During the 20th century, the magnitude and accelerated rate of human activities altered ecological and geological processes on a global scale. This era of accelerated change – now referred to as the Anthropocene (Steffen et al. 2007) – has driven professional societies and global governance organizations to call for research efforts and policy actions that ensure human survival and well-being (MA 2005; Power and Chapin 2009; Chapin et al. 2011b). In response to these challenges, the Ecological Society of America’s Earth Stewardship Initiative focuses on enhancing human well-being (Power and Chapin 2009) through the integration of environmental ethics and ecological research (Rozzi et al. 2012). Currently, in the science, technology, engineering, and mathematics (STEM) disciplines, putting the Earth Stewardship Initiative into effect during graduate school requires a student’s personal commitment (Schienke et al. 2009) and also departmental support. Furthermore, Earth Stewardship projects (ie graduate research projects that seek to advance Earth Stewardship) are “actionable”, meaning that their findings require purposeful application (Palmer 2012). Therefore, the incorporation of Earth Stewardship principles into STEM graduate research could promote diverse benefits for society, which in turn would help academic institutions respond to the growing social calls for academic reform (Whitmer et al. 2010).

In this article we begin by considering the potential benefits of incorporating Earth Stewardship principles for STEM graduate students and academic departments. We then examine how STEM graduate students can incorporate Earth Stewardship into their research, identify opportunities for educational institutions to support such research, and discuss the potential benefits of, and barriers to, linking Earth Stewardship to graduate-level studies. We draw from the interdisciplinary literature of organizational change to frame our discussion of the necessary changes in higher education institutions (HEIs) that a successful application of an Earth Stewardship focus would require.

The complexity of change in HEIs

The goals and principles of the Earth Stewardship Initiative have been well established (outlined in Table 1; Chapin et al. 2010, 2011a, 2011b). Just as with recent efforts to embrace sustainable development in universities (Waas et al. 2010), the application of the Earth Stewardship agenda will require a shift in how future STEM professionals conceptualize and conduct research. Disciplinary thinking currently limits the governing
framework of academia, thereby creating barriers for students wishing to pursue actionable and “translational” (i.e., applying findings from basic science to enhance human health and well-being) activities (Ferrer-Balas et al. 2010; Briske 2012; Palmer 2012). These barriers promote limited training and sub-specialization of graduate students (Golde and Gallagher 1999; Taylor 2011). In the quest to complete their academic degrees, students prioritize quantifiable research outputs (e.g., securing funding and authoring publications) and focus less on the social contributions of their research (O’Meara 2006). Thus, developing a research agenda that addresses human well-being requires a transformation of academia: that is to say, a deep change in the academic culture and organizational structure so that the social contribution of a research project acquires a tangible value. The energy and enthusiasm of STEM graduate students and early professionals are crucial in this transformation (Chapin et al. 2011a), but their actions need to be supported at broader academic scales to be effective (Freeland 1992; McNamara 2010).

It is widely recognized that HEIs are slow to change (Birnbaum 1991; Elton 2003). Theories of organizational change offer insight into the conditions needed to effectively produce a positive transformation. In an extensive review of the interdisciplinary literature regarding organizational change theories and higher education, Kezar (2001) argued that transitions in HEIs can be better understood – and thus enabled – by applying concepts from different change theories (in this case from evolutionary, theological, cultural, political, and social-cognition models of change). For example, transitions in HEIs can often be political in nature, given that public affairs influence the processes that govern academic institutions. On the other hand, the cultural philosophy of an institution might also determine the success or failure of a particular strategy (Kezar 2001). In this context, we consider both top-down and bottom-up models to evaluate potential activities capable of promoting change in HEIs.

Benefits of integrating Earth Stewardship practices in graduate studies projects

Other than a close agreement with personal motivations or values, why should STEM graduate students and faculty members consider becoming actors in the transformation toward Earth Stewardship? Why should academic departments provide the critical support needed to establish a more direct path toward this transformation (Figure 1)? Individuals and academic departments that become involved early in the transition may be better suited to address various professional challenges (e.g., lack of funding and a decline in academic positions [Sauermann and Roach 2012]), which in turn will advance their respective transitional processes.

Potential benefits for graduate students

Application of Earth Stewardship principles within research projects could promote the professional development of current and beginning graduate students alike. Although an academic position remains the principal career interest for some graduate students in the STEM disciplines (Gemme and Gingras 2011), there is an...
Table 1. Possible student activities and departmental actions with potential to promote Earth Stewardship

<table>
<thead>
<tr>
<th>Earth Stewardship goals (Chapin et al. 2011b)</th>
<th>Graduate student activities</th>
<th>Departmental actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Ensure equitable access to the basic needs for a good life (eg food, clean water, and health care) across countries, segments of society, and genders</td>
<td>Explore the social context of ecological issues. Example: the ITFGW investigation on social and gender aspects of water and sanitation management (ITFGW 2005).</td>
<td>Encourage research projects that address the needs of surrounding communities.</td>
</tr>
<tr>
<td>(2) Provide equitable access to opportunities for self-realization and for social and environmental stewardship</td>
<td>Select research topics that enhance human well-being or address social environmental issues. Example: the integration of communities on rainforest sustainability certification programs (Henman and Baroody 2012).</td>
<td>Seek collaborations with bridging organizations (eg community groups, nongovernmental organizations) that help connect student researchers with ongoing stewardship initiatives.</td>
</tr>
<tr>
<td>(3) Reduce unnecessary consumption and close loops on energy and material cycling</td>
<td>Investigate flows of energy, resources, or materials in multiple settings. Example: eco-efficiency of remanufacturing closed-loop supply chain waste products (Yang et al. 2011).</td>
<td>Promote active collaboration between department research projects and local sustainability initiatives.</td>
</tr>
<tr>
<td>(4) Foster an ethic of environmental citizenship built on sense of place and pride in cultural identity</td>
<td>When designing research projects, integrate components that help citizens build a better sense of place and belonging to their natural surroundings. Examples: community-based/low-technology coral-reef restoration projects (Hernández-Delgado et al. 2011); development of urban community gardens (Schmelzkopf 1995).</td>
<td>Reward faculty that ease the integration of actionable components in student research projects. Create networks with government agencies that are actively addressing environmental issues (EPA 2002).</td>
</tr>
<tr>
<td>(5) Sustain social–ecological systems and the delivery of ecosystem services now and for future generations</td>
<td>Explore research questions that address the loss of biodiversity and its connection to the delivery of ecosystem services.</td>
<td>Provide training opportunities in collaboration with organizations that seek to enhance the provisioning of ecosystem services. Example: Integrating academic programs into the DIVERSITAS approach for ecosystem studies (Laguerardie et al. 2012).</td>
</tr>
<tr>
<td>(6) Advance the study of sustainability through scientific, local, and traditional knowledge</td>
<td>Try to generate (construct) data instead of merely collecting (excavate) data (Mason 2002), while engaging cultural groups that possess first-hand knowledge in natural environments, such as fishers and hunter–gatherers (ICSU 2002).</td>
<td>Open new faculty positions and design new courses on topics about human dimensions on environmental change and social–ecological systems. Furthermore, institutions can organize international symposia about traditional knowledge (ICSU 2002).</td>
</tr>
<tr>
<td>(7) Provide education for all, including education and outreach for sustainability</td>
<td>Integrate technology and social media for citizen-science projects and educate/engage the public in culturally creative ways. Example: One of the authors (FJS-S) is the coral-reef assessor of an environmental education program for young adults on the northeast coast of Puerto Rico. This project trains area residents to become environmental leaders and serve as vectors of knowledge to their respective communities about the importance of the adjacent marine protected area (Figure 2).</td>
<td>Open available facilities for community-based symposia, citizen-science training, and networking events. Also, offer free courses to the community and develop free online courses for students about social–ecological systems and sustainability science. Avoid the paradigm that education should be only inside a classroom and find other ways to transmit information (UNESCO 2012).</td>
</tr>
<tr>
<td>(8) Foster biological, cultural, and institutional diversity to maintain a diversity of options</td>
<td>Establish a graduate mentorship project to engage high school or undergraduate students from underrepresented groups in social–ecological research. Example: “Broadening Participation of Underrepresented Groups” remains the least addressed NSF broader impacts category (Watts et al. 2013).</td>
<td>Seek strategies to overcome institutional constraints on interdepartmental networking (Whitmer et al. 2010) and support ongoing faculty diversity. Build up social justice strategies to stop structural and institutional racism (NASW 2007). Increase diversity of students within faculties and departments and promote discussion forums among students about issues concerning Earth Stewardship principles.</td>
</tr>
<tr>
<td>(9) Ensure equitable and sustainable economic activities and institutions</td>
<td>Incorporate monetary aspects of social–ecological activities and trade-offs as a component of research projects. Example: Promote equality between men and women regarding economic contribution for households and reduction of poverty (Peebles and Crowley 2012).</td>
<td>Invest in the development of interdisciplinary research centers within institutions (Whitmer et al. 2010) to create baseline information for local municipalities regarding social–ecological trade-offs.</td>
</tr>
</tbody>
</table>
increasing interest in careers outside the realm of academia (Sauermann and Roach 2012). As the number of PhD-trained scientists increases, the availability of tenure-track positions remains limited, so that academic career prospects for graduate students become more challenging (Taylor 2011). It is therefore important for STEM graduate students to develop broad skill sets, to increase their potential for securing alternative, non-academic positions.

Given the variety of fields in the STEM disciplines, we consider the job market in the field of conservation science for illustrative purposes. The conservation science job market is multidisciplinary and attracts professionals from a range of STEM disciplines (Blickley et al. 2013). If graduate students want to become more competitive in the non-academic job market, they should not be content with only fulfilling the minimum requirements for degree completion; instead, they need to focus on their own professional development and tailor their academic plans to fit their career interests and expand their future potential (Blickley et al. 2013). Usually, students need to engage in additional efforts to achieve professional development beyond their training programs. Yet research projects connected with Earth Stewardship inherently possess components that will help the student in this process. In Table 2, we list examples of Earth Stewardship-related activities that allow students to hone the most important transferable skills – those that will be valued in the government, nonprofit, and private sectors of the conservation job market (Blickley et al. 2013). Proof that a student has successfully accomplished these activities could serve as evidence of professional experience in the applications of such skills. For example, developing a strong network of stakeholders could provide the student with easier access to letters of support or opportunities to do public presentations, activities that can be used to build a strong curriculum vitae. In short, developing Earth Stewardship projects can provide students with the opportunity to work with different disciplines, methods, and theories, while also improving their chances of pursuing an academic career if they choose to remain on that path.

**Potential benefits for academic departments**

Recently, researchers have emphasized the study of appropriate metrics to evaluate the performance of academic departments (Agasisti et al. 2012), often as related to research productivity, workforce training, and the ability to secure external funding (Al-Turki and Duffuaa 2003). With reduced public funding for science, the lattermost category will likely become increasingly important. To tackle this issue, academic departments have placed an increased value on fund acquisition through non-traditional sources by tenure-track faculty (Blekic 2011). However, by facilitating compliance with funding agency requirements for “broader impacts”, support of Earth Stewardship-related research may help to maintain existing and increase future funding from traditional sources. For example, the US National Science Foundation (NSF) awards funding to STEM researchers based on the Intellectual Merit and Broader Impacts criteria of proposed investigations (Holbrook and Frodeman 2007). Thus, to secure federal dollars, basic STEM research must compete against health care or education projects whose public benefits are direct and obvious (Salter and Martin 2001). For STEM graduate students, the ability to connect their studies to society through broader impacts is challenging because their primary strength is in the intellectual arena (Holbrook and Frodeman 2007). Despite the NSF’s efforts to “bridge the gap” between science and society through its broader impacts requirement, many NSF-funded research pro-

### Table 2. Professional skills and Earth Stewardship-focused actions

<table>
<thead>
<tr>
<th>Transferable professional skill</th>
<th>Earth Stewardship actions that support skill development and practice</th>
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<tbody>
<tr>
<td>Project management/leadership</td>
<td>• Leadership of an interdisciplinary project</td>
</tr>
<tr>
<td></td>
<td>• Active incorporation of stakeholders in the research process</td>
</tr>
<tr>
<td></td>
<td>• Development of graduate-mentorship program for undergraduates or K–12 students</td>
</tr>
<tr>
<td></td>
<td>• Establishment of citizen-science projects</td>
</tr>
<tr>
<td>Interpersonal skills</td>
<td>• Active incorporation of stakeholders in the research process</td>
</tr>
<tr>
<td></td>
<td>• Consensus-building to achieve common goals</td>
</tr>
<tr>
<td></td>
<td>• Development of trusted relationships with non-academic parties</td>
</tr>
<tr>
<td>Networking</td>
<td>• Integration of organizations during all stages of the research process</td>
</tr>
<tr>
<td></td>
<td>• Collaboration with a diversity of scholars, disciplines, organizations, and stakeholders</td>
</tr>
<tr>
<td></td>
<td>• Development of interdisciplinary networks</td>
</tr>
<tr>
<td>Written and oral communication</td>
<td>• Development of positive and creative ways to engage the public</td>
</tr>
<tr>
<td></td>
<td>• Production of white papers aimed at informing public policy makers</td>
</tr>
<tr>
<td></td>
<td>• Public presentations regarding social–environmental issues of local interest</td>
</tr>
<tr>
<td></td>
<td>• Wide dissemination of created or acquired knowledge (eg through blog posts, newspaper articles)</td>
</tr>
</tbody>
</table>

**Notes:** Earth Stewardship-focused actions (right column) can provide hands-on experience and contribute to the development of skills on demand in the non-academic job market. The four most important skills in the government, nonprofit, and private sectors in the field of conservation (left column) were identified by Blickley et al. (2013).
jects are still missing this component, indicating the agency's need to stress the relevance of broader impacts in the proposal selection process (Nadkarni and Stasch 2013).

Below, we discuss a series of actions—most of which fall within at least one of NSF's broader impacts categories—that work toward advancing Earth Stewardship goals (Table 1; Chapin et al. 2011b). If academic departments facilitate the inclusion of these actions within research projects, then researchers will likely have already satisfied those broader impact requirements, thus improving the department's chance of securing funding. In fact, despite an increase in numbers of proposals with broader impact activities submitted to the NSF, many investigators do not include the results of those actions in their award abstracts, suggesting a need for wider recognition of broader impact activities by the scientific community (Watts et al. 2013).

Academic departments that support Earth Stewardship research could also help HEIs transition into more environmentally sustainable practices. Although more institutions are shifting their actions toward the goal of a sustainable society, this shift requires extensive institutional-scale change of education practices (Elder and MacGregor 2008) that is possible only at the departmental level. For example, integration of “service learning”—a form of teaching that combines traditional lectures with service to a community—requires careful attention to curriculum development and application, two processes that occur at the departmental level (Ward 1998).

Incorporating Earth Stewardship into STEM graduate research

In a bottom-up approach, graduate students and faculty members can become actors of change by including Earth Stewardship into their research and facilitating training. In general, STEM graduate students may become Earth stewards through the integration of an actionable component in their projects (see also Table 1). Action-oriented research is cross-disciplinary, considers the social implications of the investigation at hand, and seeks to apply knowledge to assist in decision making to foster human well-being (Marshall et al. 2011). Below, we provide three specific examples of research topics with enhanced potential for actionable results.

First, interdisciplinary research collaborations between biophysical and social scientists are essential to efforts to solve present and future environmental issues. Although engaging in interdisciplinary research can be challenging (due to a focus on discipline-specific methods or a lack of familiarity with other disciplines [Morse et al. 2007]), there are a growing number of proposed frameworks to facilitate project development, with questions of interest to both biophysical and social sciences (eg MacMynowski 2007; Collins et al. 2011). In addition, recently established graduate training programs that focus on interdisciplinary projects (eg NSF’s Integrative Graduate Education and Research Traineeship [IGERT]) offer graduate students opportunities to engage in research collaborations and public outreach (Figure 2) while receiving practical training (WebPanel 1; Morse et al. 2007).

Second, public participation in the research process has an impact on the environmental attitudes and behaviors of citizens (Cooper et al. 2007). For the natural scientist, however, effectively engaging the public and quantifying the societal benefits of Earth Stewardship research would likely require collaboration with social scientists. In this case, the researcher could strategically select and apply sociological metrics associated with public engagement. Alternatively, the researcher can establish translational science partnerships with relevant social organizations (eg community-based group or nongovernmental organization that regularly engages the public). Such relationships...
should involve providing stakeholders and citizens with valuable information, such as the context and potential implications of the scientific knowledge created through the research process they are part of (Briske 2012). Citizen science is also an option for a formal approach to public involvement in Earth Stewardship projects. The role of the citizen scientist has notable potential for further theoretical development and application into specific systems. For instance, citizen participation is crucial for the success of “civic ecology” practices – local environmental stewardship practices to enhance human and ecosystem well-being in urban systems (Krasny and Tidball 2012).

Third, choosing a novel research question that integrates human well-being and sustainability can be difficult for biophysical STEM graduate students due to their limited familiarity with the social sciences. In addition, the traditional approach for graduate project development includes the identification of “gaps” in disciplinary knowledge. Thus, STEM students tend to search the scholarly literature to find a gap suitable for a dissertation topic, and normally attempt to fill that gap by applying models that exclude social issues (Strang 2007). In this case, STEM students – regardless of whether they are performing basic research – can seek to develop novel research questions by establishing a link to a community of concern (eg communities that recently suffered a disaster or have endured long periods of economic decline [Krasny and Tidball 2012]), developing a project that addresses an environmental issue, or considering the broader research impacts within a social-ecological framework.

**Pioneering change: action plan for students lacking departmental support**

Motivated students in traditional STEM departments may not receive the basic guidance needed to develop the Earth Stewardship-related aspects of their project. The broad range of knowledge surrounding Earth Stewardship and sustainability science could complicate the process of selecting a particular course to follow by requiring the student to have a broad understanding of sustainability issues (Lozano 2010). More importantly, without effective guidance, students may face a fundamental challenge in establishing a clear link between their disciplinary interests and their ability to contribute to the Earth Stewardship Initiative. This link is crucial, not only in terms of maximizing the student’s professional benefits but also for developing practical metrics that quantify progress toward meeting these goals (Chapin et al. 2011b).

The first step in establishing this link between scientific study and contribution to Earth Stewardship is the recognition that social-ecological systems, occurring at multiple and nested scales, are the units of interest in Earth Stewardship. As complex adaptive systems, social-ecological systems exhibit important emergent properties such as “resilience” – defined as the ability of the system to adapt to ongoing disturbances – and “transformability” – defined as the capacity of the system to completely transform in response to the disturbance (Folke et al. 2010). In this vein, the overall goal of Earth Stewardship is to enhance the resilience of current social-ecological systems and, when necessary, to guide their transformation to support the provisioning of ecosystem services for human well-being (Chapin et al. 2010; Berman et al. 2012). By examining social-ecological systems in the context of Resilience-Based Stewardship theory (Chapin et al. 2009), it is possible to determine whether a particular action could be expected to (1) enhance – directly or indirectly – the resilience of the system, (2) reduce its vulnerability, or (3) promote desirable transformations (Walker et al. 2004). Thus, the options for framing graduate research projects that achieve Earth Stewardship outside an interdisciplinary program multiply. In short, actions that enhance the resilience and transformability of social-ecological systems also facilitate Earth Stewardship.

To emphasize this point, we present actions in three categories that could foster Earth Stewardship goals (Table 3). Each category includes actions that can occur at different scales or require different levels of effort. For instance, some students could frame their entire dissertation around action-oriented goals, such as enhancing ecosystem services in a particular region, whereas other students might concentrate on communication efforts with the public. For each category, we provide examples of actions along with a suggested metric of success and the pathways through which such actions enhance the resilience of social-ecological systems.

### Expanding departmental support

To be successful, efforts to foster change in HEIs need to be internalized in the culture and incentivized by the reward system of the institution (Freeland 1992; Stephens and Graham 2010). As the basic units of HEIs, academic departments provide the culture and structure of the reward system for their graduate programs. Traditionally, departmental support refers to the provision of funding for graduate students (eg assistantships, travel awards). Here we propose a broader perspective of the concept. For instance, academic departments could support Earth Stewardship projects through activities that facilitate training in synthesis and research integration techniques. Departments can also evaluate their goals to ensure a culture where innovative and high-risk–high-reward projects are encouraged (Palmer 2012). The reward system should reflect this encouragement through incentives for establishing new Earth Stewardship projects and recognition of successful Earth Stewardship efforts.

### Enhanced training

Information regarding the link between training and employment success among STEM graduates is sparse and
fragmented (Gaff 2002). To address this shortcoming, academic departments need to collect data on current job markets and graduate student employment, and establish baseline metrics that help to clarify the relationship between graduate STEM training and employment trends. Ideally, this information would allow institutions to provide the training necessary to develop key transferable skills for its students, who would become more competitive in the job market. As a result, more students could become part of an Earth Stewardship-trained workforce (Figure 1).

On the other hand, STEM graduate students might find that the activities to advance Earth Stewardship as suggested in Table 1 are not necessarily intuitive or easy to perform. Indeed, current barriers (e.g., disciplinary thinking, the current reward system) can make it challenging to participate in interdisciplinary collaborations and integrate social science components into a natural science project (Morse et al. 2007). Departmentally sponsored training programs and mentoring can help graduate students overcome such obstacles. In addition, regarding the possible student activities suggested in Table 3, departments can sponsor different training opportunities, depending on their discipline or experience with sustainability science. For example, STEM departments that do not usually perform environmental research can begin to organize workshops, lunch-time seminars, and similar forums to explore Earth Stewardship and sustainability efforts. Likewise, STEM departments that focus on environmental research might develop semester courses on interdisciplinary methods, hire new faculty outside of the department’s expertise, or investigate the possibility of formal interdepartmental research collaborations. Regardless of the setting, training efforts should aim to help graduate students and faculty members develop novel skills that will facilitate conceptualizing and conducting research projects that are actionable, translational, and socially relevant.

**Academic culture and the reward system**

The culture of an academic department is often dictated by its respective HEI (Sporn 1996), thus reducing the department’s capacity to influence overarching shifts in attitudes and promote visions that are necessary for broad-scale change. However, departments are also able to make independent decisions regarding their activities (Al-Turki and Duffuaa 2003), thereby allowing departments to become important “niches of innovation” from where structural changes can be generated (Kezar 2001; Stephens and Graham 2010). The department could revise its reward structure to consider faculty members’ and students’ inclusion of Earth Stewardship in their research. For example, diverse collaborations, social benefits, public engagement, and Earth Stewardship training/dissemination efforts are currently undervalued in measuring the scholastic performance of faculty and graduate students alike. These efforts can be encouraged by a reward structure in which these activities acquire tangible value (McMahon and Caret 1997). While a modification of the reward structure may not be the only incentive to promote institutional change in HEIs, it can represent an important advance toward the removal of current barriers (Kezar 2001).

In terms of funding, providing specific awards for students to implement Earth Stewardship within their

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**Table 3. Suggestions for integrating Earth Stewardship into non-interdisciplinary STEM graduate research projects**

| Pathway to resilience-based stewardship | Example of action | Metrics of success | Notes:
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Creation of formal and shadow networks</td>
<td>Establishment of a citizen-science component within the research project</td>
<td>Number of citizens involved</td>
<td>The three rows list broad categories of potential Earth Stewardship activities, whereas the three columns provide particular examples of actions in that category, suggested metrics of success, and the relation of the examples to Resilience-Based Management theory (Chapin et al. 2009).</td>
</tr>
<tr>
<td>Increased diversity of knowledge types and sources</td>
<td>Integration of stakeholders in the process of developing research</td>
<td>Number of project goals addressing a specific stakeholder concern</td>
<td></td>
</tr>
<tr>
<td>Increased adaptive capacity</td>
<td>Engage in educational activities about Earth Stewardship and sustainability</td>
<td>Number of oral, written, or social media communication efforts</td>
<td></td>
</tr>
<tr>
<td>Serve as maven of stewardship research practices</td>
<td>Establish a mentorship program for undergraduate and K–12 students</td>
<td>Number of student research projects initiated/completed</td>
<td></td>
</tr>
<tr>
<td>Reduced load of contaminants in the watershed</td>
<td>Improve water quality in a neighborhood</td>
<td>Reduced social vulnerability</td>
<td></td>
</tr>
<tr>
<td>Improved management of negative and positive feedbacks in the system</td>
<td>Identify critical variables in an urban ecosystem</td>
<td>Integration of critical knowledge into local management and policy efforts</td>
<td></td>
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research can serve as positive departmental recognition of Earth Stewardship projects, thereby strengthening the process of change within the academic culture (Stephens and Graham 2010).

■ Summary

Departmental mentoring and incentives (Figure 1) provide additional pathways that graduate students may follow in fulfilling Earth Stewardship goals. Similarly, we recognize that only a proportion of STEM students are likely to initiate Earth Stewardship projects, while the remainder will become scientists. We offer suggestions for improving the academic structure for STEM students who are already interested in Earth Stewardship and to stimulate the interest of those who have not considered such an approach.

Higher education institutions are under increased pressure to follow practices that meet social expectations of quality, time, and economic investment, and to generate knowledge that addresses contemporary world issues (Whitmer et al. 2010). This pressure can combine with other social feedbacks (eg technological advances) to alter the way students will experience higher education in the future. Following Walker’s (2012) view of the dynamics between transformations and resilience, HEIs must “learn how to change, in order not to change”. In other words, HEIs can take the lead in effecting their own transformation, thereby minimizing the likelihood of unplanned or undesirable changes. Likewise, institutions that actively embrace change at multiple scales (Crow 2010) will be better positioned to confront the problems of a rapidly changing world and to lead future research.

Following successful integration of Earth Stewardship goals, academic institutions would likely become more efficient and innovative, thereby facilitating human as well as planetary well-being. Under this new culture, the training of STEM scientists should be responsive to changes in workforce demand and social challenges. Research initiatives would be valued according to their capacity to enhance resilience and provide answers to the challenges that lie ahead.

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