11 Comparing discipline-based and interdisciplinary knowledge in university education

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As higher education is increasingly linked to national productivity alongside public and private benefits, major changes to the place and structure of higher education have followed (Marginson and Considine, 2000). As Rizvi and Lingard (2009, p. 96) discuss,

> Curriculum reform has been linked to the reconstitution of education as a central arm of national economic policy, as well as being central to the imagined community the nation wishes to construct.

Pressure placed on universities by government, society, employers and the academy itself have resulted in universities implementing curriculum changes and an increased interest in the incorporation of interdisciplinarity (Holmwood, 2010). Seen to provide students with the skills and knowledge necessary to survive in a knowledge-driven society, the inclusion of interdisciplinary subjects within a university education is often considered inevitable and a 'radical break' from disciplinarity (see Moore [2011] for discussion).

While the inclusion of interdisciplinarity within higher education curricula appears to offer an alternative to a purely discipline-based education, there has been little research into whether teaching in interdisciplinary subjects does in fact present a new paradigm. Studies of interdisciplinarity at the subject and institutional level (e.g. Barnett and Brown, 1981; Minnis and John-Steiner, 2005; Spelt et al., 2009) have tended to focus on the beneficial skills gained by students from undertaking such studies. Rather than emphasising only the skills that come from interdisciplinary teaching and learning, this research aims to address the question of how the knowledge that is taught in interdisciplinary subjects is different from or the same as that taught in the singular disciplinary environment.

The place of the disciplines and interdisciplinarity within universities

The splitting of knowledge to suit a range of purposes can be traced back at least to the trivium and quadrivium of medieval Christian schools (Bernstein, 2000; Durkheim, 1977). As knowledge changed and grew,

the disciplines emerged. Their histories, content, culture and epistemologies are simultaneously distinct, overlapping and evolving (Apostel, 1972; Becher, 1989; Squires, 1992). Through their own education and research, academics are enculturated into a particular discipline's way of knowing and what is valued as knowledge. Subjects taught within the disciplines inherit this broad context and will generally be taught by an academic that is trained in that discipline's explicit and invisible pedagogy (Bernstein, 1975; Donald, 2002).

Furthermore, academics have the ability to influence the disciplines through the creation of 'specialised rules of access and specialised power controls' (Bernstein, 2000, p. 31). Yet, while disciplines can often remain seemingly static, others exist relatively briefly, merge or expand. It is this changing nature and the commonalities between disciplines that result in some disciplines coming together (Klein, 1996). Whilst the nomenclature of interdisciplinarity is relatively new, it is in itself not a new phenomenon; it is an emergent property of the changing nature of knowledge itself.

As a result of the complex range of pursuits that are considered interdisciplinary and the large number of labels that are in common usage, interdisciplinarity is a concept that is often not clearly understood. Mansilla (2005, p. 16) defines interdisciplinarity as

> the capacity to integrate knowledge and modes of thinking drawn from two or more disciplines to produce a cognitive advancement – for example, explaining a phenomenon, solving a problem, creating a product, or raising a new question – in ways that would have been unlikely through single disciplinary means.

This definition is used in this research, as it takes into account the broad range of pursuits that are called interdisciplinary while allowing for a distinction between discipline-based and interdisciplinary subjects.

At the research level, interdisciplinarity occurs due to the boundary pushing that results from the quest for new knowledge. Interdisciplinary curricula, while often reflecting these new knowledge areas, plays a different role as it also aims to provide a response to society's beliefs around the 'purpose' of an education. Interdisciplinarity is seen to fulfil many of these purposes and provides curriculum developers with an alternative path to a more traditional education focused purely on the disciplines.

Clark (1986), in his work on the organisational sociology of higher education systems, emphasised the centrality of disciplines within the university structure. It is often within an organisational structure based around the disciplines that interdisciplinary subjects are introduced. Many interdisciplinary subjects are taught by individuals or groups of academics who belong to their own distinct disciplines and, in many cases, teach discipline-based units in addition to their interdisciplinary commitments. How these academics interpret the aims of interdisciplinary subjects will influence the knowledge that they draw upon and teach.

The logistics of bringing together multiple disciplines for the purpose of interdisciplinarity involves a complex set of variables. Disciplines can differ markedly and their content, epistemology and culture have an influence on pedagogical practices (Becher, 1989; Donald, 2002). Taking knowledge out of a discipline and into the interdisciplinary environment raises important matters about how academics teach this knowledge, why it may be different and the possible implications of such.

The site of the study

The site of the research was the University of Melbourne, an elite research university in Australia that has in recent years been ranked the top university in Australia in a number of international rankings (e.g. Shanghai Jiao Tong and Times Higher Education World University Rankings). In 2008, a major university-wide curriculum redesign was undertaken, including an alignment with the degree structure espoused by the Bologna agreement and those of North American universities. The degree restructure involved a move toward a broad three-year undergraduate degree and the incorporation of interdisciplinary subjects into the curriculum, followed by specialisation at the Master's level. The investigation consisted of six case studies of experienced academics with distinct backgrounds in discipline-based research and teaching who also taught an interdisciplinary subject. In order to understand the influence of the disciplines on interdisciplinary teaching, the academics were chosen from a range of disciplinary backgrounds: physics, ecology, philosophy, history, visual art and economics. The academics' disciplinary background is referred to here as their home discipline. Table 11.1 presents each academic's home discipline, the titles of the interdisciplinary subject taught and the topic compared across their teaching in their home discipline and interdisciplinary subject. The table also includes the knowledge structure and specialisation code as revealed through the analysis, as will be discussed later. The interdisciplinary subjects were all taught tag-team style, where the contributing academics take turns presenting their disciplinary component.

The study investigated academics' descriptions of knowledge and teaching within their home disciplines and within their interdisciplinary subjects. The aim was to characterise the underlying influences and structures, allowing for a comparison of the two contexts. Data was collected over two open-ended interviews with each of the six academics. The first interview dealt with each academic's broad perceptions of teaching and the types of students the academics were seeking to produce within their own discipline and the interdisciplinary subject. For the second interview, academics chose a topic taught within both a discipline-based and interdisciplinary subject to discuss the 'how' and 'what' of teaching across both subjects. The topics that the academics chose to compare are listed in the final column of Table 11.1. As an example, the physicist chose to compare the teaching of 'energy' to first-year physics students and to first-year

Table 11.1 Disciplinary background of participant, knowledge structure and specialisation code of home discipline, the interdisciplinary subject taught and topic compared across home discipline and interdisciplinary subjects

Home discipline of participant academic	*Knowledge structure of home discipline as revealed through the analysis*	*LCT specialisation codes of home discipline, as revealed through the analysis*	*Title of Interdisciplinary subject*	*Topic compared across home discipline and interdisciplinary subjects*
Physicist	Hierarchical knowledge structure	Knowledge code	An Introduction to Climate Change	Energy
Philosopher	Horizontal knowledge structure	Knower code	Logic, Language and Information	Truth Tables
Visual Artist/ Sculptor	Horizontal knowledge structure	Knower code	Poetics of the Body	Life Modelling
Economist	Horizontal knowledge structure	Knowledge code	Generating the Wealth of Nations	Incentives
Ecologist	Hierarchical knowledge structure	Knowledge code	An Ecological History of Humanity	Evolution of the structure of the human body
Historian	Horizontal knowledge structure	Knower code	An Ecological History of Humanity	Historiography

students studying the interdisciplinary unit *An Introduction to Climate Change*. Additionally the assessment used by the academics in each subject was analysed. All of the interviews were transcribed in full and annotated and summarised, paying attention to what was said and interpreting meaning in dialogue with the literature. This was followed by sorting the data into categories based on participants' accounts and the interview summaries. The data were then arranged according to theoretical categories drawing on Bernstein's (2000) pedagogic device. The data were divided into the fields of production, recontextualisation and reproduction. The data were then coded for the strength of Maton's (2007) epistemic relations and social relations.

The pedagogic device, knowledge structures and epistemic and social relations

The research drew on Bernstein's pedagogic device and knowledge structures (2000) and legitimation code theory (LCT) (Maton 2000; 2007; 2009).

Together, these theories provided a framework that enabled an analysis of how interdisciplinary subjects are constructed and the influences on and the form knowledge takes within this construct.

Bernstein developed his concept of the 'pedagogic device' in order to understand the basis of social reproduction. One aspect of his pedagogic device comprises a useful model of how new knowledge produced in intellectual fields is converted into curriculum and then pedagogised into a form that is teachable. It takes into account the underlying principles and participant groups responsible for the production, recontextualisation and reproduction of knowledge.

The field of knowledge production typically takes place in universities and other research institutions. Within the field of recontextualisation, knowledge from the field of production is selected and repositioned to become educational knowledge. Recontextualising rules regulate how knowledge is transformed into curriculum (pedagogised), the 'what' and 'how' (Bernstein, 1996, p. 47) of curriculum. The recontextualising rules 'regulate the formation of specific pedagogic discourse' (Bernstein, 1996, p. 43) which 'selects and creates specialised pedagogic subjects through its contexts and contents' (Bernstein, 1996, p. 46). For this study, the site of recontextualisation is also situated within the university as academics are responsible for recontextualising knowledge into curriculum for university students. It is within the field of reproduction that teaching and learning take place. Bernstein explains that the evaluative rules construct pedagogic practice 'as they define the standards which must be reached' (Bernstein, 2000, p. 115). It is in the field of reproduction that evaluation takes place and 'condenses the meaning of the whole device' (Bernstein, 1996, p. 50).

Singh (2002, p. 575) explains that the pedagogic device can be used to analyse 'the processes by which discipline-specific or domain-specific expert knowledge is converted or pedagogised to constitute school knowledge'. This study is concerned with the influences on the two contexts of disciplinarity and interdisciplinarity and how they affect the choice of knowledge for curriculum and evaluation. To consider the structuring of knowledge within the disciplinary and interdisciplinary context, the study drew on Bernstein's conceptualisation of knowledge that distinguishes between the different forms that knowledge takes in different settings (1996; 1999). 'Hierarchical' knowledge structures, typified by the natural sciences, are characterised by an 'explicit, coherent, systematically principled and hierarchical organisation of knowledge' (Bernstein, 1996, p. 172). The practitioners in an hierarchical discipline share the same knowledge base and new knowledge is developed through the testing and integration of knowledge at increasing levels of abstraction. The principle of the structuring of hierarchical knowledge moves the realisations towards more general propositions that integrate knowledge at lower levels and across an expanding range of apparently different phenomena.

In the horizontal knowledge structures of the humanities and social sciences, by contrast, the production of knowledge creates:

> . . . a series of expanding, nontranslatable, specialised languages with non-comparable principles of description based on different, often opposed, assumptions.
>
> (Bernstein, 1996, p. 173)

These disciplines are made up of a series of segmented approaches or a series of languages. Knowledge is developed through the 'accumulation of languages' (Bernstein, 2000, p. 162). Bernstein further distinguished between horizontal knowledge structures with a 'strong grammar' and those with a 'weak grammar'. Disciplines that have a strong grammar are those

> . . . whose languages have an explicit conceptual syntax capable of 'relatively' precise empirical descriptions and/or of generating formal modelling of empirical relations.
>
> (Bernstein, 1999, p. 164)

Where these powers are weaker, the discipline is said to have a 'weak grammar'.

Bernstein's model of knowledge structures focuses on the structure of new knowledge in the field of production. Whilst curriculum structure cannot be directly read off knowledge structure, some similarities have been drawn. Maton (2009) extends the knowledge model to curriculum and learning, particularly focusing on how knowledge structures specialise knowers. Hierarchical curriculum structures build upon previous units while a horizontal curriculum possesses units 'strongly bounded' from previous units. Hierarchical, or 'cumulative learning', and horizontal, or 'segmented learning', results in students' understandings either being transferred across their learning or strongly attached to a particular context (2009, p. 45).

The knowledge structures that are implicit to the field of production are made explicit in curriculum in the field of recontextualisation. This translation is often indirect, carrying some but not all of the structure with it. Bernstein's concepts provide a means for systematically describing structural differences between disciplinary and interdisciplinary subjects, thus allowing for an analysis of the structure of educational practice.

In the early stages of analysis, academics were often making a distinction between the knowledge they taught and the type of student or knower they were aiming to develop. To extend the analysis to incorporate this aspect of the data, Maton's (2000; 2007; 2009) legitimation code theory was used. LCT provides a framework to theorise the underlying principles generating discourses, knowledge structures, curriculum structures and forms of learning. The framework builds on Bernstein to bring knower structures into view. Maton draws on the 'epistemic device' to describe what principles

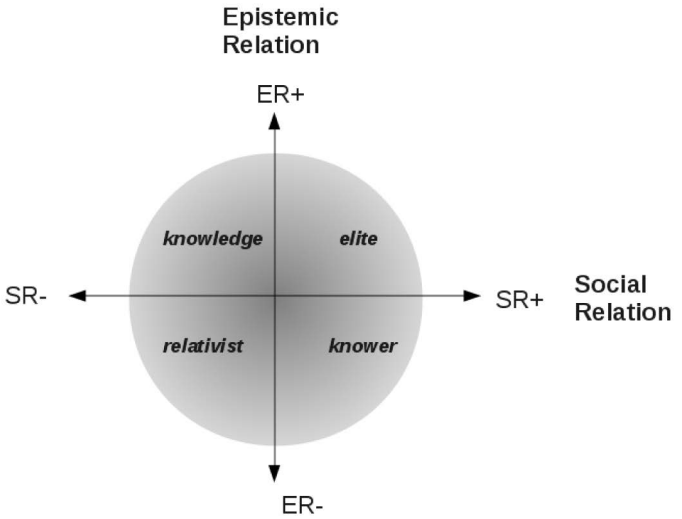

Figure 11.1 Legitimation codes of specialisation
Source: (Maton, 2007, p. 97).

generate the knowledge structures in the field of production. He looks at how knowledge claims come to be viewed as legitimate through two empirically inseparable but analytically distinct relations. The epistemic relation (ER) is the relation between knowledge and that part of the world from which knowledge is claimed (its proclaimed object of study). The social relation (SR) is the relation between knowledge and its author, the subject making the claim to knowledge.

Each relation may be more strongly (+) or weakly (–) classified and framed leading to a different emphasis in practices and beliefs. The combination of these two relations and their strengths comprises the 'specialisation codes' (ER+/–, SR+/–). Figure 11.1 illustrates the four principal specialisation codes: knowledge, knower, elite and relativist (Maton, 2007; 2009). The subjects and disciplines investigated here were all determined to have either a knower code or a knowledge code. A knower code is given when epistemic relations are emphasised and social relations are downplayed. On the other hand, a knower code is given when the disposition of knowers are emphasised and specialist knowledge and skills are downplayed. The specialisation codes allow for the factors that legitimate disciplinary and interdisciplinary subjects that academics teach to be compared and reveal any shifts in academics' practice.

Academics' accounts of discipline-based knowledge

Each of the academics were asked to provide descriptions of how they understood knowledge as being structured and what was important in their

home disciplines. These descriptions were used to determine the knowledge structure and the strength of epistemic and social relations. The following quotes provide examples of how the academics spoke of the structure of knowledge within their discipline.

The physicist described knowledge within his discipline as follows.

> It's like a spiral. That it's, if you imagine you've got a circle and around the circle you put topics in physics. Then those topics, say, become a column and that you spiral around touching on the topics over and over again as you progress through the discipline.
>
> (Physicist)

Here, the physicist reveals how understanding is built by returning to topics. This quote indicates that new knowledge builds on previous knowledge and of 'cumulative learning' (Maton, 2009, p. 45) as in hierarchical knowledge structures. Additionally, throughout the interviews this academic always remained firm about the knowledge he wanted students to understand rather than on the development of a particular type of student. This indicates a relatively strong epistemic relation to knowledge. At the same time, he placed no importance on the student being able to include their opinion, putting it in the following terms:

> It's interesting that in some subjects the lecturer or the tutor has a dialogue with the students . . . in physics, we don't have a dialogue with our students. I'm not interested in the students' views of quantum mechanics . . . your opinions about the way the world works aren't respected by the world at all.
>
> (Physicist)

For the physicist, students' views are not seen as important to developing an understanding of the discipline's knowledge. The social relations to knowledge are weaker while the epistemic relation is stronger, revealing this discipline to be orientated towards a knowledge code.

The following example shows the historian's account of her discipline in Interview 1:

> There are, because you're using all sorts of sources, and the way in which those sources are pulled together, as an explanation, will often depend on a type of theory, so someone like myself would, has come from a tradition where a sort of reconstructed Marxist understanding of society has been important in the sorts of ideas that I bring to understanding a lot of things about the modern world. But there will be other historians who have different views and the different philosophical basis from that.
>
> (Historian)

The historian is discussing the way historians can take different views and bases on which they interpret their historical sources. This excerpt demonstrates the horizontal nature of the discipline. In the interviews with the historian, other than an understanding of historiography, she never suggested particular content that she felt students had to know. This demonstrates a relatively weaker epistemic relation. However, she placed considerable emphasis on her students' interpretation and opinion, showing that the discipline emphasises social relations to knowledge over epistemic relations to knowledge, so this discipline is orientated to a knower code.

Similar representations were also revealed in the interviews with the philosopher. Here is one example of how the philosopher presented his discipline in Interview 1:

> I don't think of it primarily as a bunch of either particular theories or a particular set of ideas that at the end I want everyone to know. It's rather, the kind of image that I have in mind, and maybe this sounds a little bit like sort of dilettantish, but philosophy, when done well, is to know how to engage in a conversation . . . I mean you get five philosophers together, you'll get six different opinions at least and so it's not like we are going to hold very fast to any particular sort of methodological or disciplinary real distinctives except at some kind of fairly abstract level . . . that it is this thing about critical reflection about the theory of what . . . and a lot of that is taken from whatever that particular theory is.
>
> (Philosopher)

In the excerpt above, the philosopher reveals that rather than an understanding of particular content being the primary concern, the possession of a particular disposition is more important. The interviews with the philosopher articulated that the social relations to knowledge are dominant and so philosophy is orientated to a knower code. Like the historian, the philosopher discussed how multiple, often competing, theories play a role in the discipline, thus indicating an orientation to a horizontal structure.

Academics' accounts of comparisons of discipline-based *vis-à-vis* interdisciplinary knowledge

One component of the research analysis involved representing shifts in academics' teaching in terms of the strength of both the epistemic and social relations to knowledge. The specialisation graphs from each of the case studies are presented in Figure 11.2. These plots are heuristic devices, representing relations within qualitative data and should not be thought of as exact quantitative representations. The plots provide a representation of how the academics legitimise their teaching within the disciplinary and interdisciplinary contexts studied. Academics' teaching within their home discipline is shown at the base of the arrow and shifts in teaching within the interdisciplinary context are shown through the direction and size of the arrow.

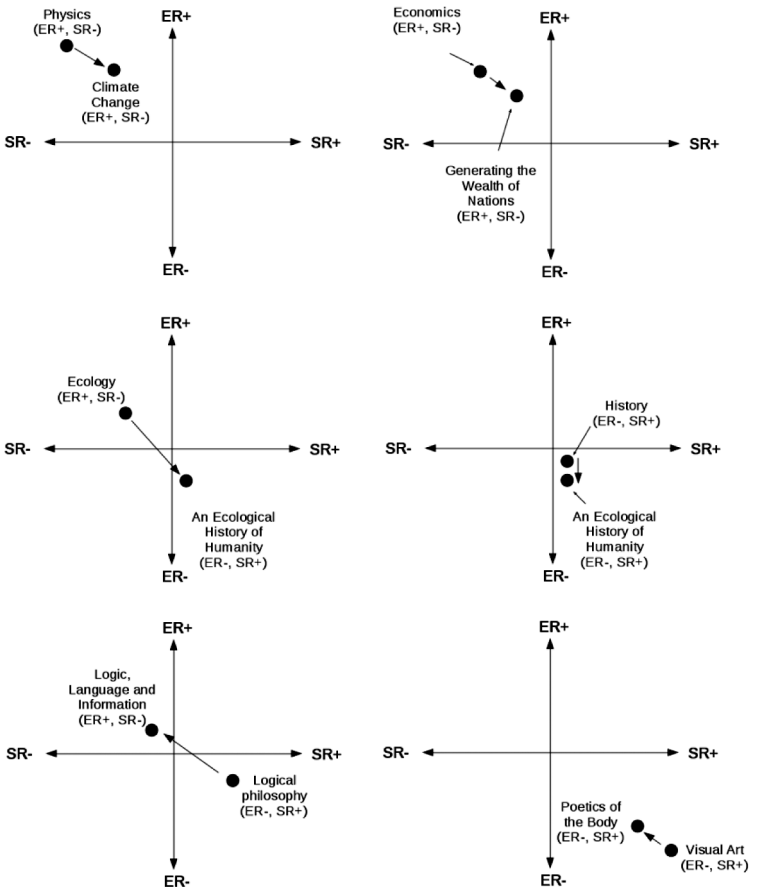

Figure 11.2 Specialisation graphs for the six academics

The specialisation graphs for the six academics reveal a number of salient features. Most significantly, a comparison of how the academics perceive the epistemic and social relations to knowledge within their own discipline and their interdisciplinary subject reveals a definite shift for each of the six academics. That is, in comparison to teaching within their own discipline, each academic makes a shift to interdisciplinary teaching with respect to how knowledge is legitimised within the respective teaching contexts.

All of the academics, with the exception of the philosopher, show a reduction to varying degrees in the epistemic relation to knowledge. An example of how academics compared the knowledge taught within disciplinary and interdisciplinary subjects is presented below. In this quote, the historian describes the differences between teaching a history subject and her interdisciplinary subject.

> The difference is that if you're teaching history, a history subject to history students, you're going into a lot more complexity of detail into the historiography into the various interpretations about and so on . . . So you can't do that in this sort of subject. So it's a question of simplifying what you're doing and certainly you don't want to call it dumbing down but you're drilling things down into central ideas.
>
> (Historian)

The way that the historian describes the leaving out of some aspects of the discipline for her interdisciplinary subject was a common point raised by all of the academics. The physicist, in his comparison of teaching the topic of energy to the first-year physics and climate change students, revealed that he does not explicitly teach the law of conservation of energy to his 'An Introduction to Climate Change' students. The academics all discussed leaving out of their interdisciplinary teaching the limitations of the topic being compared and how the topic related to other topics within their discipline. These ideas would, however, be taught in their discipline-based subjects. The reason given for this exclusion was the lack of relevancy to the interdisciplinary subject.

The academics who come from disciplines orientated towards a knowledge code (for example, physics, ecology and economics) demonstrate the greatest reduction in the epistemic relation. They have had to make the move from teaching within disciplines that have a stronger emphasis on knowledge of specific content to interdisciplinary subjects where that focus is shifted away from students knowing the specifics of disciplinary content. The artist and the historian make a comparatively smaller shift towards a weaker epistemic relation. In making the choice about what to include in the interdisciplinary subjects, some of the skills or knowledge of the intricacies of the discipline are not carried over. This results in a weakening in the relation between knowledge and that part of the world from which the knowledge is claimed. The philosopher obviated aspects of disciplinary understanding in his interdisciplinary teaching. In his case, however, these aspects related to ways of knowing that are important to a philosopher yet were deemed unnecessary in the interdisciplinary logic subject. This resulted in a weakening in the social relation to knowledge. So in each of the cases studied, the interdisciplinary knowledge transmitted lost some disciplinary depth.

The specialisation graphs also show some movement in the social relations to knowledge, with the physicist, economist and ecologist all increasing the strength of their social relation to knowledge. Again, the knowledge code disciplinarians move in the same direction. Two examples of how this phenomenon is construed in the interview excerpts are presented below. In this quote from Interview 1, the physicist is discussing what he would like students to learn from the 'An Introduction to Climate Change' subject.

> I'd like them to be better educated about the issues, and that when they, in their future lives and careers, they make decisions based on their

> understanding of climate change. . . . So informed debate is what I'd like to see as an outcome, that the graduates will be able to engage in informed debate.
>
> (Physicist)

When the physicist discussed his interdisciplinary subject, he was more concerned with developing a particular type of knower than knowledge of particular content. The ecologist also expressed a similar view when discussing what he wanted the interdisciplinary students to learn.

> There's focus on students actually developing their own interpretation of the facts as opposed to simply accepting somebody's view and then blurting it out and saying this is what so and so said. That you should be developing your own ideas.
>
> (Ecologist)

Similarly to the physicist, the ecologist in describing his interdisciplinary subject had a greater emphasis on developing a particular type of knower than on the knowledge that was important for the subject. This differs from his descriptions of his home discipline, where knowledge was highlighted.

The artist makes a small shift and the historian makes no shift in their social relation to knowledge. This is due to both their discipline-based and interdisciplinary subjects having knower codes.

The philosopher makes a shift in the opposite direction, moving from a knower to a knowledge code and thus decreasing the strength of the social relation while increasing the epistemic relation. This opposite shift can be attributed to the interdisciplinary subject, 'Logic, Language and Information', being one that has a strong focus on logic which has a stronger knowledge code, accounting for the strengthened epistemic relation. In strengthening the epistemic relation and having a limited time to present a detailed version of logical philosophy, the social relation, and so the emphasis on the knower, is reduced. Within philosophy the knower plays an important role and so the shift to interdisciplinary teaching has led to the emphasis on this integral aspect of the discipline being reduced.

The difference between the majority of the interdisciplinary subjects investigated and the subject taught by the philosopher is important to the findings of this study. The differences between these two types of interdisciplinary subjects are represented schematically in Figure 11.3. The figure depicted on the right represents an interdisciplinary subject where the topic of the subject provides the knowledge that feeds out (as represented by the arrows) to applications or contexts within the disciplines. The 'Logic, Language and Information' subject is an example, as it takes logic as a tool that can be used in many different disciplines. When such a multidisciplinary tool is the focal point, the multiple disciplines that make up the subject provide the multiple applications for that tool. Students need an understanding of the tool that is independent of any particular discipline which can then be applied to

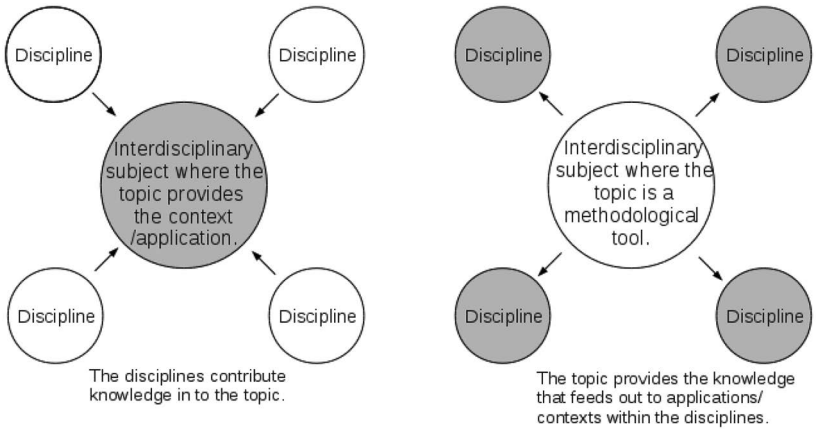

Figure 11.3 The two types of interdisciplinary subject

a number of disciplinary contexts. A similar pattern may also be the case for other interdisciplinary subjects not investigated here. For instance, an interdisciplinary statistical methods course could also be structured in a way that results in the contributing disciplines providing examples in which the tools of statistics can be applied. The other interdisciplinary subjects studied, depicted on the left of Figure 11.3, revolve around a particular problem, event or object. For these subjects, the topic provides the context or the application (e.g. 'Climate Change') and the disciplines provide the multiple tools or lenses through which the topic can be viewed. So the first form of interdisciplinary subject is an inversion of the second.

It is proposed that the form of the interdisciplinary courses determines the overall knowledge structure and therefore the way that knowledge is legitimised within those subjects. The topic, being either a tool or a context, drives the dominant relation. The 'Logic, Language and Information' subject has a strong epistemic relation as students are required to have knowledge of specific content relating to logic as a tool. This knowledge allows students to use logic within a number of disciplinary applications. When a tool is the central feature of a subject, a detailed understanding is necessary before the knowledge can be applied. So, logic with its stronger epistemic relation results in the contributing disciplines moving towards a knowledge code.

The other subjects in this study take the form where multiple disciplines provide disciplinary content or tools that contribute to a greater understanding and offer a particular lens through which a particular context or topic can be viewed. Within these subjects, less emphasis is placed on knowing particular content; academics talked more about the types of skills necessary to deal with knowledge from multiple disciplines, such as synthesis and the ability to present a coherent argument. Bernstein (1996), in his book *Pedagogy, Symbolic Control and Identity*, suggests that integrated codes deal

with ways of knowing rather than knowledge itself. A greater emphasis on knowing is reflected in the interdisciplinary subjects studied here that focus on a particular context or topic. This emphasis is also seen in the horizontal disciplines with a weaker grammar, and it is possible that these skills are more evident when learning within a knowledge structure that is (more) horizontal in nature. The different languages in more horizontally structured pursuits could be thought of as the different perspectives offered by different theorists on the same idea or different disciplinary perspectives on a topic. For example, for the subject 'An Introduction to Climate Change', disciplinary perspectives were offered to students by a physicist, a lawyer, an economist and a political scientist. These different perspectives have their own specialised languages and are not always comparable, characteristics that are also seen in the horizontal disciplines.

The knowledge-code disciplinarians have shifted toward a stronger social relation and weaker epistemic relation. This move has resulted in the way these subjects are structured and legitimised as being more closely related to horizontal knowledge structures. In effect, there has been a flattening of the hierarchical structure for teaching in the interdisciplinary context and this explains the relatively larger shift from these academics. The artist and the historian shifted their teaching the least, as their home disciplines are horizontal and have a knower code. Their interdisciplinary teaching was within subjects that revolved around a particular topic and so also have a horizontal knowledge structure. The philosopher's disciplinary teaching is within a horizontal discipline with a stronger grammar and a knower code, whereas the interdisciplinary teaching has required a shift to a knowledge code and a style of teaching that is more aligned with the hierarchical disciplines, as it requires a stronger understanding of a particular tool that can then be applied to a number of applications.

The structuring of knowledge and the way that knowledge is legitimised within subjects results in a shift between teaching within discipline-based and interdisciplinary subjects. The knowledge structure and the way knowledge is legitimised has a major influence on the epistemology of subjects and provides a new insight into the difference between interdisciplinary and disciplinary subjects.

Conclusion

Interdisciplinary subjects are being introduced into university curricula to provide students with an appreciation for a wider range of disciplines and the skills and knowledge that are believed to be important in today's society. These subjects reflect the often interdisciplinary nature of research and can provide insight into current or new areas of interest in the field of knowledge production.

The interdisciplinary subjects that were investigated for this study can be said to expose students to new knowledge areas, a wider range of disciplines, and content that encourages students to understand and bring

together multiple perspectives. However, in moving towards an education that has a greater emphasis on interdisciplinarity, it is important to consider the implications. This study has shown that the knowledge being taught in interdisciplinary subjects differs from that in discipline-based subjects. It is clear from the analysis of the data that in interdisciplinary subjects academics do not cover the same depth of knowledge that would be taught within the singular disciplines. The content that is gained from many interdisciplinary subjects may be more diverse, yet it comes at the cost of depth of disciplinary knowledge. With a trend towards including interdisciplinary subjects in university curricula, this may have consequences for the kinds of knowledge with which university students are graduating.

The majority of interdisciplinary subjects studied here tend to focus on a particular context. This approach to interdisciplinarity is strongly encouraged by much of the literature that discusses how to implement interdisciplinary curricula (e.g. Davies, Devlin and Tight, 2010; Klein and Doty, 1994; Newell, 1994). Transferability with this type of interdisciplinary subject may be an issue with recent research (Barnett, 2006; Maton, 2009; Clegg, 2011) showing students have difficulty in applying knowledge that is strongly contextualised outside of the context in which it is taught. So while students are being taught, for example, about energy, would they be able to use what they have learnt about this topic outside of the context of climate change? This issue poses an interesting curriculum challenge.

The discussion of skills has been part of a trend in recent years towards an increased emphasis on useful knowledge and preparing university students for the workforce. Closely linked to this trend, the reporting of student outcomes and, with this, skill-based outcomes, has also become a dominant discourse in university curricula. This research reveals that interdisciplinary subjects that focus on a particular topic echo Bernstein's (1996) view that integrated codes reflect a way of knowing. This form of legitimation lends itself more readily to making skills explicit. They form part of what is required to be the right type of knower and hence the inclusion of such interdisciplinary subjects within curriculum makes the discussion of skills more achievable.

Within the disciplines, the learning of skills is often tacit and deeply embedded within the learning of disciplinary content. It is possible that in an effort to give students an education that offers an explicit range of skills, some of the more tacit or implicit skills that are found in discipline-based subjects are at risk of not being taught. The loss of disciplinary depth within interdisciplinary curriculum and the consequences of such is something which needs further consideration. This loss of depth appears to come in the form of particular knowledge being left out and links to other aspects of a discipline not being made if not considered relevant to the interdisciplinary context. This may have consequences for transferability as outlined above, particularly as students will find it more difficult to make inferences (Winch, 2013) between particular aspects of a discipline's knowledge.