ON DISCIPLINES AND INTERDISCIPLINARY LEARNING

Disciplinary Divides - Where are we now?

In his famous Rede Lecture in 1959 *The two cultures and the scientific revolution*, CP Snow lamented the wide gap between the sciences and the humanities, a disciplinary divide that still persists 50 years later. Snow argued that "*There is only one way out of this…..by rethinking our education*". Educational reform has to date largely struggled to transcend disciplinary divides and embrace interdisciplinary learning (IDL) in any meaningful way, but now *Curriculum for Excellence* (CfE) aspires to do so. An essential element – and one of four contexts for learning - of the *Curriculum for Excellence* (Scottish Government 2008)*,* IDL in the STEM (science, technology, engineering and mathematics) subject area is firmly recommended in the SEEAG Report (2012). The science disciplines all share common skills (the process of cognitive enquiry we call the scientific method). While many examples of good and innovative practice in working across discipline boundaries are now emerging (Education Scotland 2013), many challenges remain to be addressed in order to embed IDL within the culture of Scottish education. Universities and employers seek students with both interdisciplinary awareness and curiosity together with the substantive STEM subject knowledge on which it is founded (Deans of Science and Engineering 2010, SEEAG Report 2012).

This review paper aims to communicate the ***nature*** and ***principles*** of interdisciplinary learning in the context of a clear understanding of the characteristics and importance of disciplines, with particular reference to the STEM subjects. The principles of IDL reviewed here may also find broader application beyond the STEM disciplines.

What is a discipline?

The concept of ***interdisciplinary learning*** cannot be properly understood without a clear understanding of the characteristics and nature of ***disciplines***, and their benefits and limitations. Disciplines as a means of structuring academic practice have been well established in UK universities since the mid 19^{th} century. A discipline is a branch of learning or domain of knowledge that is characterised by distinct objects, concepts, principles, theories, skills, tools and applications. Established disciplines also comprise groupings of 'like-minded' people with a shared language who subscribe to these principles and methods, interact with each other, and communicate and apply their knowledge and understanding in society, for example through education, research and economic activity. Although disciplines may be resistant to externally imposed change, they are continuously evolving and developing from within, especially in the STEM subjects. Their boundaries are not fixed and therefore cannot always be easily defined. The accumulation of knowledge within science disciplines leads to internal specialisation and division. Nonetheless, disciplines also possess stable characteristics that ensure that they remain distinct and identifiable.

Strengths and weaknesses of disciplines

Disciplines give *structure* and *rigour* to the development of knowledge, and are vital to sustaining and curating knowledge, and to communicating that knowledge to non-experts and to future generations. Disciplines provide a reservoir of knowledge and skills that have value in society and confer benefits to economies. A STEM discipline is characterised by its ***structure*** - concepts, principles, theories and methods - from which detailed outcomes arise, predictions may be made and theorems tested. The more fundamental the idea or skill that has been learned, the greater should be the breadth of its ***applicability*** to problems and its ***transferability*** to other domains of learning or disciplines. By contrast, if learning comprises unconnected knowledge, information or skills that are not placed within – or related to - a structured framework (such as science disciplines) they are likely to be rapidly forgotten. Good teaching should impart an understanding of the underlying structure of a subject rather than simply a mastery of facts and techniques.

However, there are also persuasive arguments against disciplinarity. The consistent focus on a single set of disciplinary phenomena may result in a lack of creative engagement with other disciplines and with the gaps between disciplines. Disciplines may be inward-looking and fail to address relevant, real-world problems. Pupils may find it difficult to make links between disciplines. Disciplinary communities guard their boundaries in competition with other disciplines, yet it is in the gaps beyond disciplinary boundaries - the ***interdisciplinary*** areas - that major new insights and breakthroughs occur. "*To see the whole is to see it in breadth, but without access to the particular vision: to see the part is to see it in depth, but in the absence of the general view*" (Becher 1989).

Interdisciplinary learning – what is it?

Although not in itself a new idea, interdisciplinary learning (IDL) has been adopted as an essential element of the *Curriculum for Excellence*. With its focus on relevant themes or problems, IDL enhances the development of all four capacities of Curriculum for Excellence: successful learners, confident individuals, effective contributors and responsible citizens.

The terminology used to describe IDL is varied and confusing. The terminology adopted here draws in large part on Chettiparamb (2007) and Harvie (2012). In ***interdisciplinary learning*** learners ***draw on two or more disciplines*** in order to advance their understanding of a subject or problem that extends beyond the scope any single discipline. Learners integrate and develop information, concepts, methodologies and procedures from two or more disciplines to gain new knowledge, understanding and skills, and commonly also to explain or solve problems. The learning may be entirely thematic insofar as the discipline boundaries are blurred. ***Contextual learning*** is an important and widely used type of interdisciplinary learning where different disciplines or curriculum areas are focused - or converge - on a context, issue or problem. Contexts are typically practical, real-world problems or issues, such as for example climate change or energy. When the disciplines are in different curriculum areas, for example sciences and social subjects, this is often described as ***cross-curricular*** learning. ***Multidisciplinary learning*** describes the ***juxtaposition of disciplines*** which may have no apparent connection or may be taught as separate entities by one teacher but related to a particular theme or topic.

Merely linking or juxtaposing discrete subjects together around a theme is not by itself interdisciplinary (as defined above), but rather multidisciplinary. In good IDL, learners tackle relevant and meaningful questions or problems that will allow them not simply to make connections between two or more disciplines but to ***draw on and develop their disciplinary knowledge, understanding and skills*** and thereby deepen their understanding of these disciplines. Only in this way will IDL enable and enhance the vital capacity to ***transfer*** and ***apply*** disciplinary knowledge, understanding and skills to new problems and into other areas of learning.

Arguably IDL cannot exist separately from disciplines but is in practice fundamentally founded on strong disciplinary knowledge, understanding and skills. Furthermore, teaching specific topics or skills without clarifying their relationship to broader and more fundamental principles (starting from the specific rather than the general) makes it difficult for learners to transfer and generalise their learning, making it useable beyond the situation in which the learning occurred. However, some recent research has shown that students undertaking IDL also obtain a deeper understanding of the links between disciplines and the transfer of learning.

Interdisciplinary learning – a dialectical process

Arguments for interdisciplinary learning stem from debates about disciplines and their limitations, either in terms of filling the gaps between disciplines or of emulating what disciplines by themselves can achieve. Successful interdisciplinarity has largely developed in higher education from *within* science disciplines in response to the recognition that major advances in scientific research typically occur at and between the disciplinary interfaces, where progress depends on making interdisciplinary connections and gaining new insights. This requires teamwork and collaboration amongst people from two or more disciplines, a practice common in industry and the workplace. There is a widely-held view that STEM education should reflect such practice. The practice of IDL in STEM subjects creates and develops awareness of wider career opportunities and stimulates curiosity and motivation, while emphasising the inter-relationships of phenomena. In STEM education, there is also a perceived need to stimulate the prior interest of learners in the material to be learned by emphasising its relevance to practical everyday problems, many of which require interdisciplinary approaches. If learners are interested in a problem they will become interested in the underlying science. Interdisciplinary problems cannot be successfully tackled within the boundaries of one discipline.

Importantly, IDL also promotes higher-order thinking skills such as creativity, critical and systems thinking, synthesis, evaluation and analysis, and is commonly associated with diverse alternative types of learning such as co-operative, inquiry-based, and contextual learning. In implementing problem-based IDL, teachers become facilitators, supporting pupils to become self-directed learners. Harvie (2012) examines the benefits of co-operative learning as a powerful pedagogical approach to facilitate self-directed IDL, in which students work together to discuss ideas, agree strategies and debate conclusions and solutions. An Education Scotland (2012) briefing paper explores the practical planning and delivery of IDL within Curriculum for Excellence, emphasising the importance of ensuring that learning builds on – and ensures progression in - existing knowledge, understanding and skills within a clear framework. This requirement presents important challenges in curriculum design.

While the use of IDL is an increasing and widely welcomed feature of learning across all sectors (Education Scotland 2013), its implementation also presents major challenges such as the need for an adequate breadth and depth of STEM knowledge, understanding and skills, especially across interdisciplinary areas, and the narrowness of the current science subject discipline base. The SEEAG Report (2012) concluded that "*The narrowness of the science discipline base in Scottish secondary schools is a poor foundation for the support and development of interdisciplinary science learning.*"

The benefits that interdisciplinary and cross-curricular learning confer on learners within and beyond the STEM disciplines have been widely recognised and welcomed, but research evidence for the effectiveness of IDL is as yet limited and largely resides in the realm of higher education, where IDL is most strongly developed and widely practised. While strongly supporting the intention of CfE to develop IDL, the SEEAG Report concluded that '*Interdisciplinary working requires that all science subjects should continue to be founded on deep and coherent pillars of knowledge and understanding. Interdisciplinary understanding will lack rigour and utility if it is not part of a structure in which the disciplines are pillars with interdisciplinary work as lintels. Without the pillars, the lintels will fall*'. In other words, to be of long-term value the delivery of interdisciplinary learning must at the same time provide substantial disciplinary knowledge and understanding (theorems and principles) that are transferable into different contexts. How is this balance to be achieved in practice? This is one of the grand challenges of CfE.

Successful development and delivery of IDL within CfE is strongly dependent on teacher skills, a deep understanding of the *nature* of IDL and its relation to the STEM disciplines, a sufficient breadth and depth of subject knowledge, understanding and skills, and expertise in curriculum design. Practical logistical issues for schools include timetabling, cost, time and working with other departments. All these challenges will require a high and sustained level of support through CPD, development of professional learning communities, reform of ITE and much more ongoing collaboration and engagement between schools, local authorities, universities and colleges, industry and other agencies. Teachers need the time to think, plan and develop IDL. By tackling these challenges through the creation of strong, interconnected support systems and the establishment of creative partnerships, a roadmap can be created to enable Scotland to be a world leader in interdisciplinary learning.

Sources

This paper draws extensively on the work of Bruner (1977), Chettiparamb (2007), Harvie (2012), Kline (1995) and the SEEAG Report (2012).

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