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Re-imagining environmental science and policy graduate education for the twenty-first century using an integrative frame

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Abstract To meet society's need to better understand and respond to ever-more complex, interwoven problems of environment, development, and society—including environmental health risks, climate change adaptation, and sustainable development—we applied an *integrative frame* to re-imagine, re-design, and deploy a professionally oriented, academically rigorous 2-year/12-unit Master of Science program. Our scholar–practitioner faculty uses the framework to tackle complex, real-world problems, emerging from a strong interdisciplinary ethos. It thus acts as a pragmatic system to guide pedagogy, curriculum, research and practice, and student experience. The frame weaves together six domains (6-D): (1) project framing, concept, and design; (2) development topics and sectors; (3) stakeholder interests, assets, and relationships; (4) knowledge types, disciplines, models, and methods; (5) variable temporal and spatial scales and networks; and (6) socio-technical capacities. At our institution, the need to replace 2.0 of 3.5 tenure/tenure-track program faculty posed both a challenge and an opportunity to re-think one of the oldest environmental science and policy programs in the USA which began in 1971. We pose and answer: What kinds of integrative educational experience, curriculum, and research practicum can best prepare environmental MS students in the twenty-first century? Two examples—one domestic, one international—illustrate the practicum.

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Introduction

Twenty-first century complexity

Climate change challenges to sustainable development exemplify well the kind of inherent complexity that graduate students need to embrace and navigate in the twenty-first century. The 5th Intergovernmental Panel on Climate Change's Assessment Report (AR5) states: "Climate change is a threat to sustainable development. Nonetheless, there are many opportunities to link mitigation, adaptation and the pursuit of other societal objectives through integrated responses. Successful implementation relies on relevant tools, suitable governance structures and enhanced capacity to respond" (IPCC 2014, p. 94). The need for educational experiences that blend social and technical perspectives is even more urgent now than in the 1980s–1990s when the sustainable development paradigm first took the global stage. In a critical reflection on the first 25 years of sustainable development work, the United Nations states: "[A] new political deal is needed, which provides a clear vision and way forward for the international community, national governments, the private sector, civil society and other stakeholders for advancing the sustainable development agenda in an integrated manner" (UN/DESA 2016, p. iii). More powerfully, the UN (UNGA 2014) notes:

> Transformation is our aim. We must transform our economies, our environment and our societies. We must change old mindsets, behaviors and destructive patterns. We must embrace the integrated essential elements of dignity, people, prosperity, planet, justice and partnership. We must

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> build cohesive societies, in pursuit of international peace and stability. And we must prioritize good international solutions through the prism of the national interest of every Member State….Such a future is possible if we collectively mobilize political will and the necessary resources to strengthen our nations and the multilateral system. We have the means and methods to meet these challenges if we decide to employ them and work together.

While the integrative rhetoric is quite loud and more widespread among a growing number of public institutions (e.g., USEPA, US National Institute of Health, US Agency for International Development), the explicit UN claim—"We have the means and methods"; all that is needed is "political will"—ignores critical difficulties and gaps in concepts and societal capacities—including, but certainly not limited to, graduate education and professional training—that undermine success (see the discussion of just this problem with the Millennium Village Project in Carr 2008, and see Downs et al. 2017). In the face of this plethora of challenges, graduate education presents opportunities to translate this rhetoric into reality. Such opportunities will not emerge from narrowly disciplinary or methodologically homogenous programs of study that have thus far produced the notion that we have the means and methods to address these challenges (Vare and Scott 2007). The changing world in which we live reinforces this challenge.

Unstable contexts

At the same time our students need to embrace complexity, they also need to be capable of engaging with intersecting contexts that are unstable and uncertain:

- Economically: a highly integrated, complex, and unstable global financial system has stretched the capacity of responsible public regulation and has produced patterns of economic inequality within and across countries that threatens their political and economic health, and that of various interdependent global economic systems, ranging from finance to food. These trends have placed additional economic stress on "disappearing" middle-income populations in the wealthiest countries, exacerbated the vulnerability of low-income people in the USA and many other countries, and widened the gap between the "haves" and "have nots" at scales from the community to the globe.
- Socially: societal unrest in the face of rising social, political, and economic inequities and injustices challenges with deep historical roots. Whether the Arab Spring, widespread public protest like the Occupy Movement in the USA, or the emergence of the Black Lives Matter movement, each embodies complex issues of inequality and injustice that have become structural parts of the modern world and therefore will not simply "go away."
- Environmentally: anthropogenic climate change is already adversely impacting the capacity of the agricultural system to feed a growing world population, amplifying drought and wildfires in arid and semi-arid regions (including the southwestern USA), and driving more frequent and severe flooding in humid regions. More frequent and severe storms—hurricanes and tornadoes—are a likely scenario for the USA, in places unaccustomed to such events and ill-prepared to mitigate their effects. Small island states like the Marshall Islands face complete loss from rising sea level. At the same time, the burden of toxic chemicals—including "emerging threats" from pharmaceutical waste—and the risks of exposure to them grow in spite of gains in laws and regulations in the USA, and in the absence of adequate protections for the vast majority of the world's rapidly urbanizing population of 7.2 billion.
- Human habitats: In 2007, the world officially became an "urban planet" with the majority of people inhabiting urban settings for the first time in human history. The trend continues unabated, with the most rapid growth happening in so-called mid-sized cities. Rapidly urbanizing, rapidly industrializing settings in middle- and low-income countries are the places where pollution burdens and health impacts, for example, are very large because of inadequate sanitation capacity and environmental regulation (Downs 2007). Development is no longer principally about rural agrarian populations, but the budgets and staffing of development donors have not caught up to this reality.

In the context of such shifts, business-as-usual development favors elites and is likely to have adverse impacts on human health and well-being (though little is known about their magnitude and extent) and accelerates climate change through the growing emission of greenhouse gases (Griggs et al. 2013).

Educational response

In their complexity and scope, the problems of the twenty-first century call for educational programming that embraces complexity by intentionally weaving together disciplinary perspectives from the social sciences, natural sciences, physical sciences, engineering, and the humanities (Ledford 2015). The governing role of social learning in improving the relationships between humans and the socio-ecological systems they inhabit, impact, and are in turn impacted by has become a topic of growing importance (Reed et al. 2010). The topic recognizes that improvements in societal understanding and response are dependent on the degree to which diverse social groups collaborate to build social and technical capacity collectively. Universities in the last three decades of the 20th

Century took a new interest in interdisciplinary efforts to engage with societal problems. These, in turn, led to theories and approaches for re-imagining the role of the university in society. They included (a) a new vision of knowledge production called *Mode-2 Science* (Gibbons et al. 1994) consistent with social learning theory; (b) the importance of university–industry–government partnerships for societal capacity building called *Triple Helix Theory* (Etzkowitz and Leydesdorff 1997); (c) the adaptation of a corporate-style culture inside the university called *Academic Capitalism* (Slaughter and Leslie 1997) or more recently "the neoliberal university"; and (d) a set of "empirical" parameters (like the strengthened steering core, the expanded developmental periphery) that characterize the *Entrepreneurial University*. The subfield of Education for Sustainable Development (ESD) has been experiencing steady growth in recent years and shows no sign of abating (Vare and Scott 2007).

Trencher et al. (2013), analyzing empirical data on over 60 cases, found five "channels" by which entrepreneurial universities are collaborating with other actors to further sustainability: (1) knowledge management—academics create, process, and diffuse knowledge to stakeholders; (2) demonstration projects and experiments for unproven technologies; (3) technology transfer and economic development centered on low-carbon, "green" technologies; (4) restoration and/or transformation of degraded urban areas; and (5) socio-technical innovation processes, e.g., food system innovation driven by social learning by multiple actors in concert. These channels serve to help us systematically consider diverse ways universities can model and stimulate innovations, with graduate students being centrally involved. Integrative education approaches—like the one illustrated here using the 6-D frame—embraces social and technical complexities, and make space for constructive dialog about the applicability of theories, how and when they need to be contextualized in terms of specific settings and places (what works and why, and what does not), and the need for vibrant theory-meets-practice interaction. *The purpose of this paper* is to show how an integrative framework was used to re-imagine, re-design, and deploy a longstanding environmental science and policy program: Master of Science in Environmental Science and Policy (ES&P) at Clark University. In this effort we have taken an adaptive, evolutionary approach, building on successful aspects of our program over the past 45 years, but also taking account of the enormous changes within universities and in society that have occurred over that period. Reimagining one pivotal program also called on us to reimagine the role of universities and higher education during this era.

Institutional context

Re-imagining ES&P was—and is—part of an ongoing faculty-driven conversation and re-design effort initiated in Fall 2014, one tasked with re-imagining "environmental sciences and studies" at Clark, involving the natural sciences, social sciences, and humanities. The focus in this paper is on ES&P, but it is central to a larger institutional discourse that poses: How does Clark University re-imagine its existing environmental sciences/studies activities and/or create new ones—through stronger internal and external collaborations and synergies—to increase its reputation and revenue through impactful research, improve competitiveness for graduate students, increase success in competitions for funding, create more innovative engaged research projects, and link all of this to increase its impact in the world? Myriad institutions and programs nationwide and internationally are facing the same, or similar challenges and charges, so we hope this case can be informative in strengthening the role of higher education—especially professional MA/MS/MEng/MPH/MBA degree programs—in responding to twenty-first century problems.

A short history

The first stage of ES&P (ES&P 1.0) began under different names – Technology and Man; Science, Technology & Society (STS) – in the period from 1971 to mid-1980s. It began as an interdepartmental experiment driven primarily by forward-looking faculty members in the Natural Sciences and in Geography and Economics and with its initial support from a five year Sloan Foundation grant. Their driving interest was to create a place where natural scientists and social scientists could collaborate to explore the interrelationships among science, technology, society, and the natural environment. Characteristic of the approach was taking a systems view along with a focus on specific problems. ES&P1.0 was one of the first programs in the USA—and also the world—to create an intentional space for "deep" interdisciplinary work of this kind, at a pivotal time when public concerns about the adverse impacts of toxic chemicals and nuclear power on human health and the environment were ascendant and being translated into sentinel federal laws. Administratively, the program had a faculty member solely identified with the program, committed contributions from the program founders, and a University-wide advisory group. The University maintained these commitments as promised in the Sloan grant. Another name change, to Environmental Technology, and Society (ES&P2.0) in the mid-1980s, marked a re-focusing on the need for sound environmental science and social science to work in concert to influence the US domestic policymaking/regulatory process; strengthening the science–policy bridge remains core to ES&P's mission.It included a restructuring of the program to offer graduate degrees through a merger with an Environmental Affairs program run by the Graduate School of Geography. The combined program was expanded beyond the sum of the two constituents. Two new faculty members were hired to replace the original single person, a 0.5 position was formalized, so that the program budget became 3.0 faculty equivalents. Later on the name was finally changed to ES&P to better reflect the policy dimension.

In 2000, Clark undertook yet another experiment. It brought together ES&P and the *International Development Program*, both with trailblazing histories. ID faculty had helped pioneer participatory, community-based development approaches in Africa through the late 1980s and 1990s. The new entity—*International Development, Community & Environment* (IDCE)—interdisciplinary niche and more global reach. Faculty and student numbers grew substantially for 10 years (peaking at about 18 full-time, permanent faculty and 170 MA/MS students in 2011/2012). This marriage of development and community studies (primarily social science, esp. anthropology) with environmental science and policy, and the addition of two new graduate programs—*Community Development & Planning* (CDP) and *Geographic Information Science for Development and Environment* (GISDE)—marked the third major stage of ES&P (ES&P3.0). These shifts appear to come at 14-15 year intervals. IDCE became the enabling culture to grow ES&P3.0 at the nexus of environment and development, now with global as well as domestic reach, and still leveraging its historical ethos: "where natural science and technology meet social science and policy."

Student research projects and student-led initiatives, often based on their research, have from the beginning been central to ES&P. Energy was the first arena, and can serve as an example. Even before the 1973 oil embargo, students were studying Clark's energy system as embedded in the regional and national systems. Those efforts built a strong collaboration between students and faculty and the university physical plant. The accomplishments included substantial improvements in energy efficiency and the building with some DOE support of a National Demonstration of cogeneration linked to the utility grid. (Decarolis et al. 2000). Other examples include the following:

1 Campus energy self-studies in collaboration with the University Physical Plant beginning in 1971. Outcomes include substantial improvements in campus energy efficiency over a period of more than four decades and the creation of a National Demonstration of Grid-Connected Cogeneration.
2 Creation of a student-designed and managed recycling center in 1992 that is still running successfully today(Mass. OTA 2013).
3 Student initiatives for a sustainable university in 2006. Outcomes include establishment of an ongoing course, The Sustainable University, beginning in 2006. In 2007, Clark joined the American College and University Presidents Climate Commitment;, established a University Environmental Sustainability Task Force of students, faculty administrators, and physical plant staff;, and created a full-time administrative position for a sustainability coordinator. These efforts continue (Mass OTA 2013).

ES&P 4.0

The need to replace 2.0 tenure/tenure-track positions out of 3.5 total ES&P positions in IDCE (one departure and one retirement) in 2014 precipitated an urgent consideration of whether ES&P could reboot, and if so how. While we paid close attention to our roots and reputation, we largely started with a blank sheet of paper and the charge: *How can ES&P remain competitive and how can it strengthen its contribution to understanding and solving twenty-first century problems that involve complex interrelationships among environmental, economic, and social systems?* The initial 8-month process of re-imagining involved dialogs with faculty, external experts (senior academics and environmental employers), alumni, current students, staff (esp. Student Services, Career Development as well as Admissions, Marketing, and Communications), and administrators (Provost, Graduate Dean, Research Dean). There were also numerous small meetings between the ES&P Coordinator, IDCE Director, and other faculty with direct "environmental" interests (Physics, Chemistry, Biology, Math and Computer Science, Geography, Graduate School of Management, Philosophy, Visual and Performing Arts, the George Perkins Marsh Research Institute, and the Mosakowski Institute for Public Enterprise). In these dialogs, we discussed the generative process itself, desired outcomes, ES&P's mission and purpose within the larger university context, its vision, niche, core values, topical foci, desired competencies, the career trajectories for students, and the opportunities for synergy and mutual benefit among academic programs. This successful "bottom-up meets top-down" process has been essential to the effort to date, driven by a broad-based commitment to the charge and a recognition that environmental science and studies are fundamental to the University's own mission and future. The process to date has yielded two approved tenure-track positions, the first resulting in a top-flight hire for AY 16/17 (climate change adaptation expertise, chemical engineering background) and the second for recruitment in 16/17 (natural resource governance focus). It has also helped drive stronger synergy in the IDCE Department's curriculum, across programs, including the promotion of the interdisciplinary Team Practicum model.

Mission

The mission of ES&P is twofold: (1) to educate and train twenty-first century professionals to understand, then help solve, problems that involve complex interrelationships

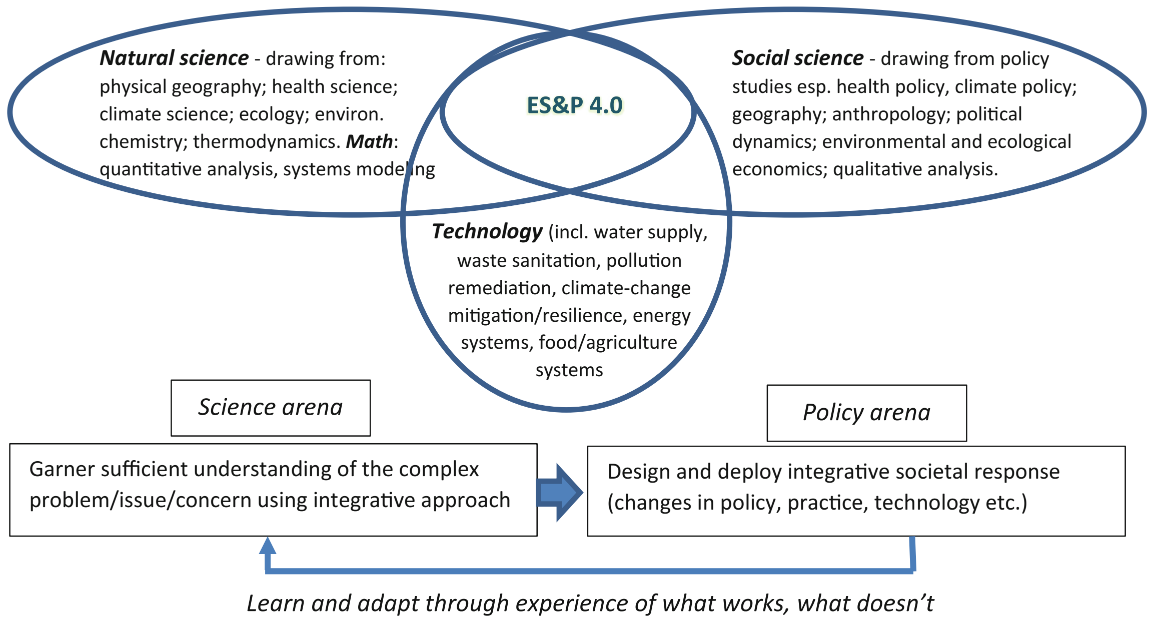

Fig. 1 ES&P's ethos and niche reside at the nexus of natural science, technology, and social science, connecting knowledge and understanding of complex problems with societal responses

among environmental, economic, and social systems, and (2) to apply research, via translational research efforts, to practice—in partnership with diverse stakeholders—in a manner that improves the understanding and solution of complex socio-ecological problems.

Niche

Why do students come to ES&P at Clark? The primary reason is that our interdisciplinary culture resonates with those students: *a place where natural science and technology meet social science and policy*. The international development, community development and GIS learning and application opportunities with our sister programs are also a draw. Few competitors operate at this important nexus, instead tending to emphasize one aspect or another (Fig. 1). Interrogating and solving complex socio-ecological problems requires such integration, and our students identify with this niche. During the 12-unit MS, students gain breadth by exposure to the diverse disciplinary perspectives represented in Fig. 1 and gain depth through their choice of specialized electives and during in their Final Project, which offers the Team Practicum option (see "Curriculum" section).

Identity

ES&P4.0 is primarily a program designed for professional impact since it serves graduate students who will become twenty-first century professionals. The combination of critical, integrative thinking, research training, and practical skills makes it a professionally oriented program with strong academic rigor. Alums who use the program as a jumping-off point for doctoral studies undertake MS Thesis work individually or as task leaders of the Team Practicum.

Thematic foci

Balancing breadth with depth is hard, but desirable, even at the 2-year MS level. While our approach is broad and integrative (see "Integrative framework" section), we attain depth through three thematic foci of ES&P3.0, personified by the three tenure/tenure-track positions that undergird the program (one existing since 2001, one new hire for AY 16/17, one approved position for 17/18). These are the following: (1) how pollution impacts human health (e.g., children's environmental health in New England, see "Holliston Health Project, Massachusetts, USA" section); (2) how climate change impacts humans, and how those impacts can be mitigated (e.g., climate change vulnerability and adaptation of socio-ecological systems); and (3) natural resource governance (subfield to be specified: food or watershed stewardship and policy in an era of toxics and climate change are candidates). These foci were driven by four criteria: (1) global and domestic urgency; (2) degree of synergy within the IDCE Department, and secondarily with the School of Geography (our most closely aligned campus colleagues); (3) strategic importance to the University's mission; and

(4) alignment with ongoing and emerging professional opportunities.

Integrative framework

The framework we used to guide ES&P 4.0 program design, and to guide our contribution to the trans-discipline of *environment, development, and society* (EDS) is a critical synthesis. We drew on decades of empirical evidence about EDS work (see UN/DESA 2016; UNGA 2014; Downs 2001, 2007), five IPCC Assessment Reports (since 1990, incl. IPCC 2014), our experiences with two global environmental assessments (Millennium Ecosystem Assessment and GEO-4), and climate change policy experience (Brown et al. 2015; USAID 2014), as well as the authors' experiential knowledge. The recently developed framework consists of *six domains (6-D)* that help systematically identify and bridge gaps in environment, development, and society work (Downs et al. 2017; Downs and Mazari 2017).

Domain 1: project concept, framing, and design

Identifying then bridging gaps in an EDS project, and hence practice, has a logical beginning in its conception, framing, and design. Projects tend to be driven from the top by powerful actors in central government, donor agencies, and knowledge/technology elites, rather than local communities who bear most of the risks. Thus, the institutional incentives for these actors outweigh the concerns and interests of the less powerful social actors who are supposed to be the primary recipients of EDS benefits (for a discussion of this challenge at USAID, see Natsios 2010). In this way, traditional EDS practice overemphasizes technological aspects and devalues social aspects, and this failing arguably constitutes the biggest risk to EDS progress (see, for example, Carr 2011; Mitchell 2002; Escobar 1995; Ferguson 1994). To confront the EDS challenges of our era, students must learn to not merely balance the social and the technological aspects, but rather actively integrate them at the outset during conception. It is also essential that MS students—and other EDS students—pay close attention to *project design*, not merely to project management. A course on *EDS Project Design* is key, one that contemplates all stages—preparatory, assessment, planning, implementation, monitoring, and adaptation—using an adaptive approach (after Holling 1978; Walker et al. 2004; Berkes et al. 2000).

Domain 2: EDS topics and sectors

Integration across different sectors, topics, and issues—e.g., water, energy, health, food, the economy, climate resilience, social justice—forms the second major domain. Linked together, they comprise complex social, political, cultural, economic, and technological systems which interact with natural environmental systems and are often dependent on their ecological integrity. Students need to think across sectors and be able to model the linkages among them and with environments. In our own practice, we use *gateway sectors* to galvanize public attention and interest (e.g., children's health) and as ways to navigate more complex EDS systems. We also use *keystone sectors* (e.g., water, energy) to simplify complexity by exploring their governing influences on many other sectors and the EDS system as a whole (e.g., for EDS in the Mexico City context, see Downs and Mazari 2017). The interrelationships among sectors should be integral to the MS curriculum (including the Team Practicum), and an *EDS Systems Modeling* course is a priority elective. The revised core class *Climate-Change Science and Policy* (including impacts assessment, mitigation, adaptation, and resilience building) encourages integration and systems thinking.

Domain 3: EDS stakeholder interests, relationships, and assets

At its core, the 6-D framework focuses attention on stakeholders and social actors, recognizing that the relationships among them govern success (Downs 2007). They include donors, government agencies, non-governmental organizations, community-based organizations, academics, and businesses. Social actors are a key source of knowledge (domain 4) that helps define, understand, and solve complex problems (see, for example, how livelihood decision-making helps navigate complex systems in Carr 2014). The resulting social network (domain 5) also determines the resources and capacities (domain 6) mobilized to achieve solutions (Carr 2013). Unless this core dimension is given prominence, top-down, technocentric approaches will dominate, as discussed in domain 1. As a response to top-down development, the practice of bottom-up *participatory development* began before the 1980s with ad hoc engagement by both the IDSC and ES&P strands of what would become IDCE. Systematic treatment of participatory processes largely began in the 1980s (see, for example, Chambers 1995, 1997, 2008), with Clark's International Development Program among its early champions. However, participatory development practices have been insufficient on their own to challenge convention (Carr 2011; Chhotray 2004; Cornwall 2003, 2008; Leal 2007). Since 2000, the calls for top-down-meets-bottom-up approaches—collaborative multi-stakeholder processes—have become louder (Downs 2001, 2007; UN/DESA 2016; others). Such efforts have been an ongoing aspect of our research program (examples are Frohmberg, et al. 2000, Quigley et al. 2001, Downs et al. 2010, 2011, Webler et al. 2017). The course *Sustainable Development Assessment and Planning* is an elective that has evolved over 12 years; beginning life as an environmental impacts assessment (EIA) course, it now uses the 6-D framework to design and develop EDS projects and critique existing ones and identifies social innovations among stakeholders (collaborations, networks), followed by technological ones, as the desired driver of EDS progress (Downs 2008).

Domain 4: knowledge types, disciplines, models, and methods

Each stakeholder group possesses particular knowledge and tools of value to understanding and solving complex EDS problems: academic knowledge, professional knowledge, and indigenous and experiential knowledge. The integration of this knowledge pool runs counter to the strong tendency of education toward specialization, even in fields like environmental science and policy that are intended as integrative. For example, climate change adaptation and hydro-meteorological disaster risk reduction, while closely related fields, focus on different geographic and temporal scales and often employ the same terms but different ways such that their efforts become incompatible (Schipper and Pelling 2006; Mercer 2010). An even more fundamental source of EDS project failings, is that local knowledge is often seen as illegitimate, or of lesser value, than the scientific framings of inquiry wielded by powerful EDS actors (Roncoli et al. 2002; Davis 2005; Mercer et al. 2010 and, from ES&P project experience, Frohmberg et al. 2000, Quigley et al. 2001, Webler et al 2017). ES&P 4.0 makes explicit throughout its curriculum that stakeholder and knowledge integration are core to its ethos. Figure 1 shows a high level of interdisciplinarity to be key to its identity and niche. The illustrative Team Practicum (see "Team practicum" section) is designed using a 6-D frame, with two mainstays: (a) community–researcher collaboration driven by community concerns, leveraging local knowledge, and (b) interdisciplinarity with depth and breadth, arising from strategic interinstitutional partnerships on the research side. We prefer the term *interdisciplinarity* (as opposed to trans-disciplinarity) because it emphasizes the emergence of new knowledge from the interactions among disciplines, with researchers lending—then blending—perspectives, framings, and methods from their disciplinary formations.

Domain 5: variable temporal and spatial scales, and networks

EDS work calls for short-, medium-, and long-term timeframes to be considered in parallel and for them to be adapted as work progresses. Short terms (1–3 years) are appropriate for tackling urgent problems quickly, and doing this well serves to reinforce stakeholder engagement and build trust. Short frames also align with the terms and interests of political leaders. Medium terms (10 years) are increasingly being used by stakeholders in the private sector, as well as some donors, for investment planning and scenario modeling (e.g.—notably—in the energy sector as they consider climate change response scenarios). Longer terms (20 years +) are frames traditionally used for aspirational sustainable development assessment and planning, as well as climate change modeling (e.g., the recent Sustainable Development Goals for 2030, IPCC climate scenarios out to 2100). Students need to be able to think at these differing timescales and be trained to work with stakeholders to reconcile short-, medium-, and long-term interests that may seem incompatible. The time dependency of human–environment interactions is central to the environmental science core course *Fundamentals of Environmental Science* and is a cross-cutting theme throughout the curriculum.

As for the spatial scale aspect, it is common for EDS projects to pay insufficient attention to influences that operate at a larger scale than the project scale, for example, a city's dependence on water sources from multiple external basins (see Downs and Mazari 2017). It is very important for students to be able to contemplate that socio-ecological systems involve pressures, changes in state, impacts, and responses that operate at variable spatial and temporal scales. For ES&P 3.0 education and research, we work closely with our sibling Geographic Information Science for Development and Environment (GISDE) Program, encouraging students to take GIS and remote sensing courses and to incorporate spatial analysis into their Final Project/Team Practicum.

The importance of adequate spatial scale also pertains to replication and the scaling up of localized success using socio-technical networks. There is significant promise in this regard to project designs that contemplate the creation of EDS innovation networks that can operate at varying spatial scales and can distribute and amplify positive impacts and enabling capacities. Information and capacities may be shared among projects with a diversity of topical foci and stakeholders, operating in diverse settings and contexts. They succeed or fail depending on the quality and integrity of communication and information sharing among the stakeholders at each site and among the sites.

Domain 6: socio-technical capacities

The ability of society to understand and address complex EDS problems, and to pursue a more sustainable human development path, appears to depend on integrating six interdependent levels of capacity (precursor to the 6-D approach, see Downs 2001, 2007): (1) political and financial seed capital to initiate and catalyze projects; (2) human resources, education, and training; (3) shared information and knowledge resources (domain 4); (4) policymaking, governance, and regulation; (5) appropriate technologies and infrastructure; and (6) enterprise development to support human health and well-being. Each level can be further broken down into discrete operational pieces.

Worthy of note is that while *education* is integral to strengthening the capacity of human resources, it is but one component of an integrative capacity building system, which itself resides in our model within the larger 6-D frame. The catalytic power of education is manifest when it enables the relationships among the different levels and domains to be

Table 1 Ten strategic competencies (sources include ECO 2007; DeGalan and Middlekrauff 2008; Fasulo and Walker 2007; and others)

Competency	Description	How
1. Creative, critical thinking and problem solving	Framing and understanding issues in diverse ways; constructively challenging conventional ways; crafting creative, strategic responses to complex problems by factoring in a rich set of criteria, informed by sustainability principles	Core to coursework and team practicum
2. Scientific/technical literacy	Having command of the technical and scientific languages and theoretical paradigms used to describe problems/issues while being critical of limitations of any paradigm, drawing from natural sciences, engineering, social sciences, and humanities	Cumulative via coursework and during practicum
3. Integrative analysis/synthesis	The ability to use *systems modeling* to understand dynamic human–environment systems, explore policy implications, and integrate across sectors/topics/issues	Modeling course and in linkages between course, practicum design
4. Critical policy perspective	A well-developed understanding of the policy implications and policy relevance of scientific knowledge, as well as the social, economic, and cultural contexts of policy, and the politics/power dynamics that influence—often drive—public policy	Core to coursework and team practicum
5. Quantitative, qualitative, and narrative research and data analysis skills	A command of *mixed-methods* approaches consistent with our integrative signature	Cumulative via coursework and during practicum
6. GIS and Information and Communication Technologies	A working knowledge of GIS, core competency with Excel®, SPSS®, or other stats software, and databases	GIS courses, coursework projects, practicum
7. Practical field and/or lab experience	A working knowledge of how to design environmental field studies including sampling techniques and field measurement	Team practicum, internships with professionals
8. Knowledge of partnership approaches	A working knowledge of what it takes to bring together and collaborate with multiple stakeholders—stakeholder engagement and dialog, conflict mediation	Team practicum
9. Communication competency	Writing skills, oral skills (incl. presentations and running meetings), multilingual ability (esp. in countries, regions of interest for student)	Cumulative via coursework and during practicum
10. Motivation, initiative, resilience, and drive	Intangibles, nevertheless important core attributes that we should seek to nurture and develop in classes, research projects, and mentoring/advising	Team practicum, class projects, attentive mentoring

activated. This logic suggests that educational programs designed with *multi-domain integration* as the organizing principle (rather than simply knowledge acquisition or skills/competencies)—in professional EDS Masters degrees like ES&P—have the strongest potential to prepare students to think about, design, and deploy innovative projects, fundamentally changing the way society responds to complex challenges.

Competencies

To further inform program development, and further validate the 6-D frame, we undertook interviews with employers and a literature review of desirable professional competencies and skills that employers seek (ECO 2007; DeGalan and Middlekrauff 2008; Fasulo and Walker 2007). Ten strategic competencies emerged (Table 1). We mapped the existing and proposed curriculum against these desired abilities to determine coverage and

Table 2 ES&P curriculum

Course (no. of units, E, U, P)	Topical focus of faculty	6-D domain	Competencies (see Table 1)	Synergies with other programs
Core (5.0)[a]				
1. Fundamentals of environmental science (1.0, E)	Environmental health science, sustainability	Sectors, knowledge	2, 5	Physics, geography, chemistry
2. Decision methods for environmental management (1.0, E)	Environmental management	Stakeholders	4, 8	Geography, management
3. Environmental governance and policy (1.0, U)	Natural resource governance and conflict	Sectors, stakeholders	1–5	IDSC, GISDE, geography
4. Climate change, environment, and development (1.0, E)	Climate change mitigation, adaptation, resilience	Sectors, stakeholders, knowledge	1–5	IDSC, GISDE, geography
5. Research or practice project[b] (E, U)	Tends to be one focus but is integrative	All	1–10	GISDE, CDP, IDSC
Electives (7.0)[a] sampling only				
Sustainable development assessment and planning (E)	Sustainability	All	1, 3, 4, 8	IDSC, CDP, GISDE, geography
Landscape ecology (E)	Natural resource governance	Knowledge, temporal/spatial scales	2, 5, 6	GISDE, geography
GIS for environmental science and policy (E)	All foci			GISDE, geography
Introduction to remote sensing (E)				GISDE, geography
Critical pedagogy for social and environ. justice (P)	All foci	Sectors, stakeholders, knowledge	1–5	CDP, IDSC
Economic fundamentals for international development (E)	Sustainability		1, 2, 4	IDSC
Microfinance, gender, and neoliberalism (E)			1, 2, 4	IDSC
Education and development (E)		Capacities	1, 2, 4	
Knowledge-driven industries (E)		Knowledge	2, 4	CDP
Qualitative research methods (E)	All foci	Knowledge, scales	2, 5	
Quantitative analysis (E)			2, 5	Geography
Systems modeling (E, U)	Sustainability, all foci	Sectors, stakeholders, knowledge	1, 2, 3	IDSC, CDP, GISDE, geography
Food, environment and health (E)	Sustainability, health, and natural resource governance		1, 3, 4, 6, 8	
Environmental and social epidemiology (E)	Environmental health science		2, 5	IDSC, CDP, GISDE
Sustainability transformations (E)	Sustainability		1, 4	
Natural resource management (E, U)	Natural resource governance		1–4, 6–8	IDSC, CDP, GISDE, geography
Integrated assessment models (P)	All foci	All	1–6, 8	

E existing, *U* being updated and/or amplified, *P* prospective

[a] As a department, we are moving to reduce the number of core classes from 5.0 to 3.0 or 4.0 (including the Team Practicum)

[b] Options to satisfy the core research/practice requirement include the preferred Team Practicum, an individual research paper, a professional project (internship based), or an individual thesis. A thesis requires two readers instead of one and is roughly 2× the work of the other options; a thesis could also happen as a major part of a Team Practicum. Team Practicum best fits the 6-D frame

gaps. It is possessing a combination of most of these that seems to give students and alums a competitive edge when they interview for jobs. Handing a prospective employer a copy of the Team Practicum or individual Final Project—especially if it speaks to the advertised position—is the other key element, along with strong faculty recommendations.

Curriculum

Core and electives

Table 2 shows how the topical foci of program faculty, the 6-D framework, the strategic competencies (Table 1), and program synergies are used to design and map the ES&P 3.0 curriculum. The program's synergies with its sibling programs in IDCE (IDSC, CDP, and GISDE; see "A short history" section) and with Geography are of particular importance so that reimagining ES&P also benefits the parent department and its most closely aligned cousin on campus. Currently, the minimum number of units for the MS degree is 12.0, with 5.0 core classes providing the common base and at least 7.0 electives (each of which include a significant skill or competency). Notably, to serve the interests of integrative learning and flexibility across the MS and MA programs, making it a departmental signature, we are moving to reduce the number of core classes from 5.0 to 3.0 or 4.0 (including the Team Practicum).

Team practicum

We present two examples—one domestic, one international—to illustrate how the integrative 6-D approach informs the design of ES&P 3.0 Team Practicums that students might become involved in during their tenure as students. This educational experience is designed to equip them as professionals to lead and/or promote the design and deployment of progressive environment, development and society projects, programs, policies, practices, and technologies.

Holliston Health Project, Massachusetts, USA

Since 2014, ES&P and GISDE faculty and students have collaborated with local stakeholders in the Town of Holliston, Massachusetts, USA, to investigate the vulnerability of the shallow aquifer-based drinking water supply to pollution and explore whether there are associations between children's early life-stage exposures to contaminants and health outcomes. The concept and design of the project (domain 1) is that it is community centered, driven by the concerns of residents, and that the complexity of the environmental exposures and potential health risks, as well as the social and political complexities (discord among residents and between concerned residents and local government), requires an integrative 6-D type approach. The sectors/issues (domain 2) center on the EDS keystone issues of children's health and drinking water supply—but also link to sanitation, waste management, environmental pollution, and policy. The stakeholders (domain 3) include local residents, local government (an elected Board of Selectmen—a common model in New England), state environmental and public health agencies, and academic researchers.

Knowledge integration (domain 4) is achieved by incorporating local knowledge during the research and mobilizing experts from three institutions: Clark University's IDCE Department (ES&P and GISDE Programs); Boston University's Environmental Health Science Department; and Department of Preventive Medicine at Mount Sinai Hospital. The requisite interdisciplinarity is achieved by the close integration of the following key disciplines: environmental exposure science, hydraulic engineering, groundwater modeling, GIS spatial analysis, and GIS cloud-based, participatory assessment (Clark); environmental epidemiology and biostatistics (BU); and early-life biomarker analysis (MSH). The temporal scales of interest (domain 5) include (1) pollution history going back to the 1970s (e.g., of TCE in groundwater, Hg spills); (2) a retrospective exposure timeframe from 2005 onwards, considering children 6–10 years old now who have drunk local water since birth and whose mothers drank local water during pregnancy; and (3) a 12-month window to monitor water quality using our own well (e.g., Mn variability). On the spatial side, the scale is determined by the locations of supply wells and by the aquifer system and its larger hydrological system. Socio-technical capacities ("Domain 6: socio-technical capacities" section) that are emphasized in the development stage of the work are levels 1–3 (political and financial seed capital, education and public awareness raising, and information resources). The policy and technology responses will be informed by the results of this stage.

Since AY 14/15, two team practicums have resulted. Team 1 (five students, class of 2015) carried out profiling of four pollution sources prioritized by the community–researcher collaborative, environmental profiling, and drinking water system mapping. Team 2 (five students, class of 2016) is carrying out a more detailed assessment of the aquifer's vulnerability to criteria pollutants, determining gaps in water quality monitoring, and drawing out policy and regulatory implications. A third team (2016–2018) is involved in linking the exposure science with the design of an epidemiological study that explores the association between early life-stage exposures in young children and adverse health outcomes. A fourth team (2016–2018) is going to pilot a web-based community health atlas (interactive GIS platform) to be populated by data from the local community, including health and environment data, with the academic researchers as data receivers, QC/QA keepers, and analysts.

Fijian Islands, South Pacific (prospective)

To illustrate the international context for ES&P 4.0 practicums using this approach, we turn to the Fijian Islands. For the past decade or so, Fiji has been experiencing more frequent, intense flooding each year, representing a significant change in their weather and climate. Island nations are among the most vulnerable places on Earth to the adverse impacts of climate change and climate instability, because of inundations from sea level rise, from flooding from intense, prolonged precipitation, and from severe storms that wreak havoc on populations, vital infrastructure, and settlements (IPCC 2014). The good news is that development funders like the UN, World Bank, Asian Development Bank, European Union, and others are making *climate change resilience* a priority. However, at the same time more funding is being made available to island nations to become “climate change resilient,” this is exposing the urgent need to build sufficient integrative capacity to design and execute resilience projects that can work and be adaptive to highly dynamic and uncertain conditions.

Using this proposed practicum, MS students would work with faculty to understand existing approaches to development (incl. governance), development sectors, and socio-technical systems (food, water, energy, transportation, health/EMS, telecommunications, flood mitigation, disaster preparedness and response, etc.) and their relative resilience/sustainability. In addition, climate change scenarios of the future and recent climate data would be assembled to estimate the *envelope of plausible futures* to which Fiji needs to become more resilient. The next stage of this work is to turn this prospective project into a real one by creating a partnership with the University of Fiji, government agencies, NGOs, businesses, and donors. Central to this model, faculty and students from Clark and U. Fiji would form bi-directional teaching and research teams and exploit the 30 U. Fiji campuses across the nation as nodes of the EDS innovation network (see “Domain 5: variable temporal and spatial scales, and networks” section). They would work with a full array of stakeholders to build resilience and sustainability using the integrative 6-D approach.

Peer programs

ES&P has for many years had to be competitive within a large pool of environmental/sustainability programs. The number of programs in the same or similar arena as ES&P is growing steadily, numbering roughly 100 in 2011, and estimated at 120–130 in 2015. Of particular relevance given our defined niche, the arena of EDS and “sustainability” is also growing quite fast. For instance, the *University of Masstricht* announced their new Master Program in Sustainability Science and Policy for AY 2011/2012. *Arizona State University* has both an MS and an MA in Sustainability at their School of Sustainability. *Columbia University* has a recent Master of Science in Sustainability Management co-sponsored by the Earth Institute and the School of Continuing Education. As part of our re-design process and due diligence, we also identified 23 graduate programs that seemed closest in terms of their stated goals and compared ES&P 4.0 with those programs to ensure its competitiveness. Leading programs are tending to emphasize the development of an array of practical skills and competencies over simple knowledge acquisition. The key way ES&P is trying to distinguish itself is twofold: (1) we are a small research university that seeks partnerships with the wider society on pressing and emerging problems, and (2) our home department promotes an interdisciplinary, scholar–practitioner profile for its faculty and an *integrative* approach to pedagogy, research, and practice—one that challenges conventional, more fragmented academic settings and cultures.

Conclusion

Understanding and responding to complex environment, development, and society (EDS) challenges of the twenty-first century requires us to actively re-think how we design and deploy educational programs, especially at the level of professionally oriented Master’s degrees. Integrative approaches derived from experiential knowledge and empirical evidence of what is working and what is not—that both balance and integrate social and technical aspects—can inform this process and provide guidance. Integrative EDS educational programs have the potential to inspire and prepare students to become innovators and integrators. Collaborative, team-based real-world projects—that also serve as practicums—reinforce the coursework and the ethos and reach well beyond the university to the wider society for greater impact. While our focus in this paper has been on one pivotal program, we are also being called upon to re-imagine the role of universities/higher education during this unstable and uncertain era, strengthening its core mission to educate and generate knowledge and amplifying its impact.

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