Developing an Interdisciplinary, Distributed Graduate Course for Twenty-First Century Scientists

HELENE H. WAGNER, MELANIE A. MURPHY, ROLF HOLDEREGGER, AND LISETTE WAITS

Graduate programs have placed an increasing emphasis on the importance of interdisciplinary education, but barriers to interdisciplinary training still remain. We present a new model for interdisciplinary, cross-institution graduate teaching that combines the best of local teaching, distance learning, and experiential learning to provide students and faculty with a unique collaborative learning experience and interdisciplinary research skills. We summarize the lessons learned from a highly successful implementation of this course model in the new field of landscape genetics, which integrates concepts and methods from population genetics, landscape ecology, and spatial statistics. The distributed nature of the course allowed sections to be offered locally that would not have been offered otherwise because of the lack of complementary expertise at local institutions. Students gained hands-on experience in interdisciplinary, Web-based and international research collaboration with group projects. A final synthesis meeting was invaluable for course assessment, manuscript development for group projects, and professional networking.

Keywords: blended learning, experiential learning, landscape genetics, international research collaboration
viability, connectivity, and local adaptation (Manel et al. 2003, Holderegger and Wagner 2006, 2008, Storfer et al. 2007, 2010, Segelbacher et al. 2010), which are key to understanding, minimizing, and predicting the impacts of anthropogenic landscape alteration and global climate change (Lubchenco 1998, Thuiller 2007). The training of graduate students in landscape genetics is often limited by individual research groups’ having strength in either population genetics or landscape ecology but not both, by a lack of availability of specialized complementary expertise within a single institution, and by barriers to scientific communication and collaboration across disciplinary boundaries (Storfer et al. 2007, Balkenhol et al. 2009). We addressed these challenges by developing a graduate course in landscape genetics that provided students at eight participating institutions from North America and Europe with an integrated, interdisciplinary, distributed graduate course (IDGC); with training in interdisciplinary online research collaboration across institutions; and with networking opportunities.

An IDGC as a blended teaching model
An IDGC combines the best of local teaching (personal face-to-face interaction with instructors and with fellow students), distance learning (learning from international experts in an inclusive, accessible online environment), experiential learning (hands-on professional experience such as collaborating on a research project aimed at publication), and an international summer-school-type course (intensive format and international networking) (Garrison and Vaughan 2008).

The 2010 IDGC on landscape genetics followed the structure outlined in table 1, reaching a total of 107 students (22% MS students, 70% PhD students, 8% postdoctoral fellows and others) and 20 instructors (academics, research scientists, and postdoctoral fellows) from 15 universities and three government research institutes in six countries.

A year before the course, 11 faculty members and graduate student representatives attended a five-day preparation meeting at NCEAS in Santa Barbara, California. Prior to the meeting, all of the instructors exchanged draft lecture slides for peer feedback. The revised lectures were live recorded at the preparation meeting, using Marratech Web-conferencing technology (Google, Mountain View, California) provided by NCEAS. About half of the lectures were rerecorded after the meeting, when all of the instructors were sufficiently experienced with the technology to do so independently. At the meeting, each 50-minute live lecture was followed by a 1-hour discussion, with the aim of facilitating integration across topics and preparing instructors to lead interdisciplinary local seminar discussions outside of their specific area of expertise. The content and format of the computer lab exercises and group projects, as well as the course logistics, were finalized.

Following an initial Web conference, 13 recorded lectures presented weekly by experts provided a broad introduction to the field and a common base for interdisciplinary communication. Each lecture was complemented by assigned readings and followed by a local seminar discussion and two weekly online meet-the-expert sessions with the instructor who gave the lecture. Depending on locally defined credit options, the students would also complete a weekly computer lab exercise that was based on the material provided by the expert. The computer lab assignments provided hands-on experience with the simulation and analysis of landscape genetic data, whereas the in-class student activities were focused on the interpretation of results from such analyses.

In parallel with the course, 34 students and postdoctoral fellows chose to participate in one of seven interdisciplinary, interuniversity, and international group projects, with 4–6 participants per project. Participation in the project was an additional credit option and not a required component.

### Table 1. Overview of course organization and lessons learned from the 2010 interdisciplinary, distributed graduate course in landscape genetics.

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Suggested improvements for the next version of the course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation meeting</td>
<td>Five-day meeting of faculty to record lectures, discuss and integrate lectures and labs, plan course organization</td>
<td>This can be replaced by online meetings in the second year of the course</td>
</tr>
<tr>
<td>Lecture course</td>
<td>Two video conferences; 13 prerecorded lectures (50 minutes each), 1–3 readings per week</td>
<td>A weekly live Web-based lecture, podcast for flexibility, coauthored textbook</td>
</tr>
<tr>
<td>Local seminar</td>
<td>Discussion of lecture, readings, and student activity in local seminar group, led by local instructors</td>
<td>A fixed time slot should be implemented right after the lecture to collect questions, address simple ones, and identify those that should be addressed to the expert</td>
</tr>
<tr>
<td>Meet-the-expert board</td>
<td>After each lecture, two set times for meeting with expert online, discussion board for further questions or discussions</td>
<td>A fixed time slot should be added after the lecture and after the local seminar, which could be organized as a video conference between all of the participating institutions</td>
</tr>
<tr>
<td>Computer labs</td>
<td>Instructed by the weekly expert, the lab exercises were implemented and converted into assignment outlines by local instructor</td>
<td>A book should be developed with a structured format, including an in-class activity and a tested computer lab for each topic</td>
</tr>
<tr>
<td>Group projects</td>
<td>Interdisciplinary groups of four to six students and two to four experts were created, across institutions; predefined topics were used, and a group report was to be created by the end of semester, with the goal of publication</td>
<td>The topics, milestones, and deliverables should be well defined; a two-term course option should be offered for developing the project into a manuscript for publication</td>
</tr>
<tr>
<td>Synthesis meeting</td>
<td>Five-day meeting with peer review of reports, work on publications, networking</td>
<td>Funding should be found for this invaluable course component!</td>
</tr>
</tbody>
</table>
of the course. Supported by between two and four instructors as group-project experts and using existing data sets or computer simulations, each group designed a study to address a methodological problem identified by the experts, produced a written report, and gave an online presentation during a Web conference in the final week of class. One group developed a landscape genetics Web page. Through this experiential learning, the students gained hands-on research experience and learned to collaborate in interdisciplinary teams, using Web technology for online meetings and file sharing.

After the course, 17 group-project participants (2 or 3 from each project) and 10 instructors attended a five-day synthesis meeting at NCEAS that was devoted to course assessment (see below), peer feedback on the project reports, intensive collaboration on turning the project reports into publishable manuscripts, and networking. Each student was asked to review one of the other group-project reports; additional feedback was provided by all of the instructors. For each project, a course of action was defined, and each group worked intensively on the revision of analyses and of the manuscript, interacting with off-site group members online. To facilitate professional networking, the students had the opportunity to give a short presentation of their own research and to participate in mentorship lunches with individual instructors.

The student and faculty experience

We assessed perceptions and outcomes with classroom-assessment techniques (Angelo and Cross 1993). A fully anonymous class survey at the end of the course, which included ratings of course aspects, demographic, and open-ended questions (see the supplemental appendix, available online at http://dx.doi.org/10.1525/bio.2012.62.2.11), was followed by an in-depth discussion of the survey results with the faculty and students during the synthesis meeting and a second fully anonymous online survey after the synthesis meeting. Overall, the response rates in the class survey at the end of the course were relatively high (73 out of 117 students, 62%; 15 out of 20 instructors, 75%), and there was no statistically significant difference in response rate (Fisher’s exact test, \( p = .313 \)) between the group-project participants (64.7%) and the students who did not participate in a group project (54.2%). During the synthesis meeting, the results from the class survey were presented and discussed with all of the students and instructors participating in the meeting, with the goal of revising the course for a second offering in 2012 (see below). The student participants of the synthesis meeting (response rate = 88.2%) and all of the course instructors (response rate = 60.0%) were asked to fill in another survey after the synthesis meeting. The supplemental appendix summarizes the results from all of the surveys, indicating for each question the source survey, the respondent group, and the item’s response statistics. In the following sections, we use the quantitative survey results to evaluate key aspects of the course design, and we illustrate the overall learning experience with direct quotations from open-ended questions.

Interdisciplinary training.

New models of graduate education are required in highly technical, cutting-edge fields such as landscape genetics. This is reflected in the motivations for both student and faculty participation in the IDGS. The most common motivation for students to enroll in the course was “for personal research needs” (62%, 73 students, appendix question 22), although the opportunity to work with people from other universities was also a strong contributing factor (41% of the students). Only 30% of the students had already begun work in landscape genetics research, whereas 42% were planning to do so in the future (67 students, appendix question 27). The instructors were primarily motivated to participate in the IDGC by their own research in landscape genetics (80%), the opportunity to teach with other instructors (53%), and student need (47%, 15 instructors, appendix question 22).

The students and instructors agreed that the model of graduate education was successful in improving mastery of the subject material. The students reported that they improved in their understanding of the three core subject areas of population genetics (change in mean from 3.58 to 4.01 on a scale of 1 [very poor] to 5 [very good], paired \( t \)-test, \( p < .001 \)), landscape ecology (3.23 to 3.76, \( p < .001 \)), and spatial analysis (2.94 to 3.27, \( p < .001, 67 \) students), but even more strongly in their ability to critically read and evaluate landscape genetic papers (3.06 to 3.82, \( p < .001, 67 \) students) and to analyze their own landscape genetic data (2.38 to 3.38, \( p < .001, 66 \) students) (appendix question 2). The instructors confirmed the overall improvement in student understanding of all three subject areas, with average ratings of the improvement per subject area between 3.42 and 3.58 on a scale of 1 (very little) to 5 (very much) (12 instructors, appendix question 2). This indicates that we created a learning environment that had a positive impact on student learning and instructor satisfaction (Fink 2003). The written responses from the students reflected the achievement of learning outcomes (appendix question 31): “Outstanding—the kind of class that makes graduate studies worth it. Well presented and the material quickly got me up to speed.... Despite my lack of background in genetics and landscape ecology, I never felt like I was getting too far behind or could not contribute anything.” “The lectures provided an excellent introduction and overview to the field. I will keep them for reference for my future work.” “Perhaps most surprising was that I did not have any issues understanding the ‘language’ used in the class by professionals outside my field.”

The written responses from the faculty members also portrayed similar reflections on the students’ achievement. One faculty member stated (in response to appendix question 31), “This was a fantastic experience for my students and me. We all learned a tremendous amount and gained a new perspective on our own research. This course also opened my eyes to how graduate education can (and should!) be done.”
Distributed course model. Both the students and the instructors were very satisfied with the overall course design, although the instructors more so than the students (instructors’ mean \(M = 8.08\) on a scale of 1 to 10, students \(M = 7.59\), two-tailed \(t\)-test, \(p = .001\), appendix question 4a). In contrast, the students were considerably more satisfied with the introduction of the major concepts of landscape genetics than were the instructors (\(M = 8.22\) and 7.62, respectively; two-tailed \(t\)-test, \(p = .002\), appendix question 4c), probably because of differences in the depth of experience in the field between the students and the instructors.

When they were asked to rate the importance of the course components for student learning, the students and the instructors generally agreed. The students, however, placed the highest value on additional explanations and group discussions in local seminar groups, whereas the instructors gave significantly more weight to group projects, computer labs, and recorded lectures (figure 1; appendix question 3). One student wrote (in response to appendix question 31), “I personally found the postlecture discussions in the local group setting very helpful to my own research.”

The higher ratings of distributed components by the instructors may reflect their awareness that they could not have taught the highly technical, interdisciplinary material as effectively and competently on their own. Depending on the weekly topic, up to 8 of 11 instructors (\(M = 31\%\)) felt that they would have been unable to teach the individual lectures, and up to 9 of 11 (\(M = 55\%\)) would not have been able to develop individual labs (appendix question 28). Only one institution had offered a course in landscape genetics prior to the IDGC, whereas following the course, eight instructors from other institutions planned to teach a local course in this field in the future (appendix question 29). Interestingly, the students perceived their local instructors as equally competent as the weekly experts (paired \(t\)-test, 67 students, \(p = .072\)), whereas the faculty rated the weekly experts as more competent (13 instructors, \(p = .027\), appendix question 6). Consequently, 34% of the students, but only 23% of the instructors, would prefer a local course taught by one or two instructors (appendix question 17). The students may not have realized how different the course would be without the contribution of the external faculty. However, many of the students explicitly commented on the added value of the experts from different fields (appendix questions 31): “It was obvious that all instructors and teaching assistants were working within their strengths, interests, and passions, which made the lectures the most excellent lectures in my student career.” “Interacting with experts from all the different fields inspired me to think more broadly about how I can approach this field from many different angles.”

The instructors specifically valued the opportunity for professional development (appendix question 31): “Co-teaching with experts from all related fields, both locally and within the [IDGC] group, made me feel confident about teaching a seminar in landscape genetics that I would never have taught on my own.” “It is difficult to find the time to do professional development, and this course provided a great service to the students while simultaneously enhancing my knowledge and skills in landscape genetics.”

**Figure 1.** Average ratings of the importance of course components for improving students’ understanding and skill level of the students (gray, \(n = 67\)) and of the faculty (white, \(n = 13\)) on a scale of 1–5 (1, very little; 5, very much). The asterisks (*) indicate a significant difference (at \(\alpha = .05\)) between the students’ and the instructors’ responses to appendix question 3.

**Technology.** The novel course design and technology provided learning opportunities in their own right, as one student wrote (in response to appendix question 31): “I also feel as though participating in the [IDGC] was something outside of my comfort zone, so it helped me gain confidence in collaborating with others in a field where I am a novice.”

Discussion of the survey results at the synthesis meeting revealed that although some students found the recorded lectures less engaging, being able to preview, stop, and backtrack through the lectures helped both less-experienced students and non-native English Speakers to better understand the course material. This supports the trend toward inclusive and more-accessible education (Burgstahler and Cory 2008). The control over lecture playback may have contributed to the students’ very high ratings of their ability to understand lectures in English given by native (\(M = 4.66\)) and non-native English-speaking (\(M = 4.27\)) instructors (1, very poor; 5, very good; appendix question 8).

Many students need incentives and technical support to engage in online communication and collaboration, potentially for the first time in their careers. Technical challenges may have discouraged the students from participating individually in weekly online meet-the-expert sessions, which may have contributed to a low average
rating ($M = 2.54$ on a scale of 1 [very little] to 5 [very much], appendix question 3) of the value of this course component for student learning. This interpretation is supported by the low ratings of ease of use of Marratech (appendix question 7a) by the students ($M = 5.95$, on a scale of 1–10), whereas the instructors, who were more experienced with the technology, found it easier to use ($M = 7.00$). Participation in the discussion board was not systematically promoted by the instructors and remained extremely limited, which resulted in a very low mean usefulness rating ($M = 4.12$, on a scale of 1–10, appendix question 7c) that can only partly be explained by a lack of ease of use ($M = 7.1$, appendix question 7b).

**Collaborative research projects.** During the semester, the group-project participants reported having spent an average of 58 hours (standard error = 14.3) on the project, and the group-project experts spent an average of 43 hours (standard error = 18.5, appendix question 10), although these numbers were highly variable in both groups. Both the students participating in group projects ($M = 6.64$ before the project and $M = 7.64$ after the project, on a scale of 1–10, 22 students, paired $t$-test, $p = .014$, appendix question 9d) and the experts ($M = 5.78$ before and $M = 7.0$ after, 9 instructors, $p = .010$) rated their groups’ ability to communicate across disciplines at the end of the semester much higher than at the beginning of the group project. Interestingly, the group-project experts perceived the groups as having collaborated significantly less effectively on average than did the project participants ($M = 6.5$ for the experts and $M = 7.2$ for the students, on a scale of 1–10, $p < .001$, appendix question 9e), whereas the students rated the support by the experts higher than did the experts themselves ($M = 8.3$ for the students and $M = 7.6$ for the experts, $p < .001$, appendix question 9f). Overall, 86% of the group-project participants and 90% of the group-project experts would participate in or supervise a similar project again (appendix question 15). The students wrote (in response to appendix question 33), “The group project was the best aspect of the class. I learned SO much!” “Learning through doing, on real data really helped to solidify and entrench the concepts brought up in lecture. It is also pretty rare to have the opportunity to work towards a publication-quality project for a course. It was a ton of work, but having the motivation of publication made it all the more exciting.”

**Synthesis meeting.** The synthesis meeting was critical for building communication skills, integrating across universities, and producing research products. Both the students ($M = 9.33$) and the instructors who attended the meeting ($M = 9.00$ on a scale of 1–10, appendix question 12a) rated the overall experience with the synthesis meeting exceptionally high. After the synthesis meeting, the participating students rated the overall experience with the group project ($M = 8.53$, appendix question 12b), their group’s ability to communicate across disciplines ($M = 9.00$, appendix question 12d), and their level of confidence that their project will result in a publication ($M = 8.53$, appendix question 12c) much higher than they did before the meeting. This optimism was well founded, because to date, one manuscript is published (Landguth et al. 2011), three have been submitted, and the Web page is published online (https://groups.nceas.ucsb.edu/landscape-genetics). One student wrote (in response to appendix question 35), “So much work was done on the group projects. For the group work, the synthesis meeting could be considered Popeye on spinach… a great guy everyday, but look out for something amazing when that can is opened!”

In terms of total contribution to student learning for those students who attended the synthesis meeting, the students and instructors gave roughly equal importance to the group project (both $M$s = 29%, appendix question 14), but the students ($M = 33%$) rated the contribution of the synthesis meeting significantly higher than did the instructors ($M = 25%$, $p = .026$), who therefore placed more importance on the distributed course. The instructors found the synthesis meeting very important for planning a future course (appendix question 14), especially in terms of revising course design ($M = 4.33$; 1, very little; 5, very much) and course delivery ($M = 4.17$).

Notably, 88% of the graduate students selected to attend the synthesis meeting were not supervised by any of the course instructors, which demonstrates that the IDGC provided unique interdisciplinary research training and networking opportunities to many more students than those already being trained in the instructors’ labs. The students wrote (in response to appendix questions 33, 35, 36), “To get to meet and brainstorm with so many scientists whose work I respect and have their input on my own was a treasure.” “I made several connections that could result in a post doc position, and at the very least, I met scientists that I can collaborate with in the future.” “I would say that this workshop was career changing!” “Meetings like this are incredibly important for bringing people together, both more-experienced and younger scientists. We cannot advance the field alone, and meetings like this are so valuable for all involved as well as the field itself.”

**Conclusions**

The proposed changes for a second offering of the IDGC in landscape genetics reflect the key lessons that were learned from this study (table 1). A multiday preparation meeting is essential to initiating a distributed interdisciplinary course, because it allows faculty to develop the common ground, integration across topics, and technical skills necessary for them to teach the course. Online meetings may suffice for preparing a second installment of the course with the same principal faculty. Further integration can be achieved by coauthoring a textbook or primer and a companion book with student activities and outlines for computer lab assignments, which is an ongoing goal of this IDGC effort. The computer lab exercises typically required testing and
adaptation to local conditions by instructors at each institution. Peer review, standardization, and testing are crucial for labs, and the availability of introductory textbook materials prior to the course would help students review or fill in gaps in prerequisite background knowledge.

The technical challenges included sharing large video files and a mixed quality of lecture recordings, plus occasional connection problems during online meetings. The logistical challenges involved the timing of two live videoconferences spanning 10 time zones, differences in university coursework starting dates, and spring break timing at the participating institutions. The recorded lectures allowed independent scheduling of weekly seminars and spring break accommodation at each institution, except during the first and last week, with live Web conferences.

Although technological solutions for Web conferencing are advancing rapidly, integrating the best of local and online teaching remains a challenge that became a major focus of attention during the discussion of the survey results at the synthesis meeting. The students suggested that lectures by weekly experts that are recorded live with a student audience would be more engaging than prerecorded lectures. Online lectures should, nevertheless, be archived to provide important added value, particularly for students speaking English as a second language. Online meetings with experts may be more effective if they are part of a weekly seminar rather than if they require students to join independently, which would lead to underutilization of this resource. In the future, we will use an e-learning environment to implement live Web-based lectures, followed by local breakout groups and a plenary online discussion. To make the course available to students who attend nonparticipating institutions, we plan to offer an online-only section in which participants meet in an online breakout room for the local seminar discussion.

Group projects aimed at publication provide powerful and rewarding learning opportunities but need to be carefully designed by faculty to ensure that the projects are feasible within a reasonable time frame and produce ultimately publishable results. Projects typically require a second semester to reach publication level but provide students with invaluable training in the research and publication processes and in effective online research collaboration. The interdisciplinary group-project format may be suitable as a research requirement for a course-based master’s degree or professional-certification program (Colwell 2009).

Finally, a synthesis meeting is an essential element, both for the success of group projects and for networking. Funding should be secured in order to offer professional-enhancement awards for students to attend the meeting, with selection of students based on their own justification of anticipated career benefit and on rankings by project leaders and local instructors. There are various options for obtaining funding for such meetings from traditional funding agencies, professional societies, and universities. For example, we have obtained funding to support the next offering of this IDGS course and synthesis meeting in spring 2012 from the American Genetics Association and the Canadian Institute of Ecology and Evolution. Nonacademic partners may be willing to sponsor student awards, as with the NASA–MSU (Michigan State University) Professional Enhancement Awards for students to attend the International Association for Landscape Ecology’s North American chapter’s annual meetings.

Interdisciplinary training opportunities in research disciplines that address complex systems-level problems and integrate methods from emerging technologies are critical for the development of the next generation of scientists and university teachers (Zarin et al. 2003, CFIR 2005, Balkenhol et al. 2009, Öberg 2011). The IDGC presented here offers a new graduate-teaching model for developing and implementing course work in highly technical interdisciplinary research areas by drawing on faculty expertise that is distributed at different institutions around the globe. We hope that the lessons learned from the IDGC in landscape genetics will inspire and enable others to adopt this successful course model to provide future scientists with the interdisciplinary knowledge and technical, professional, and personal skills to become leaders and creative agents for change.

Acknowledgments
This work resulted from a Distributed Graduate Seminar (“Landscape Genetics: Developing Best Practices for Testing Landscape Effects on Gene Flow”) conducted through the National Center for Ecological Analysis and Synthesis, a center funded by the National Science Foundation (grant no. EF-0553768); the University of California, Santa Barbara; and the State of California. We thank all of the instructors and students of this course for their contributions to the course and for their participation in the course-evaluation surveys. We thank Marie-Josée Fortin, Cleo Boyd, Cherie Werhun, and three anonymous reviewers for helpful comments on earlier versions of this manuscript.

References cited


Helene H. Wagner (helene.wagner@utoronto.ca) is affiliated with the Department of Ecology and Evolutionary Biology at the University of Toronto, Ontario, Canada. Melanie A. Murphy (melanie.murphy@uwyo.edu) is affiliated with the Department of Ecosystem Science and Management at the University of Wyoming, in Laramie. Rolf Holderegger (rolf.holderegger@wsl.ch) is affiliated with the Swiss Federal Research Institute for Forest, Snow, and Landscape Research WSL, in Birmensdorf, Switzerland. Lisette Waits (lwaits@uidaho.edu) is affiliated with the Department of Fish and Wildlife at the University of Idaho, in Moscow.