What do Students do? Training, Research and Learning : Developing skills for the next generation of near-surface geophysicists.

*Nigel J. Cassidy and Jamie K. Pringle

Applied and Environmental Geophysics Group, School of Physical and Geographical Sciences, Keele University, Staffordshire, ST5 5BG. United Kingdom.

*Corresponding author n.j.cassidy@esci.keele.ac.uk.

Abstract

In the past decade, degree programmes throughout Europe have changed dramatically and near-surface geophysics is now commonly taught as a minor component of other undergraduate geoscience and related degree programmes. As a consequence, there has been a distinct change in the nature, scope and content of geophysical degrees and the skills set that graduates obtain throughout their studies. As an introduction to the Special Issue on Student-Based Research, this commentary article discusses the expectations of employers, the competencies and skills of our undergraduate and postgraduate students and how these have changed over time. We highlight skill gaps and suggest ways in which the near-surface geophysical community can address these needs in a pragmatic and cost efficient manner. We hope to illustrate that a greater collaboration between industry and academia is the way forward and that innovative, cross-sector approaches to student learning and research are the solution to at least some of our problems.

Keywords — University education, student learning, degrees, research training.

What do students do?... A good question. As academics and University-based supervisors of a range of undergraduate, Masters and doctoral research projects we often find ourselves asking exactly that. Yet, student-based research can often be our most rewarding work as we can run projects without constraints and little political or finance pressure (as long as the funds are there in the first place). As such, the unfettered access to bright, enthusiastic minds can make the process of undergraduate/postgraduate teaching and research an enjoyable and highly rewarding one for us, the academics. But is this what the majority of the near-surface geophysical community wants? We would argue not. Free-thinking, open-minded students with novel ideas are a joy for us to work with but the industrial and commercial sector is really looking for intelligent, competent, skilled, diligent, hard-working, professional-minded employees with a mix of practical and theoretical skills. To a company, the ability to be flexible (malleable?) and pro-active in one's own career development is just as (or possibly more) important than having an in-depth knowledge of geophysical theory – this is the reality of non-academic geophysics. In 2006, the "Geophysics Education in the UK" review was published, commissioned by the British Geophysical Association (BGA) on behalf of the Royal Astronomical Society and Geological Society of London (Khan, 2006). It looked at a range of educational and employability factors associated with geophysics degrees in the UK and covered the full range of geophysical disciplines (e.g., exploration, whole-Earth and near-surface geophysics). It makes interesting reading and provided a snapshot of geophysics in the UK at that time, which mirrored similar changes in the nature of European and North American education (Corbett et al., 2005; Gonzales and Keane, 2009). The report highlighted the value of undergraduate geophysics degrees and how they should provide students with a programme of rigorous training in physical sciences and the key technical skills required for research and industry (Manduca, 2008). Any degree programme should offer a sophisticated range of multi-disciplinary geoscientific analysis and computing skills, as well as the necessary team-working, research, presentation and other transferable skills needed to function in a competitive marketplace. Is this actually the case, however? In the report, it is interesting to compare the skills that the students gained in their degrees against what the employers actually wanted (figure 1). Employers identified field-based skills and practical experience as being key, yet it seems that data handling and IT-based skills were what the students most frequently 'gained' during their studies. The students' relative lack of subject-specific skill experience (e.g., in physics, geology, laboratory work and even geophysics!), in comparison to the more generic transferable skills, such as teamworking, project management, interpersonal skills, etc., is in stark contrast to what employers wanted of their incoming graduates. Multi-disciplinary and transferable practical skills are very important to employers in general (HE Academy Report, 2005; Dalrymple and Miller, 2006) and both undergraduate and Masters-level University courses have these embedded into their programmes as a matter of course (Horton, 2001; Hill et al., 2004). However, they are not considered vital by employers and, therefore, have we lost sight of what is *really* needed in a geophysics degree, at any level (undergraduate or postgraduate)? At the time of the BGA's report (2006), it would appear so. Such experiences were also shared by colleagues in the international oil industry (Loudin, 2004; 2007) and given that the report highlighted the gradual decline of UK-based geophysics education in the past two decades prior to the report (a 50% reduction in student numbers in 20 years), it would also seem that that the academic/educational community was failing to meet the needs of employers and students alike. The reasons for this decline were complex; a reduction in school/college leavers with strong physics and mathematical backgrounds, the development of qualifications in combined sciences rather than pure physics, a lack of exposure to geophysics prior to university, the perceived difficulty of the subject by incoming students, graduate debt, University courses being discontinued on economic grounds, declining research, etc.

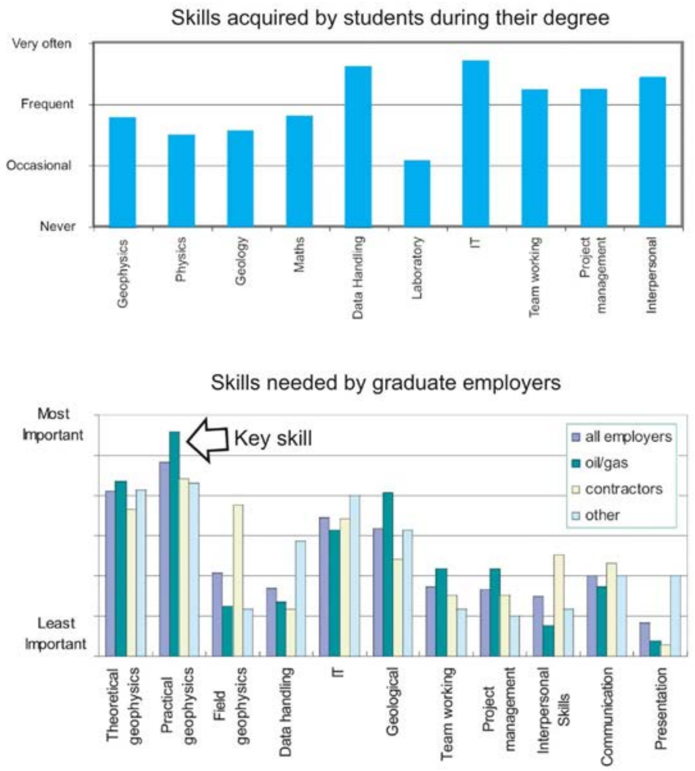

Figure Caption

FIGURE 1. Student skill competencies and employer needs, as documented in the 2006 “Geophysics Education in the UK” BGA review (Adapted from Khan et al., 2006).

However, that was the situation in 2006 and the international financial, industrial and educational climate has changed dramatically since then. Degree programmes throughout Europe have changed, particularly so in the U.K., and near-surface geophysics is now commonly taught as a minor component of other undergraduate geoscience degree programmes and more recently, civil engineering, environmental science, archaeology and forensic science courses. Whether this is a good thing for the future is debatable, but what it does reflect is a growing diversity in the training development and ultimate destination of geophysics-related graduates. Although the bulk of geophysics graduates are still employed within the oil and gas sector (~25%), there have been significant openings in the mining, water, environmental and geotechnical industries. In the environmental sector alone, the skills set of a graduate geophysicist is commensurate with that expected of 'well-rounded' environmental scientist (Thomas, 2008). As such, "Environmental Geophysics" is one of the subject areas that is benefiting from an expansion in student numbers. Unfortunately, this means that Universities are adapting environmental sciences courses to meet a perceived market need and 'bolting in' geophysical elements to existing programmes. Again, is this really what employers want?

In 2009, as part of a wider initiative on student employability and skills development, a consultation programme was started at Keele University that aimed to link the needs of the European environmental geophysics survey sector with developments in the University's undergraduate and Masters-level education programme. The study is on-going but there are some interesting initial outcomes from the work that reflect the current status of geophysical education both in the UK and in Europe. We consulted with a number of UK-based, medium-sized survey companies and research-orientated commercial bodies operating internationally and asked them to comment on their recent graduate intakes. Some of their comments are illuminating...

- *"Graduates have relevant degrees, good all round skills, but their communication skills are a bit lacking. They rarely have fieldwork and data processing experience but are not bad at getting up-to-speed."*

- *"We tend to recruit from higher-level graduates. We will take summer placement students, depending on work, and if bright, may recruit them. Graduates have consistent skills, but are less focused on the job or easily side-tracked."*

- *“We recruit at MSc or PhD level. Most graduates have specialist skills but the key for us is multi-disciplinary skills. Most degrees are focussed on one subject with few courses applying multiple techniques in combination, which is usual in modern geophysical investigations. Graduates are weak on which techniques to apply. Practical case studies are not being taught.”*

- *“We receive poor, speculative CVs with a lack of literacy skills. We generally take MSc or PhDs as graduate level applicants don’t have the necessary experience, rigour, numeracy, commercial awareness and, crucially, fieldwork experience. Geophysics modules often teach out-of-date techniques due to dated University equipment. Postgraduate level students are much more astute.”*

- *“In the Last 5 years, recruiting graduates has not worked well. Graduates are not up-to-speed with the commercial realities/awareness of short timescales, how equipment is used, the difficulty of client requirements and the tendency to focus on the end result rather than on the methods. We tend to recruit from competitors in industry with experience. A broad range of knowledge is important to us and graduate degrees seem to be more focused towards passing exams rather than developing understanding. Our work is physical, demanding, often in inclement site conditions and with the pressures of timescales, etc. An awareness of this would save some graduates from entering the wrong field.”*

- *“Graduates have less numeracy skills than before and courses have less practical elements and a lack modern equipment. Most courses are focused towards the petroleum industry rather than near-surface.”*

- *"We pick from known University graduates who like fieldwork and are independent thinkers. Their application of knowledge is generally good but we see a lack of business skills/awareness - Mistakes cost us money. It is usually eighteen months before we can trust them to work on their own. We train by mentoring and they either stay for 12 months or 10 years! It's practical work, of a rigorous nature with short deadlines – some don't like it."*

These comments make harsh reading for anyone in higher education but probably resonate with our industrial colleagues. It is clear that we have still to address many of the issues that were highlighted in the 2006 BGA report but, on the positive side, our industrial participants did praise the dedication of those graduates who did 'make the grade' in the end. There also seems to be a unique sense of community within the near-surface geophysical sector that leads to a wider appreciation of the subject area and a willingness to employ good practice. Whether this is a real or perceived notion is hard to tell, but the employers' feedback does suggest that the successful graduates are generally open-minded, bright and develop the appropriate theoretical knowledge and scientific rigour quickly. They also seem to enjoy doing what they do; job satisfaction is high.

Unfortunately, employers do cite filling geophysicist vacancies as one of their most difficult and time consuming tasks. Are employers expecting too much? Do graduates expect too much? It is clear from the comments that higher-level degrees are preferred (MSc and PhDs) and that there is an observed difficulty with graduates being able to grasp the realities of the commercial world (e.g., liasing with clients, handling contracts, dealing with restricted project budgets and tight timescales, etc). It could also be argued that there seems to be a degree of misplaced optimism on behalf of the graduates as they enter the commercial world. Salaries in the near-surface sector are not as high as those in the petroleum industry and the work can be demanding both physically and mentally. A lack of real-world awareness by graduates seems to be an issue and some employees seem ill-prepared for the rigours of site work and the lower financial rewards in our industry. That said, many graduates think that this is balanced by the wider range of experiences they gain in their employment and the ability to develop their careers technically, rather than through conventional ‘management’ routes. What is evident from the on-going consultation is that current undergraduate degrees are not providing the right level of knowledge, practical training and equipment awareness needed to deliver highly employable graduates to the market. As educators, we find this concerning. The comments are fair but it is difficult to provide all students with every skill needed in a single undergraduate degree course. Equipment access and familiarity is an issue and although most Universities understand the need for having up-to-date equipment for student use, in the current financial climate having regular purchases of the latest equipment is both unrealistic and untenable. Providing students with appropriate levels of field/practical skills in equally problematic and costly. Fortunately, we have seen a recent renaissance in the provision of fieldwork-related geoscience learning in the US (Whitmeyer and Mogk 2009) but whether this is sustainable is questionable. Experiences on this side of the Atlantic seem to suggest that this is a short-term trend, rather than anything more permanent (EAGE, 2009). Put simply, extensive undergraduate fieldwork programmes are just too expensive for most Universities, either in lecturers’ time or physical cost. There is immense pressure on academic staff to increase student numbers (i.e., income), reduce course costs and make efficiencies in our teaching hours. As educators, we dislike this as much as our industrial colleagues, but it is an unfortunate fact of current University life. Fieldwork and laboratory intensive degree programmes will suffer budget restrictions – it’s a reality.

The implications of the global financial squeeze are clearly illustrated by the recommendations of the recent report by Lord Browne into "Higher Education Funding & Student Finance" commissioned by the UK government in October 2010 (Browne, 2010). It recommended that the cap on University tuition fees was to be removed and that free-market economics used to dictate the supply and demand for degrees in the UK. The government wishes to shift the cost of University education away from the state and into the hands of the student. In practice, this means that the current flat fee rate of £3,290 (~€3,800 or $5,000) per year for a science degree would be abolished and that Universities could charge what they wanted. Geophysics at one of the 'best' UK Universities may, therefore, cost a student £12,000 per year by 2012 (~€13,500 or $19,000) and at least £7,000 (~€8,000 or $11,000). This fee rate was considered the likely minimum that most Universities will charge anyhow. The rights or wrongs of this situation could be argued, but either way is does it mean that UK University fees will be on a par with the top US institutions and considerably more expensive than their European counterparts (for the time being at least – European governments may follow the UK's example in the future). Costly courses, such as geophysics, will undoubtedly suffer and the more expensive fieldwork and practical elements of a degree will be the first victims of any financial cull.

So, we face an uncertain future, particularly in the UK. Where do we stand? What can we do? It is easy to apportion blame; Universities could provide better courses, industry could support more students, students could take more responsibility for their education and careers, etc., etc. But, this is not the right approach. To improve student learning and provide industry with appropriately skilled graduates it is important that academia and industry work together in a more inclusive, yet transparent, way. One thing is certain, however, that both Universities and industry are short of cash for grand initiatives. Whatever we do must be developed in a logical, cost effective manner. What can be done?

Firstly, the whole sector must revise its expectations and assumptions of what modern geophysics degrees are, and what skills a graduate will obtain at the end of the process. Degree courses have changed considerably over the past few years in response to a combination of financial pressures, government initiatives to develop more transferable skills (at the request of industry) and the requirements of the Bologna declaration on European degrees, which aimed to harmonise undergraduate and postgraduate degree education across all European countries. The outcome of all this is a change to wider, more generic learning and less of a focus on gaining in-depth specialist knowledge. Employers must realise that undergraduate degrees are not the same as they were ten, or even five, years ago and the skills set of a graduate in 2010 will be significantly different to those from 2001. However, the harmonising of degree requirements at Masters level has led to the recent development of some very exciting and specialist Masters courses across a number of European Universities. Under the umbrella of programmes such as Erasmus Mundus and the IDEA league, new collaborative courses are being developed that fill the gaps left by the closure of traditional ‘geophysics’ Masters (e.g., Master of Science in Geospatial Technologies - http://geotech.uni-muenster.de; Masters in Earthquake Engineering and Engineering Seismology - www.meees.org; MSc in Applied Geophysics - http://www.idealeague.org). Although welcome developments, these are still traditional Masters in that they are generally full or part time study in an academic institution. They may not suit every undergraduate, particularly with increasing levels of individual graduate debt, but at least there is now a growing supply of specialist courses across the EU.

Doctoral degrees are also evolving. There is a distinct, and deliberate, shift way from academically-driven, pure research doctorates taking five or more years and, instead, a focus towards shorter-term (3-5 years) industrial-led, applied research with significant elements of business and generic skills development. This is good news for industry (as long as they can afford to fund the doctoral degree programmes) but academia still has to adapt. Many PhD supervisors still consider doctorates as “research only” and that learning other non-research related skills gets in the way of a student’s studies. Unfortunately, many PhD students feel the same way. As academics, we have to revise our mind-set and adapt to the changing landscape of PhD funding in Europe and encourage our students to do the same. Similarly, there needs to be a willingness from industry to support PhD research and help provide funding for their future employees’ development.

What else can we do? It is important to tailor our current degree programmes appropriately to address industry concerns. This is not an easy task as the rigid and often highly bureaucratic administration systems in place at Universities makes it difficult to change significant elements of a course in timescales of less than a year or so. One possible way is to provide a common, broad-based theoretical programme to geophysics across all relevant undergraduate degree programmes and then encourage Universities to work collaboratively to develop multi-institution fieldtrips and practical-based modules (e.g., see Pringle et al., 2010). This has the advantage of economies of scale, the sharing of equipment, wider learning experiences and efficiencies in staff time. However, it would require inter-University cooperation on a regional scale, which would be fine for many academic staff as we often work collaboratively in research anyhow.   Nevertheless, it would mean a completely new way of working for many University institutions, who are always reluctant to change, and pressure would be needed from industry to get them to consider this approach seriously. It is possible (as the EU Erasmus Mundus and other programmes have shown); it's just that there needs to be a willingness to take the ideas forward.

Creating long-terms links between industry and academia is vital as well, and not just through large programmes of sponsored degrees and Doctorates (as is common in petrochemical industry). The near-surface sector cannot afford such schemes and smaller, more cost efficient ways are needed. At Keele University we are currently developing a "shadowing" placement programme where our University-based PhD students are encouraged to undertake a short industrial placement shadowing an experienced member of industrial staff. In return, the company sends a relatively new member of staff to shadow one of us (the academics) to get access to research for professional development, exposure to new students and an insight into current academic ways or learning. The key to success is running it on a "free-cost" basis. The university does not charge the company fees or learning costs and we do not expect the placement student to be paid by the company; it is all part of their PhD training. The benefits are obvious and it is an ideal way of providing each party with exposure to the parts of the sector they are less familiar with. It also encourages research collaboration with the potential for highly relevant projects and the development of new technologies (as illustrated by the papers in this Special Issue). It will all take time to put in place and, again, a willingness by industry to participate in the programme. In practice, there no reason why this cannot be extended to more experienced members of staff from both industry and academia. As lecturers, we would welcome the opportunity to experience the 'coal-face' of commercial geophysics and pass on this knowledge to our students. Likewise, we imagine that many experienced industrial geophysicists would be more than happy to teach and instruct our students, particularly in field and practical skills. It would certainly go a long way to addressing the issue of student skills and the lack of industry awareness.

However, it would mean a greater degree of intra-sector collaboration and more cohesion between practitioners and educators.

All sounds great, yes? So why don't we do it now? In some ways we do, sort of. Many courses have industry-based speakers as part of their programmes and undergraduate placements are common. But this is not enough and, ultimately, does not provide the degree of 'immersion' that is needed to really understand the skills needs of industry and the processes that define education in universities. Again, we can do this; it just takes time and the desire to do so. Fortunately, there are things we can do right now that do not demand too much of our individual time/effort but will make a significant difference to the learning experiences of our students in the end. We can all be more pro-active at setting up industrial-led, final year, field-based geophysics independent or group research projects for interested students to gain critical skills. Many of our industrial partners say that summer placements are, generally, a good idea but, ultimately costly. Volunteer internships are uncommon in the UK, and particularly so in the geosciences sector, and there is a reluctance by industry to develop such programmes in the current financial climate. There is also the issue of the 'worth' of such programmes to students whose graduating debt may be more than £50,000 (~€57,000 or $80,000). It is better to embed such experiences into industrial-led dissertation projects (Masters and undergraduate) but, despite our best efforts, we find it very difficult to encourage industry to join in on such activities. Expectation and perception are probably the issues here. Industry is cautious about losing IPR, market position, ideas, etc., and often considers academia as being too slow to react and over-bureaucratic. Academic often considers industry as too restrictive, demanding and money-orientated. Whether this is all true can be argued, but the simple fact is that we are not working together enough. As academics we need to encourage and reassure industry that we are not going to undermine their technological developments, IPR, etc., and develop joint projects that are directly related to the concerns/needs of industry. Likewise, industry has to understand that, yes, Universities do act slowly, have complex bureaucratic administrative procedures and that staff time is always in demand. There should also be more of a combined willingness to be open about technologies and disseminate good practice for the benefit of everyone. It is easy to say that graduates do not possess the right skills needed for practical fieldwork, but when there is a reluctance to share thoughts on good practice across the sector, it is difficult to embed these ideas into the learning programme. We should all be pro-active in disseminating good practice and allow our non-restricted data sets and results to be freely used for the creation of sector-wide scenario-based learning materials. We should also be a bit more flexible with way we utilise equipment. Universities cannot afford the latest state-of-the-art equipment for teaching alone and although industrial demonstration days provide excellent exposure to new techniques, they can never replace real hands-on experience. We should be encouraging industry to allow academia access to in-house equipment (through projects or student-led, problem-solving group exercises, etc.) and academia should, in return, be willing to help support industry with the development of these technologies without demanding a slice of IPR or payment. Controversial yes, but it would give new undergraduates and postgraduate students the vital training they need in the latest geophysical techniques and help bridge the perceived skills gap.

Ultimately, we are undergoing a significant change in the way that higher education operates and degrees (and graduates) will never be the same again. We need to rise to these challenges and work collectively to enhance the student experience, embed the necessary skills in to our degree programmes and draw in a greater degree of industry involvement into our courses and research. Easier said than done, yes, but our experiences over the past few years have shown that the issues do not go away. We must think of innovative ways to address graduate weaknesses and find efficient, cost effective ways of filling these skills gaps. What we have discussed in this article are just ideas, some of which will be popular, some less so, but we have to do more than just debate these issues *ad infinitum*. As a sector, we need to encourage action and develop effective ways of working together. Otherwise, we will suffer collectively and find it even harder to recover when global economy rebounds.

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