J Environ Stud Sci (2011) 1:181–188
DOI 10.1007/s13412-011-0038-8

Capstones and practica in environmental studies and sciences programs: rationale and lessons learned

Philip Camill · Kathleen Phillips

Published online: 13 September 2011

Abstract Environmental Science and Studies (ESS) programs grapple with the need to address several important, and sometimes competing, goals in curricula, such as understanding coupled human–natural systems, interdisciplinary approaches, problem solving, science literacy, informed citizenship, and career preparation. Hands-on projects that allow students to apply their academic learning to the real world in the form of capstone projects and practica offer the potential to meet many of these goals. In June 2010, a session was convened at the Association for Environmental Studies and Sciences (AESS) annual conference at Lewis and Clark College in Portland, Oregon, to discuss the benefits of these projects for student learning and to share practical experience of facilitating these types of projects and associated courses on different campuses across the country. This special issue of JESS features eight case studies of ESS capstone course projects at various institutions, from small liberal arts colleges to large research institutions. These examples serve as templates for instructors hoping to start similar programs at other institutions or to adapt new projects in existing capstone courses. This paper synthesizes the collective lessons learned from these case studies. We found that that while these case studies help instructors achieve some similar learning goals, several important differences exist, suggesting that curricula and the demands faced by instructors in the emerging field of ESS are still quite varied.

Keywords Capstone · Practicum · Experiential learning · Pedagogy · Community · Environmental studies and sciences · Education · Curriculum · Assessment · Student-centered learning

P. Camill (✉)
Environmental Studies Program and Earth and Oceanographic Science Department, Bowdoin College,
6700 College Station,
Brunswick, ME 04011, USA
e-mail: pcamill@bowdoin.edu

K. Phillips
Emmett Interdisciplinary Program in Environment and Resources, School of Earth Sciences, Stanford University,
473 Via Ortega,
Stanford, CA 94305, USA
e-mail: kphill@stanford.edu

Introduction

The interdisciplinary field of environmental studies and sciences (ESS) is rapidly growing and evolving as a result of the urgency of social and environmental challenges, increased institutional focus on interdisciplinarity, the rise of sustainability and resilience as organizing frameworks, and strong student and faculty interest. Assessing ESS program and curricular goals is important for determining whether the field is coalescing around a core set of principles and, if so, for developing effective approaches for delivering these skills and perspectives. In the largest national survey of ESS programs to date, Vincent and Focht (2011) identified four key characteristics that define the field of interdisciplinary environmental education: (1) a focus on the interface between human and natural systems (coupled systems); (2) a holistic educational approach that includes key concepts from the natural sciences, social sciences, applied fields, and humanities; (3) an emphasis on instilling disciplinary synthesis and systems thinking cognitive skills; and (4) a goal of preparing graduates to be informed citizens and sustainably oriented problem solvers. In addition, several skills were commonly valued across programs, including (but not limited to) critical thinking, synthesis, oral communication, project management, personnel management, information management,

advocacy and outreach, mass communication, creativity, technical and academic writing, problem solving, field research, community engagement, and leadership.

Delivering diverse sets of knowledge, skills, and interdisciplinary/integrative learning experiences is challenging for many ESS programs. Advanced capstone and practicum courses provide unique, high-impact opportunities for incorporating many of these skills and perspectives into ESS curricula. Capstone projects or practica are culminating educational experiences at the undergraduate or graduate level that allow students to gain hands-on experience working in groups, often with off-campus clients, and to deal with real-life environmental problems similar to those encountered in professional occupations. In interdisciplinary programs, these projects can be used to get students to work at integrating the various disciplines they have been studying in the classroom as well as strengthening general education aims such as informed citizenship, science literacy, and gaining professional skills. These courses are well established in sociology, education, psychology, nursing, engineering, computer science, communications, business, and ESS programs. Seventy-five percent of all baccalaureate interdisciplinary environmental programs, ~40% of master's-level programs, and 16% of PhD programs require an advanced synthesis/capstone course (methodology described in Vincent and Focht (2011), data unpublished).

There are several motivations for using capstones and practica in higher education—most of which are consistent with the broader aims of ESS curricula—including synthesis and application of previous knowledge, experiential learning, professional development and praxis, informed citizenship and life competencies, and curricular assessment.

Synthesis and application of previous knowledge

One role of capstones is to emphasize the application and synthesis of prior knowledge rather than the acquisition of new knowledge (Rowles et al. 2004). This goal aligns curricula to Bloom's taxonomy (Goldstein and Fernald 2009), with lower-level courses providing knowledge, skills, and abilities while more advanced capstones provide application and mastery to new situations (Vandecreek and Fleischer 1984; Schaefer 2004; Sullivan and Thomas 2007).

Experiential learning

Capstones and practica are often implemented using experiential and problem-based-learning (PBL) frameworks (Levia and Quiring 2008). Goldstein and Fernald (2009) suggest that capstones should de-emphasize course content in favor of student-centered learning, empathic listening, affective and experiential learning, collaborative learning and self-evaluation, and writing assignments that focus on personal and professional growth. "Learning by doing" is often cited as one of the reasons why capstones and practica are popular with students (Vandecreek and Fleischer 1984; Smith and Lev-Ari 2005). Brown and Benson (2005) suggest that capstones offer students more opportunity to be thoughtfully self-reflective and make sense of their educational programs in a systematic way.

Professional development and praxis

There is strong belief that capstones and practica help students transition from student to post-graduate roles as employees and lifelong learners (Brooks et al. 2004; Rowles et al. 2004; Brown and Benson 2005). Capstones and practica have been lauded for helping students engage complex, open-ended problems (Padmanabhan and Katti 2002; Hannah and Sullivan 2005; but see Jenkins et al. 2002) and apply math, science, GIS, and engineering skills to solve real-world problems (Gnanaprag 2008). Students gain experience in project management, leadership, teamwork, written and oral communication, and professional networking, often integrating knowledge and ideas into an overall culminating project (Hannah and Sullivan 2005; Paul 2005). Students sometimes learn how to function like consulting firms or individual-based practices, with rotating project management and assignment of tasks, interaction with outside clients and practitioners, and appreciation for real-life constraints of problem owners (Padmanabhan and Katti 2002; Hannah and Sullivan 2005; Todd and Magleby 2005; Gnanaprag 2008; Pilskalns 2009). Meeting the needs of an external constituency (Rowles et al. 2004) can help students apply core knowledge to a project sponsored by a partner (Todd and Magleby 2005), which, in some cases, can be a motivating factor for sponsors when the dollar value of the students' work is significant (Gnanaprag 2008). Durso (1997) notes that when research questions are of interest to students and community partners, students often work harder compared to other courses.

Professional development opportunities may be especially relevant to students in ESS curricula. A recent study found that management is the most frequent occupation held by environmental science graduates with a bachelor's degree (Carnevale et al. 2011). The most frequent industry of employment for environmental science graduates is professional services (i.e., consulting), followed by public administration (Carnevale et al. 2011).

Informed citizenship and life competencies

By addressing socioeconomic, environmental, and political issues associated with contemporary problems, students in capstone courses gain appreciation for integrity, citizenship,

a life of personal value and meaning, and connecting the personal, professional, and the public (Brooks et al. 2004). In this regard, capstones also provide an important vehicle for civic science literacy (Miller 1998, 2004; Rowles et al. 2004). Capstones and practica can also help students develop an understanding of the ethical context in which many real-world problems are situated (Catalano 2004; Schaefer 2004) as well as several life-long competencies, such as the capacity to adapt to and participate in change, deal with problems and make reasoned decisions in unfamiliar situations, reason critically and creatively, adopt a more universal or holistic approach to problems, practice empathy, appreciate other perspectives, and identify personal strengths and weaknesses and undertake appropriate remediation (Engel 1991; Dunlap 2005). In some cases, capstones and practica can boost self esteem (Dunlap 2005, but see Wright 2010) and help foster a spirit of entrepreneurship (Pilskalns 2009) mainly because students are given the chance to succeed at post-graduate opportunities while still in school (Pilskalns 2009).

Curricular assessment

Given the increasing focus on assessment of student learning in higher education (Brooks et al. 2004), capstones and practica are increasingly used as tools for assessing student learning, departmental curricula, and university-wide general education requirements (Rowles et al. 2004; Kerrigan and Jhaj 2007; Levia and Quiring 2008; Ewell et al. 2011). The recent National Institute for Learning Outcomes Assessment (NILOA) report indicates that capstones are the most commonly used method of curricular assessment (Ewell et al. 2011). By setting explicit learning outcomes and understanding the prerequisite knowledge and skills with which students enter capstone courses, faculty can identify linkages to and deficiencies in the antecedent courses of the curriculum (Vandecreek and Fleischer 1984; Catchings 2004; Berheide 2007). Moreover, these advanced experiences often allow students to make sense of their overall education in a systematic way (Brown and Benson 2005) and can create a community of instructors focused on student learning (Fernandez 2006). Initial assessments of capstones and practica show that they are successful in helping colleges and universities deliver general education proficiencies. Brooks et al. (2004) found that students often rated the capstone experience higher than disciplinary-based, major requirement courses for helping them achieve general education learning goals, as documented by the percentage students identifying the degree to which the capstone vs. disciplinary courses met the following goals to a great or moderate degree: working collaboratively (95% vs. 67%), taking initiative and demonstrating leadership (83% vs. 61%), understanding the motivations, intentions, and emotions of oneself and others (78% vs. 59%), clarifying personal values (88% vs. 48%), recognizing and reconciling moral differences (67% vs. 41%), service, social justice, and civic responsibility (86% vs. 38%), self-respect (77% vs. 56%), respect for differences and human dignity (81% vs. 59%), personal integrity (80% vs. 66%), written communication (89% vs. 78%), and oral communication (85% vs. 79%).

Capstones and Practica in Environmental Studies and Sciences Curricula

Despite the prevalence of capstone experiences in ESS curricula, the perceived and assessed values they deliver in terms of student learning, and the potential for unifying the varied goals of ESS programs, very little has been published on ESS capstones (Koether et al. 2002; Schaefer 2004; Levia and Quiring 2008). We, therefore, lack understanding of their effectiveness in improving student learning and supporting broader ESS curricular aims. There have been, as yet, no analyses of the similarities and differences among ESS capstone courses, which would provide insights on shared learning goals of ESS programs as well as challenges with which programs struggle. There are also few well-described examples of ESS capstones that could be used "off-the-shelf" and adapted by faculty at other colleges and universities.

At the 2010 Association for Environmental Studies and Sciences (AESS) conference at Lewis and Clark College (Portland, OR, USA), we convened the session "Environmental Capstones and Practica" to initiate a discussion of the kinds of capstone courses offered in ESS curricula, major lessons learned, assessment outcomes, and challenges to undertaking capstone courses. The Capstones and Practica in Environmental Studies and Sciences Curricula feature in this issue of the *Journal of Environmental Studies and Sciences* (JESS) will highlight several of the capstone case studies from the AESS conference in addition to other newly developed capstone experiences.

In this introductory article, we provide an overview of these case studies, examining the role of capstones in ESS curricula, learning and assessment outcomes, and the lessons learned, including challenges facing capstone instructors and students. We analyze similarities and differences among the case studies to identify points of consensus and outstanding issues that could help improve the effectiveness of ESS curricula and assess the extent to which the varied goals of ESS programs are being met. We examine capstone courses from a range of institutions, including private liberal arts colleges, public universities, and private universities.

This article is followed by eight, more detailed case studies of ESS capstone experiences that can be adapted to

other curricula. Each of the case study articles follows a consistent format that facilitates comparison of courses and ensures the consistency of information provided across institutions. We have asked contributing authors to describe the rationale for the capstone courses, the capstone context in the curriculum, logistical considerations, learning goals, capstone structure, assessments and products, and challenges and lessons learned. Information is also included on the nature of instructor roles, financial considerations when running the capstones, striking a balance between traditional needs of courses (e.g., content, basic skills) vs. experiential learning, and tips on how to teach the capstones. Each case study also presents hyperlinks to supplementary materials, such as project examples, course products, partner organizations, and assessment rubrics.

Structure and purpose of capstones in ESS curricula

We found that most case studies fulfilled the general goals of ESS programs identified by Vincent and Focht (2011). All case studies addressed issues related to coupled human–natural systems and emphasized professional preparation and skills development, including research and documentation, communication, group collaboration, writing, and time management (Table 1). The study by Kleier and Gould (this issue) describes environmental impact assessments as a tool for professional skills development and preparing students for the job market. The study by Banschbach and Letovsky and the study by Lynch and Boulay (this issue) emphasized developing and practicing management and leadership skills as important professional development goals. Helping students become better-informed citizens was an implicit or explicit goal of a majority of capstones (Table 1). Kleier and Gould (this issue) describe an assignment in their capstone course where students write letters to comment on a current Environmental Impact Statement, thus participating directly as informed citizens. Science literacy was often accomplished through the acquisition of new content and skills (see Kleier and Gould, Banschbach and Letovsky, Kaza and Anderson, this issue), but it was also gained through the use of the scientific method and helping students learn how to learn (Table 1). The study by Abbott (this issue) describes an approach where students work through the complete research process from identifying an appropriate question through conducting independent research to, in some cases, preparing research for publication. The emphasis on skills development suggests that instructors are not simply relying on antecedent courses in the ESS curriculum to provide these skills but that the capstone courses offer opportunities for further skills learning, remediation, refinement, and practice. Although all case studies mentioned the importance of interdisciplinary scholarship, research, and understanding in ESS programs, about half of them stated the integration of multiple disciplines and demonstrating interdisciplinary scholarship as a key learning goal in the capstone courses (Table 1). This suggests that these capstones courses may be serving one of two roles: (1) providing students with a forum for integrating the different disciplines they have learned during their ESS programs and the practice of interdisciplinary scholarship skills; or (2) providing discipline-specific opportunities to gain practical skills, science literacy, prepare for careers, or become better-informed citizens. One study (Banschbach and Letovsky, this issue) used a novel approach to implement interdisciplinary learning goals: combining biology and business majors in a single capstone and devoting significant class time for students to teach one another about their respective major fields before forming integrated project groups. Similarly, only about half of the case studies described analyzing data to solve a real-world problem to be a primary goal of the course.

Table 1 Analysis of capstone course learning goals

Learning goals	Number of responses
Addressing a coupled human–natural issue	8
Professional preparation and skills development (library research, communication, group collaborations, writing, time management, etc.)	8
Science literacy	8
Informed citizenship	5
Collect and analyze data to solve a real-world problem	5
Integration of more than one discipline	5
Develop independent research skills	2
Learn and apply leadership skills	2
Teach their discipline to another group	1

The majority of the capstones discussed here fit into the curriculum as culminating, experiential-learning projects that are generally completed towards the end of a student's educational program (Table 2). Most of the specific studies presented here are required for graduation, while the rest are one of several options from which students may select to fulfill their graduation requirements (Table 2). Peer evaluation of student-generated projects was used in over half of capstones to good effect (Table 2). Abbott (this issue) notes that repeated peer review allowed students to have ongoing conversations and to support each other in their projects. Phillips and Doyle (this issue) found that peer review also allowed for a rich diversity of content feedback for students in the case where students and instructors come from a wide range of disciplines. These results suggest that these

Table 2 Analysis of capstone course structure and logistics

Course logistics	Number of responses
Format focused on development of final report/presentation required	8
Experiential learning	6
Offers a real-world learning and professional experience	6
Students work in groups	5
Specific course required for graduation	5
Students select/design their own projects	5
Peer evaluation	5
Collaboration with off-campus clients	4
Students conduct academic research	2

features are important components of ESS curricula, filling a unique role by offering students the opportunity for non-traditional learning and professional development through hands-on real world projects, participating in the research process, and developing leadership, group collaboration, and research skills.

Aside from the common learning goals identified, there were some substantial differences in the goals and approaches of the capstone case studies presented here (Tables 1 and 2). Interdisciplinary learning and real-world problem solving were not shared by all of the capstone case studies, although they are a central tenet of ESS curricula more generally. Other important differences included project selection, collaboration with community partners, and emphasis on leadership. In some capstones, students selected their own projects and worked individually or in self-selected groups while in other capstones, projects were pre-selected by instructors, and students worked together in large, sometimes whole-class groups. Some capstones focused on conducting academic research, while others emphasized working with off-campus clients and developing professional skills. Faced with growing enrollment pressures, the University of Vermont has developed three models for the capstone experience: (1) a traditional thesis, (2) an internship with a community partner, and (3) an integration of advanced courses (Kaza and Anderson, this issue). These results suggest that while many of the general goals of ESS programs and curricula are being met at different institutions, there are also differences that arise as a result of institutional/instructor goals, student needs, and available resources.

Assessments and products of ESS capstones

The products generated from these ESS capstones tended to reinforce skill development in the liberal arts tradition (i.e., interdisciplinary integration, leadership, synthesis, application, writing, presentation) and a focus on student learning within a classroom context. Some of the case studies included web links to well-developed capstone project archives (Kaza and Anderson, Lynch and Boulay this issue) that serve as a useful dissemination to other instructors. Few included the production of deliverables useful for community partners. The study by Camill (this issue) is an example of students functioning as a consulting team, producing a product (climate action plans) that saved community partners (local municipalities) the time and money required to produce a similar study. This focus on consulting and product generation is similar to capstones in applied fields, such as engineering, where developing products for community partners is often a highly valued component of the educational experience (Padmanabhan and Katti 2002; Hannah and Sullivan 2005; Gnanaprag 2008). Some of the capstones have the benefit of generating publications for students and faculty (see Camill, Abbott, this issue), which is useful for student and faculty professional development (Gnanaprag 2008).

There was a wide variety of assessment techniques used in the ESS capstone courses in this issue (Table 3). The majority of capstones emphasized a final written product, active participation/discussion, and peer review, while assignments assessing progress, a final oral presentation, and student self-evaluations were also common. Less commonly used assessments included self-reflection/debriefing at the beginning of class periods, developing proposals, community partner assessments of student work, quizzes/exams on course content, and student teaching (Table 3). These results indicate that there is a mix of summative assessments (usually graded assignments after a period of learning) and formative assessments (usually nongraded and adaptive feedback emphasizing self-reflection and improvement), but instructors tended to prefer summative tools, which some have argued empha-

Table 3 Analysis of capstone course assessments techniques

Assessment topic	Number of responses
Written product (report, poster, paper, website)	8
Participation/class discussion	6
Peer evaluation	5
Progress assignments	5
Presentation	5
Self-evaluation	5
Self-reflection/debriefing	2
Project proposal	2
Quizzes/exams	1
Community partner evaluation of students	1
Student teaching	1

sizes student accountability and course grades over enhancing the quality of learning and teaching (Levia and Quiring 2008). The majority of cases focused on student learning outcomes rather than program assessment and general education goals. The exception is the study by McKenny et al. (this issue), which describes how Pacific Lutheran University uses the capstone course as a measure of student ability to integrate methods and different academic perspectives and the ability of the Environmental Studies Program to provide these prerequisite skills. This emphasis on student learning outcomes distinguished these ESS capstone courses somewhat from previously published studies, which document an increasing role of using capstone courses to evaluate university-wide general education goals (Rowles et al. 2004; Kerrigan and Jhaj 2007; Levia and Quiring 2008).

Lessons learned and challenges with ESS capstone courses

Consistent with previous studies in other disciplines, these case studies suggest that ESS capstone courses offer many potential benefits. Most importantly, they are a vehicle for promoting professional preparation, skills development, the development of informed citizens and leaders, scientific literacy, interdisciplinary learning, project management, and problem solving. Capstones can empower students at the end of their academic degree work to move forward in the field after graduation with the skills and self-confidence to effect positive change in their careers. Lynch and Boulay (this issue) note that "in evaluations, students consistently identify…the capstone…as one of the most transformational learning experiences in their college careers" at the University of Oregon and that "the professionalism gained by the students…makes them competitive when seeking both environmental non-profit and government positions." Kleier and Gould (this issue) and Camill (this issue) show how environmental impact assessments and climate action planning can be used as effective tools that lead directly to employment opportunities for students. Abbott (this issue) reported that a number of his students at Stetson University published peer-reviewed papers on their capstone project research. Kaza and Anderson (this issue) report that given a new option for completing an internship to fulfill their capstone requirement, 17% of students took advantage of this opportunity, and many noted that they appreciated the addition of professional development to the curriculum. Camill (this issue) notes that his capstone students at Bowdoin College reported an average score of 6.73 on a scale of 1–7, strongly agreeing with the statement "I gained practical skills and perspectives in this class compared to traditional lecture-only formats." Success stories like these show that capstone projects can deliver when it comes to preparing students for occupations and industries commonly sought by environmental science graduates, including management, consulting, and public administration (Carnevale et al. 2011). Capstones also allow ESS students to integrate their knowledge across disciplinary boundaries. Banschbach and Letovsky (this issue), who had a learning goal for students to teach their discipline to students in another discipline, indicated that 61.1% of their business majors and 84.6% of their biology majors self-reported that they learned subject area content from the other discipline through their capstone course. One student reported becoming interested in renewable energy through the capstone and thus pursuing a summer internship in that field (Banschbach and Levotsky, this issue). Kaza and Anderson (this issue) describe how the three capstone models at the University of Vermont use interdisciplinary scholarship as a main learning goal and point of assessment. Phillips and Doyle (this issue) also reported success with students at Stanford University, who leveraged their interdisciplinary capstone experiences to launch careers, including a start-up company created by one student after graduation based on a capstone business plan to help companies increase energy efficiency and lower their carbon footprints.

In addition to these positive outcomes in ESS capstones, instructors also described several challenges, which can be useful for identifying outstanding issues that could help improve the effectiveness of ESS curricula. The most commonly cited challenge involved the logistics of coordinating activities within the academic schedule and coordinating the schedules of instructors when more than one was involved (Table 4). Almost half of the capstones indicated that fostering strong commitment by students to the project as well as finding time for busy faculty to become involved given the demands of project-based courses and theses can be difficult (Table 4). The next most commonly cited challenges included the resource-intensive nature of cap-

Table 4 Analysis of perceived capstone course challenges

Challenges identified	Number of responses
Timing in schedule, coordination among instructors	6
Commitment by students and faculty	4
Resource intensive	3
Skill development (advanced skills challenging, basic skills missing)	2
Community engagement/expectations	2
Mismatched expectations between instructors and students	1
More guidance needed on activities	1
Students taking charge of own learning	1
Preconceptions of what ESS should be	1
Overcoming faculty hesitations	1
Data quality	1
Assessing the capstone experience	1
Managing group documents	1

stone projects, difficulties with skills development (students finding advanced skills challenging or instructors noting that students are entering capstone courses with a lack of basic prerequisite skills), and the engagement/expectations of the community partners (Table 4). However, eight additional challenges were unique to individual capstone courses: There were sometimes mismatched expectations between instructors and students, students needed more guidance on open-ended activities, students were unaccustomed to taking charge of their own learning, some students had preconceived notions of what ESS was (thereby limiting the range of potential project designs), faculty might initially be reluctant to run an open-ended project-based course de-emphasizing content, a lack of data or poor data quality had the potential to make project logistics challenging, and the assessment of capstone projects and managing group documents can be difficult (Table 4). These results suggest that faculty and student scheduling and commitment in busy academic schedules, as well as resource availability, are important to consider. Enrollment pressures will likely exacerbate these factors as ESS majors and capstone courses grow in popularity. ESS programs will need to develop strategies for mitigating these challenges, and the University of Vermont model of multiple capstone options is one possibility (Kaza and Anderson, this issue). Many other challenges appeared to be idiosyncratic to the structure and context of the course, project, curriculum, and community.

Previously published studies of capstones from other fields identified similar challenges and tensions, such as the negative perception of open-ended projects by some engineering students (Jenkins et al. 2002) and the time required to develop community-based projects (Wright 2010), but they also offer additional insights. Hascher et al. (2004) suggested that striking a balance between theory and praxis is important. Most of the ESS case studies presented here tended to emphasize the practical aspects of application, integration, and leadership, writing, and public presentation over delivering new course content. Since most courses in ESS curricula tend to emphasize theory (content), offering the opportunity for praxis in a capstone course does not come at the expense of theory; rather, it is an opportunity for students to apply previously learned theory in a real-world context (Vandecreek and Fleischer 1984; Schaefer 2004; Sullivan and Thomas 2007; Goldstein and Fernald 2009). Others make a distinction between the capstone/practicum and vocational training, with the former being about producing marketable skills for a specific job and the latter enhancing the goals of the liberal arts education (Vandecreek and Fleischer 1984). The case studies presented in this issue show that vocational training and liberal arts learning goals can often be achieved simultaneously. In the field of computer science, Wright (2010) cautioned that the applied nature of capstones may ill prepare students for the realities of a rapidly shifting job market. Specifically, the change to web-based programming is requiring very different skill sets than are traditionally taught, and advanced projects intended to mimic the "real world" may be too difficult for college seniors, which could negatively affect self-esteem.

Conclusion

Capstone and practicum projects are an important component in ESS and other disciplinary and interdisciplinary curricula at institutions ranging from small liberal arts colleges to large research universities. Although the sample size featured in this special issue is small ($n=8$), we found that individual capstone courses are capable of attaining many of the broad goals important to most ESS curricula. This is an exciting outcome, suggesting that significant value added can be achieved with the capstone model. Moreover, as experiential learning and student-centered learning become more widely adopted in higher education, capstone courses can provide an important pathway into the curriculum for these approaches. Finally, because ESS topics and courses often necessarily focus on the identification and understanding of difficult environmental problems, capstone project courses can also provide an antidote to the "gloom and doom" that this creates.

The analysis we have begun in this special issue opens up rich, new opportunities for integrating capstones, ESS curricular development, and faculty professional development. Perhaps most importantly, there is significant need for improved description and dissemination of ESS capstone course projects. This provides two important outcomes. First, it will facilitate a more comprehensive analyses of what works across a wide range of institutions and will help to identify challenges that can be overcome through shared experiences. We recognize that ESS curricula are constrained by institutional structure, available faculty, and resources, which can lead to some of the differences in learning goals, capstone structure, outcomes, and challenges identified in the case studies presented here. These issues need to be examined further. Second, instructors starting out in capstone courses or ESS programs wishing to initiate or adapt new capstone projects need templates from other institutions, accompanied by teaching instructions or other metadata. Although some ESS programs, such as Middlebury College (http://www.middlebury.edu/academics/es/work/communityconnectedlearning/envs0401) and the University of Vermont (http://library.uvm.edu/jspui/handle/123456789/253), have publically accessible databases of past capstone projects, there are no resources, to our knowledge, where instructors can access in-depth pedagogical wisdom from colleagues teaching capstones, similar

to what is presented in the case study articles in this special issue. To accomplish this task of better capstone project and metadata dissemination, we recommend the establishment of a central clearinghouse of capstone and practicum courses, together with attendant descriptions of learning goals, capstone structure, outcomes, and challenges, that can be hosted on the AESS website.

Acknowledgments We wish to thank the authors of the conference papers at the 2010 AESS session "ESS Capstones and Practica" for helping us initiate this stimulating conversation about ESS curricula and to our colleagues who contributed papers to this special issue of JESS. Special thanks to the many students, support staff, administrations, funding sources, and community partners who make these kinds of learning experiences possible. We are grateful to two anonymous reviewers and Shirley Vincent for comments that improved this manuscript.

References

Berheide CW (2007) Doing less work, collecting better data: using capstone courses to assess learning. Peer Review 9(2):27–30

Brooks R, Benton-Kupper J, Slayton D (2004) Curricular aims: assessment of a university capstone course. J Gen Educ 53(3–4):275–287

Brown AH, Benson B (2005) Making sense of the capstone process: reflections from the front line. Education 125(4):674–692

Carnevale AP, Strohl J, Melton M (2011) What's it worth? The Economic Value of College Majors. Georgetown University Center on Education and the Workforce

Catalano GD (2004) Senior capstone design and ethics: a bridge to the professional world. Sci Eng Ethics 10:409–415

Catchings B (2004) Capstones and quality: the culminating experience as assessment. Assessment Update 16(1):6–7

Dunlap JC (2005) Problem-based learning and self-efficacy: how a capstone course prepares students for a profession. Educ Technol Res Dev 53(1):65–85, ISSN 1042-1629

Engel CE (1991) Not just a method but a way of learning. In: Boud D, Feletti G (eds) The challenge of problem-based learning. Kogan Page, London, pp 22–33

Ewell P, Paulson K, Kinzie J (2011) Down and in: assessment practices at the program level. University of Illinois and Indiana University, National Institute for Learning Outcomes Assessment (NILOA), Urbana

Durso FT (1997) Corporate-sponsored undergraduate research as a capstone experience. Teach Psychol 24(1):54–56

Fernandez NP (2006) Integration, reflection, interpretation: realizing the goals of a general education capstone course. About Campus 11(2):23–26

Gnanaprag N (2008) Industrially sponsored senior capstone experience: program implementation and assessment. J Prof Issues Eng Educ Pract 134:257–262

Goldstein G, Fernald P (2009) Humanistic education in a capstone course. Coll Teach 57(1):27–36

Hannah AS, Sullivan KT (2005) Bridging the gap between academics and practice: a capstone design experience. J Prof Issues Eng Educ Pract 131(1):59–62

Hascher T, Cocard Y, Moser P (2004) Forget about theory—practice is all? Student teachers' learning in practicum. Teachers Teach Theor Pract 10(6):623–637

Jenkins SR, Pocock JB, Zuraski PD, Meade RB, Mitchell ZW, Farrington JJ (2002) Capstone course in an integrated engineering curriculum. J Prof Issues Eng Educ Pract 128:75. doi:10.1061/(ASCE)1052-3928(2002)128:2(75) (8 pages)

Kerrigan S, Jhaj S (2007) Assessing general education capstone courses: an in-depth look at a nationally recognized capstone assessment model. Peer Review 9(2):13–16

Koether M, McGarey D, Patterson M, Williams DJ (2002) Interdisciplinary undergraduate education: environmental studies. Chem Educ Today 79(8):934–935

Levia DF Jr, Quiring SM (2008) Assessment of student learning in a hybrid PBL capstone seminar. J Geograph High Educ 32(2):217–231

Miller JD (1998) The measurement of civic science literacy. Public Underst Sci 7:203–223. doi:10.1088/0963-6625/7/3/001

Miller JD (2004) Public understanding of, and attitudes toward, scientific research: what we know and what we need to know. Public Underst Sci 13(3):273–294. doi:10.1088/0963-6625/7/3/001

Padmanabhan G, Katti D (2002) Using community-based projects in civil engineering capstone courses. J Prof Issues Eng Educ Pract 128:12–18. doi:10.1061/(ASCE)1052-3928(2002)128:1(12)

Paul MJ (2005) Carving a capstone: senior design at the University of Delaware. J Prof Issues Eng Educ Pract 131:90–97. doi:10.1061/(ASCE)1052-3928(2005)131:2(90)

Pilskalns O (2009) An entrepreneurial approach to project-based courses. Comp Sci Educ 19(3):193–204

Rowles CJ, Koch DC, Hundley SP, Hamilton SJ (2004) Toward a model for capstone experiences: mountaintops, magnets, and mandates. Assessment Update 16(1):1–2, 13–15

Schaefer J (2004) Environmental ethics from an interdisciplinary perspective: the Marquette experience. Worldviews 8(2–3):336–352

Smith K, Lev-Ari L (2005) The place of the practicum in preservice teacher education: the voice of the students. Asia-Pacific J Teach Educ 33(3):289–302

Sullivan B, Thomas SL (2007) Documenting student learning outcomes through a research-intensive senior capstone experience: bringing the data together to demonstrate progress. N Am J Psychol 9(2):321–330

Todd R, Magleby SP (2005) Elements of a successful capstone course considering the needs of stakeholders. Eur J Eng Educ 30(2):203–214

Vandecreek L, Fleischer M (1984) The role of practicum in the undergraduate psychology curriculum. Teach Psychol 11(1):9–14

Vincent S, Focht W (2011) Interdisciplinary environmental education: elements of field identity and curriculum design. J Environ Stud Sci. doi:10.1007/s13412-011-0007-2

Wright K (2010) Capstone programming courses considered harmful. Comm ACM 53(4):124–127