

PROMOTING INTEGRATIVE LEARNING IN FIRST-YEAR SCIENCE

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Introduction

At University College Cork (UCC), prospective students apply to enter one of several broad science streams: Computer Science; Biological and Chemical Sciences; Environmental and Earth System Sciences; Genetics; Chemical Sciences; Mathematical Sciences; or Physics and Astrophysics. In Environmental and Earth Systems Sciences, the first-year programme is presented as a set of eight discrete science modules delivered by six different departments. Although we hope that first-year science students will gain a solid and broad foundation across the sciences, coordinators report that students have difficulty transferring their knowledge and skills from one module to another. Indeed, assessment practices in the modules lead students to believe that the courses are standalone and separate. In addition, students are encouraged to spend some time at another university.

In this potentially fragmented experience of modularisation and mobility, it is up to the students to make the connections between modules if they can, and to make sense of the information and concepts with which they are bombarded. Of course, some do better at this than others. This chapter considers what can be done to help all students gain a more integrated experience of first-year science, by framing its concerns in relation to the emergence of integrative learning as a theoretical issue and a classroom practice. The chapter explores the challenges and benefits of integrative learning through a case study of first-year science at UCC.

What is Integrative Learning?

In 1998, the Association of American Colleges and Universities (AAC&U) issued a *Statement on Liberal Learning*, urging higher education institutions to help students connect up the various aspects of their learning. Boyer's (1990) influential analysis of the nature of scholarship is given much credit for this initiative. Boyer categorised the different facets of scholarship into the scholarship of discovery, application, integration and teaching. His interpretation of the scholarship of integration urges us to consider and research the connections within and between disciplines. Some of the early literature stemming from Boyer's work discusses the challenges of connecting learning across the disciplines and introduces the term "integrative learning" (Graff, 1991; American Association of Colleges, 1991).

Undoubtedly, integrative learning took place before Boyer's work, but much good practice went unreported. Teachers in the disciplines did not have a common teaching and learning language. Subsequently, the AAC&U (2002, p. 21) called on universities to change their practices to help students develop their capacities to be "integrative thinkers who can see connections in seemingly disparate information, and draw on a wide range of knowledge to make decisions", emphasising that the goal of educators is to help prepare "students who can adapt the skills learned in one situation to problems encountered in another". This call caused some teachers to examine what they were doing already, and to make small modifications to improve integrative learning. Studies began to emerge, in unpublished reports, portfolios and websites, as well as published reports (Association of American Colleges and Universities, 2002; Colby *et al*, 2003).

In 2003, with liberal arts colleges in mind, the Carnegie Foundation for the Advancement of Teaching (CFAT), together with the AAC&U, undertook a national project, *Integrative Learning: Opportunities to Connect* (Association of American Colleges and Universities, 2004–07). It focused attention on practice, as well as on institutional commitment to integrative learning. Capturing this campus activity, Huber and Hutchings (2004) published *Integrative Learning: Mapping the Terrain*, a useful and motivational review of the situation at that time. Appended to this was a “Statement on Integrative Learning”, which highlights a broad concern about the “fragmented landscape” of the undergraduate experience. It notes that integrative learning, which could address this concern:

comes in many varieties: connecting skills and knowledge from multiple sources and experiences; applying theory to practice in various settings; utilising diverse and even contradictory points of view; and, understanding issues and positions contextually (Huber and Hutchings, 2004, p. 13).

In this vision, integrative learning includes integrating on-campus learning with experiences in the “real world”, aligning different approaches and different models, and integrating learning over time.

The work of the CFAT, AAC&U and others has opened up and continues to develop a language for discussion of integrative learning. Questions about what integrative learning might look like and how we can encourage it continue to be asked. A starting point for addressing these questions is consideration of the characteristics of students who are integrative learners.

Characteristics of Integrative Learners

Building the capacity for integrative learning requires a commitment and intentionality on behalf of learners (Huber and Hutchings, 2004). This capacity includes, for example, the ability to ask meaningful questions about complex issues and problems in order to create an integrative framework and a more holistic understanding (Klein, 2005). Intentional learners:

- have a sense of purpose that keeps them on track with their learning
- are self-aware and understand something of their own learning processes
- are self-directed learners with explicit learning goals
- will fit fragmentary information into a “learning framework”
- can ask probing questions to help achieve their learning goals
- can monitor and reflect on their own efforts
- can make choices that promote learning
- know when to ask for help.

All students can benefit from strengthening these sorts of characteristics.

How Teachers Can Encourage Intentional, Integrative Learning

Huber and Hutchings (2004) suggest that we can scaffold intentional learning with intentional teaching. The characteristics of intentional teaching for integrative learning can be distilled from the case studies reported from the Integrative Learning Project (Association of American Colleges and Universities, 2004–07). Teachers who have these characteristics:

- are integrative thinkers themselves
- understand something of how students learn
- make integrative learning an explicit goal, objective or learning outcome

- are comfortable with a range of teaching strategies from which they can draw
- design opportunities for students to connect up their learning
- make purposes explicit to students
- encourage work-based learning
- use assessment methods that encourage integrative thinking and learning
- are willing to take risks with their teaching and, where appropriate, stand back and “gift the learning to the learner” (Malone, 2002)
- construct and systematically investigate questions related to student learning and disseminate practice, thereby practising scholarship.

Members of the Carnegie Academy for the Scholarship of Teaching and Learning (CASTL) team at the CFAT have synthesised the findings of the Integrative Learning Project in public reports (Gale 2006; Huber, 2006; Hutchings, 2006; Miller, 2006). The findings are divided into four strands that capture the depth and breadth of integrative learning, and indicate how students’ integrative learning can be increased:

- curriculum design
- pedagogy
- assessment
- faculty development.

Curriculum design

Huber (2006, p. 2) believes that design at the programme level is important but warns that “getting everyone to think beyond the level of the course is a challenge”. She urges teachers and curriculum designers to “build links into the regular curriculum, and create opportunities for *all* students to integrate their learning at multiple points *throughout* their college careers”. She advocates starting early, because building capacities to integrate learning takes time.

Pedagogy

Given a supportive curriculum, certain pedagogies and teaching strategies are known to provide rich opportunities for integrative learning. These include problem-based learning, seminars, learning communities and e-portfolios. Intentional teaching can be based on the use of one or more of these pedagogies to design a course, or a whole programme for integrative learning (Gale, 2006; Hutchings, 2006).

Assessment

Thoughtful assessment opportunities can promote and demonstrate integrative learning within courses and within programmes. Miller (2006) points out that practice necessarily varies from campus to campus, so that good-quality teaching and assessment are aligned. He believes that a complex outcome, such as integrative learning, can be defined operationally by what students do when engaged in the outcome.

Faculty development

These good practices do not just happen. Teachers in higher education need assistance and guidance, as do students, to engage in integrative learning. For students to engage in integrative learning, their teachers must model it. This is not something that comes naturally to all. Indeed, Hutchings (2006, p. 1) says:

there are few mechanisms for knowing how well students connect ideas across courses (be it within the discipline or across fields, between curriculum and co-curriculum, or between academic work and engagement with social and community issues), making it difficult to get integrative learning clearly on the agenda or seen as something that needs further attention.

In response to these issues, Hutchings (2006) advocates staff development that engages teachers as integrative learners. If staff themselves experience collaborative learning and problem-based learning groups, they will begin to develop a toolkit for integrative teaching, thus promoting students' integrative learning. Additionally, Miller (2006) advocates making high-quality examples of students' integrative work public, so that staff can be kept in touch with what is expected, and build their understanding of how it can be developed. Hutchings draws a persuasive picture of "developed" staff helping students to map out connections between cross-cutting literacies.

Although Boyer stated that the scholarship of integration is explicitly about connection-making, the scholars at CASTL have concluded that all four of Boyer's scholarships advocate and encourage integrative learning. They agree with Leskes (2004) that universities, once informed, will see integrative learning as one of the hallmarks of a good undergraduate education.

Case study: First-year Science at UCC

Irish universities are not liberal arts colleges, but the message from the Integrative Learning Project is nevertheless pertinent to them. Recent moves towards modularisation in our universities mean that fragmentation is becoming a common feature of programmes, even of those specialising in one particular discipline. In these circumstances, helping students to connect their learning is a worthwhile endeavour.

Recently, I have been involved in the redesign of a geology residential field course. Geology is the central science from which all other sciences emanate – at least, this is what I tell my students on their first day at UCC. Together, we map out what the study of geology involves, and where geology meets, overlaps and connects with other science disciplines. In the past, students were left to make further connections themselves. The newly redesigned field course incorporates assessment and learning activities that help first-year students develop capacities to connect and integrate their learning – capacities that should stay with them and develop during the rest of their studies and beyond. The rest of this paper presents this field course as a case study in fostering integrative learning in first-year science.

The case study describes:

- the role of the field course in geoscience learning in general, with commentary on its potential for facilitating integrative learning, and with particular reference to the first year field course.
- the importance of small-group work in facilitating integrative learning in this field course
- how various field and campus activities encouraged students to make disciplinary and interdisciplinary connections in this course
- the importance of reflection on learning – and learning to reflect – in the development of integrative learning in this field course
- how this field course's assessment was designed to support integrative learning.

I carried out some action research to study aspect of teaching and learning on this course, employing a wide variety of data-collection methods to capture the complexity of student learning in the field setting. I looked at integrative learning from several angles, and produced both qualitative and quantitative data, allowing a degree of triangulation. From this, rich insights and complex interactions emerged. A detailed description of activities and how they contributed to students' integrative learning is given in Higgs (2007); some examples are highlighted below.

The Role of the Field Course in Geoscience Learning

For the geoscientist, the field course is an important component of what Schulman (2005) calls the "signature pedagogy". It is where students can go out into the natural environment and potentially practice the work of professional geoscientists. Each year, however, colleagues debate whether residential field courses for first-year students should continue. Student feedback suggests field courses are popular, but when asked to apply the learning they have gained from field courses – in the form of synthesis, for example the construction of a two-dimensional cross section – students often cannot demonstrate understanding. This calls into question the usefulness of the field experience. In the US, for example, Colby *et al* (2003) report cases where potentially rich experiences have appeared to result in shallow learning. Hawley (1996) suggests possible reasons for this, noting that in geoscience fieldwork, the dominant style is the 'Cook's tour' which is characterised by a didactic teaching approach with passive student interaction. In other words, the field course can be like a lecture-in-the-field, with students writing down whatever the lecturer says, rather than recording their own observations and interpretations. Students who can write quickly and neatly are rewarded when the notebooks are collected for assessment. There may be little opportunity for students on the course to practice being scientists. Thomas (1998) warns that educators must be clear about the purpose of field courses, and concludes that there are still important questions to be answered, such as those concerning student learning processes in field-based learning. He suggests that if we can answer these questions, we can make the most of "being there".

After all, the field setting, or natural laboratory, has the potential to show us that everything is connected, and can offer authentic opportunities for students to see and feel that this is the case, helping them to develop the capacities needed for integrative thinking and learning. Why is this important? Klein (2005, p10) explains that in the current changing and unexpected contexts, "the answers they [students] seek and the problems they will need to solve as workers, parents and citizens are 'not in the book'". As science professionals, geoscience students must be prepared for an unpredictable career path, possibly in mining, environmental science, geophysics, forensic science, engineering geology, science teaching and local government, among others. As citizens, all graduates will need lifelong learning skills, and an understanding of the interconnections within and between the sciences.

The Field Course

The field course described below is a three-day residential course that forms part of the first-year module, (An Introduction to the Geological History of Ireland), at UCC. Student numbers are usually around eighty.

In the redesign of the first-year field course, my intention was that my students and I would integrate our geology learning with learning in those disciplines that overlap at the margins, such as chemistry, physics, biology and maths. We would look at a geological problem through the eyes of a physicist, for example. We would be interested in new understandings

and the value added by exploring these overlaps. At the same time, connections within the discipline would be strengthened. I included explicit reference to integrative learning in the course objectives and learning outcomes,

Small-group work

Small group work has been shown to be a pedagogy that has good potential for fostering integrative learning (Huber and Hutchings, 2004). Therefore, in 2005, we introduced a new emphasis on small-group work. Beginning on campus, students worked in small groups on projects related to the field area: this enabled them to develop both prior knowledge of the area, as well as questions they wanted to answer. Each small group included a new “angle” or area of science in their project. The groups presented interim progress reports to their peers, which opened up dialogue among the student groups.

Recognising and using valid feedback is an important characteristic of integrative learners, and the small-group work embedded opportunities for giving and receiving it. For example, discussion of the process of researching took place, and review of each others’ work helped students to move their learning forward. Student feedback was shared and discussed in the wider group, giving all students the opportunity to hear each others’ views. This feedback was timely, allowing students to act on it and improve their work as it developed during the course.

The emphasis on small-group work was echoed in the field, with a shift from lectures-in-the-field to a series of seminars-in-the-field. It is important to bear in mind that geologists are always enthusiastic in the field, and love to “tell the story”. In other words, field work can become very teacher-centred. In contrast, the seminar is “a pedagogy wherein everyone has a voice and each person’s ideas are valued, a venue for exploring varied perspectives, an opportunity to experiment, a way to flesh out skeletal ideas through the challenge of friendly critics” (Gale, 2005).

The group collaborative work on campus began to build learning communities that made the subsequent residential field trip more effective. The students had begun to get to know each other and develop ways of working together and supporting each other. During the field trip, students carried out activities in their small groups along the north coast of County Antrim, with leaders to guide their work.

Disciplinary and Interdisciplinary Connection-making

In their small-group projects, students were encouraged to make disciplinary and interdisciplinary connections, as well as connections between new and existing knowledge. For example, a project on landslips moved from geological considerations to the role of vegetation in promoting or controlling landslips, and from the effect on local communities to the engineering solutions adopted on the north coast of Ireland. In another project, students researching groundwater went beyond the geological description of aquifers and considered the potential hazard of pollution, which necessarily connected them to local agriculture and industry in Northern Ireland. The work clearly showed that first-year students are able to carry out collaborative research projects, and indeed that having a purpose for the work (visiting the area of study) and a responsibility (bringing the information to the rest of the large group) motivated them to engage.

Activities during the field trip also provided opportunities for authentic work-based learning, which became important in facilitating integrative learning for the students. For example, a

field workbook was used to encourage students to record their own observations. Questions in the workbook were used to elicit group discussion and initial interpretation where appropriate. Each evening, synthesis activities were carried out back at base. These mirrored the work of professional field geologists, where all information is recorded in a geological column, and/or a geological cross-section. These activities helped students piece together the clues they had found during the day. In the subsequent focus group, all agreed that the evening sessions “were needed to pull things together”.

In addition, opportunities for connection-making with other science disciplines were increased and made more explicit during the field trip. I used the metaphor of “wormholes” (pathways to parallel universes) to describe field activities that required students to connect with “parallel” course modules in the first-year science programme. One wormhole activity simply involved taking a soil pH test when a new bedrock type was encountered. The values obtained were later compared, and showed marked differences in soil pH. This allowed students to connect to prior work they had done in biology and chemistry, and potentially to go on to discuss weathering, the carbon cycle and global warming, thus linking ancient rocks to present-day environmental issues.

Later examples of wormhole activities provided more discussion and connection-making opportunities. One example involved a shallow geophysical survey related to a land development proposal, in which students had to connect geology and geomorphology to concepts they had encountered in physics. This led to discussion of applied geology, the needs of the local community and potential employment opportunities – always of interest to students!

At first, there was some resistance to this idea of thinking outside the discipline; indeed, only a small number of students felt “safe” working in this way. In the examples noted above, however, we made the purpose of the activity clear to students, which was a key factor in student engagement. And, as the field course progressed, students (and leaders) became more comfortable with the idea that all things are connected. Students realised that they did have prior knowledge that could be brought to bear in discussions. Subsequent wormhole activities linked:

- campus laboratory classes with field work in a revision exercise at Cushendun
- the history of science with contemporary understandings of field evidence at Portrush (a key site for scientific controversy in the 18th century)
- rock properties, landslips and local community at Garron Point
- geological time and contemporary juxtaposition of strata at Murlough Bay.

These worm-hole activities showed that *everything* is connected by some pathway, making student learning unpredictable. I likened them to the neuronal networks and connections of the brain, giving each of us our own mind (Greenfield, 2004). This can assist in preparing students for the uncertainty they will meet as science professionals and citizens.

Reflection on Learning and Learning to Reflect

Integrative learners must “learn how to learn”, so opportunities for this were woven into the disciplinary programme. For example, sections of the field workbook contained reflective questions, and operated like a reflective journal, providing a safe place for students to integrate metacognition and disciplinary understandings. (The term “reflective journal” was

not used explicitly at this stage, however, because it would have met with resistance from leaders, and sounded like “a chore” or “not scientific” to students.)

An important opportunity for reflection on learning occurred on the last evening of the field trip, after a challenging daytime activity with messy evidence supporting two separate hypotheses. On this occasion, student groups were asked to defend their interpretation of the evidence they had collected. Most of the small groups had come to a consensus about their evidence, but many modified their interpretations in the light of evidence and argument from other groups. Questions in the workbook asked students to reflect on this process: “What did you learn from others in your group?” and “What did you learn from other groups?” Some students revealed more than others about their learning. They became aware that their peers were making meaning of what they were seeing. Indeed, among other things, the students learned that being a scientist involves accepting that there is not always an easily identifiable, right answer. Students reported that this integration of challenging fieldwork and subsequent discussion was their favourite activity.

How well were students integrating their learning? The answer to this question was revealed partly by students’ responses when they were asked, “What questions remain?” We identified six levels of question complexity in their responses, which concurred with Green’s (2004) model of student questioning, and which could be mapped to six levels of attitude to learning. For example some students simply asked ‘What is the right answer?’ while others essentially composed research questions that demonstrated their understanding of the problem. An interesting point to make is that all of the students could have formulated the more complex questions. They all had appropriate prior knowledge. It requires an attitude to push learning further, and to demonstrate commitment to resolving conflicts in knowledge.

We also asked students to record their “ah-hah” moments during the course: “What became clear?” “How did it happen?” Students described these moments in their own words in their workbooks. This was tremendously revealing, and gave leaders keen insights into where students find difficulty connecting their learning. Difficulty occurs particularly on campus in lectures and practical classes. For example, students found it difficult to visualise portions of the Earth in three space dimensions and integrate changes in the time dimension. The description of “ah-hah” moments gained in complexity towards the end of the course, indicating that students were beginning to articulate their learning better.

Before the field experience, we used a questionnaire to ask students about how they learn best. Their responses indicated their belief that they learned best from teacher-centred activities, from being lectured to, listening, being instructed, memorising and obtaining “good notes”. Only 11 students noted that social learning, such as asking questions and discussing with friends, is important, even though they were all deeply involved in such activities.

The results of a second questionnaire completed by students on the last evening of the field course clearly showed that team-working and other social learning skills had moved up the scale. This was confirmed by written reflections in the students’ final reports, which showed that they were beginning to understand the importance of collaboration and social learning. Typical comments in the reports included:

- The group met up on five occasions to discuss and organise the project ... these sessions allowed members to work as a team and suggest useful sources of reference for other members to pursue.
- During the trip we extracted bits of information that related further to our project, amalgamating with what we had already researched.

In addition to the new importance attached to social learning in the second questionnaire, two explicitly integrative skills – drawing on existing knowledge and questioning – were also given a relatively high importance, even though only two students (out of a total of 80) had included “questioning” in their responses on the initial questionnaire. The second questionnaire also indicated the students felt they were lacking in the skills of prioritising, decision-making, making judgements and challenging assumptions, all important skills for integrative learning.

The student engagement showed us that traditionally we have not sufficiently challenged students. This came across in a subsequent focus group meeting, when the most physically and mentally demanding activities stood out as the most enjoyable. Many of the “ah-hah” moments involved “messy” data, that only came together with a struggle. But this made for robust connections. This idea connects with my interest in students’ breakthrough thinking (Perkins, 2000). Does a breakthrough occur when a wormhole activity succeeds? Is this an “ah-hah” moment?

Assessment

When I designed the course’s summative and formative assessment, I asked myself: “How will I know whether students’ integrative learning has increased?” I ruled out a campus-based terminal examination as an inauthentic form of summative assessment for a field-based course. Instead, I designed a group assignment, which awarded students:

1. 10 percent for satisfactory participation
2. 20 percent for the final group report
3. 60 percent for the field workbook students used to record field evidence, discussion and reflections on learning
4. 10 percent for “attitudes to learning”.

This fourth component is a new concept in fieldwork assessment. Field course leaders have long recognised that students whose participation is particularly beneficial to the group of learners do not always get the best marks, and in extreme cases can even fail because a notebook is incomplete. This component attempted to reward and promote integrative learning by assessing students’ attitudes to learning in the field. To do this, I modified a table by Gronland (1999), related to Bloom’s affective domain, which included assessment criteria that progressed from “attentive; asks for clarification; volunteers; demonstrates commitment to improving” through several categories up to “concerned with bringing the different pieces of learning together; resolving conflicts in knowledge; sees the need for planning; proposes; revises; solves; internalises”. Although this was a rather blunt instrument for measuring complex qualities, it began to redress the emphasis in student assessment.

These forms of summative assessment were new to first-year students, and the students therefore needed careful guidance and monitoring. An important part of this guidance was provided by formative assessment, which took the form of continuing observation of and

dialogue with students and formed part of every activity. It included several types of feedback, including what Hounsell (1997) calls “feed-forward” – that is, feedback intended to help the flow of learning.

Insights into Integrative Learning

After observing all of the activities, questions, potential worm-holes and so on, I have come to some conclusions about integrative learning:

- There are connections that students make themselves.
- There are connections that leaders or peers provoke.
- There are connections that leaders or peers point out.

The evidence shows that students do not belong to one of these categories alone, but move between them depending on the complexity of the connection, and their attitude, motivation or inclination. Some students, however, will be in the first category more often than others.

These observations map well onto Ritchhart’s (2002) internal–external model of dispositions, which describes:

- dispositional action, where patterns of behaviour are self-initiated, intentional and consciously controlled
- assisted action where patterns of behaviour rely on a combination of internal and external triggers
- coerced action, where patterns of behaviour occur only in the presence of external supports and motivation.

Ritchhart allows movement back and forth between the three. His findings concur with those described above in that it is not always that students lack the ability to make connections, but rather that they lack the inclination. Ritchhart calls this the ability–action gap. Thus we must ask how we can encourage students to close the ability–action gap. Ritchhart (2002, p. 51) calls for students to have “the opportunity for practice and reinforcement within meaningful contexts”. This is exactly what the field activities and evening discussions aim to do. With this understanding, we can perhaps do this better.

To help close the gap the student must be aware of the opportunities, and know what action is appropriate. For appropriate actions in the field to be reinforced, and consistency of approach internalised, leaders also need to be aware of their own behaviours. Leaders who try to promote a disposition may not succeed if they do not themselves have that disposition.

What Did the Teachers Learn?

Turning the spotlight from students to ourselves as educators, what habits of mind and attributes do we need if we are to help students build capacity to be integrative learners? It seems that if we do not make connections beyond our own areas of interest, we are unlikely to encourage students to do it.

On this field course, we, as group leaders, had to stand back and let the students take over some of the activities. Not all leaders were comfortable with this. On the other hand, the residential arrangement meant that leaders did have multiple conversations about what was

working and what insights we were getting. Ideas were generated about how things might work better. Back on campus, where these conversations are rare, the first-year programme is our “group project”. We must work as an effective group. What we learn, and how we respond, affects student learning. Talking to colleagues about student learning could create “a culture of connection-making”. Indeed, the student focus group asked that staff talk to each other and link up the learning. They listed specific topics where they recognised connection-making would be valuable. We should follow the lead of the students who wrote in their own group project that “we meet together to exchange tips and see how it is all pulling together”.

More recently, some of the key findings published in the 2006 reports of the Integrative Learning Project were mapped against elements of this first-year course (Higgs, 2007). This process identified integrative opportunities that can be consolidated and strengthened in the future. It also highlighted “gaps” in the geoscience programme. This has led to future recommendations for improved student learning. These recommendations include:

- Integrative learning should be an explicit programme learning outcome.
- Links between courses within the programme should be strengthened, and we should provide multiple opportunities for students to connect their learning over the four years.
- Staff need support in the design of curriculum, assessment and teaching strategies that have been shown to promote integrative learning.

Conclusions

The field course described here was designed to maximise opportunities for integrative learning, and to help students develop their capacities to become integrative thinkers and learners. The design of the course was experimental, and a broad range of opportunities (some unintentional) resulted. At the start of the field component, students had a narrow perception of how they learned, with a high dependence on teacher-centred activities. By the end of the field course, students demonstrated a clearer picture of their learning skills; in particular, they recognised a range of skills that contributed to integrative learning. To help all students to recognise the broad range of ways in which they are learning is a worthy over-arching outcome for a geoscience programme.

The improvements made to this field course were designed to enhance student learning and engagement. The emphasis on small-group work had an immediate impact on student engagement when it was introduced. We also found that students engaged in the learning when they saw a purpose. Indeed, the students’ favourite activities were the most challenging ones. Moreover, the redesigned residential course gave students time to make connections, and to reflect on their learning. In addition, it is clear that increased opportunities for integrative learning can motivate students to persist in a programme, or even increase their learning efforts. Between 2004 and 2006, the number of students choosing to progress to study Geology increased by 500 percent. Of course, other factors could have played a part in this increase, but when staff were asked informally for their opinions about the increased demand for the BSc in Geology, they all believed the field course was a major factor. On the basis of the evidence collected, we concluded that first-year geoscience residential field courses can be highly effective in the promotion of science students’ integrative learning.

It would have been difficult to negotiate this level of transformation in a staff meeting on campus. We now have a disciplinary community of staff who are actively involved in the

first-year field course, can discuss pedagogy (without necessarily knowing the word), and have greater insight into the students who choose to study geology in their second year.

References

- American Association of Colleges (1991) *The Challenge of Connecting Learning*. Washington DC: Association of American Colleges.
- Association of American Colleges and Universities (1998) *Statement on Liberal Learning* [online]. Washington DC: AAC&U. Available from: http://www.aacu.org/About/statements/liberal_learning.cfm [accessed 13 August 2008].
- Association of American Colleges and Universities (2002) *Greater Expectations: A New Vision for Learning as a Nation Goes to College*. Washington DC: AAC&U. Available online from: <http://greaterexpectations.org/> [accessed 13 August 2008].
- Association of American Colleges and Universities (2004–07) *Integrative Learning: Opportunities to Connect* [online]. Washington DC: AAC&U. Available from: http://www.aacu.org/integrative_learning/index.cfm [accessed 13 August 2008].
- Boyer, E. (1990) *Scholarship Reconsidered: Priorities of the Professoriate*. San Francisco: Jossey-Bass.
- Colby, A., Ehrlich, T., Beaumont, E. and Stephens, J. (2003) *Educating Citizens: Preparing America's undergraduates for Lives of Moral and Civic Responsibility*. San Francisco: Jossey-Bass.
- Gale, R. (2005) "The magic of learning from each other", in *Carnegie Perspectives* [online]. Stanford CA: Carnegie Foundation for the Advancement of Teaching. Available from: <http://www.carnegiefoundation.org/perspectives/sub.asp?key=245&subkey=574> [accessed 14 August 2008].
- Gale, R. (2006) *Fostering Integrative Learning through Pedagogy* [online]. Stanford CA: Carnegie Foundation for the Advancement of Teaching. Available from: http://www.carnegiefoundation.org/files/elibrary/integrativelearning/uploads/pedagogy_copy.pdf [accessed 14 August 2008].
- Graff, G. (1991) "Colleges are depriving students of a connected view of scholarship", *The Chronicle of Higher Education*, 13 February. A48.
- Green, L. (2004) Towards a model of student questioning. *Final report June 2004*, CASTL
- Greenfield, S. (2000) *The Private Life of the Brain*. New York Penguin.
- Greenfield, S. (2004) "The child", in *Reconsidering Science Learning*, eds E. Scanlon, P. Murphy, J. Thomas and E. Whitelegg. London: Routledge Falmer.
- Gronland, N.E. (1999) *How to Write and Use Instructional Objectives*. (6th ed.). Bellevue, WA: Merrill Press.
- Hawley, D. (1996) "Changing approaches to teaching Earth-science fieldwork", in *Geoscience Education and Training: In Schools, Universities, for Industry and Public Awareness*, eds D.A.V. Stow and G.H.J. McCall. Rotterdam: A.A. Balkema. pp. 243–253.
- Hawley, D. (1998) "'Being there': a short review of field-based teaching and learning", in *Examples of Good Practice in Earth Science Learning and Teaching: Fieldwork* [UK Geosciences Fieldwork Symposium: Proceedings]. Plymouth: Higher Education Academy Subject Centre for Geography, Earth and Environmental Sciences (GEES). pp. 9–16. Available online from: <http://www.gees.ac.uk/essd/field.htm#HawleyD> [accessed 14 August 2008].
- Higgs, B. (2007) "Promoting integrative learning in a first year Earth Science field course", MA thesis, University College Cork.
- Hounsell, D. (1997) "Essay writing and the quality of feedback", in *Student Learning: Research in Education and Cognitive Psychology*, eds J.T.E. Richardson, M.W. Eysenck and D. Warren-Piper. Milton Keynes: SRHE/Open University Press.
- Huber, M.T. (2006) *Fostering Integrative Learning through the Curriculum* [online]. Stanford CA: Carnegie Foundation for the Advancement of Teaching. Available from:

- http://www.carnegiefoundation.org/files/elibrary/integrativelearning/uploads/curriculum_copy.pdf [accessed 13 August 2008].
- Huber, M.T. and Hutchings, P. (2004) *Integrative Learning: Mapping the Terrain*. Stanford CA: Association of American Colleges & Universities and the Carnegie Foundation for the Advancement of Teaching. Available online from: <http://www.carnegiefoundation.org/dynamic/publications/mapping-terrain.pdf> [accessed 13 August 2008].
- Huber, M.T. and Hutchings, P. (2005) *The Advancement of Learning: Building the Teaching Commons*. San Francisco: Jossey-Bass.
- Hutchings, P. (2000) "Approaching the scholarship of teaching and learning", in *Opening Lines: Approaches to the Scholarship of Teaching and Learning*, ed. P. Hutchings. Stanford CA: Carnegie Foundation for the Advancement of Teaching. pp. 1–10.
- Hutchings, P. (2006) *Fostering Integrative Learning through Faculty Development* [online]. Stanford CA: Carnegie Foundation for the Advancement of Teaching. Available from: http://www.carnegiefoundation.org/files/elibrary/integrativelearning/uploads/faculty_development_copy.pdf [accessed 13 August 2008].
- Klein, J.T. (2005) "Integrative learning and interdisciplinary studies", *Peer Review*, vol. 7, no. 4, pp. 8–10.
- Leskes, A. (2004) "Foreword", in *Integrative Learning: Mapping the Terrain*, by M.T. Huber and P. Hutchings. Stanford CA: Association of American Colleges & Universities and the Carnegie Foundation for the Advancement of Teaching. pp. iv–v. Available online from: <http://www.carnegiefoundation.org/dynamic/publications/mapping-terrain.pdf> [accessed 13 August 2008].
- Malone, L. (2002) Peer critical Learning. *Final report* CASTL. Carnegie Foundation for the Advancement of Teaching website. Available online from <http://www.carnegiefoundation.org/> [accessed 28 October 2008].
- Miller, R. (2006) *Fostering Integrative Learning through Assessment* [online]. Stanford CA: Carnegie Foundation for the Advancement of Teaching. Available from: http://www.carnegiefoundation.org/files/elibrary/integrativelearning/uploads/assessment_copy1.pdf [accessed 13 August 2008].
- Mino, J. (2006) Link-Aloud. *Final report* CASTL. Carnegie Foundation for the Advancement of Teaching
- Perkins, D. (2000) *The Eureka Effect: The Art and Logic of Breakthrough Thinking*. New York. Norton.
- Ritchhart, R. (2002) *Intellectual Character*. San Francisco: Jossey-Bass.
- Shulman, L.S. (2005) "Signature pedagogies in the professions", *Daedalus*, vol. 134, no. 3, pp. 52–59.
- Stone Wiske, M. (ed.) (1998) *Teaching for Understanding: Linking Research with Practice*. San Francisco: Jossey-Bass.