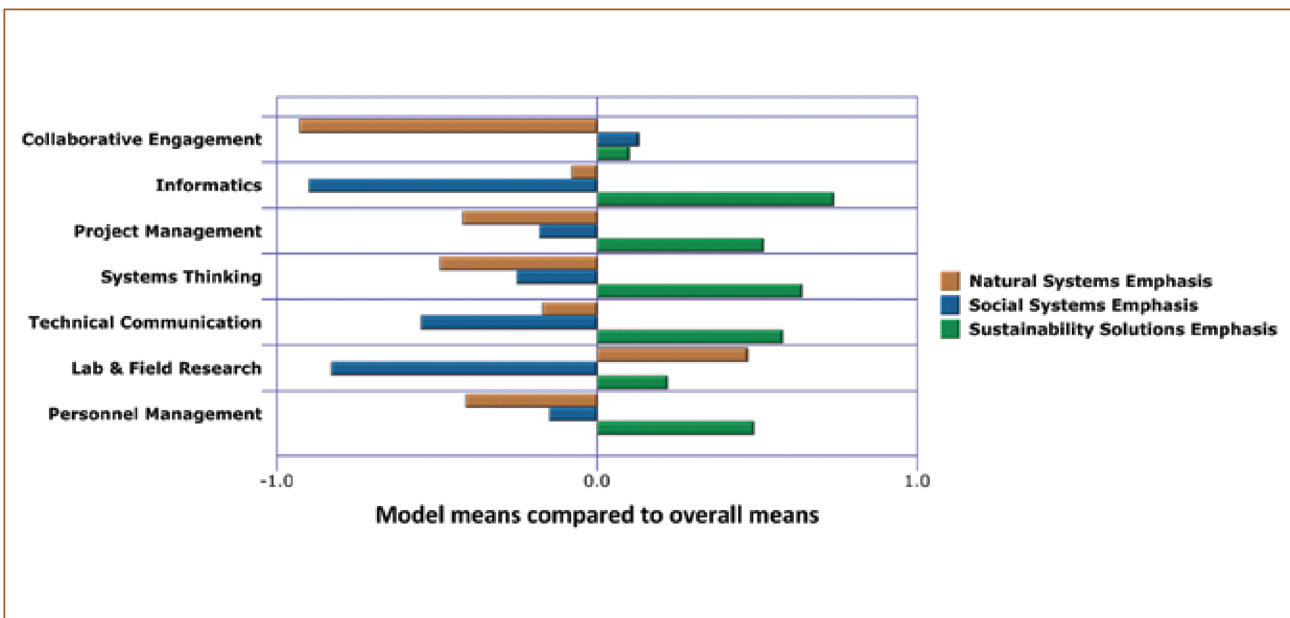


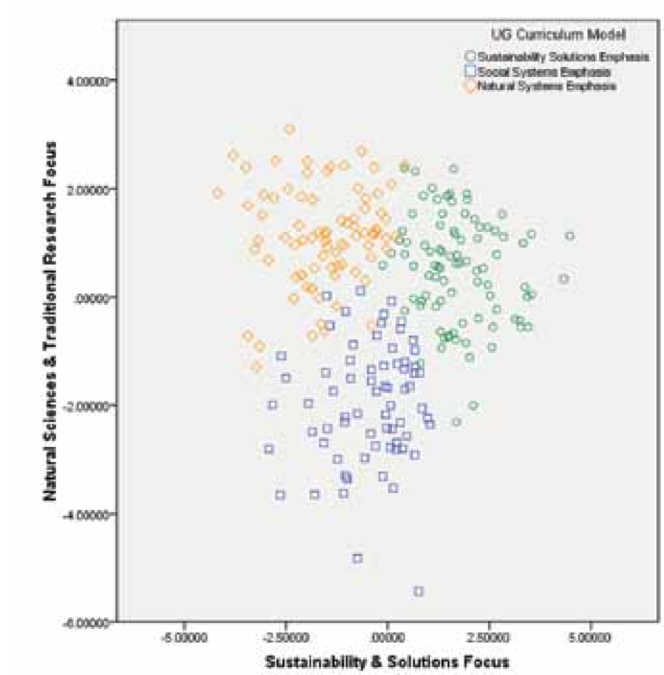
Figure 6. Undergraduate IES skill component means by curriculum model



9. The bars illustrate the mean factor scores for each of the components (factors) of the groups of programs aligned with the three approaches and their relationship to the mean factor score for all IES programs included in the survey which = 0.

Figure 7 illustrates how the undergraduate IES degree programs included in the survey align with the three models and the relationships between the models based on two dimensions that discriminate among the three groups (the discriminant analysis is discussed below).

Figure 7. Undergraduate IES degree programs plotted on two dimensions



Discriminant analysis revealed two significant functions that explain the differences between the three models. The first dimension (X axis) accounts for 55% of the variance between the model groups, and the second dimension (Y axis) 45%.[10] Standardized correlation coefficients reveal that ten of the fourteen knowledge and skills components are most strongly correlated with the first function while the remaining four are more strongly correlated with the second function (Table 5). The first function is characterized by strong positive correlations (≥.3) with all but three components—*Laboratory and Field Research* skills, *Physical Sciences* knowledge and *Life Science* knowledge. These three components are positively correlated with the second function. Three components are positively correlated (≥.3) with both functions: *Informatics* skills, *Built Environment* knowledge and *Technical Communication* skills. Based on these associations the dimensions are given descriptive labels: the first *Sustainability and Solutions Focus*, and the second *Natural Sciences and Traditional Research Focus.*

10. The discriminant analysis is robust; the Box's M test significance is .000 and 94% of the cases were correctly classified.

Table 5. Undergraduate discriminant analysis correlation coefficients

Knowledge/skills component	Sustainability & Solutions Focus	Natural Sciences & Traditional Research Focus
Collaborative Engagement Skills	.704*	-.263
Sustainability Knowledge	.588*	-.276
Built Environment Knowledge	.531*	.311
Social Sciences Knowledge	.501*	-.494
Systems Thinking Skills	.455*	.060
Systems Knowledge	.450*	-.007
Humanities Knowledge	.364*	-.153
Project Management Skills	.345*	.030
Technical Communication Skills	.344*	.283
Personnel Management Skills	.343*	.019
Informatics Skills	.479	.560*
Laboratory & Field Research Skills	.003	.557*
Physical Sciences Knowledge	.066	.492*
Life Sciences Knowledge	.101	.431*

*Largest absolute correlation between each variable and any discriminant function.

The three different approaches to undergraduate IES education reflect the views of IES program administrators regarding their preferences for each of the degree programs they offer. The popularity of the three models are roughly equal; the *Sustainability Solutions Emphasis* model represents 37% of the undergraduate degree programs included in the survey, the *Natural Systems Emphasis* model 34%, and the *Social Systems Emphasis* model 29%.

The three models are also similar in enrollment trends (Table 6). Degree programs associated with the *Sustainability Solutions Emphasis* and *Social Systems Emphasis* models have higher proportions of growing programs (both 68%), but the majority of *Natural Systems Emphasis* degree programs also report growing enrollments (57%).

Table 6. Undergraduate IES curriculum models and enrollment trends

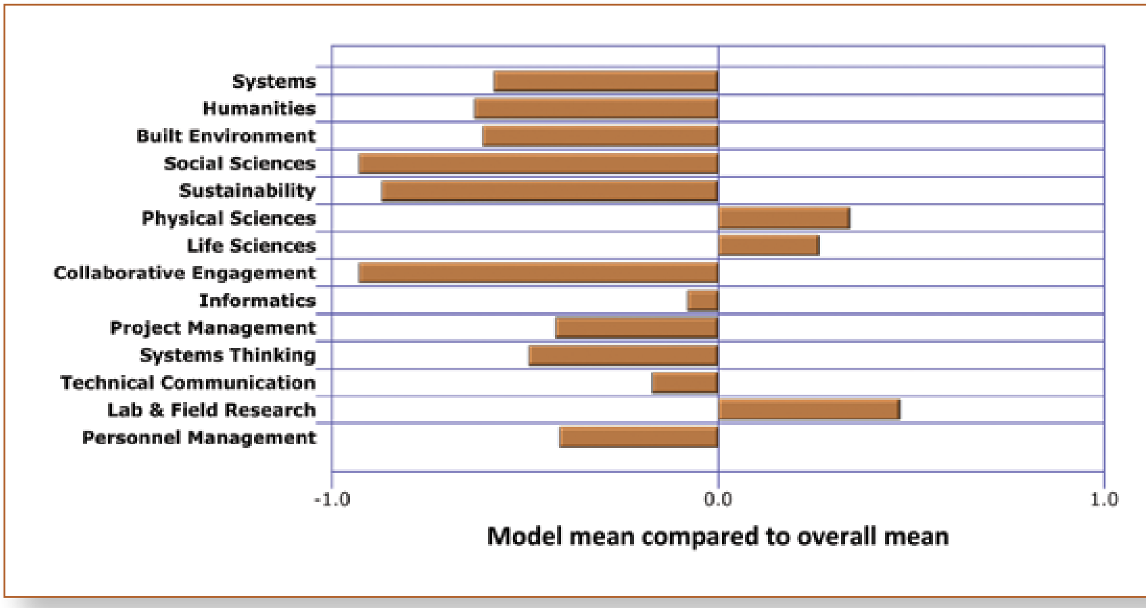
Curriculum model	Rapid growth (n=45)	Growth (n=85)	Steady (n=65)	Decline (n=8)
Sustainability Solutions Emphasis	26%	42%	26%	5%
Social Systems Emphasis	27%	39%	34%	0%
Natural Systems Emphasis	14%	43%	37%	6%

The Natural Systems Emphasis Model

The *Natural Systems Emphasis* approach to curriculum design emphasizes knowledge of the natural sciences and technical research and analysis centered on laboratory and fieldwork skills. It has an analytic orientation that emphasizes traditional scientific skills and expertise in the natural sciences. *Natural Systems Emphasis* aligned programs prepare students to conduct interdisciplinary analyses to develop understanding of the complexity of ecosystems and the biosphere, anthropogenic stressors, and the interactions of social and natural systems.

This model places highest emphasis on the *Laboratory and Field Research* skills and *Physical and Life Sciences* knowledge (Figure 8). Compared with the other two models, it places much lower emphasis on most of the other knowledge and skills components—especially *Collaborative Engagement* skills, *Social Sciences,* and *Sustainability*. The emphases on *Informatics* and *Technical Communication* skills are close to the mean for all degree programs.

Figure 8. Knowledge and skills component mean scores for Natural Systems Emphasis model



Degree programs associated with the *Natural Systems Emphasis* model are statistically:

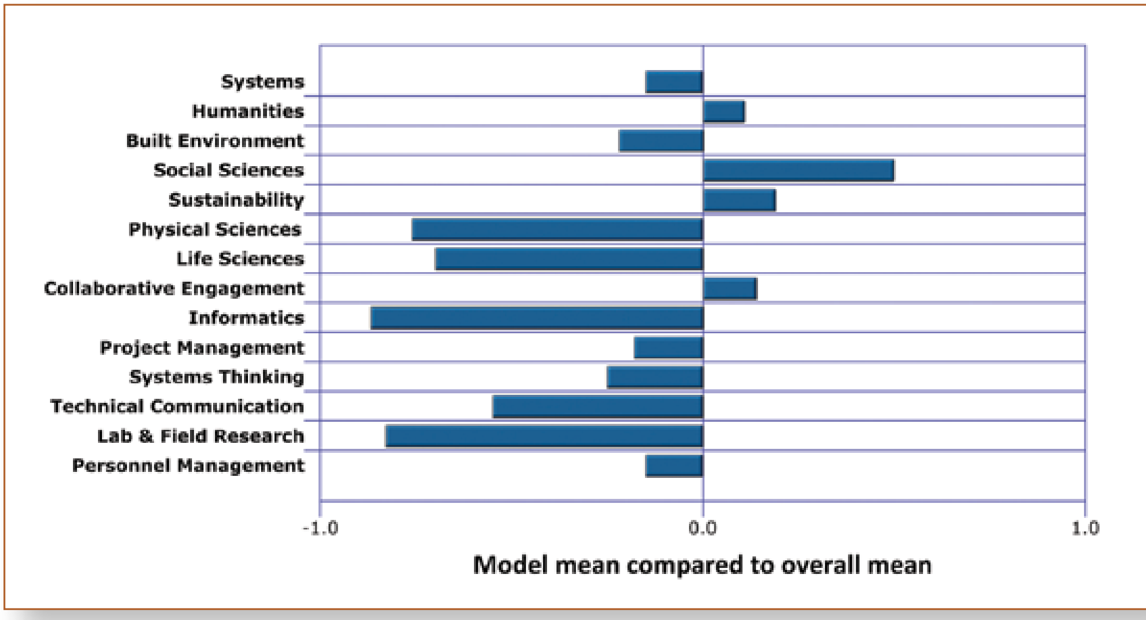
- Most likely (of the three models) to be named environmental science(s) or have another science-focused name.
- Most likely to be a Bachelor of Science program.
- Most likely to require participation in a field research course or equivalent experience.
- Least likely to require participation in an applied project (e.g. demonstration, community service, campus).
- Least likely to include study abroad as an option to meet requirements.

The Social Systems Emphasis Model

The *Social Systems Emphasis* approach to curriculum design emphasizes knowledge of the social sciences and collaborative engagement skills. The orientation for this model is societal and institutional change with a focus on public awareness and an emphasis on economics, policy and governance processes. *Social Systems Emphasis* programs prepare students to understand how political institutions, societal and industrial processes, and individual choices contribute to practices that can either threaten or create resilient and sustainable human-nature interfaces.

This model places highest emphasis on the *Social Sciences* knowledge component and the *Collaborative Engagement* skills component (Figure 9). Compared with the other two models, it places much lower emphasis on *Physical and Life Science* knowledge and on *Informatics, Technical Communication* and *Laboratory and Field Research skills.* In general, this model is the opposite of the *Natural Systems Emphasis* model.

Figure 9. Knowledge and skills component mean scores for Social Systems Emphasis model



Degree programs associated with the *Social Systems Emphasis* model are statistically:

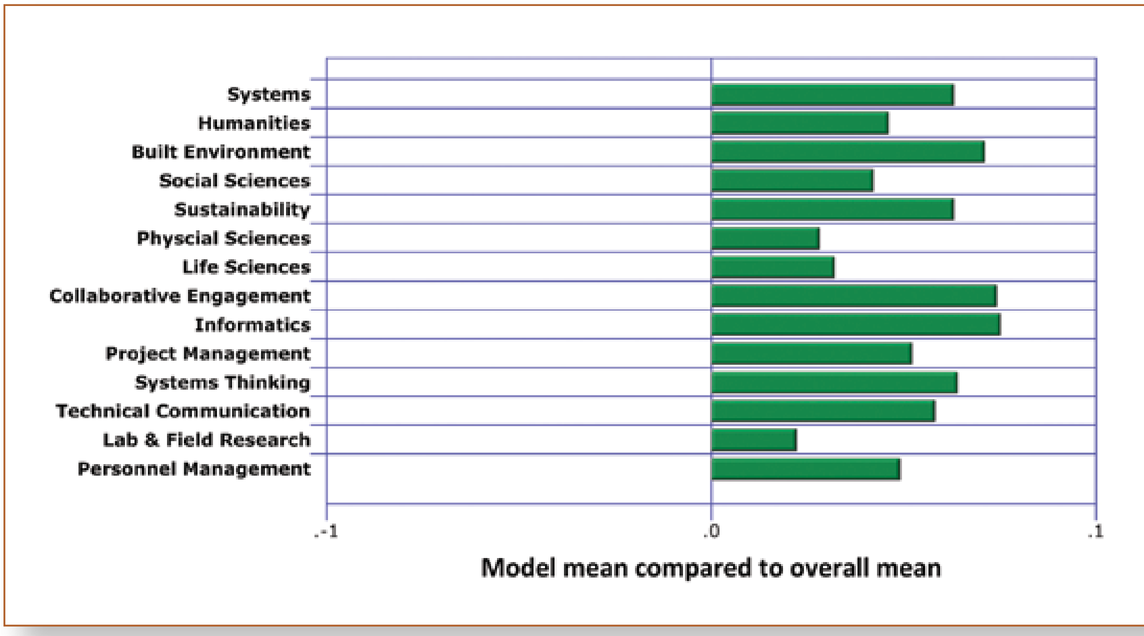
- Most likely to be named environmental studies(s) or have sustainability or policy in the degree name. Most of the degree programs with sustainability in their name are aligned with this model, although the emphasis on the sustainability component is lower than the emphasis in the *Sustainability Solutions Emphasis* model. The two models have different mean rating scores on the individual sustainability knowledge areas reflecting differing levels of importance placed on the various aspects of sustainability (see Appendix C).
- Most likely to be a Bachelor of Arts program.
- Least likely to require participation in a field research course or equivalent experience.
- More likely to require participation in an applied project (e.g. demonstration, community service, campus).
- Most likely to include study abroad as an option to meet requirements.

The Sustainability Solutions Emphasis Model

The *Sustainability Solutions Emphasis* approach to curriculum design emphasizes a systems-oriented approach that encompasses a broad range of knowledge and skills. This approach has an orientation that emphasizes solutions development through collaborative engagement processes and informatics. *Sustainability Solutions Emphasis* programs prepare students to solve complex environmental problems using integrated processes that directly inform policy and management decisions to effectively manage human-natural systems interfaces.

This model places highest emphasis on *Systems, Built Environment,* and *Sustainability* knowledge and *Collaborative Engagement, Informatics,* and *Systems Thinking* skills (Figure 10). It emphasizes a broader range of skills that the other two models, including *Project* and *Personnel Management* skills. This model shares some characteristics with both the other models but adds additional emphasis on systems understanding and collaborative solutions development. This model also places higher importance on the humanities than the other two models, acknowledging the crucial role of culture and cultural adaptation in transforming social systems.

Figure 10. Knowledge and skills component mean scores for Sustainability Solutions Emphasis model



Degree programs associated with the *Sustainability Solutions Emphasis* model are statistically:

- Most diverse in their names. There are relatively equal proportions of programs named environmental science(s) and environmental studies in this group. About a fifth of the programs with sustainability in their names and most of the programs with natural resources in their names are also aligned with this model.
- The degree programs aligned with this model are 40% BA/60% BS, a more balanced distribution than the other two models where almost all programs were either a BS (*Natural Systems Emphasis*) or a BA (*Social Systems Emphasis*).
- Most likely to require students to participate in an applied project (e.g. demonstration, community service, campus).
- Similar to the *Natural Systems Emphasis* model in more likely to require a field research course or equivalent.
- Similar to the *Social Systems Emphasis* model in more likely to include study abroad as an option to meet requirements.

Graduate Knowledge and Skills Components in Ideal Curricula

Interdisciplinary Knowledge Components

Factor analysis of the ratings of the 41 knowledge areas for graduate IES programs revealed eight interdisciplinary knowledge components labeled *Green Design, Natural Sciences, Governance and Policy,* *Humanities, Natural Resources, Sustainability, Business,* and *Ecology*. Each component represents a dimension of IES knowledge and is characterized by significant correlations with a subset of the 41 knowledge variables with each variable aligned with the component to varying extents. The names of the components are based on the knowledge areas significantly correlated with the component and the magnitude of the correlations. For example, the *Sustainability* component includes concepts from three knowledge areas—environmental sustainability, sustainability concepts and social sustainability—with environmental sustainability the most highly correlated with this component (Table 7).[11]

Tables 7 and 8 illustrate the relationships among the original 41 knowledge variables and the eight interdisciplinary IES knowledge components, and the interrelationships among the eight components. The center column in Table 7 lists the eight interdisciplinary knowledge components. The right column lists the knowledge areas significantly correlated with each component and the magnitude of the correlations. The left column illustrates that the *Green Design, Governance and Policy, Humanities, Natural Resources,* and *Sustainability* components are highly correlated with each other (≥.4) forming a unified interdisciplinary knowledge group labeled *Sustainable Systems. Business* is also included in this group because it is moderately correlated with four of the five components (all but *Governance and Policy*). The *Natural Sciences* component is only moderately correlated with one component—*Green Design*; the *Ecology* component isn't significantly correlated with any other component. These two components form a distinct knowledge area labeled *Natural Sciences.* Table 8 shows the relationships (correlations) between the eight components in ideal IES graduate curricula. Figure 11 illustrates the correlations between the eight components to form a knowledge model for ideal graduate curricula design (solid lines connecting the components indicate a stronger correlation, dotted lines a weaker but still significant correlation).

The *Green Design* component accounts for 32% of the explained variance; this component best explains (predicts/distinguishes) how program administrators' importance ratings fall into the eight components of interdisciplinary IES knowledge. The second component, *Natural Sciences,* accounts for 13%. The other six components account for only small proportions (<10% each) and therefore are less important in distinguishing differences among graduate IES degree curricula. Two knowledge variables were not significantly correlated with any of the eight components—systems analysis and sustainability science—indicating that these knowledge areas may be cross-cutting across graduate IES curricula or are distinct knowledge focal areas.

Although graduate IES programs emphasize, combine and incorporate the eight interdisciplinary knowledge components into their courses and curriculum designs in myriad ways, the knowledge model provides a shared framework for understanding how these components are structured in ideal graduate IES degree curricula (Figure 11). All but three of the knowledge areas included in the survey had mean ratings of low, moderate or high importance in ideal IES graduate curricula (see Appendix D). Averaging the mean ratings of the knowledge areas correlated with each interdisciplinary knowledge component indicates that six of the eight are of moderate to high mean importance (*Sustainability, Ecology, Governance and Policy*, *Business, Natural Sciences,* and *Natural Resources*) and two are of low mean importance (*Green Design* and *Humanities*) in ideal IES graduate curricula overall (but not necessarily in specific degree programs).

11. The eight component IES knowledge model is robust; all but two of the 41 knowledge variables—systems analysis and sustainability science—are significantly correlated with at least one knowledge component, the total variance explained was 71%, the goodness-of-fit test of the model was highly significant at p>.000, and Cronbach's alpha scores confirm the reliability of the composition of each component (KMO=.8; Bartlett test sig.=.000).

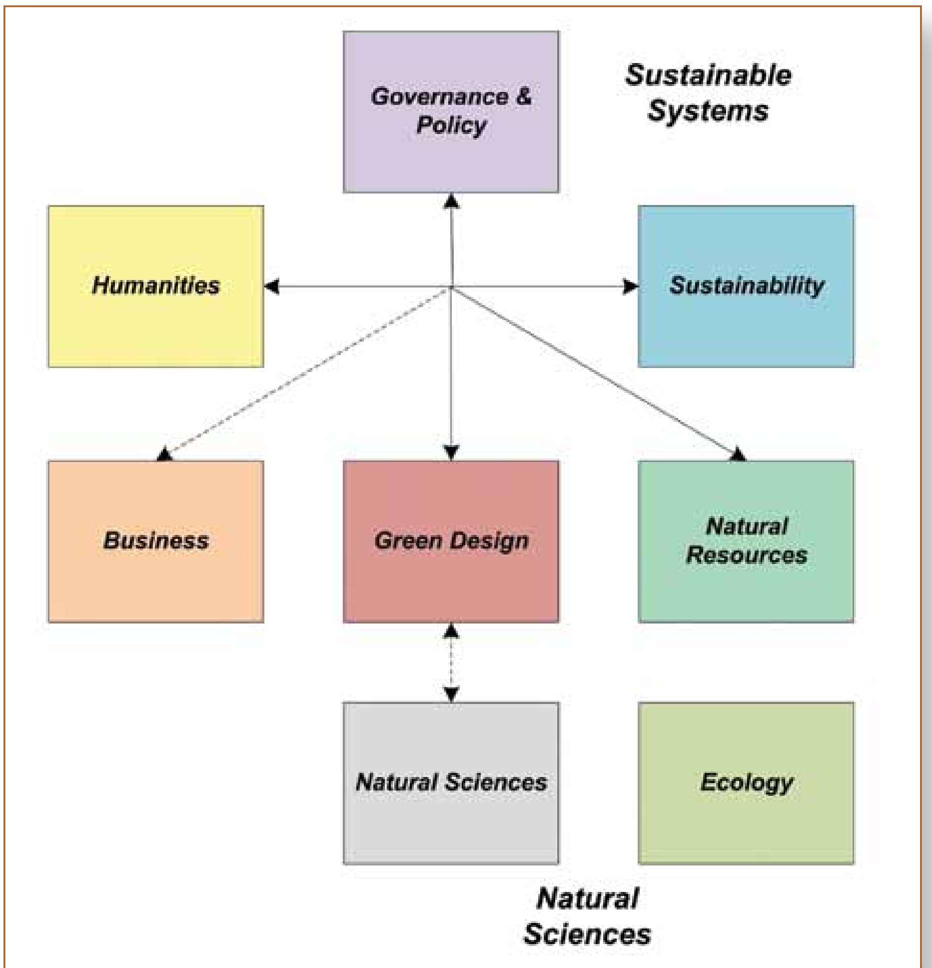
Table 7. Graduate IES interdisciplinary knowledge components

Combined IES knowledge group	IES knowledge component	Knowledge area (correlation with component)
Sustainable Systems	Green Design	green materials design (.905) waste (.824) human health (.798) architecture (.793) planning & built environment (.671) energy systems (.583) business (.536) engineering & technology (.482) water systems (.368) food systems (.333)
	Governance and Policy	political sciences (.889) sustainability governance (.688) economics (.674) policy & public administration (.668) behavioral social sciences (.560) human health (.511) environmental justice (.417) social sustainability (.390) business/economic sustainability (.374)
	Humanities	arts & aesthetics (.917) literature (.842) religion (.773) language arts (.708) philosophy & ethics (.603) history (.571) education (.400)
	Natural Resources	geography (.762) natural resources management (.716) agriculture (.643) ecology (.499) research design & ethics (.451) education (.407) geosciences (.363) climate change (.338) planning & built environment (.331)
	Sustainability	environmental sustainability (.835) sustainability concepts (.696) social sustainability (.500)
	Business	business (.448) business/economic sustainability (.394) climate change (.375) energy systems (.324)
Natural Sciences	Natural Sciences	chemistry (.931) physics (.905) biology (.745) other physical sciences (.690) other life sciences (.633) geosciences (.597) engineering & technology (.474)
	Ecology	ecology (.448) biology (.338)

Table 8. Graduate IES interdisciplinary knowledge components correlation matrix

Knowledge component	Green Design	Natural Sciences	Governance and Policy	Humanities	Natural Resources	Sustain-ability	Business	Ecology
Green Design	1.000	.284	.431	.500	.491	.519	.260	-.106
Natural Sciences		1.000	-.238	.039	.207	-.006	.119	.136
Governance and Policy			1.000	.416	.498	.455	.227	-.091
Humanities				1.000	.450	.266	.253	-.019
Natural Resources					1.000	.425	.308	-.004
Sustainability						1.000	.263	-.057
Business							1.000	.198
Ecology								1.000

Figure 11. Graduate IES interdisciplinary knowledge model



The graduate knowledge component correlation model reveals a structure similar to that of the undergraduate model—a *Sustainable Systems* focus on the interconnections of coupled natural and human systems defined and influenced by green design and manufacturing, governance and policy processes, the humanities, human behavior, cultural milieus, natural resources management and sustainability-oriented business practices. The *Natural Sciences* also form a distinct knowledge area only weakly associated with the *Sustainable Systems* knowledge group. The graduate model differs from the undergraduate model in that a focus on *Green Design* is the most important factor distinguishing graduate programs from each other, followed by the *Natural Sciences*.

The *Ecology* component isn't significantly correlated with the other knowledge components indicating it forms a distinct knowledge focal area. However, ecology is also correlated with the *Natural Resources* component and is thus part of the *Sustainable Systems* knowledge group. Ecology, natural resources management, sustainability concepts, environmental sustainability, and climate change are the knowledge areas with the highest mean importance ratings for IES graduate programs. Previous studies indicate that the natural sciences and ecology are viewed as foundational knowledge for all IES programs.

Integrated Skills Components

Factor analysis of the ratings of the 38 skills areas for graduate IES programs discovered eight integrated skills components labeled *Project Management, Analysis, Public Communication, Anticipatory Thinking, Social Research, Literature Research, Interdisciplinary Communication* and *Field Research.* Similar to the knowledge components, each IES skills component is also an amalgam of various skills that correlate with the component to various extents. For example, *Social Research* includes three skills—social research, normative thinking and cultural competence—with social research skills the most highly correlated with this component (Table 9).[12]

Tables 9 and 10 illustrate the relationships among the original 38 skills variables and the eight integrated IES skills components, and the interrelationships among the eight components. The center column in Table 9 lists the eight integrated skills components. The right column lists the skills areas significantly correlated with each component and the magnitude of the correlations. The left column illustrates that the *Project Management, Public Communication, Anticipatory Thinking, Social Research, Interdisciplinary Communication,* and *Literature Research* components are inter-correlated (≥.3 correlation with more than one other component) to create an integrated skills group labeled *Solutions Development*. The *Analysis* and *Field Research* components are moderately correlated with each other forming a distinct *Research & Analysis* skills group. Table 10 shows the relationships (correlations) between the eight components in ideal IES curricula. Figure 12 illustrates the correlations between the eight components to form a skills model for ideal graduate curricula design (solid lines connecting the components indicate a stronger correlation, dotted lines a weaker but still significant correlation).

The *Project Management* component accounts for 27% of the explained variance; this component best explains (predicts/distinguishes) how program administrators' importance ratings fall into the

12. The eight component IES skills model is robust; all but one of the 38 skills variables—archival research—are significantly correlated with at least one skills component, the total variance explained was 68%, the goodness-of-fit test of the model was highly significant at p>.000, and Cronbach's alpha scores confirm the reliability of the composition of each component (KMO= .8; Bartlett test sig.=.000).

eight components of integrated IES skills. The second component, *Analysis*, accounts for 14%. The other six components each account for only small proportions (<10%) and therefore are less important in distinguishing among graduate IES degree curricula. One skills variable was not significantly correlated with any of the eight components—archival research—indicating that it may be cross-cutting across graduate IES curricula or a distinct skill.

Although graduate IES programs emphasize, combine and incorporate the eight integrated skills components into their courses and curriculum designs in myriad ways, the skills model provides a shared framework for understanding how these components are structured in ideal graduate IES degree curricula (Figure 12). All of the skills included in the survey had mean ratings of low, moderate or high importance in ideal IES graduate curricula (see Appendix D). Averaging the mean ratings of the skills correlated with each integrated skills component indicates that all eight are of moderate to high mean importance in ideal IES graduate curricula (*Interdisciplinary Communication, Anticipatory Thinking, Literature Research* and *Field Research* are highest, followed by *Social Research, Analysis, Public Communication,* and *Project Management*).

Analysis of the graduate skills factor model reveals a two part model. The first skills group is focused on solutions development centered on project management informed by social and literature research and engaged with the public and various experts and stakeholders via interdisciplinary/intercultural communication. The second group is focused on research skills centered on field research coupled with laboratory, analytical and modeling skills.

The 2008 knowledge and skills models were based on combined undergraduate and graduate programs data as analysis of both groups revealed very similar factor structures and cluster structures. The 2012 survey and analysis included more knowledge variables (41 versus 16) and more skills variables (38 versus 23). The number of graduate programs included in the new survey is also greater and comprises a larger proportion of the total degree programs. The new analyses reveal distinctive factor and cluster structures for undergraduate and graduate programs, and therefore results are reported separately.

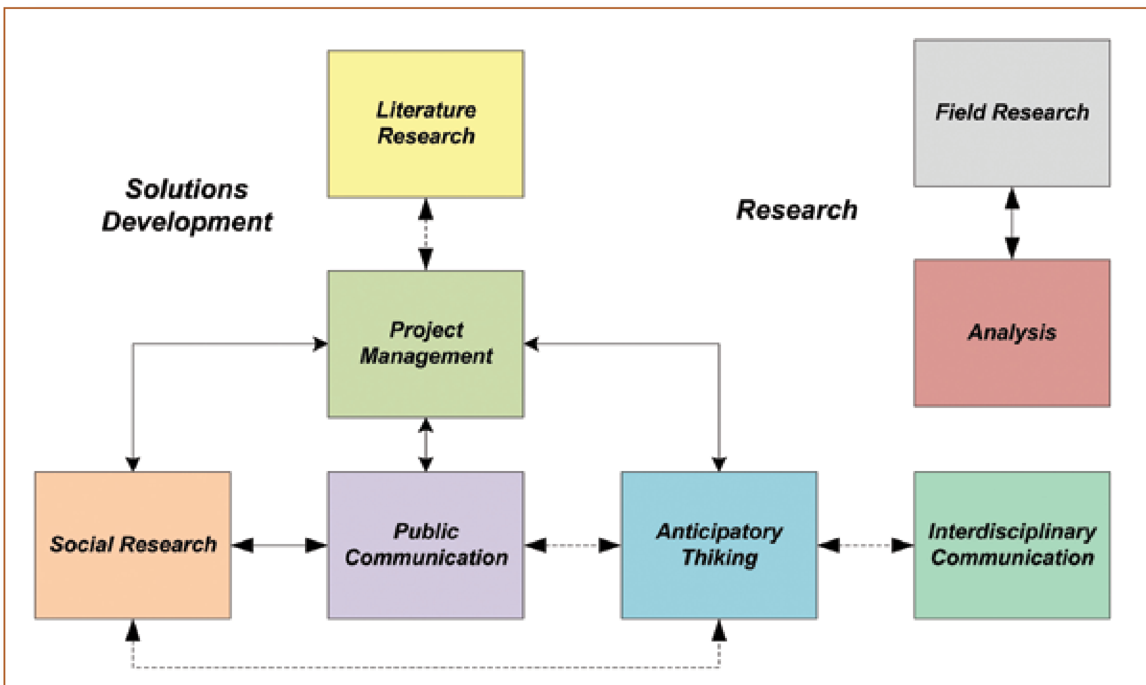
Table 9. Graduate IES integrated IES skills components

Combined IES skills group	IES skills component	Skills (correlation with component)
Solutions Development	Project Management	planning & reporting (.809) personnel management (.803) project management (.775) assessment & reporting (.694) collaborative decision making (.664) organizational learning/development (.561) conflict resolution (.486) teamwork (.347) advocacy & outreach (.323) community engagement (.360)
	Social Research	social research (.910) normative thinking (.724) cultural competence (.572)
	Public Communication	media communication (.861) internet communication (.786) creative & journalistic writing (.688) interdisciplinary/intercultural communication (.561) creativity (.530)
	Anticipatory Thinking	anticipatory thinking (.699) problem solving (.699) creativity (.634) critical thinking (.564) strategic thinking (.535) analysis (.530) information literacy (.488) normative thinking (.449) synthesis (.405)
	Interdisciplinary Communication	interdisciplinary/intercultural communication (.540) oral communication (.486) spatial analysis (.430) problem solving (.375) technical & academic writing (.371) statistics (.337)
	Literature Research	literature research (.531) critical thinking (.436) teamwork (.382) analysis (.354) leadership (.332)
Research & Analysis	Analysis	information management (.793) mathematics (.770) computer programming (.707) decision science (.640) statistics (.544) laboratory research (.488) technical & academic writing (.418) media communication (.341)
	Field Research	field research (1.013) laboratory research (.469)

Table 10. Graduate IES skills components correlation matrix

Skills component	Project Management	Analysis	Public Communication	Anticipatory Thinking	Social Research	Literature Research	Interdisciplinary Communication	Field Research
Project Management	1.000	.077	.547	.348	.618	.248	.179	-.093
Analysis		1.000	-.020	.237	-.246	.047	.152	.440
Public Communication			1.000	.271	.583	.138	.045	-.137
Anticipatory Thinking				1.000	.320	.116	.266	.129
Social Research					1.000	.228	.093	-.281
Literature Research						1.000	.227	-.074
Interdisciplinary Communication							1.000	.237
Field Research								1.000

Figure 12. Graduate IES interdisciplinary skills model



Analysis of the graduate skills factor model reveals a two part model. The first skills group is focused on solutions development, centered on project management that is informed by social and literature research, and engaged with the public and various experts and stakeholders via interdisciplinary/intercultural communication. The second group is focused on research skills, centered on field research coupled with laboratory, analytical and modeling skills. The lack of strong correlations between the *Research* components and the *Solutions Development* components indicates these skills form a distinct skills focal area.

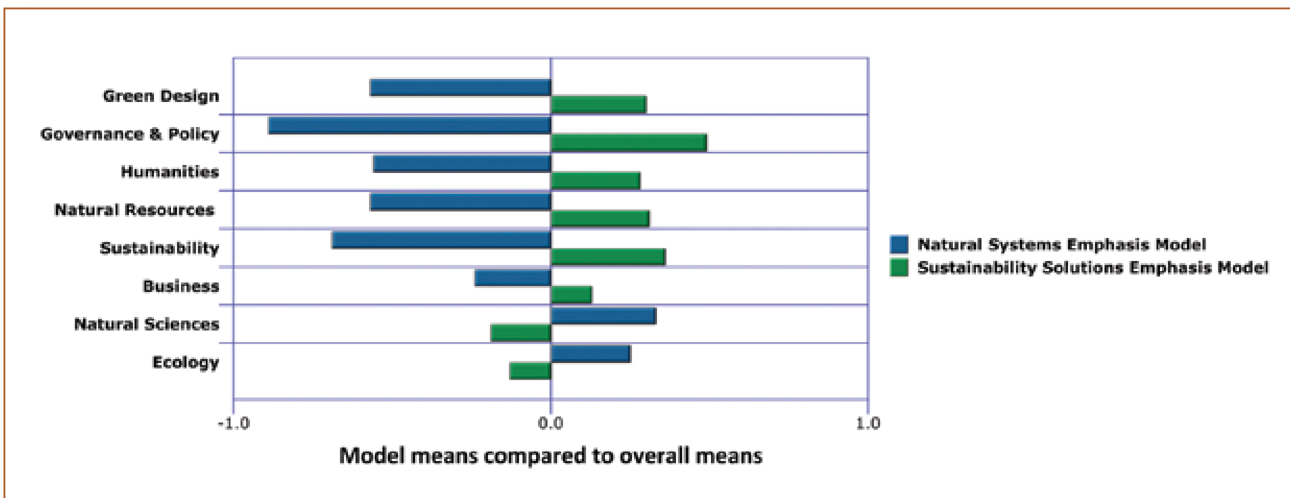
Graduate Models for Curriculum Design

The ideal models for IES graduate programs were determined from a cluster analysis of the eight knowledge and eight skills component scores (derived from the ratings of the 41 knowledge and 38 skills areas). The analysis revealed two ideal approaches or models for graduate IES education.

The two models are labeled *Natural Systems Emphasis* and *Sustainability Solutions Emphasis* based on the knowledge and skills components each emphasizes. Each model emphasizes different knowledge and skills components to prepare graduates for different types of sustainability-oriented problem solving. The models are characterized by their mean component scores and by the degree types aligned with each model. All of the MA degree programs are aligned with the *Sustainability Solutions Emphasis* model as well as three-fourths of the professional master's degrees. All degree programs named environmental studies or that include sustainability, policy, humanities or social science in their names are aligned with the *Sustainability Solutions Emphasis* model, as well as almost all of the degree programs that include the terms energy, policy, management, natural resources, water/watersheds, and systems in their names. Environmental science(s) programs are relatively evenly split among the two models. Most degree programs with the terms engineering, marine/coastal, and earth/geosciences in their names are aligned with the *Natural Systems Emphasis* model.

The two approaches represent the views of groups of program administrators that rate the ideal curricular components—the eight interdisciplinary knowledge components and the eight integrated skills components—in similar ways. Figures 13 and 14 illustrate how the mean importance ratings for each of the two ideal approaches—*Natural Systems Emphasis* and *Sustainability Solutions Emphasis*—differ from the overall mean for all IES graduate programs and from each other.[13]

Figure 13. Graduate IES knowledge component means by curriculum model



13. The bars illustrate the mean factor scores for each of the components (factors) of the groups of programs aligned with the three approaches and their relationship to the mean factor score for all IES programs included in the survey which = 0.

Figure 14. Graduate IES skill component means by curriculum model

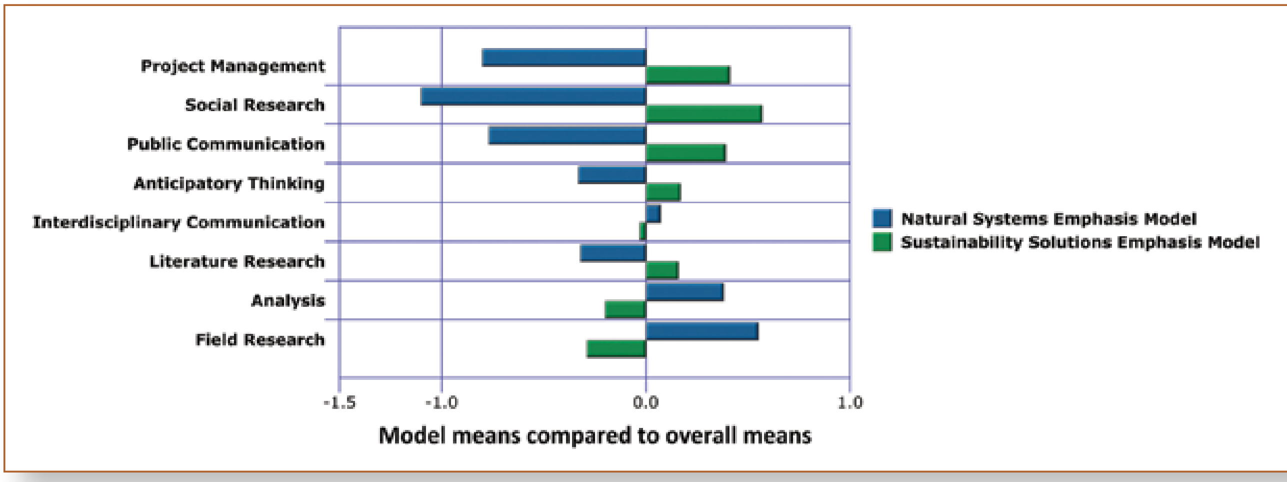
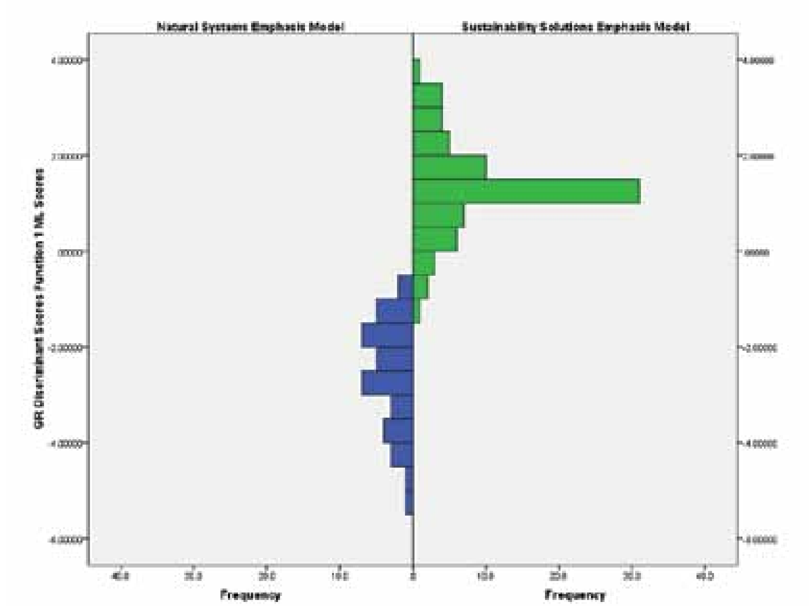


Figure 15 illustrates how the graduate IES degree programs included in the survey aligned with the two models and the relationships between the models based on dimension that discriminates among the two groups (the discriminant analysis is discussed below).

Figure 15. Graduate IES degree programs plotted on discriminating dimension



Discriminant analysis revealed one significant function that explains the differences between the two models.[14] Standardized correlation coefficients reveal that twelve of the sixteen knowledge and

14. The discriminant analysis is robust; the Box's M test sig.=.000 and 97% of the cases were correctly classified.

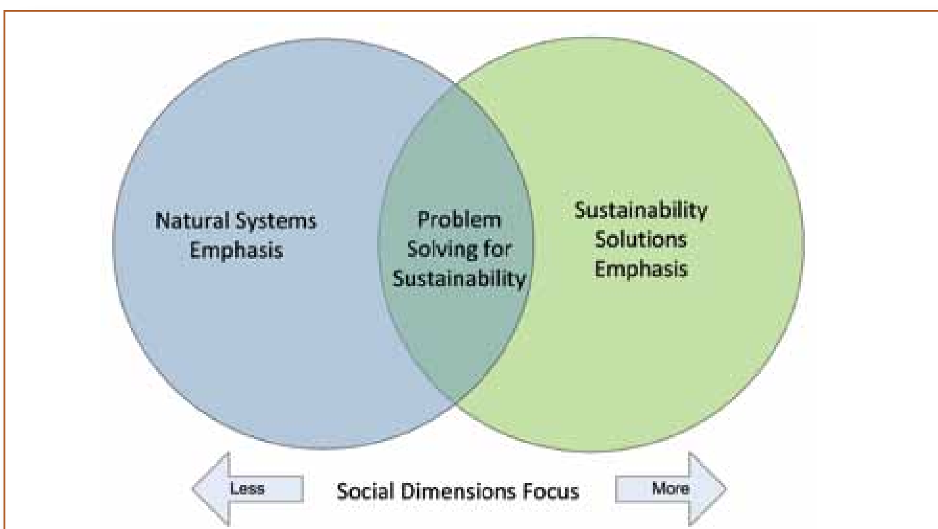
skills components are positively correlated with the function while the remaining four are negatively correlated (Table 11). The function is characterized by strong positive correlations (≥.3) with three skills components—*Social Research, Project Management,* and *Public Communication*—and two knowledge components—*Governance and Policy* and *Sustainability*. Based on these relationships the dimension is given the descriptive label *Social Dimensions*.

Table 11. Graduate discriminant analysis correlation coefficients

Knowledge/Skills Component	Social Dimensions Focus
Social Research Skills	.761
Governance & Policy Knowledge	.526
Project Management Skills	.402
Public Communication Skills	.378
Sustainability Knowledge	.331
Natural Resources Management Knowledge	.261
Green Design Knowledge	.248
Humanities Knowledge	.245
Literature Research Skills	.145
Anticipatory Thinking	.140
Ecology	.122
Business	.106
Interdisciplinary Communication	-.029
Natural Sciences	-.140
Analysis Skills	-.160
Field Research Skills	-.236

Figure 16 illustrates a unified framework for understanding graduate IES programs in the United States based on the cluster and discriminate analyses. The two models are not opposed to each other; instead they overlap so that some graduate IES programs are situated on the boundaries of the two models.

Figure 16. A framework for understanding graduate IES programs in the U. S.



The popularity of the two models differ markedly—the *Sustainability Solutions Emphasis* model comprises two-thirds (66%) of the graduate programs included in the survey and the *Natural Systems Emphasis* model one third (34%). The two models are similar in enrollment trends (Table 12). Degree programs aligned with the *Sustainability Solutions Emphasis* model are slightly more likely to report a growth trend but are also more likely to report a decline trend while programs aligned with the *Natural Systems Emphasis* model tend to report stable enrollment.

Table 12. Graduate IES curriculum models and enrollment trends

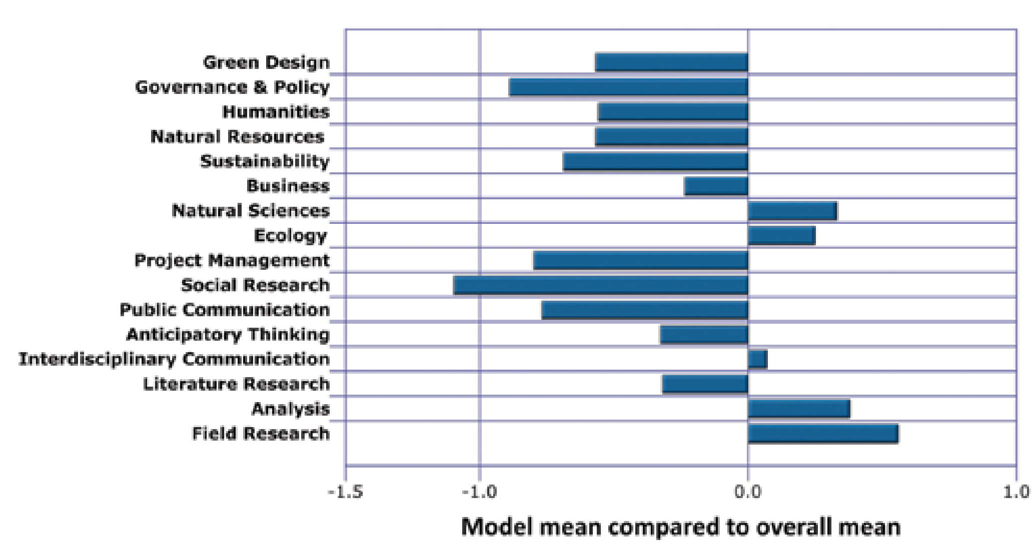
Curriculum model	Rapid growth (n=2)	Growth (n=24)	Steady (n=59)	Decline (n=10)
Natural Systems Emphasis Model	0%	23%	70%	7%
Sustainability Solutions Emphasis Model	3%	26%	59%	12%

The Natural Systems Emphasis Model

The *Natural Systems Emphasis* approach to curriculum design emphasizes knowledge of the natural sciences and technical research and analysis centered on fieldwork. It has an analytic orientation that emphasizes traditional scientific skills and expertise in the natural sciences. *Natural Systems Emphasis* aligned programs prepare students to conduct interdisciplinary analyses to develop understanding of the complexity of coupled human-nature systems.

This model places emphasis on *Natural Sciences* knowledge and *Field Research* and *Analysis* skills (Figure 17). Compared with the *Sustainability Solutions Emphasis* model, it places much lower emphasis on most other knowledge and skills components—especially *Governance and Policy* and *Sustainability* knowledge and *Social Research, Project Management,* and *Public Communication* skills.

Figure 17. Knowledge and skills component mean scores for Natural Systems Emphasis model



Degree programs associated with the *Natural Systems Emphasis* model are statistically:

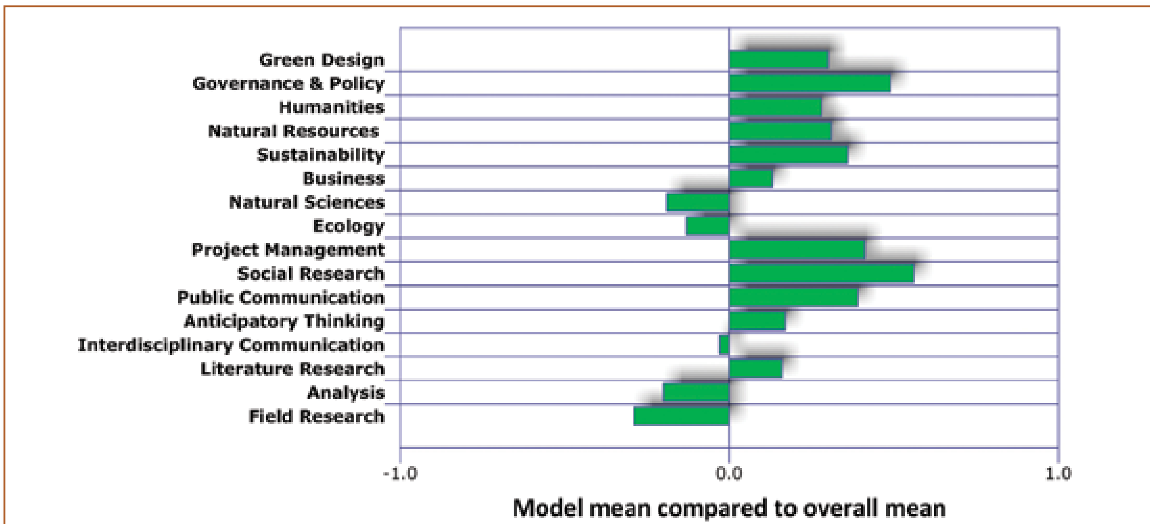
- More likely to include programs focused on marine/coastal systems, geosciences, and engineering—almost all of the degree programs in these categories are aligned with this model. About half of the environmental science(s) programs are aligned with this group.
- Less likely to be a professional master's or MA. The degree types are 34% doctoral, 58% MS, 0% MA and 8% professional master's programs.

The Sustainability Solutions Emphasis Model

The *Sustainability Solutions Emphasis* approach emphasizes social systems, natural resources and sustainability knowledge and solutions development skills that engage stakeholders. This approach has a professional orientation that emphasizes development of solutions through collaborative decision making processes (for example the development of watershed management plans, or the implementation of environmental management systems in private and public sector entities). *Sustainability Solutions Emphasis* programs prepare students to solve complex environmental problems using integrated processes that directly inform policy and management decisions to effectively manage human-natural systems interfaces. These processes are ideally iterative; management plans and policies are regularly assessed and adapted based on results, new knowledge and technical advances.

This model places highest emphasis knowledge of *Governance and Policy* knowledge and *Social Research* skills (Figure 18). This curriculum model is focused on a broader range of knowledge and skills than the *Natural Systems Emphasis* model.

Figure 18. Knowledge and skills component mean scores for Sustainability Solutions Emphasis model



Degree programs associated with the *Sustainability Solutions Emphasis* model are statistically:

- More likely to include programs focused on environmental studies, sustainability, energy, water, policy, management, natural resources, systems or social sciences/humanities. Half of the environmental science(s) programs are aligned with this model.
- The degree types are 23% doctoral, 43% MS, 18% MA and 16% professional master's programs.

Conclusion

The IES academic field and workforce have developed in response to the evolving environmental movement and its influence on the sociopolitical and economic milieus of the United States and other developed and developing countries. Sherburne Abbott, the Associate Director for Environment and Energy in the federal Office of Science and Technology Policy, has identified five waves of the environmental movement that have influenced IES academic programs and workforce needs: (1) the preservation movement 1850-1890, (2) the natural resources management movement 1890-1950, (3) the ecological movement 1950-1970, (4) the regulatory movement 1970-1990, and (5) the sustainability movement 1990-present.

The knowledge and skills competencies and the models for ideal curriculum design described in this report mirror these influences—the preservation of natural resources and ecosystems through understanding of natural systems and anthropogenic perturbations, the critical role of policy, governance, behavior and culture in advancing or hindering environmental and sustainability goals, and the understanding that achieving sustainability is a "systems challenge that cannot be addressed by separately optimizing pieces of the system." Success involves "engaging stakeholders throughout the process; integrating environmental, economic and social dimensions; using a strong science base and processes that link science and decision making; and researching stakeholder agreement on the nature of important connections."[15]

An analysis by Brand and Karvonen (2007) argues that an "ecosystem of expertise" is needed to effectively develop, implement, and manage sustainability projects. This expertise should include: (1) an "outreach expert who communicates effectively to non-experts," (2) an "interdisciplinary expert who understands the overlaps of neighboring disciplines," (3) a "meta-expert who brokers the multiple claims of relevance between different forms of expertise," and (4) a "civic expert who engages in democratic discourse with experts and non-experts".[16] These forms of expertise align well with IES programs' ideal approaches to curriculum design: *Natural Systems Emphasis* (interdisciplinary expert), *Social Systems Emphasis* (outreach expert and civic expert), and *Sustainability Solutions Emphasis* (meta-expert). Humanities-focused programs (a subset within the *Social Systems Emphasis* model) bring awareness to civil society and help shape cultures that support positive change (outreach expert and civil expert).

Diversity is an important strength of IES programs, but it is important to clearly delineate how these programs differ from other disciplines and professional fields and to define their role in academia, society and the national workforce. The NCSE's research program provides a framework for understanding the diversity of IES programs and clearly differentiates the competencies of IES graduates from the competencies of graduates of other programs.

15. National Academy of Sciences 2013. *Sustainability for the Nation: Resource Connection and Governance Linkages.* National Academy Press: Washington DC.

16. Brand, R., and A. Karvonen. 2007. The Ecosystem of Expertise: Complementary Knowledges for Sustainable Development. Sustainability: *Science, Practice & Policy* 3(1): 21-31.

Appendix A – Methodology

Acknowledgements

The NCSE research conducts relies on the time and efforts of the environmental, sustainability, energy and related programs' leaders who participate. Their contributions are greatly appreciated.

Methodology

The ongoing NCSE education research program addresses four broad research questions designed to inform and facilitate discussion on IES program field identity and essential knowledge and skills:

1. What are the perspectives among IES program leaders regarding curriculum design? What do they have in common and how do they differ?

2. What dimensions underlie the inclusion of various knowledge and skill areas in IES program curricula? How are these areas related and how may they be combined into interdisciplinary knowledge and skills areas?

3. What types of ideal curriculum models of IES program curricula exist? What are the characteristics of each model?

4. How are administrative and degree program attributes related to ideal curriculum types? What do these relationships indicate concerning program structure and evolution?

A combination of social sciences qualitative and quantitative statistical methods was used to answer these questions including: qualitative emergent theme analysis, Q methodology, multiple regression, maximum likelihood factor analysis, principal components analysis, SPSS two-step cluster analysis, Ward's cluster analysis, discriminant analysis, analysis of variance (ANOVA) and Kruskal Wallis analysis of variance by ranks (KWANOVA). Kruskal-Wallis is a non-parametric test of the difference in the shape or location (central tendency) of the populations underlying two or more groups.

The research program has conducted three phases of research: (1) an initial survey and Q methodology analysis with a sample comprised of 61 Council of Environmental Deans and Directors (CEDD) members completed in 2008, and (2) a nationwide census, survey and analysis with a sample of 291 respondents representing IES programs awarding 343 degrees completed in 2008, and (3) a nationwide census, survey and analysis with a sample of 262 respondents representing IES programs awarding 354 degrees completed in 2012.

Phase I. The first phase of the curriculum study sought to answer the first research question about the number of perspectives on environmental program curriculum design that program administrators hold, how these perspectives differ, and what they have in common.

Q methodology is a technique for systematically revealing subjects' perspectives and has been widely used as a research tool for empirically determining the perspectives of participants in a variety of processes. It can be used to identify various viewpoints and perceptions about a particular situation, provide insight into the attributes of each perspective, explicitly outline areas of consensus and conflict, and assist in developing a common view. This method was used to discern the various perspectives regarding environmental program curriculum design held by the administrators of IES programs at institutions that participate in CEDD.

The Q methodology study was conducted in three steps: (1) an online survey to obtain opinions on curricular design and program characteristics, (2) an online Q sorting exercise to ascertain perspectives on curricular design and to access conflicts and characterize the nature of debate, and (3) data analysis to investigate relationships between the perspectives and program attributes (multiple regression, descriptive statistics).

Q Study Sample. This first phase of the study was conducted in 2003 with volunteer participants from the CEDD membership who identified themselves as administrators of IES programs (see Appendix A for the list of participating institutions). Respondents included 61 CEDD members representing IES programs at 57 institutions of higher education. A subset of the respondents—44 CEDD members representing 42 institutions—participated in the Q sorting exercise.

The representativeness of the sample was compared using proportions for the Q survey sample data and the census IES program data collected in preparation for the national survey at α=.05 (two tailed test). Four parameters were tested: institution control (public or private-not-for-profit), institution basic Carnegie class, institution U. S. census division, and program degree type (name/level). The sample was found to be representative for all four parameters.

Phases II and III. The second and third phases of the research are designed to answer the remaining three research questions: (1) the identity of the dimensions that underlies the inclusion of knowledge and skill areas in IES program curricula, (2) the number and characteristics of ideal curricular models for IES education; and (3) how administrative and degree program attributes may be related to the ideal curriculum types and what these relationships indicate concerning program structure and evolution.

These two phases were each conducted in three steps: (1) identification of all U. S. programs awarding baccalaureate and graduate level IES degrees, (2) an online survey to obtain IES program administrators' views on program structure and curriculum design, and (3) data analyses appropriate for each of the three research questions.

Several statistical methods were used to analyze the data gathered by the survey. First, descriptive statistics appropriate to each question were calculated and responses to the open-ended questions coded according to emergent themes. Second, exploratory factor analysis (maximum likelihood method) was used to determine the factors (dimensions) underlying the importance ratings of knowledge areas and skills in ideal program curricula. Third, principal component analysis followed by SPSS two-step method clustering was used to reveal groups of administrators who prefer similar ideal curricular models. Fourth, discriminant analysis was used to confirm the cluster solution and aid in interpretation of the results. Finally, two types of analysis of variance tests were used to explore relationships among ideal curriculum types, knowledge and skill factors, and other program and degree program features: one-way analysis of variance (ANOVA) for scale variable data and Kruskal-Wallis one-way analysis of variance by ranks (KWANOVA) for ordinal and categorical variable data. The significance level was set at α=.05 for all analyses.

National Survey Sample for 2012. The 2012 survey of U.S. interdisciplinary environmental program administrators was conducted during August-December 2012. Program administrators are the targeted respondents because they are expected to be most familiar with their programs and because many programs do not employ their own faculty, but instead rely on faculty from other academic units.

The survey was limited to U. S. baccalaureate and graduate degree-granting programs that focus on the human-nature interface from a broad interdisciplinary perspective. This population included all degree programs named environmental science(s) or environmental studies as well as degree programs with related names such as sustainability, environmental policy, environmental management, environmental systems, natural resources management, and energy. Programs that offer only associate degrees, minors/certificates, and professional degrees in allied fields such as environmental engineering, environmental law, environmental health and safety, environmental chemistry/toxicology, environmental geology/hydrology, conservation biology, sustainable agriculture, forestry/rangeland management, environmental economics, natural resource geography, and environmental statistics were not included.

Altogether, a total of 1,151 interdisciplinary environmental programs at 838 institutions awarding 1.859 degrees were identified as meeting the selection criteria.

Completed survey responses were received from administrators of 289 of the 1,151 programs awarding 354 degrees (see the list of participating institutions and units/programs in Appendix A). This sample was sufficient to measure correlations between attributes with a power of 0.90 to detect a 0.20 effect size at α=0.05; statistical frequencies have a margin of error of ±5%.

The representativeness of the sample was assessed by comparing four defining program attributes between the sample and target population at α=0.05: institution basic Carnegie class, institution control (public or private-not-for-profit), institution census division, and degree types (name/degree level). The sample was found to be representative for all four parameters.

Exploratory Factor Analysis. Exploratory (maximum likelihood) factor analysis was used to explore administrators' judgments of the importance (using a 4-point Likert scale from minimal, to low, to moderate, to high) of 41 knowledge areas and 38 skills in an ideal curriculum for each degree offered (these knowledge areas and skills were vetted by a number of experts). Factor analysis reduced the knowledge and skill ratings into a fewer number of groups of similarly rated sets. These factors represent potential broad interdisciplinary core competency areas and reveal how the disciplinary knowledge areas and skills are related to each other in idealized environmental program curricula.

Maximum likelihood factor extraction was used because it includes a statistical goodness-of-fit test and allows generalizations from an unbiased sample to a population of either subjects or variables. The validity of the factor structure and model is established by the maximum likelihood goodness-of-fit test and by testing the reliability of each factor using Cronbach's alpha reliability coefficient (value ≥ 0.7 indicates that the variables loading on the factor are sufficiently similar). Model goodness-of-fit tests for both the knowledge factor solution and skill factor solution are highly significant at p<.000; all of the factors were shown to be reliable.

Five criteria can be considered when determining the number of factors to retain for interpretation. All five criteria were evaluated. The popular Kaiser criterion was selected, which recommends retaining all factors with eigenvalues ≥ 1.

Factor rotation is used to simplify data structures by rotating factor axes so that the variables are loaded maximally on only one factor (minimizes unexplained variance). Orthogonal rotation maintains factor independence while oblique rotation allows factors to correlate. Oblique rotation should be used if factors are believed to be related. Since it was suspected that knowledge and skills factors are related, an oblique (Promax) rotation method was employed for the primary analysis and then compared the results to an orthogonal (Varimax) rotation.

The meaning of each factor is interpreted using factor loadings. A factor loading is the Pearson correlation coefficient of original variables (in this study, the importance ratings of knowledge and skill areas) with a factor. Factor loadings indicate an association of the variable with a factor and ranges from 1 (perfect positive association) to -1 (perfect negative association). The relative importance of each variable is indicated by the magnitude of the squares of the factor loadings. In social science research, 0.32 is cited as a conservative value for the minimum loading of a variable on a factor because it equates to approximately 10% overlapping variance. This value was used as the critical value for this study.

Cluster Analysis. Factor analysis, followed by SPSS two-step clustering method was used to identify groups of program administrators who prefer similar ideal curriculum models.

Cluster analysis is used to combine or classify objects into groups using a predetermined selection criterion. The resulting clusters will exhibit high internal (within cluster) homogeneity and high external (between-cluster) heterogeneity. It allows the researcher to group cases into similar groups.

In cluster analysis, multicollinearity results in a weighting process that affects the analysis; multicollinear variables are implicitly weighted more heavily. Since several of the importance-rated variables exhibited multicollinearity, factor analysis was used to group similarly rated variables prior to clustering. Reducing the original importance rating variables into sets of knowledge and skill components eliminated multicollinearity while retaining all variables and their variances in the analysis.

The SPSS two-step method was selected as the most appropriate clustering method for this study because of the characteristics of the clustering algorithm and because it provides graphical outputs that aid interpretation.

Because cluster analysis involves a subjective judgment on an optimal cluster solution, it is important to validate the solution. Three methods were used to insure the validity and practical significance of the results. First, the sample was randomly split into two groups and the results compared. Then two different clustering algorithms (SPSS two-step method and Ward's method) were used and the results compared. Finally, descriptive discriminant analysis was used to test the fidelity of cluster membership using the original important rating variables, and analysis of variance tests were conducted using program attribute variables to demonstrate significant differences between clusters. The discriminant analysis revealed dimensions that separate the clusters; all are highly significant predictors at $p<0.001$. A number of significant differences in degree program attributes between the clusters were evident.

Relationships. Finally, two types of analysis of variance tests ($\alpha=.05$) were used to explore relationships among ideal curriculum types, knowledge and skill factors, and other program and degree attributes: one-way analysis of variance (ANOVA) for scale variables and Kruskal-Wallis one-way analysis of variance by ranks (KWANOVA) for ordinal and categorical variables. Kruskal-Wallis is a non-parametric test of the difference in the shape or location (central tendency) of populations underlying two or more groups.

Appendix B - List of Participating Institutions and Units/Programs

Institution	City	State	Academic Unit
Abilene Christian University	Abilene	TX	Department of Agriculture & Environmental Sciences; College of Arts & Sciences
Air Force Institute of Technology-Graduate School of Engineering & Management	Wright Patterson AFB	OH	Department of Systems and Engineering Management
Albright College	Reading	PA	Interdisciplinary Studies: Environmental Studies Program
Allegheny College	Meadville	PA	Department of Environmental Science and Studies
American University	Washington	DC	Global Environmental Politics Program; School of International Service
Antioch New England Graduate School	Keene	NH	Department of Environmental Studies
Appalachian State University	Boone	NC	Environmental Science Program; College of Arts and Sciences
Appalachian State University	Boone	NC	Sustainable Development Program; University College
Appalachian State University	Boone	NC	Interdisciplinary Studies; University College
Aquinas College	Grand Rapids	MI	Environmental Science Program
Arizona State University	Tempe	AZ	School of Earth and Space Exploration
Arizona State University	Tempe	AZ	School of Human Evolution and Social Change; College of Liberal Arts and Sciences
Arizona State University-West Campus	Glendale	AZ	Division of Mathematical and Natural Sciences; New College of Interdisciplinary Arts and Sciences
Asbury College	Wilmore	KY	Department of Natural Science
Assumption College	Worchester	MA	Department of Natural Science; Undergraduate Programs
Auburn University	Auburn University	AL	Environmental Science Program; Department of Agronomy and Soils; College of Agriculture (College of Engineering and the College of Sciences and Mathematics Partner)
Augsburg College	Minneapolis	MN	Environmental Studies Program
Austin College	Sherman	TX	Center for Environmental Studies
Bard College	Annandale-on-Hudson	NY	Bard Center for Environmental Policy
Barnard College	New York	NY	Department of Environmental Science
Bentley University	Waltham	MA	Department of Natural and Applied Sciences and the Office of Sustainability
Biola University	La Mirada	CA	Environmental Science Program; School of Arts and Sciences
Boise State University	Boise	ID	Environmental Studies Program; College of Social Sciences and Public Affairs
Boston University	Boston	MA	Marine Science Program; College of Arts and Sciences
Boston University	Boston	MA	Department of Global Development; Graduate School of Arts and Sciences
Brandeis University	Waltham	MA	Sustainable International Development Graduate Program; School for Social Policy and Management
Bucknell University	Lewisburg	PA	Environmental Studies Program; College of Arts and Sciences

California Institute of Technology	Pasadena	CA	Environmental Science and Engineering Program; Division of Chemistry and Chemical Engineering, Division of Engineering and Applied Sciences, and Division of Geological and Planetary Sciences
California Polytechnic State University-San Luis Obispo	San Luis Obispo	CA	Department of Natural Resources Management; College of Agriculture, Food and Environmental Sciences
California State University-Chico	Chico	CA	Department of Geological and Environmental Sciences; College of Natural Science
California State University-East Bay	Hayward	CA	Department of Geography and Environmental Studies; College of Letters, Arts and Social Sciences
California State University-Los Angeles	Los Angeles	CA	Department of Biological Sciences; College of Natural and Social Sciences
California State University-Monterey Bay	Seaside	CA	Division of Environmental Science and Policy; College of Arts, Humanities and Social Sciences
California State University-Sacramento	Sacramento	CA	Department of Environmental Studies: College of Social Sciences and Interdisciplinary Studies
California State University-San Bernardino	San Bernardino	CA	Environmental Science Program; Department of Chemistry and Biochemistry and Department of Geological Sciences; College of Natural Sciences
Carleton College	Northfield	MN	Environmental Studies Program
Carnegie Mellon University	Pittsburgh	PA	Environmental Policy Program; College of Humanities and Social Sciences
Carnegie Mellon University	Pittsburgh	PA	Energy Science, Technology and Policy Program
Chatham University	Pittsburgh	PA	School of Sustainability and the Environment
Clark University	Worchester	MA	International Development, Community and Environment Graduate Programs; Graduate School of Management
Clarkson University	Potsdam	NY	Clarkson Institute for a Sustainable Environment
Cleveland State University	Cleveland	OH	Department of Urban Studies; College of Urban Affairs
Cleveland State University	Cleveland	OH	Department of Biological, Geological, and Environmental Sciences; College of Sciences and Health Professions
Colby College	Waterville	ME	Environmental Studies Program; Division of Interdisciplinary Studies
Colgate University	Hamilton	NY	Environmental Studies Program; Division of Natural Sciences and Mathematics
College of Charleston	Charleston	SC	Environmental Studies Master's Program; School of Science and Mathematics
College of Saint Benedict	Collegeville	MN	Department of Environmental Studies
College of William and Mary	Williamsburg	VA	Environmental Science and Policy Program; School of Arts and Sciences
Colorado College	Colorado Springs	CO	Environmental Program
Colorado Mesa University (formerly Mesa State College)	Grand Junction	CO	Department of Physical and Environmental Sciences
Colorado State University	Fort Collins	CO	Department of Forest and Rangeland Stewardship; College of Natural Resources
Colorado State University	Fort Collins	CO	Department of Human Dimensions of Natural Resources; College of Natural Resources

Columbia University	New York	NY	Department of Earth and Environmental Sciences; Columbia College
Cornell University	Ithaca	NY	Environmental Science and Sustainability Program; College of Agriculture and Life Sciences
Cornell University	Ithaca	NY	Department of Natural Resources; College of Agriculture and Life Sciences
Creighton University	Omaha	NE	Energy Technology Program, College of Arts and Sciences
Curry College	Milton	MA	Department of Science and Math
Daemen College	Amherst	NY	Interdisciplinary Programs, Division of Arts and Sciences
Denison University	Granville	OH	Environmental Studies Program
DePaul University	Chicago	IL	Department of Environmental Science and Studies; College of Science and Health
Dickinson College	Carlisle	PA	Department of Environmental Studies
Doane College	Crete	NE	Environmental and Earth Sciences Program; Department of Biology
Dordt College	Sioux Center	IA	Environmental Studies Program
Drake University	Des Moines	IA	Environmental Science and Policy Program; College of Arts and Sciences
Duquesne University	Pittsburg	PA	Center for Environmental Research & Education; School of Natural and Environmental Sciences
Earlham College	Richmond	IN	Environmental Science and Studies Program
Eastern Mennonite University	Harrisonburg	VA	Department of Biology
Eastern Michigan University	Ypsilanti	MI	Interdisciplinary Environmental Science and Society Program; College of Arts and Sciences
Eastern Nazarene College	Quincy	MA	Department of Biology and Chemistry
Eastern New Mexico University	Portales	NM	Department of Physical Sciences; College of Liberal Arts and Sciences
Elizabethtown College	Elizabethtown	PA	Environmental Science Program; Department of Biology
Elon University	Elon	NC	Department of Environmental Studies; College of Arts and Sciences
Emory University	Atlanta	GA	Department of Environmental Studies; College of Arts and Sciences
Eureka College	Eureka	IL	Environmental Science Program; Division of Science and Mathematics
Evergreen State College	Olympia	WA	Environmental Studies Graduate Program
Ferrum College	Ferrum	VA	Environmental Planning and Development Program; School of Natural Science and Mathematics
Fordham University	Bronx	NY	Environmental Policy Program; Fordham College at Rose Hill and Lincoln Center
Furman University	Greenville	SC	Department of Earth and Environmental Sciences
George Washington University	Washington	DC	Department of Geography; College of Arts and Sciences
Goucher College	Baltimore	MD	Environmental Studies Program
Haskell Indian Nations University	Lawrence	KS	Environmental Science Program; College of Arts and Sciences
Hawaii Pacific University	Honolulu	HI	Global Leadership and Sustainable Development Programs; College of Humanities and Social Science

Hendrix College	Conway	AR	Environmental Studies Program
Heritage University	Toppenish	WA	Department of Sciences; College of Arts and Sciences
Hobart William Smith Colleges	Geneva	NY	Department of Environmental Studies
Illinois Institute of Technology	Chicago	IL	Environmental Management and Sustainability Program; School of Business
Indiana University-Bloomington	Bloomington	IN	School of Public and Environmental Affairs
Iona College	New Rochelle	NY	Department of Biology; School of Arts and Sciences
Judson University	Elgin	IL	Department of Science and Math
Kings College	Wilkes-Barre	PA	Department of Environmental Studies
Knox College	Galesburg	IL	Department of Biology; College of Arts and Sciences
Lenoir-Rhyne University	Hickory	NC	School of Natural Sciences and Reese Institute for Conservation of Natural Resources
Lenoir-Rhyne University	Hickory	NC	Sustainability Studies Program; Center of Graduate Studies
Lewis University	Romeoville	IL	Environmental Science Program; College of Arts and Sciences
Lincoln Memorial University	Harrogate	TN	Environmental Science Program; Undergraduate Programs
Long Island University-C. W. Post	Brookville	NY	Department of Earth and Environmental Science; College of Liberal Arts and Sciences
Louisiana State University and Agricultural & Mechanical College	Baton Rouge	LA	Coastal Environmental Science Program; School of the Coast and Environment
Louisiana State University and Agricultural & Mechanical College	Baton Rouge	LA	Department of Environmental Sciences; School of the Coast and Environment
Loyola University Chicago	Chicago	IL	Department of Environmental Science; College of Arts and Sciences
Marygrove College	Detroit	MI	Environmental Science Program; Undergraduate Programs
Marylhurst University	Marylhurst	OR	Department of Interdisciplinary Studies; College of Undergraduate Studies
Maryville College	Maryville	TN	Environmental Studies Program
McPherson College	McPherson	KS	Department of Natural Science; Division of Science and Technology
Merrimack College	North Andover	MA	Environmental Studies and Sustainability Program; School of Liberal Arts
Messiah College	Grantham	PA	Department of Biological Sciences; School of Science, Engineering, and Health
Michigan State University	East Lansing	MI	Environmental Science and Policy Program
Michigan Technological University	Houghton	MI	Department of Social Sciences; College of Arts and Sciences
Minnesota State University-Moorhead	Moorhead	MN	Department of Physics & Astronomy; College of Social & Natural Sciences
Montana State University	Bozeman	MT	Ecology and Environmental Science Program; Department of Ecology; College of Letters and Sciences; Department of Land Resources & Environmental Sciences; College of Agriculture
Moravian College	Bethlehem	PA	Environmental Studies and Sciences Program
Naropa University	Boulder	CO	Environmental Studies Program; School of Natural and Social Sciences
New College of Florida	Sarasota	FL	Environmental Studies Program
New Mexico Institute of Mining and Technology	Socorro	NM	Department of Earth and Environmental Science

New School	New York	NY	Environmental Policy and Sustainability Management Program; School of International Affairs, Management, and Urban Policy
North Carolina State University at Raleigh	Raleigh	NC	Environmental Science Program; Division of Undergraduate Academic Programs; Provost's Office
North Carolina State University at Raleigh	Raleigh	NC	Natural Resources BS Program, Department of Forestry and Environmental Resources; College of Natural Resources
North Carolina State University at Raleigh	Raleigh	NC	Department of Forestry and Environmental Resources; College of Natural Resources
North Carolina State University at Raleigh	Raleigh	NC	Natural Resources MS Program; Department of Forestry and Environmental Resources; College of Natural Resources
North Carolina State University at Raleigh	Raleigh	NC	Professional Science Master of Environmental Assessment Program; College of Natural Resources and College of Agriculture and Life Sciences
North Dakota State University	Fargo	ND	Natural Resource Management Program; School of Natural Resource Sciences; College of Agriculture, Food Systems, and Natural Resources
Northern Michigan University	Marquette	MI	Department of Earth, Environmental and Geographical Sciences; College of Arts and Sciences
Northwest Indian College	Bellingham	WA	Native Environmental Science Program
Norwich University	Northfield	VT	Department of Geology and Environmental Science; School of Mathematics & Science
Ohio State University	Columbus	OH	Environmental Science Graduate Program; Graduate School
Ohio Wesleyan University	Delaware	OH	Department of Geology and Geography
Oklahoma City University	Oklahoma City	OK	Department of Biology; College of Arts & Sciences
Olivet Nazarene University	Bourbonnais	IL	Department of Physical Sciences; College of Arts and Sciences
Oregon Institute of Technology	Klamath Falls	OR	Environmental Sciences Program; College of Health, Arts and Sciences
Oregon State University	Corvallis	OR	Water Resources Graduate Program, Graduate College
Pace University	New York	NY	Environmental Studies Program; College of Arts and Sciences
Pennsylvania State University	University Park	PA	Environment and Natural Resources Institute; College of Agricultural Sciences
Piedmont College	Demorest	GA	Department of Natural Science; School of Arts and Sciences
Polytechnic Institute of New York University	Brooklyn	NY	Department of Technology, Culture and Society
Portland State University	Portland	OR	Department of Environmental Science and Management; School of the Environment; College of Liberal Arts & Sciences
Portland State University	Portland	OR	Systems Science Graduate Program; Office of Graduate Studies
Prescott College	Prescott	AZ	Environmental Studies Graduate Program
Prescott College	Prescott	AZ	Sustainability Science and Practice Program
Ramapo College of New Jersey	Mahwah	NJ	Sustainability Studies Program; School of Social Science and Human Services
Randolph College	Lynchburg	VA	Environmental Studies Department
Randolph-Macon College	Ashland	VA	Environmental Studies Program
Regis University	Denver	CO	Environmental Studies Program; College of Liberal Arts

Rice University	Houston	TX	Environmental Analysis and Decision Making Program, School of Natural Sciences
Richard Stockton College of New Jersey	Pomona	NJ	Environmental Studies Program; School of Natural and Mathematical Sciences
Richard Stockton College of New Jersey	Pomona	NJ	Sustainability Program; School of Natural Science and Mathematics
Rochester Institute of Technology	Rochester	NY	Environmental Science Program; College of Science
Rochester Institute of Technology	Rochester	NY	Golisano Institute for Sustainability
Rutgers University-New Brunswick	New Brunswick	NJ	Department of Human Ecology; School of Environmental and Biological Sciences
Rutgers University-New Brunswick	New Brunswick	NJ	Department of Environmental Sciences; School of Environmental and Biological Sciences
Rutgers University-Newark	Newark	NJ	Professional Science Master's Program; Graduate College
Sage Colleges	Troy	NY	Environmental Studies Program; Russell Sage College
Saint John's University	Queens	NY	Environmental Studies Program; College of Liberal Arts and Sciences
Saint Lawrence University	Canton	NY	Department of Environmental Studies
Saint Louis University	Saint Louis	MO	Center for Sustainability
Saint Louis University	Saint Louis	MO	Integrated and Applied Sciences Program; Graduate College
Saint Olaf College	Northfield	MN	Department of Environmental Studies
Saint Peters College	Jersey City	NJ	Department of Chemistry; College of Arts and Sciences
Saint Vincent College	Latrobe	PA	Environmental Science Program; School of Natural Sciences, Mathematics and Computing
Salisbury University	Salisbury	MD	Environmental Studies Program; College of Liberal Arts
Santa Clara University	Santa Clara	CA	Department of Environmental Studies and Sciences; College of Arts and Sciences
Seattle University	Seattle	WA	Department of Environmental Science; College of Science & Engineering
Siena College	Loudonville	NY	Department of Environmental Studies; School of Science
Sierra Nevada College	Incline Village	NV	Department of Science and Technology
Sierra Nevada College	Incline Village	NV	Interdisciplinary Studies Program
Smith College	Northampton	MA	Environmental Science and Policy Program
Soka University of America	Aliso Viejo	CA	Environmental Studies Program
Southeast Missouri State University	Cape Girardeau	MO	Environmental Science Program; College of Science and Mathematics
Southern Illinois University-Carbondale	Carbondale	IL	Department of Forestry; College of Agricultural Sciences
Southern Illinois University-Edwardsville	Edwardsville	IL	Environmental Sciences Program; College of Arts and Sciences
Southern Methodist University	Dallas	TX	Environmental Science and Studies Program; College of Humanities and Sciences
Southern Nazarene University	Bethany	OK	Department of Biology; College of Natural, Social and Health Sciences; Division of Science and Mathematics
Southern New Hampshire University	Manchester	NH	Environmental Management Program; School of Arts and Sciences
Southwestern University	Georgetown	TX	Environmental Studies Program
Stephen F. Austin State University	Nacogdoches	TX	Division of Environmental Science; College of Forestry and Agriculture
Stephen F. Austin State University	Nacogdoches	TX	College of Liberal & Applied Arts

Stetson University	Deland	FL	Department of Geography and Environmental Science; College of Arts and Sciences
Stonehill College	Easton	MA	Environmental Studies Program
Suffolk University	Boston	MA	Environmental Studies Program; Department of Interdisciplinary Studies; College of Arts and Sciences
SUNY-Binghamton	Binghamton	NY	Department of Geological Sciences and Environmental Studies; Division of Science and Mathematics
SUNY-Brockport	Brockport	NY	Department of Environmental Science and Biology; School of Science and Mathematics
SUNY-Cobleskill (College of Agriculture and Technology)	Cobleskill	NY	Center for Environmental Science and Technology; School of Agriculture and Natural Resources
SUNY-Oneonta	Oneonta	NY	Environmental Sciences Program
SUNY-Potsdam	Potsdam	NY	Environmental Studies Program; School of Arts and Sciences
SUNY-Purchase	Purchase	NY	School of Natural and Social Sciences
SUNY-Stony Brook	Stony Brook	NY	Sustainability Studies Program; College of Arts and Sciences
SUNY-Syracuse (College of Environmental Science and Forestry)	Syracuse	NY	Department of Forest and Natural Resource Management
SUNY-Syracuse (College of Environmental Science and Forestry)	Syracuse	NY	Department of Environmental Studies
Susquehanna University	Selinsgrove	PA	International Studies: Sustainable Development, Interdisciplinary Programs
Syracuse University	Syracuse	NY	Department of Physics; College of Arts and Sciences
Tennessee Technological University	Cookeville	TN	Environmental and Sustainability Studies Program; College of Arts and Sciences
Tennessee Technological University	Cookeville	TN	Environmental Sciences Doctoral Program; College of Arts and Sciences
Texas A & M University	College Station	TX	Department of Ecosystem Science and Management, College of Agriculture and Life Sciences
Towson University	Towson	MD	Environmental Science and Studies Program; College of Science and Mathematics
Towson University	Towson	MD	Environmental Science and Studies Graduate Program; College of Science and Mathematics
Trinity College	Hartford	CT	Environmental Science Program
Tufts University	Medford	MA	Environmental Studies Program, School of Arts and Sciences
Union College	Schenectady	NY	Environmental Science, Policy and Engineering Program; Department of Geology
Union Institute & University	Cincinnati	OH	Environmental Studies and Sustainability Program
University at Buffalo	Buffalo	NY	Environmental Studies Program; Office of Interdisciplinary Degree Programs, College of Arts And Sciences
University of Akron	Akron	OH	Department of Geology and Environmental Science; College of Arts and Sciences
University of Alabama	Tuscaloosa	AL	Department of Geography; College of Arts and Sciences
University of Alabama	Tuscaloosa	AL	Marine Science Program; Departments of Biological Sciences, Chemistry and Geological Sciences; College of Arts and Sciences
University of Arizona	Tucson	AZ	School of Natural Resources and the Environment; College of Agriculture and Life Sciences

University of Arizona	Tucson	AZ	Water, Society and Policy Program; College of Agriculture and Life Sciences and College of Social and Behavioral Sciences
University of Arkansas	Fayetteville	AR	Department of Crop, Soil, and Environmental Sciences; College of Agricultural, Food & Life Sciences
University of Arkansas	Fayetteville	AR	Environmental Dynamics Program; College of Arts and Sciences
University of Baltimore	Baltimore	MD	Environmental Sustainability and Human Ecology Program; Division of Science, Information Arts and Technologies; College of Arts and Science
University of California-Berkeley	Berkeley	CA	Department of Environmental Science, Policy and Management; College of Natural Resources
University of California-Los Angeles	Los Angeles	CA	Institute of the Environment and Sustainability Center for Interdisciplinary Instruction; Division of the Institute of the Environment; College of Letters and Science
University of California-Los Angeles	Los Angeles	CA	School of Physical Sciences
University of California-Riverside	Riverside	CA	Department of Environmental Sciences; College of Natural and Agricultural Sciences
University of California-Riverside	Riverside	CA	Department of Environmental Sciences; College of Natural and Agricultural Sciences
University of California-San Diego	La Jolla	CA	Department of Education; Scripps Institution of Oceanography
University of California-Santa Barbara	Santa Barbara	CA	Environmental Studies Program; Division of Mathematical, Life, and Physical Sciences; College of Letters and Science
University of California-Santa Barbara	Santa Barbara	CA	Marine Science Graduate Program; Division of Mathematical, Life, and Physical Sciences; College of Letters and Science
University of California-Santa Cruz	Santa Cruz	CA	Environmental Studies Department; Division of Social Sciences
University of Central Florida	Orlando	FL	Office of Interdisciplinary Studies; Office of Undergraduate Studies
University of Colorado-Boulder	Boulder	CO	Environmental Studies Program; College of Arts and Sciences
University of Connecticut	Storrs	CT	Department of Natural Resources and the Environment; College of Agriculture and Natural Resources
University of Connecticut	Storrs	CT	Environmental Science Program; College of Agriculture and Natural Resources and College of Liberal Arts and Sciences
University of Delaware	Newark	DE	Environmental Science and Studies Program; Department of Geography; College of Earth, Ocean and Environment
University of Delaware	Newark	DE	Center For Energy and Environmental Policy
University of Denver	Denver	CO	Department of Geography; Division of Natural Sciences and Mathematics
University of Hawaii-Manoa	Honolulu	HI	Department of Natural Resources and Environmental Management; College of Tropical Agriculture and Human Resources
University of Houston	Houston	TX	Department of Earth and Atmospheric Sciences; College of Natural Sciences and Mathematics
University of Idaho	Moscow	ID	Environmental Science Program; College of Letters, Arts, and Social Sciences
University of Illinois-Springfield	Springfield	IL	Department of Environmental Studies; College of Public Affairs and Administration
University of Illinois-Urbana-Champaign	Champaign	IL	Global Studies Program; College of Liberal Arts and Sciences
University of Illinois-Urbana-Champaign	Champaign	IL	School of Earth, Society and the Environment; College of Liberal Arts and Sciences

University of Illinois-Urbana-Champaign	Champaign	IL	Department of Natural Resources and Environmental Sciences; College of Agricultural, Consumer, and Environmental Sciences
University of Iowa	Iowa City	IA	Environmental Sciences Program; College of Liberal Arts and Sciences
University of Kentucky	Lexington	KY	Natural Resources and Environmental Science Program; College of Agriculture
University of Maine	Orono	ME	School of Marine Sciences; College of Natural Sciences, Forestry, and Agriculture
University of Maine-Machias	Machias	ME	Division of Environmental and Biological Sciences
University of Massachusetts-Boston	Boston	MA	Department of Environmental, Earth and Ocean Sciences; College of Science and Mathematics
University of Massachusetts-Lowell	Lowell	MA	Department of Environmental, Earth and Ocean Sciences; College of Science and Mathematics
University of Miami	Coral Gables	FL	Division of Marine Affairs and Policy; School of Marine and Atmospheric Science
University of Michigan-Ann Arbor	Ann Arbor	MI	Program in the Environment; School of Natural Resources and Environment and the College of Literature, Science, and the Arts
University of Michigan-Ann Arbor	Ann Arbor	MI	School of Natural Resources and the Environment Program; College of Literature, Science and the Arts
University of Michigan-Flint	Flint	MI	Department of Earth and Resource Science; College of Arts and Sciences
University of Minnesota-Twin Cities	Minneapolis	MN	Natural Resources Science and Management Graduate Program; College of Food, Agricultural and Natural Resource Sciences
University of Missouri-Columbia	Columbia	MO	Department of Soil, Environmental and Atmospheric Sciences; School of Natural Resources; College of Agriculture, Food and Natural Resources
University of Missouri-Kansas City	Kansas City	MO	Environmental Studies Program; College of Arts and Science
University of Montana	Missoula	MT	Department of Ecosystem and Conservation Sciences; College of Forestry and Conservation
University of Mount Union	Alliance	OH	Environmental Science Program; Department of Biology; Division of Math and Science
University of Nebraska-Lincoln	Lincoln	NE	Environmental Studies Program; College of Agricultural Sciences and Natural Resources and College of Arts and Sciences
University of Nevada-Reno	Reno	NV	Department of Natural Resources and Environmental Science; College of Agriculture, Biotechnology, and Natural Resources
University of New England	Biddeford	ME	Department of Environmental Studies; College of Arts and Sciences
University of New Mexico	Albuquerque	NM	Department of Earth and Planetary Sciences; College of Arts and Sciences
University of New Mexico	Albuquerque	NM	Water Resources Program, University College
University of North Carolina-Asheville	Asheville	NC	Department of Environmental Studies
University of North Carolina-Chapel Hill	Chapel Hill	NC	Curriculum for the Environment and Ecology; College of Arts and Sciences
University of North Carolina-Pembroke	Pembroke	NC	Department of Biology; College of Arts and Sciences
University of Oklahoma	Norman	OK	Interdisciplinary Perspectives on the Environment Program, College of Arts and Sciences
University of Pennsylvania	Philadelphia	PA	Vagelos Integrated Program in Energy Research

University of Portland	Portland	OR	Department of Environmental Science; College of Arts and Sciences
University of Rochester	Rochester	NY	Department of Chemical Engineering; School of Engineering and Applied Sciences
University of Saint Francis-Illinois	Joliet	IL	Environmental Sciences Program; Department of Natural Sciences; College of Arts and Sciences
University of Saint Thomas-Texas	Houston	TX	Department of Environmental Science and Studies; School of Arts and Sciences
University of San Francisco	San Francisco	CA	Graduate Program In Environmental Management; College of Arts and Sciences
University of South Dakota	Vermillion	SD	Sustainability Program; College of Arts and Sciences
University of South Florida-St. Petersburg	St. Petersburg	FL	Department of Environmental Science, Policy, and Geography; College of Arts and Sciences
University of Tennessee	Knoxville	TN	Department of Forestry, Wildlife and Fisheries; College of Agricultural Sciences and Natural Resources
University of Texas-San Antonio	San Antonio	TX	Department of Civil and Environmental Engineering; College of Engineering
University of Utah	Salt Lake City	UT	Environmental and Sustainability Studies Program; College of Social and Behavioral Science
University of Utah	Salt Lake City	UT	Environmental Humanities Graduate Program; College of Humanities
University of Vermont	Burlington	VT	Environmental Program
University of Vermont	Burlington	VT	Environmental Sciences Program
University of Vermont	Burlington	VT	Rubenstein School of Environment and Natural Resources
University of Washington-Seattle	Seattle	WA	School of Environmental and Forest Sciences; College of the Environment
University of Washington-Tacoma	Tacoma	WA	Urban Studies Program
University of West Florida	Pensacola	FL	Department of Environmental Studies; College of Arts and Sciences
University of Wisconsin-Madison	Madison	WI	Nelson Institute for Environmental Studies and The College of Letters and Science
University of Wisconsin-River Falls	River Falls	WI	Department of Plant and Earth Science; College of Agriculture, Food and Environmental Science
University of Wisconsin-River Falls	River Falls	WI	Sustainable Management Program (Consortium with UW-Extension, UW-Stout, UW-River Falls, UW-Superior)
University of Wisconsin-Stout	Menomonie	WI	Applied Science Program; College of Science, Technology, Engineering and Mathematics
University of Wisconsin-Stout	Menomonie	WI	Sustainable Management Program (Consortium with UW-Extension, UW-Stout, UW-River Falls, UW-Superior)
University of Wyoming	Laramie	WY	School of Energy Resources (collaborates with the Colleges of Arts and Sciences, Engineering and Applied Science, Agriculture, Business, Education, and Law, School of Environment and Natural Resources)
University of Wyoming	Laramie	WY	School of Environment and Natural Resources
Ursinus College	Collegeville	PA	Environmental Studies Program
Utah State University	Logan	UT	Department of Environment and Society; College of Natural Resources
Valparaiso University	Valparaiso	IN	Environmental Science Program; College of Arts and Sciences

Vassar College	Poughkeepsie	NY	Environmental Studies Program
Vassar College	Poughkeepsie	NY	Department of Earth Science and Geography
Virginia Polytechnic Institute and State University	Blacksburg	VA	Environmental Science Program; College of Agriculture & Life Sciences
Virginia Polytechnic Institute and State University	Blacksburg	VA	Executive Master of Natural Resource Program; College of Natural Resources and Environment
Viterbo University	La Crosse	WI	Environmental Sustainability Program; School of Letters and Sciences and School of Business
Washington and Jefferson College	Washington	PA	Environmental Studies Program; Department of Biology
Washington and Lee University	Lexington	VA	Environmental Studies Program
Washington College	Chestertown	MD	Environmental Studies Program; Division of Natural Sciences
Wayne State University	Detroit	MI	Environmental Science Program; College of Liberal Arts and Sciences
Wellesley College	Wellesley	MA	Environmental Studies Program
Wells College	Aurora	NY	Environmental Studies Program; Division of Natural and Mathematical Sciences
Western Carolina University	Cullowhee	NC	Environmental Science Program; College of Arts and Sciences
Western Kentucky University	Bowling Green	KY	Cohort Programs, Division of Extended Learning and Outreach
Western New England College	Springfield	MA	Sustainability Program; College of Arts and Sciences
William Paterson University of New Jersey	Wayne	NJ	Department of Environmental Science; College of Science and Health
Wilson College	Chambersburg	PA	Environmental Studies Program
Winthrop University	Rock Hill	SC	Environmental Sciences and Studies Program; College of Arts and Sciences
Wisconsin Lutheran College	Milwaukee	WI	College of Arts and Sciences
Yale University	New Haven	CT	School of Forestry and Environmental Studies
Youngstown State University	Youngstown	OH	Department of Geological and Environmental Sciences; College of Science, Technology, Engineering & Mathematics

APPENDIX C – Knowledge and Skills Survey Question

Program administrators were asked to complete the question on knowledge and skills for each IES degree program their unit/program administers.

The following question is designed to: (1) determine your opinion on the importance of knowledge and skills competencies for degree program graduates (regardless of how they are obtained; formally or informally), and (2) the emphasis on knowledge and skills areas in this degree program's current curriculum.

Base your answers on the degree type, the typical student earning the degree, and the required components of the degree. Include general education course and electives if an integral part of the degree; exclude if not. Please only select "variable" when the curriculum varies substantially for the majority of students.

KNOWLEDGE AREA	IMPORTANCE IN IDEAL CURRICULUM				EMPHASIS IN CURRENT CURRICULUM				
	MIN/ NONE	LOW	MOD	HIGH	MIN/ NONE	LOW	MOD	HIGH	VARI-ABLE
NATURAL SCIENCES									
Chemistry	❍	❍	❍	❍	❍	❍	❍	❍	❍
Physics	❍	❍	❍	❍	❍	❍	❍	❍	❍
Earth Sciences/Geology	❍	❍	❍	❍	❍	❍	❍	❍	❍
Biology	❍	❍	❍	❍	❍	❍	❍	❍	❍
Ecology	❍	❍	❍	❍	❍	❍	❍	❍	❍
Other Physical Sciences (e.g. oceanography, atmospheric sciences)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Other Life Sciences (e.g. zoology, botany, microbiology)	❍	❍	❍	❍	❍	❍	❍	❍	❍
SOCIAL SCIENCES									
Policy and Public Administration (e.g. law and regulation, policy analysis, program evaluation, organizational theory)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Economics (e.g. microeconomics, macroeconomics, ecological)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Behavioral Social Sciences (e.g. sociology, anthropology, psychology, organization development, cultural studies)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Political Science (e.g. government, voter behavior, international agreements, conflict studies)	❍	❍	❍	❍	❍	❍	❍	❍	❍
HUMANITIES									
History (e.g. environmental, natural, political, cultural)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Literature (e.g. classic environmental, expression of ideas through literature)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Arts and Aesthetics (e.g. expression of ideas through the arts and design)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Religion (e.g. theology, philosophy)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Philosophy and Ethics (e.g. ontology, epistemology, logic, values, culture, diversity)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Language Arts (e.g. structure, meaning, metaphor)	❍	❍	❍	❍	❍	❍	❍	❍	❍

KNOWLEDGE AREA	IMPORTANCE IN IDEAL CURRICULUM				EMPHASIS IN CURRENT CURRICULUM				
	MIN/ NONE	LOW	MOD	HIGH	MIN/ NONE	LOW	MOD	HIGH	VARI- ABLE
APPLIED/PROFESSIONAL									
Engineering and Technology (e.g. principles, methodologies, design)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Planning and Built Environment (e.g. urban planning, land use planning)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Architecture (e.g. LEED, green design)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Business (e.g. management, marketing, organizational theory)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Green Materials Design (e.g. green chemistry, molecular toxicology, life cycle analysis)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Human Health (e.g. toxicology, epidemiology, risk, nutrition)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Agriculture (e.g. soils, range management, organic, sustainable)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Waste (e.g. recycling, reduction, management)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Education (e.g. pedagogy, curriculum design, outreach)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Research Design and Ethics (e.g. approaches, methods, ethical considerations)	❍	❍	❍	❍	❍	❍	❍	❍	❍
INTERDISCIPLINARY									
Systems Analysis (e.g. complexity, modeling, structure)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Geography (e.g. physical, economic, cultural)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Natural Resources Management (e.g. conservation, forestry, fisheries)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Energy Systems (e g. sources & supplies, impacts)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Water Systems (e.g. scarcity, allocation, hydrology)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Food Systems (e.g. security, distribution, production)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Climate Change/Disruption (e.g. causes, adaptation, solutions)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Environmental Justice (e.g. history, etiology)	❍	❍	❍	❍	❍	❍	❍	❍	❍
SUSTAINABILITY									
Sustainability General Concepts (e.g. characteristics, indicators, values)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Environmental Sustainability (ecosystems and natural resources sustainability)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Business/Economic Sustainability (economic development and business practices for sustainability)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Social Sustainability (social aspects of sustainable development/sustainability)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Sustainability Science (scientific and technological solutions)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Sustainability Governance (standards, protocols, reporting, organizations)	❍	❍	❍	❍	❍	❍	❍	❍	❍

SKILLS AREA	IMPORTANCE IN IDEAL CURRICULUM				EMPHASIS IN CURRENT CURRICULUM				
	MIN/ NONE	LOW	MOD	HIGH	MIN/ NONE	LOW	MOD	HIGH	VARI- ABLE
COGNITIVE/INTELLECTUAL									
Critical Thinking (e.g. discernment, type I and II errors, causation versus association)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Analysis (e.g. reductionism, structure versus function, component studies)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Problem Solving (e.g. solution analyses, logical approaches)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Creativity (e.g. innovation, synergism, aesthetics)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Synthesis/Systems Thinking (e.g. integration, complexity, analyze across domains and scales)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Anticipatory Thinking (e.g. future scenario analysis and evaluation)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Normative Thinking (e.g. understand issues of justice, equity, and ethics in decision making)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Strategic Thinking (e.g. design and implement strategies)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Information Literacy (e.g. information source and content discovery and evaluation)	❍	❍	❍	❍	❍	❍	❍	❍	❍
COMMUNICATION									
Technical and Academic Writing (writing for technical and scientific reporting)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Creative and Journalistic writing (writing for specific venues)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Oral Communication (e.g. articulation, presentation, persuasion)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Media Communications (e.g. broadcast media, video production)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Internet Communications (e.g. internet, social media)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Interdisciplinary/Intercultural Communication (e.g. understanding different perspectives, epistemologies)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Conflict Resolution (e.g. communication facilitation)	❍	❍	❍	❍	❍	❍	❍	❍	❍
RESEARCH									
Literature (e.g. literature review, abstract preparation)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Archival (e.g. historical materials)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Field (e.g. techniques and practices, instrumentation, data collection, interpretation)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Laboratory (e.g. techniques and practices, instrumentation, data collection, interpretation)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Social Science (e.g. survey design, sampling strategies, interviewing, ethnography)	❍	❍	❍	❍	❍	❍	❍	❍	❍

SKILLS AREA	IMPORTANCE IN IDEAL CURRICULUM				EMPHASIS IN CURRENT CURRICULUM				
	MIN/ NONE	LOW	MOD	HIGH	MIN/ NONE	LOW	MOD	HIGH	VARI-ABLE
NUMERACY AND TECHNOLOGICAL									
Mathematics (e.g. algebra, calculus trigonometry)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Statistics (e.g. probability, uncertainty, measures of central tendency, variance, association)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Spatial Analysis (e.g. geographic information systems (GIS), remote sensing, interpolation)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Computer Programming (e.g. modeling algorithms)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Decision Science (e.g. optimization, criteria identification, modeling)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Information Management (e.g. database structures and analytic protocols, data organization and retrieval)	❍	❍	❍	❍	❍	❍	❍	❍	❍
MANAGERIAL/INTERPERSONAL/COMMUNITY ENGAGEMENT									
Personnel Management (e.g. recruitment, training, tasking, evaluation)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Project Management (e.g. budget, logistics)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Collaborative Decision Making (e.g. analysis and deliberation, multi-criteria decision analysis, conflict management)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Environmental and/or Sustainability Planning and Reporting (e.g. ISO 14000, CSR, SAS)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Environmental Assessment & Planning (e.g. preparation of NEPA environmental assessment and impact statements)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Teamwork (e.g. working as part of a team)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Leadership (e.g. supervise tasks and teams of people, initiate and implement strategies)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Cultural Competence (e.g. cultural, diversity understanding)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Community Engagement (e. g. stakeholder processes, relationship building, service learning)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Organizational Learning/Development (e.g. empowering groups to see their patterns, and create positive change from within)	❍	❍	❍	❍	❍	❍	❍	❍	❍
Advocacy and Outreach (e.g. media, policymaker, business leader, and public education and engagement)	❍	❍	❍	❍	❍	❍	❍	❍	❍
OTHER KNOWLEDGE AND SKILLS									
Other knowledge or skills and their importance and emphases in current curriculum:									

APPENDIX D – Knowledge and Skills Mean Importance Ratings

Knowledge and Skills Areas	Undergraduate IES Mean	Graduate IES Mean
	3=high importance, 2=moderate importance, 1=low importance, 0=minimal/no importance	
Natural Sciences Knowledge		
Ecology	**2.33**	**2.09**
Biology	**2.20**	1.69
Earth Sciences/Geology	**2.03**	1.72
Chemistry	1.96	1.54
Other Physical Sciences (e.g. oceanography, atmospheric science)	1.47	1.45
Other Life Sciences (e.g. zoology, botany, microbiology)	1.36	1.22
Physics	1.24	1.30
Social Sciences Knowledge		
Policy and Public Administration	**2.05**	1.93
Economics	1.91	1.72
Political Science	1.72	1.43
Behavioral Social Sciences (e.g. sociology, anthropology, psychology, organizational development)	1.61	1.61
Humanities Knowledge		
Philosophy & Ethics	1.67	1.11
History	1.53	1.07
Literature	1.28	.61
Arts & Aesthetics	1.03	.53
Language Arts	.99	.46
Religion	.94	.39
Applied/Professional Knowledge		
Research Design and Ethics	1.79	1.93
Waste	1.63	1.22
Agriculture	1.48	1.32
Human Health	1.39	1.13
Planning & Built Environment	1.38	1.38
Business	1.09	1.16
Green Materials Design	1.07	.81
Engineering & Technology	1.03	1.29
Education	1.02	.96
Architecture	.89	.75
Interdisciplinary Knowledge		
Climate Change/Disruption	**2.34**	**2.05**
Water Systems	**2.08**	1.93
Natural Resources Management	1.96	**2.01**
Energy Systems	1.88	1.51
Environmental Justice	1.80	1.47
Geography	1.64	1.56
Systems Analysis	1.63	1.74
Food Systems	1.63	1.32
Sustainability Knowledge		
Environmental Sustainability	**2.48**	**2.28**
Sustainability General Concepts	**2.43**	**2.10**
Sustainability Science	1.89	1.66

Knowledge and Skills Areas	Undergraduate IES Mean	Graduate IES Mean
	3=high importance, 2=moderate importance, 1=low importance, 0=minimal/no importance	
Sustainability Knowledge (continues)		
Social Sustainability	1.87	1.74
Business/Economic Sustainability Practices	1.72	1.56
Sustainability Governance	1.68	1.61
Cognitive/Intellectual Skills		
Critical Thinking	**2.84**	**2.77**
Problem Solving	**2.77**	**2.73**
Analysis	**2.53**	**2.51**
Synthesis/Systems Thinking	**2.51**	**2.57**
Information Literacy	**2.51**	**2.24**
Creativity	**2.32**	**2.31**
Normative Thinking	**2.24**	**2.04**
Anticipatory Thinking	**2.22**	**2.22**
Strategic Thinking	**2.22**	**2.16**
Communication Skills		
Oral Communication	**2.63**	**2.69**
Technical & Academic Writing	**2.54**	**2.65**
Interdisciplinary/Intercultural Communication	**2.03**	**2.04**
Conflict Resolution	1.73	1.73
Internet Communication	1.61	1.43
Creative & Journalistic Writing	1.49	1.35
Media Communication	1.41	1.33
Research Skills		
Field	**2.46**	**2.20**
Literature	**2.35**	**2.42**
Laboratory	**2.26**	1.79
Social	1.89	1.92
Archival	1.44	1.33
Numeracy and Technological Skills		
Statistics	**2.37**	**2.41**
Spatial Analysis	**2.28**	**2.17**
Mathematics	**2.04**	1.71
Information Management	1.33	1.45
Decision Science	1.26	1.49
Computer Programming/Modeling	1.08	1.23
Managerial/Interpersonal/Community Engagement Skills		
Teamwork	**2.53**	**2.39**
Community Engagement	**2.20**	**2.01**
Leadership	**2.13**	**2.19**
Cultural Competence	**2.02**	1.79
Collaborative Decision Making	1.79	1.94
Advocacy & Outreach	1.74	1.59
Organizational Learning/Development	1.60	1.62
Environmental Assessment & Reporting	1.53	1.65
Environmental/Sustainability Planning & Reporting	1.29	1.33
Project Management	1.19	1.52
Personnel Management	.89	.88

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