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Environmental studies and environmental science today: inevitable mission creep and integration in action-oriented transdisciplinary areas of inquiry, training and practice

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Abstract Since the 1970s when the first "named" environmental studies (ENST) and environmental science (ENSC) training programs emerged to tackle the growing crises facing the natural world and humanity, those two areas of inquiry and practice have remained rather distinct. However, as the complexity of environmental problems grows, it is apparent that transdisciplinary perspectives and teams represent the only means to identify and implement effective solutions. Despite the fact that ENST and ENSC programs often exist at the same institution, they tend to be housed in different faculties (i.e. ENST is often in humanities and social sciences, whereas ENSC is often in science). We argue that, as the demand for broadly trained highly qualified personnel able to work in all aspects of problem identification and solutions increases, neither ENST nor ENSC on their own is sufficient to achieve desirable policy and management outcomes. Those in ENST increasingly are expected to be competent in evidence assimilation and analysis, while those in ENSC are expected to recognize the value of the human dimension and embrace their role as knowledge brokers well versed in policy and management. The days of distinct ENST and ENSC programs are numbered as we re-envision how we think about, teach and practice ENST and ENSC. Failure to integrate these areas of inquiry will retard their collective ability to achieve the outcomes that are so needed in the face of dramatic human-induced rapid environmental change. The inherent overlap of ENST and ENSC must be embraced which means modulating our thinking, training and practice related to the environment.

Keywords Environmental studies · Environmental science · Transdisciplinary · Integration

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Introduction

You are working at a student recruitment fair, and a potential student or their parent approaches with the inevitable question—what is the difference between your environmental studies (ENST) and environmental science (ENSC) programs? When we graduated from environmentally oriented undergrad programs a number of years ago, we could have both spit out a brief, well-articulated, almost rehearsed statement that clearly differentiated ENST and ENSC (i.e. ENST is focused on competencies in policy, governance and the human dimension, while ENSC is focused on competencies in biology, earth sciences, chemistry and physical geography; Fig. 1). However, through time in the classroom and especially through interactions with real-world problems and stakeholders, our vision has changed. We acknowledge that there are hybrid programs, but for the most part, since named environmental programs began in the 1970s (Maniates and Whissel 2000), most programs have often been kept distinct. Does an undergraduate student really need to make a choice as to whether they are better suited towards ENST or ENSC as they depart high school as we require them to do today (Auer 2010)? Are we able to perfectly partition training such that

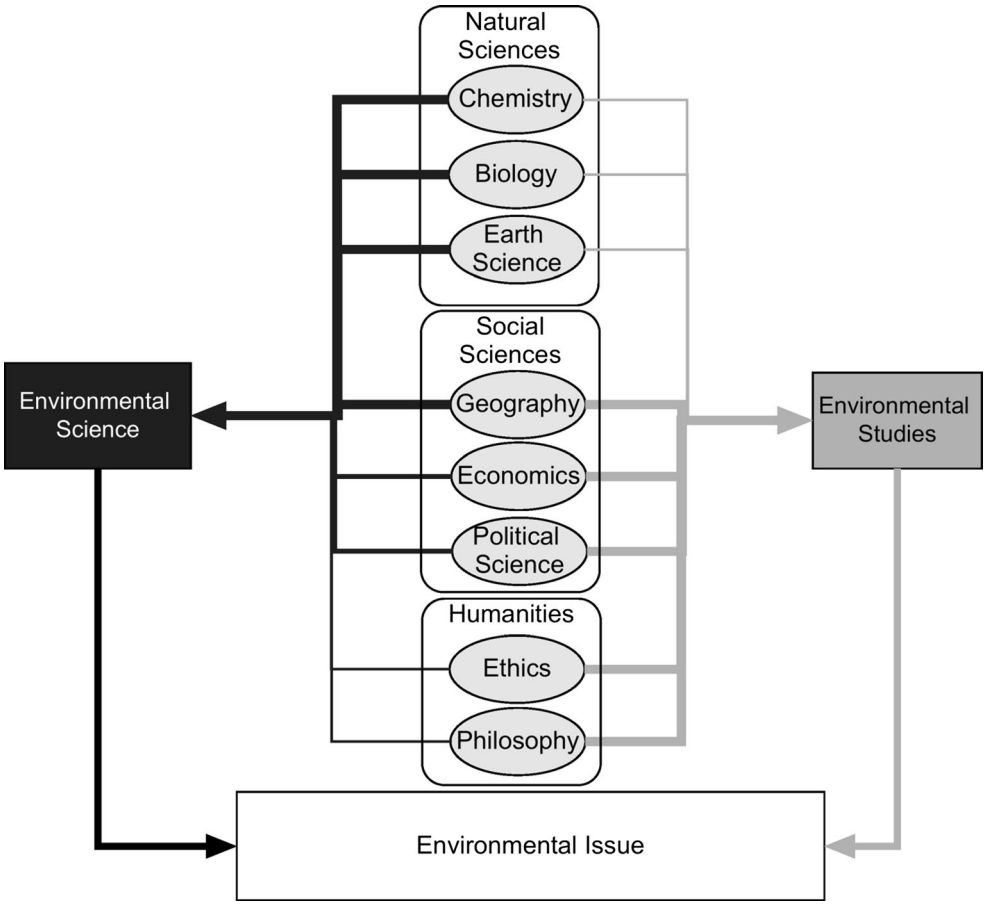

Fig. 1 Diagram showing the transdisciplinary nature of environmental studies (ENST) and environmental science (ENSC). Although both fields typically place a different research emphasis on addressing environmental topics, as shown by the thickness of the connecting lines, these differences are highly complementary rather than contrasting in addressing environmental issues

graduates are well versed to tackle problems that are either aligned with ENST or ENSC? As the complexity of environmental problems continues to grow (Vitousek et al. 1997) and based on an apparent movement towards collaboration across disciplinary lines (Turner 2000; Benda et al. 2002), perhaps it is time to consider the future of ENST and ENSC. Here, we present a viewpoint that both ENST and ENSC have undertaken substantial mission creep, whereby the lines between the two are beyond blurred and best described as integrated. It is our assertion that this outcome was inevitable given the action-oriented nature of environmental inquiry and practices as well as the inherent recognition that environmental problems have inextricably linked (see Benda et al. 2002) socio-cultural and scientific components. Rather than trying to pretend that ENST and ENSC are best served by maintaining independent streams of inquiry and training, we argue that it is time for a new vision and present a path for achieving better training, scholarly inquiry and professional practice that yield more immediate and effective evidence-based outcomes. The framework that we present will hopefully serve as a starting point for discourse regarding the preparation of environmental professionals such that their skill set and approach to problems are consistent with the realities of the task at hand.

On the state of integration

As concern over the environment grew in the 1960s and 1970s and the realization that a transdisciplinary (note—see Table 1 for definitions of transdisciplinarity, interdisciplinarity and multidisciplinarity given that all terms are used in various

Table 1 Definitions of multiple disciplinary research and learning

Multidisciplinary	Interdisciplinary	Transdisciplinary
Research done in parallel or sequentially but from a discipline-specific perspective to address a common problem	Researcher done jointly but still from a discipline-specific perspective to create a coherent whole that is more than the sum of the disciplines to address a common problem	Research done jointly using shared conceptual framework integrating and altering discipline-specific approaches and in so doing transcends the discipline traditional boundaries to address a common problem

Based from Rosenfield (1992) and Choi and Pak (2006)

places in the paper yet have important, at times subtle, differences) approach was needed to address environmental issues, ENST and ENSC programs began to be formed at universities to the point where today, there are in excess of 1000 environmental programs at colleges and universities in North America (Clark et al. 2011a). The roots of these programs help to explain the historical separation between these disciplines. ENST, with a focus on human-environment interactions, generally grew out of the social sciences, philosophy or the humanities, whereas ENSC grew out of the natural science disciplines often as an offshoot of Forestry, Agriculture, Earth Science, Chemistry or Biology Departments depending, in part, on the research focus of the institution. We acknowledge that some ENST and ENSC undergraduate programs in North America do not follow this norm. Maniates and Whissel (2000) evaluated 128 undergraduate programs and found that there were numerous ENST programs that were based largely on a natural science core and ENSC programs that emphasized policy and political economy. This does not detract from our argument and simply emphasizes that ENST and ENSC programs vary widely in terms of naming conventions. For those scholars active in the environment realm, it is quite apparent (in terms of scholarship, training, administration and granting agencies) that there have been two traditional perspectives (one more human dimension oriented and one more natural science oriented) no matter what they are called. This traditional division between the social and natural sciences, both in terms of university administration and granting agencies (e.g. in Canada the Social Sciences and Humanities Research Council versus the Natural Sciences and Engineering Research Council), helps to explain the traditionally low level of integration between these disciplines (Fig. 2). Over the years, however, the lines between the social and natural sciences have become increasingly blurred in addressing environmental topics and research projects as both ENST and ENSC pull from a variety of traditional disciplines, although with a different emphasis (Fig. 1). This ever increasing blurring of the lines between ENST and ENSC research has formed highly complementary research programs where there is strong potential for integration (Fig. 2). Indeed, the type of integration we believe is needed is not unlike the concept of a "second environmental science" focused on human-environment interactions as proposed by Stern (1993) or the conceptual framework for integrative human-environment research presented by Newell et al. (2005). We argue that the most fruitful and rapid advances in addressing complex environmental problems likely happen where integration is extensive or complete. At some level, this desired state is simply organic (informal) and represents an inevitable mission creep whereby the problems and solutions require it. That is, no one stood up and said "we need to integrate". However, there may also be more formal mechanisms for integration that could be considered. van Kerkhoff (2005) described a framework for analysing integration in environmental science and policy describing integration activities both within and beyond science and across activities and structures. Here, we argue that we should be doing anything and everything possible to foster integration through, for example, training, team building and research funding to optimize integration.

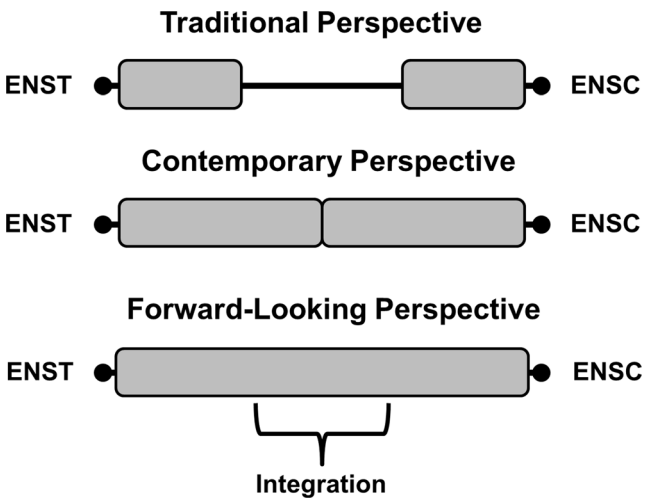

Fig. 2 Schematic of level of integration between environmental studies (*ENST*) and environmental science (*ENSC*) through time

One means of exploring the integration is to consider the recent activities of the Association for Environmental Studies and Science (AESS). For example, they state that they are "not a confederation of disciplines". Moreover, they acknowledge that "broad advances in environmental knowledge require disciplinary, interdisciplinary and transdisciplinary approaches to research and learning". That is, they recognize the inherent value in the disciplines and sub-disciplines that collectively comprise ENST and ENSC, yet there is also no explicit notion that ENST and ENSC are different or should be treated as separate entities. Both Soulé and Press (1998) and Maniates and Whissel (2000) present fascinating arguments and perspectives on ENST and ENSC in terms of undergraduate programming, pedagogy and unit organization. The words "coherence" and "rigour" are raised as areas in need of further thought in what Maniates and Whissel (2000) call the "linked" fields of ENST and ENSC. We support both concepts but suggest that coherence and rigour will best be achieved by working backwards—that is, identifying the skills and knowledge needed to solve complex environmental problems and achieve sustainability to inform program architecture—a position recently articulated by Winner and Champion (2012) and Clark et al. (2011a). Clark et al. (2011a) noted that environmental programs have struggled to integrate disciplines and train students to be effective problem solvers and provide a number of strategies to address that issue (also see Clark et al. 2011b for specific ideas). They are also one of the few groups of authors to explicitly recognize that the ENST and ENSC divide in terms of educational programs that are not

only real but also problematic. Nonetheless, they did not go so far as to call for complete integration as we do here. Cooke (2011) argued that we owe it to future generations to ensure that those we train have the skills and the passion to work on complex real-world problems, which requires new ways of thinking about research and education (e.g. involving transdisciplinary approaches).

To some extent, those working in the applied fields of ENST and ENSC are used to a norm that demands collaboration and reaching across disciplinary and institutional barriers that all too often stifle interaction and interdisciplinary team-building (Sankar et al. 2007). Yet, the level of integration between ENST and ENSC seems to be less realized than one might expect beyond superficial platitudes. Although there are a number of reasons that could potentially explain the lack of integration, perhaps the biggest barrier is historical. For example, despite the fact that ENST and ENSC programs often exist at the same institution, they tend to be housed in different faculties (i.e. ENST is often in humanities and social sciences, while ENSC is often in science). Indeed, they often compete for the same students at the level of the institution, and young recruits (and their parents) are often confused about the differences between these two programs. When there is competition to maintain boundaries to justify the existence of two programs, there is an inherent disincentive to integrate formally or informally.

Integration versus specialization

Through our training, we often need to specialize in a chosen discipline, but it is important that as we develop, we continue to work on integrating aspects of ENSC and ENST into our research and teaching. Without a concerted effort at integration, ENSC and ENST will inevitably become increasingly specialized. One of the major obstacles with increased specialization is the development of sub-discipline-specific language and paradigms that make collaboration with researchers outside your discipline increasingly difficult (Fisher et al. 2011). This can lead to vastly different interpretations of environmental problems and solutions that can result in a lack of any concrete action being taken to address the problem (Fig. 3).

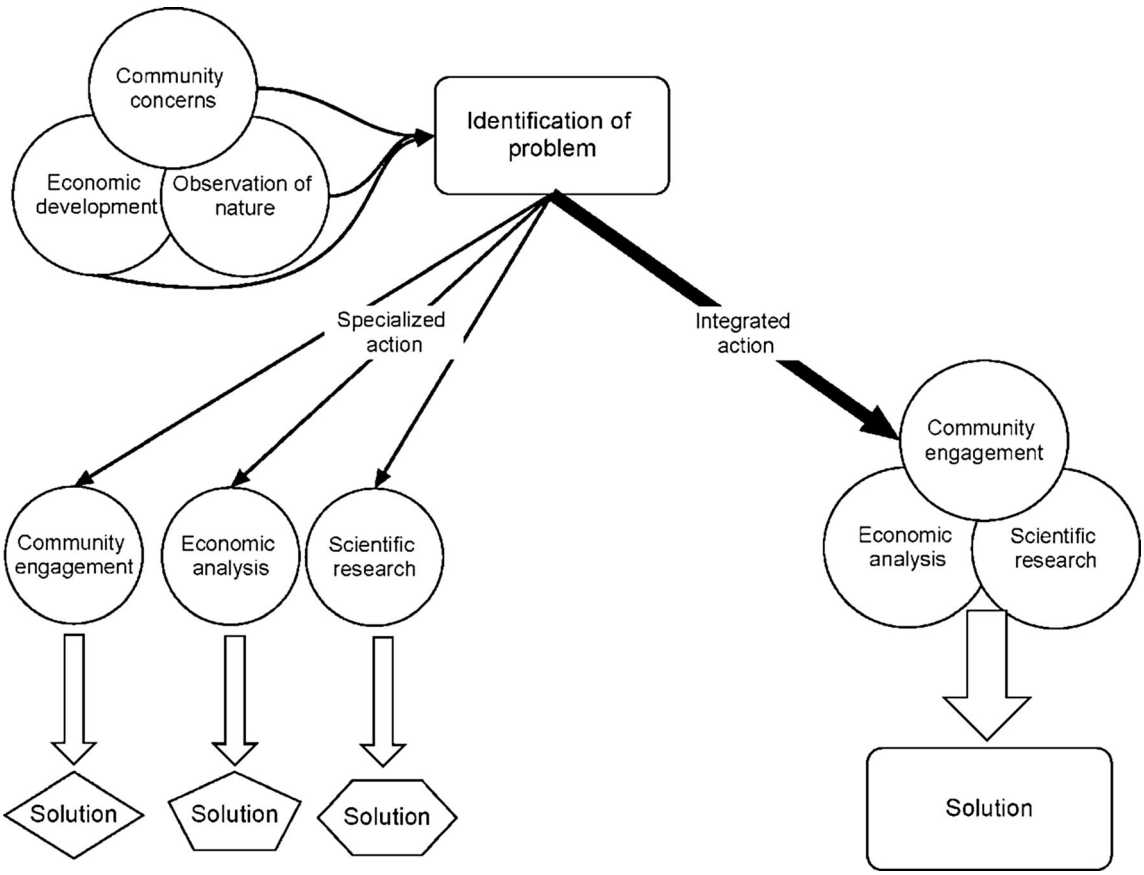

Fig. 3 Schematic of research paths on environmental topics. Identification of environmental research problems rarely arises from a single domain, and it is often difficult, or even undesirable, to disentangle the drivers of environmental research problems. By taking a specialized research approach to solving environmental problems, multiple solutions may arise which may be contrasting, making it difficult to resolve the best solution. In contrast, by taking an integrated approach to the research problem from the start, it is increasingly likely that a single actionable solution is identified which is more likely to be implemented

It is therefore important that as environmental researchers, we constantly work towards integration as opposed to ever more detailed specialization.

To do this, we need to rethink discrete ENSC and ENVS academic units. At a minimum, there needs to be integration of faculty and students between units. For example, faculty members should be provided with explicit informal and formal opportunities for collaboration (in terms of research; note—this must include tools and processes to facilitate collaboration; Jeffrey 2003) and co-teaching. Given that ENSC and ENST graduates will undoubtedly be working together, educational and training opportunities that align and integrate students from both realms are essential. Joint discussion and especially group project courses should be the minimum. Similarly, professors should be encouraged to supervise undergraduate student research projects from both realms. The establishment of these highly integrated units would help overcome key institutional barriers to collaborative training and research (Fisher et al. 2011). We are not advocating that environmental programs become a "university in miniature" as warned against by Soulé and Press (1998) and recognize their point that diversity needs to be limited within programs to ensure that students obtain a depth of knowledge expected of a university degree. However, Soulé and Press (1998) also stress that diversity should not be limited between programs with an environmental focus, and we argue that exposure to this diversity through, for example course requirements, research groups and graduate student committees, should be fostered rather than discouraged.

The imperative for integrating ENST and ENSC

There are a number of practical and conceptual reasons why we believe that it is imperative to integrate ENST and ENSC. Here, we present what we consider to be the primary reasons for doing so.

Understanding and overcoming the complexity of environmental problems

Environmental problems are often complex given that they involve a variety of biotic and abiotic elements spanning biology, chemistry, earth science, geography, etc. as well as the human dimension (including economics, social science, politics). Indeed, some environmental problems are so complex that they are considered to be "wicked problems" (Salwasser 2004) where there is a high degree of scientific uncertainty, complex interdependencies and deep disagreement in values within the stakeholder community (Allen and Gould 1986; Balint et al. 2011). The best way to understand and address complex environmental problems (e.g. climate change; Hulme 2009) is through transdisciplinary research (Rhoten and Parker 2004) that combines ENST and ENSC perspectives. Moreover, when moving from research to action (e.g. decision-making, management), it is essential to understand the uncertainty associated with research findings (Hilborn 1987; Ludwig et al. 1993) and identify optimal solutions that address stakeholder concerns to the extent possible (Balint et al. 2011). Evidence evaluation and stakeholder engagement, which can be integrated using existing frameworks (e.g. Bardwell 1991), both require deep understanding of core elements of ENST and ENSC such that neither is sufficient on their own.

Overcoming barriers to knowledge mobilization and application

Generation of scientific findings does not guarantee that they will find their way to those that need them or that they will ever be applied (e.g. used to support decision making, used in management). Indeed, there is growing recognition that knowledge mobilization is a critical element of the scientific process. Unfortunately, scientists are not particularly well known for their ability to mobilize knowledge such that it reaches the receptor community in the correct form and in a timely manner. Many science-based government agencies now have units devoted to knowledge translation and knowledge transfer to connect their science units and their policy and management clients (receptors). To address environmental problems in a timely manner, it is critical that knowledge is translated and mobilized such that it can be applied. Those active in the scientific arena are increasingly expected to take the extra effort to mobilize knowledge beyond simply disseminating work through the peer-reviewed literature. The skill set for translating and mobilizing knowledge has grown out of developments in the social science field (Bennet et al. 2007) but is often left to intermediaries (i.e. knowledge brokers; Cooper 2010)—those that work at the interface or ideally integration of ENST and ENSC. There is need for more professionals that have an integrated perspective on knowledge generation, mobilization and application.

Realization that human behaviour drives environmental problems and solutions

Humans are central to environmental problems and solutions given that they typically constitute the basis for the problem (or are affected by it in the case of natural disasters; Vitousek et al. 1997) and represent the path to a solution (Schultz 2011). Although science is ideally the basis for policy and management action when we attempt to manage the natural and physical environment, the reality is that most policy and management instruments focus on trying to alter human behaviour. Therefore, although environmental education initiatives cover a spectrum of approaches and interventions (Monroe et al.

2008), ultimately, they are focused on modifying human behaviour (Asch and Shore 1975; Hungerford and Volk 1990). Engaging members of society in ways that result in meaningful and lasting changes in behaviour is thus a common goal of those involved in ENSC and ENST (De Young 1993). Those engaged in research and scientific aspects of environmental problems cannot think or operate in isolation of humans just like those that approach problems from more of an ENST perspective need to base their activities on credible science. Increasingly, there is a movement towards the incorporation of social science components into applied ENSC studies such that it is possible to understand the barriers to stakeholder uptake of findings, characterize human perceptions/values and incorporate such knowledge into the application of findings. This can be extended whereby stakeholders are engaged in scientific research (i.e. citizen science; Silvertown 2009) which is yet another realization of where ENST and ENSC overlap and are inherently integrated.

Recognition that science and technology are insufficient to solve environmental problems

We can use science and technology to solve all environmental problems right? Turns out that there are a growing number of high-profile examples where environmental science and technology have failed to deliver effective solutions. Huesemann (2001) presents three reasons for this apparent failure using pollution control as a case study and concludes that it is necessary to address the root cause of environmental deterioration. Specifically, Huesemann (2001) notes that efforts must be made to overcome the materialistic values that he argues are the primary driver for both overpopulation and overconsumption. As such, the notion that solving environmental problems through science and technology is a fallacy when social and moral problems prevail. In some cases, scientific knowledge has made environmental controversies worse. Sarewitz (2004) presents a fascinating (and now highly cited) account of how scientific inquiry is inherently and unavoidably subject to becoming politicized in environmental controversies. The author concludes that the value bases of disputes underlying environmental controversies must first be explored through political means before science can play an effective role in solving problems. Relatedly, Oreskes (2004) suggests that science does not produce "logically indisputable proofs" about the natural world rather it demands scrutiny, re-examination and revision which are subject to diversity in individual political, cultural and economic perspectives. Collectively, these examples emphasize that science and technology (i.e. ENSC) are in fact insufficient to solve environmental problems and that understanding the social, cultural and political elements (which typically are considered to fall in the realm of ENST) must be understood and addressed simultaneously in an integrated manner.

Linking scientific and traditional and local knowledge

It has become increasingly obvious to scientists that traditional and local knowledge is required to help understand, appreciate and solve environmental problems (Kimmerer 2002; Mazzocchi 2006; Folke 2010). Similarly, there have been arguments made that scientific knowledge can help complement traditional and local knowledge and provide a different vantage point on environmental problems. In fact, traditional and local knowledge are recognized as equivalent to scientific knowledge by the United Nations (1998). Scientific and traditional and local knowledge are typically highly complementary because, as pointed out by Kimmerer (2002), scientific and traditional and local knowledge have much in common because they both arise from the systematic observation of nature and can be highly complementary. Policy makers, environmental managers and granting agencies are increasingly calling for a strengthening of ties between these two equal knowledge systems; however, without transdisciplinary training, students will rarely encounter both forms of knowledge as equal partners, and it remains unclear if they will be able to make full use of both forms of knowledge in addressing environmental problems.

How do we foster integration?

So, what should the path forward look like? When students graduate and embark on their professional lives, they tend to work on issues and problems (and solutions) often defined as a specific "project". Such projects tend not to be labelled by discipline. Instead, a team is developed that has the necessary expertise including the ability to work collaboratively. Even academic researchers tend to develop their research program around questions and issues and are simply required to fit that program into one of the relevant disciplinary units. For context, how often does one introduce themselves as an "environmental studier" or "environmental scientist"? A recent survey of PhD dissertations in the pro-quest database revealed that researchers were abandoning traditional disciplinary labels (Bowman et al. 2014). Instead, scholars are thought to move freely across disciplinary boundaries and identify with topics instead of disciplines (Bowman et al. 2014) as is demonstrated by the fact that scholars are often hired by different labelled units than where they completed their studies (Sugimoto et al. 2011). Indeed, some have even gone so far as to provide interview guidance for those seeking academic appointments in environmentally oriented interdisciplinary programs (Clark and Steelman 2013). Bowman et al. (2014) muse that traditional disciplines may no longer be the gold standard. However, they also articulate that structures need to be in place to evaluate people on their topical distinctions rather

than on their disciplinary affiliations. It is unclear whether environmental studies and science are in such a position but given that grants and scholarly publishing outlets increasingly tend to be issue or topic based and cross-traditional disciplines (Morillo et al. 2003), it would appear that mechanisms already exist for peer evaluation. Extending that to traditional student training and evaluation fits with concepts such as problem-based learning (Dochy et al. 2003) and collaborative group projects.

Perhaps we need to be training our students in ENSC and ENST in how to do transdisciplinary thinking and collaboration—rather than just assuming it will happen when the time is needed. Pennington (2008) describes the application of learning frameworks to identify receptive environments for collaboration and processes that facilitate cross-disciplinary interactions. She concludes that collaboration is a complex system of people, scientific theory and tools that must be intentionally managed—something that is rarely done. Is there a role for educators in ENST and ENVS to serve as "facilitators to orchestrate effective environments and interactions" (Pennington 2008), thus ensuring that our trainees are not stuck in a disciplinary construct (Turner 2000) and have the ability to work on comprehensive projects with diverse teams? Admittedly, although both of us consider ourselves interdisciplinarians, neither of us has had any explicit training on *how* to do transdisciplinary research or to incorporate such a paradigm into our teaching. Fortuin et al. (2013) suggest that environmental systems analysis serves as a logical approach for developing cognitive interdisciplinary skills that enhance holistic thinking, promote problem analysis and solutions that integrate disciplinary knowledge and methods, and impart a reflective approach to research and problem solving. We see much promise for this approach in that it contributes to the attainment of competencies in the three interdisciplinary knowledge areas identified by Vincent and Focht (2011) which we regard as a forward-looking perspective on training of environmental professionals.

There are a growing number of published case studies that demonstrate how transdisciplinary issues can be incorporated into university curricula while training students in critical analysis (Hammer and Söderqvist 2001). Ryser et al. (2009) note that interpersonal relationships are at the core of collaborative team work and the extent to which interdisciplinary thinking can be achieved through such experiential learning will always be influenced by social interaction mechanisms (e.g. previous experiences, gender, leader-participant dynamics). In other words—it is not easy and is unlikely to be effective without it being steered appropriately! Future workshops at AESS and other relevant conferences/workshops/training opportunities focused on how to teach and instil transdisciplinary paradigms into collaborative team work would certainly be useful (see Clark et al. 2011c for detailed summary of professional development needs for environmental transdisciplinarians). The benefits could be manifold in that it would enable instructors to help learners develop specific skills related to collaborative team work and transdisciplinarity needed to address complex environmental problems. Courses at the undergraduate and graduate level could be populated by students with diverse backgrounds without encountering problems with the "jack of all, master of none" given that there would be individual-level specialization. Essentially, such courses could be capstones but should be integrated throughout training and not simply left to the last year of a program.

Conclusions

The days of distinct ENST and ENSC programs are numbered as we re-envision how we think about, teach and practice ENST and ENSC. We have argued that failure to re-engineer and integrate these areas of inquiry will retard their collective ability to achieve the outcomes that are so needed in the face of dramatic human-induced rapid environmental change. We present a paradigm which recognizes the inherent overlap of ENST and ENSC yet goes one step further to call for complete integration. There are genuine opportunities for modulating our thinking, training and practice related to the environment that would be achieved through integration of ENST and ENSC. There have been some recent promising developments in what Clark et al. (2011b) refer to as the "environmental program movement" where academic institutions are attempting to "produce graduates who can help societies and governments solve pressing technical, management and policy problems involving natural resources, environmental quality and social justice". That said, such programs (often in the form of a school, college or faculty of the environment) then tend to subdivide into various units that tend to resemble the classical ENST and ENST divide. In terms of research, there are a growing number of transdisciplinary research groups, but rigorous and fully integrated educational programs are lacking.

We recognize that an obvious omission in this paper is a formal discussion of environmental engineering. It represents the "other" major named environmental program. We certainly see merit in the inclusion of environmental engineering knowledge and techniques in modern environmental problem solving; however, unlike ENST and ENSC, the ability to integrate and connect at least in a training context is more constrained by the rigid course requirements associated with the professional accreditation of engineering programs (i.e. P. Eng.). There is a growing movement towards the accreditation of ENST and ENSC programs (e.g. Smardon 2011) which is useful for setting standards but may also constrain interaction and integration. To that end, we submit that those entities that engage in accreditation as well as educational institutions and units involved in training need to engage in open discourse

related to the integration of ENST and ENSC. We are certain that there will be alternate views (e.g. Chapman 2007), with additional benefits and disbenefits identified by the diverse community of professionals. Nonetheless, we think that the time is correct to embark on such debate given the imperatives identified above including the fact that environmental problems continue to grow in number and complexity such that this changing landscape demands adjustments to the thinking, training and practice related to the environment.

From our perspective, it has been the realities of research and practice where we have been forced to fully integrate ENST and ENST. We argue that it is time to do the same in the classroom. The perspectives provided by Soulé and Press (1998) and Maniates and Whissel (2000) are noteworthy, but 14+ years later, we feel that we are now in a different place where integration is necessary. As outlined above, environmental practitioners must often work along the entirety of the spectrum, and the idea of having discrete ENSC or ENST labels seems archaic. Vincent and Focht (2011) submit that the renewed focus of environmental programs is aligned with the concept of "sustainability science" ([SUSC] Komiyama and Takeuchi 2006) which incorporates and considers social, political, cultural, ecological and technological aspects of environmental problems while explicitly acknowledging scale (temporal and spatial) and systems-oriented thinking. Seager (2008) argued that sustainability science cannot be realized without interdisciplinarity, so organizing programs around SUSC given its dependence on interdisciplinary may promote meaningful advances towards its realization. In that sense, one could ask whether SUSC in fact is the label that should be applied to describe the complete integration. We are rather indifferent in terms of what programs are called—what is important is that meaningful integration does occur and that it is supported by rationale and intelligent curriculum, training and program architecture that prepares the next generation of environmental professionals while facilitating scholarly interactions within the research community and development of real solutions. We look forward to continued discourse on the best way to teach, practice and integrate ENST and ENSC to lead to meaningful changes in human behaviour, desirable policy outcomes and ultimately a healthy planet. Sharing examples of successful (and failed) integration of ENST and ENSC in terms of curriculum development, pedagogy, institutional structures, research projects and real-world environmental problem solving is needed to help refine the ideas presented here and ensure that integration yields the desired educational and environmental outcomes.

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