Chapter 21
Developing Students' Disciplinary Literacy? The Case of University Physics

John Airey and Johanna Larsson

Abstract In this chapter we use the concept of *disciplinary literacy* (Airey, 2011a, 2013) to analyze the goals of university physics lecturers. Disciplinary literacy refers to a particular mix of disciplinary-specific communicative practices developed for three specific sites: *the academy*, *the workplace* and *society*. It has been suggested that the development of disciplinary literacy may be seen as one of the primary goals of university studies (Airey, 2011a).

The main data set used in this chapter comes from a comparative study of physics lecturers in Sweden and South Africa (Airey, 2012, 2013; Linder, Airey, Mayaba, & Webb, 2014). Semi-structured interviews were carried out using a disciplinary literacy discussion matrix (Airey, 2011b), which enabled us to probe the lecturers' disciplinary literacy goals in the various semiotic resource systems used in undergraduate physics (i.e. graphs, diagrams, mathematics, language).

The findings suggest that whilst physics lecturers have strikingly similar disciplinary literacy goals for their students, regardless of setting, they have very different ideas about whether they themselves should teach students to handle these disciplinary-specific semiotic resources. It is suggested that the similarity in physics lecturers' disciplinary literacy goals across highly disparate settings may be related to the *hierarchical*, *singular* nature of the discipline of physics (Bernstein, 1999, 2000).

In the final section of the chapter some preliminary evidence about the disciplinary literacy goals of those involved in physics teacher training is presented. Using Bernstein's constructs, a potential conflict between the hierarchical singular of physics and the horizontal region of teacher training is noticeable.

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Going forward it would be interesting to apply the concept of disciplinary literacy to the analysis of other disciplines—particularly those with different combinations of Bernstein's classifications of hierarchical/horizontal and singular/region.

Keywords Disciplinary literacy · undergraduate physics · knowledge structures · singulars versus regions · comparative education

21.1 Introduction

Traditionally, science—and in particular undergraduate physics—has been viewed as a difficult subject for students to master. From the early 1990s to the present day, there has been a great deal of concern internationally about falling enrolment, student drop-out and the quality of education given to undergraduates (American Association of Physics Teachers, 1996; European Commission Expert Group, 2007; Forsman, 2015; Johannsen, 2013; Seymour & Hewitt, 1997). In an attempt to understand and address these concerns both the National Research Council in the USA and the Council on Higher Education and Institute of Physics in South Africa have recently undertaken reviews of the undergraduate physics education offered in their respective countries (CHE-SAIP, 2013; National Research Council, 2013). One of the themes that emerged in the US report is that 'Current practices in undergraduate physics education do not serve most students well' (National Research Council, 2013, p. 18). This theme is also echoed in the South African report where it was concluded that it is 'imperative that deep-seated changes regarding the length of the undergraduate programme and the way it is taught and monitored be introduced' (CHE-SAIP, 2013, p. 32).

In this chapter we use the notion of *disciplinary literacy* (Airey, 2011a, b, 2013) to both describe and problematize the goals of undergraduate physics lecturers in Sweden and South Africa. This is potentially important because the development of disciplinary literacy may be seen as one of the primary goals of university studies (Airey, 2011a) and high school physics.

The aspects of disciplinary literacy we have chosen to discuss are issues that have bearing on undergraduate physics and that we hope others may find interesting. Whilst our aim is to present a comparative analysis of the disciplinary literacy goals of physics lecturers in two countries, the thinking behind this chapter, as with the rest of this book, is that it can also function as a point of entry for the reader into aspects of the field of literacy in higher education. However, the description we present is selective and far from exhaustive.

21.2 Literacy

Traditionally, literacy has been framed in terms of the ability to read and write. Indeed the first truly international definition of literacy stated that, 'a literate person is one who can, with understanding, both read and write a short simple statement on his or her everyday life' (UNESCO, 1958). This definition was later broadened so that literacy was associated with 'the ability to identify, understand, interpret, create, communicate and compute, using printed and written materials associated with varying contexts' (UNESCO, 2004, p. 13).

An even broader definition of literacy was later put forward at a Nordic conference on the theme:

> … communicative practices that shape the world we live in, determine how we read and write the world, how we see, understand and shape the relationship between ourselves, nature and our communal life. (Nordic Educational Research Association, 2009)

Here we can see a movement away from a strict focus on reading and writing towards a range of communicative practices, a theme to which we will return later.

21.3 Literacy in the Academy

In the academy the term literacy has mainly been used when referring to courses where students learn to read and write academic texts. Traditionally these courses have attempted to provide students with the necessary tools to complete their study program and are often given as a type of remedial help. Such courses frequently use genre analysis and corpus linguistics to provide students with general advice on the various forms of academic writing (Björk & Räisänen, 2003; Swales, 1990; Swales & Feak, 2004). In many of these courses academic writing is seen as a sort of academic *acculturation* or *socialization* where student writing gradually starts to mirror the broad differences in different disciplinary norms that have been identified (Becher & Trowler, 1989). A number of writers have questioned the learning outcomes of such courses since they rarely deal with questions of power, identity construction and the development of a personal academic voice in academic writing—see for example Ivanič (1998) and Lillis and Scott (2007). Here, Lea and Street (1998) adopt the term *academic literacies* (plural) in order to highlight the fact that there are competing voices in the academy (see Duff, 2010 for a presentation of this academic literacies discussion).

21.4 Language Choice in the Academy

In many countries, two or more languages are used in university education. This naturally has consequences for what is viewed as relevant to the term literacy. In the Nordic countries, for example, the term *parallel language use* has been proposed, where two (or more) languages are expected to be used in parallel in higher education (Josephson, 2005). As Phillipson (2006, p. 25) points out, although parallel language use is 'an intuitively appealing idea', it is also a 'somewhat fuzzy and probably unrealistic target'. Here, Airey and Linder (2008, 2011) have linked the idea of parallel language use to the notion of *bilingual scientific literacy*.

In their studies of Swedish undergraduate physics courses they found that very few physics lecturers had concrete goals for the parallel development of disciplinary language skills. Airey and Linder conclude with a recommendation that each course syllabus should specify not only disciplinary learning outcomes, but also in which language(s) those outcomes will be. This proposal has received some international attention, with at least one university designing its language policy around the idea (Fortanet-Gomez, 2013). An overview of the discussion of language choice in the academy can be found in Airey, Lauridsen, Raisanen, Salö, and Schwach (2017).

21.5 Multimodality

Thus far the description of literacy in the academy presented here has been limited to written language—that is literacy as the ability to read and write in the academy (cf. Norris and Phillips' (2003) notion of fundamental scientific literacy in the following section). This traditional focus on written text has been problematized by Lemke (1998) who points out that scientists integrate resources over a range of semiotic systems in order to handle problems that would otherwise be impossible to solve. Other semiotic resource systems used in science are, for example, graphs, diagrams, sketches, gesture, mathematics, spoken language, tables, apparatus and simulations. Following Gibson (1979), Kress, Jewitt, Ogborn, and Tsatsarelis (2001) wonder whether different semiotic resource systems have different *affordance*s for knowledge representation, that is, whether say, spoken language is better for certain tasks and diagrams are better for other tasks. Based on this work, Fredlund, Airey, and Linder (2012) suggested the term *disciplinary affordance*. Airey (2015) defines disciplinary affordance as '*the agreed meaning making functions that a semiotic resource fulfils for a particular disciplinary community*'. In this respect Airey (2009) has argued that there is a critical constellation of semiotic resources that students need to become fluent in as a necessary (but not sufficient) condition for appropriate construction of disciplinary knowledge. When teachers understand the disciplinary affordances of the range of semiotic resources available with respect to a given concept they are better placed to design learning tasks that activate this critical constellation (see e.g. Fredlund, Airey, & Linder, 2015). Often, the disciplinary affordances of semiotic resources are not immediately apparent to students. In such cases, the semiotic resources will need to be 'unpacked' (Fredlund, Linder, Airey, & Linder, 2014). Disciplinary-specific resources that have been unpacked in this way lose much of their disciplinary power in the process, but their pedagogical affordance is greatly increased (Airey, 2015). For teachers, then, striking a balance between the disciplinary affordance and pedagogical affordance of the semiotic resources they use is crucial for effective teaching and learning (see for example Airey & Linder 2017). Finally, Airey and Linder (2008) point out that each individual semiotic resource requires two types of control, interpretive (equivalent to reading a written text) and generative (equivalent to writing a text). Thus literacy in the academy entails not only a question of which semiotic resources students need to learn to control, but also which type of control is needed, interpretive or generative.

21.6 Scientific Literacy

There are many meanings ascribed to the word literacy. For example a simple internet search easily identifies: biological, historical, engineering, musical, medical, economic, computer, psychological and cultural literacies. The list could probably become quite long. When literacy is used in this way it often signals a metaphorical relationship—readers are expected to take their own associations to literacy and apply them to a new situation. The same can be said for scientific literacy. Here, Norris and Phillips (2003) have characterized scientific literacy in terms of two aspects, fundamental and derived. Fundamental scientific literacy has a direct link to the original definition of literacy and refers to the ability to read and write in the natural sciences. Derived scientific literacy, however, refers to a range of competencies such as knowledgeability about science, the ability to think scientifically, the ability to distinguish science from nonscience, an understanding of the nature of science, feeling comfortable discussing science topics and the ability to critically appraise science. By extension, fundamental scientific literacy can be seen to apply to all the semiotic resource systems mentioned in the previous paragraph.

A further division in scientific literacy has been observed by Roberts (2007) who identifies two visions of scientific literacy, where vision I refers to scientific literacy for use in the academy, whilst vision II refers to scientific literacy for use in society. We will return to these two visions of scientific literacy in our discussion of disciplinary literacy in the next section.

Laugksch (2000) enumerates some of the ways in which scientific literacy has been used. He points out that ever since its introduction by Hurd (1958) its meaning has been undefined and difficult to pin down. Laugksch concludes by suggesting that when researchers use the term scientific literacy they should be very clear about presenting what they mean. In the next section we address Laugksch's critique of scientific literacy by turning to a new term, *disciplinary literacy*, the development of which has previously been suggested as one of the overarching goals of undergraduate studies (Airey, 2011a).

21.7 Introducing Disciplinary Literacy

The main criticism of the term scientific literacy, then, is that it does not have a clear, unambiguous definition—that is the term means different things to different people. In this section we briefly describe the thinking behind our use of the term disciplinary literacy and offer a definition. In comparison with scientific literacy, to date there have only been a small number of people who have used the term disciplinary literacy (McConachie et al., 2006; Shanahan & Shanahan, 2012; Tang, Ho, & Putra, 2016). An extensive overview can be found in Moje (2007). Here one can already see the different directions that the term is starting to take. Following Laugksch's advice we will now explain what *we mean* when we use the term disciplinary literacy.

Gee (1991) sees language as divided into one primary and many secondary discourses. Primary discourse is the oral language learned as a child, whereas secondary discourses are other specialized communicative practices that we learn for use in other sites in society outside the home. Gee defines *literacy* as the control of these secondary discourses. Building on Gee's definition and broadening it to include semiotic resource systems other than language, Airey (2011a) claims disciplinary literacy involves learning to control a range of disciplinary communicative practices. He defines disciplinary literacy as follows:

> The ability to appropriately participate in the communicative practices of a discipline. (Airey, 2011a)

One remaining question is that of the site in society that disciplinary literacy refers to. Clearly, disciplinary literacy refers to communicative practices for the academy; however, Airey (2011a) argues that disciplinary literacy, like scientific literacy, can also involve developing communicative practices about the discipline for use in society in general. Similarly, one further potential site is the world of work, since there are, of course, a number of vocational disciplines where the majority of the communicative practices developed relate to future requirements on the job market. Thus, we argue that all disciplines potentially develop disciplinary literacy for three specific sites: society, workplace and academy (Airey, 2011a, 2013). This can be represented visually by the disciplinary literacy triangle shown in Fig. 21.1 (Airey, 2011a).

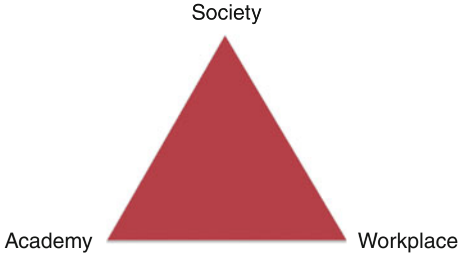

Fig. 21.1 The disciplinary literacy triangle. Disciplinary literacy involves developing communicative competence for three specific settings: Society, Workplace and Academy. The positioning of a given discipline within the triangle is dependent on the relative emphasis placed on developing communicative competence for each of the three settings Airey (2011a)

21.8 The Disciplinary Literacy Triangle

The disciplinary literacy triangle is a diagram that can be used to represent in broad terms the disciplinary literacy goals envisaged for a course or degree programme. Using the definition of disciplinary literacy, the relative emphasis placed on developing communicative practices for the three sites: society, workplace and academy can be visualized by placing a cross somewhere within the triangle.

Clearly different disciplines will have different priorities. So whilst history lecturers might place their emphasis on developing communicative practices for the academy say (i.e. less of a workplace emphasis), we might expect lecturers in vocational programmes such as nursing, to place more emphasis on communicative practices for the workplace and society (i.e. less of an academy focus). Moreover, we can also expect different specialists within the same discipline to have different priorities.

21.9 Knowledge Structures

Bernstein (1999) attributes the differences between disciplines to differences in knowledge structures. He describes two quite different knowledge structures within the academy: *hierarchical* and *horizontal*. In this division, disciplines such as the natural sciences have predominantly hierarchical knowledge structures. These disciplines develop through integration of new knowledge with knowledge that has previously been developed. In this way, disciplines with hierarchical knowledge structures manage to '[…] create very general propositions and theories, which integrate knowledge at lower levels' (Bernstein, 1999, p. 162). On the other hand, disciplines with predominantly horizontal knowledge structures (such as the humanities) develop by introducing new ways to describe the world. Crucially, these new descriptive 'languages' need not be compatible with each other. For example, a postcolonial approach to literature need not be coherent with a feminist reading of the same text, rather it is the new aspects that are brought into focus in these two approaches that are of interest. Martin (2011) compares development in hierarchical knowledge structures to a growing triangle whilst he compares development in horizontal knowledge structures to the development of new languages of description (Fig. 21.2).

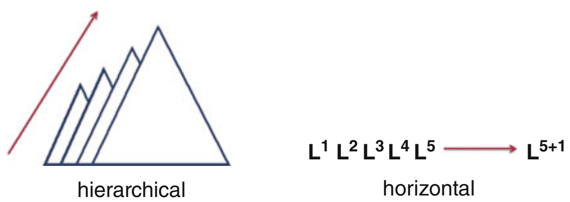

Fig. 21.2 Progression in hierarchical and horizontal knowledge structures (adapted from Martin, 2011, p. 42)

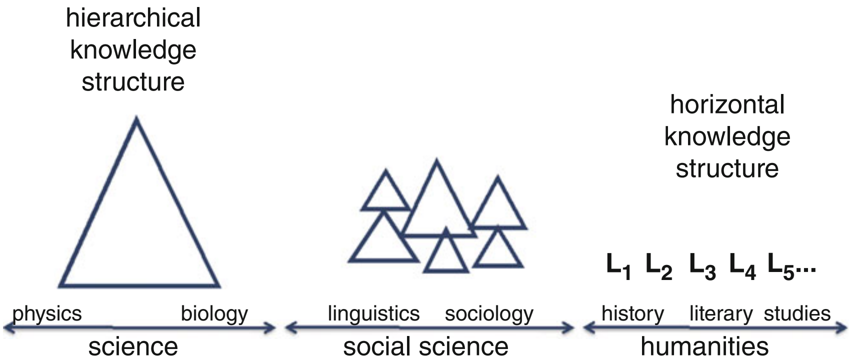

Fig. 21.3 Bernstein's knowledge structures across disciplines. Physics has a hierarchical knowledge structure, whilst disciplines such as education have more horizontal knowledge structures (adapted from Martin, 2011)

Bernstein (1999) pointed to physics as the discipline with the most hierarchical knowledge structure (Fig. 21.3).

21.10 Singulars and Regions

Bernstein (2000) also introduced the analytical categories singulars and regions. A singular is a discipline with strong boundaries such as physics, history and economics. Singulars generate strong inner commitments centred around their perceived intrinsic value. Regions are disciplines in which a number of singulars are brought together in an integrating framework. While singulars face inwards, regions face both inwards and outwards recontextualizing singulars for use in everyday life. In Bernstein's terms, education is a horizontal region, whereas physics is a hierarchical singular.

21.11 Disciplinary Literacy: A Summary

Figure 21.4 shows schematically the four main areas we have discussed thus far in this chapter. These are (proceeding anticlockwise around Fig. 21.4 from the right hand side) the parallels between disciplinary literacy and scientific literacy, the widened focus on a range of semiotic resources (rather than just written language), the definition of disciplinary literacy with the focus on three different sites, and, following Bernstein (1999, 2000), the role of the type of discipline on attitudes to disciplinary literacy.

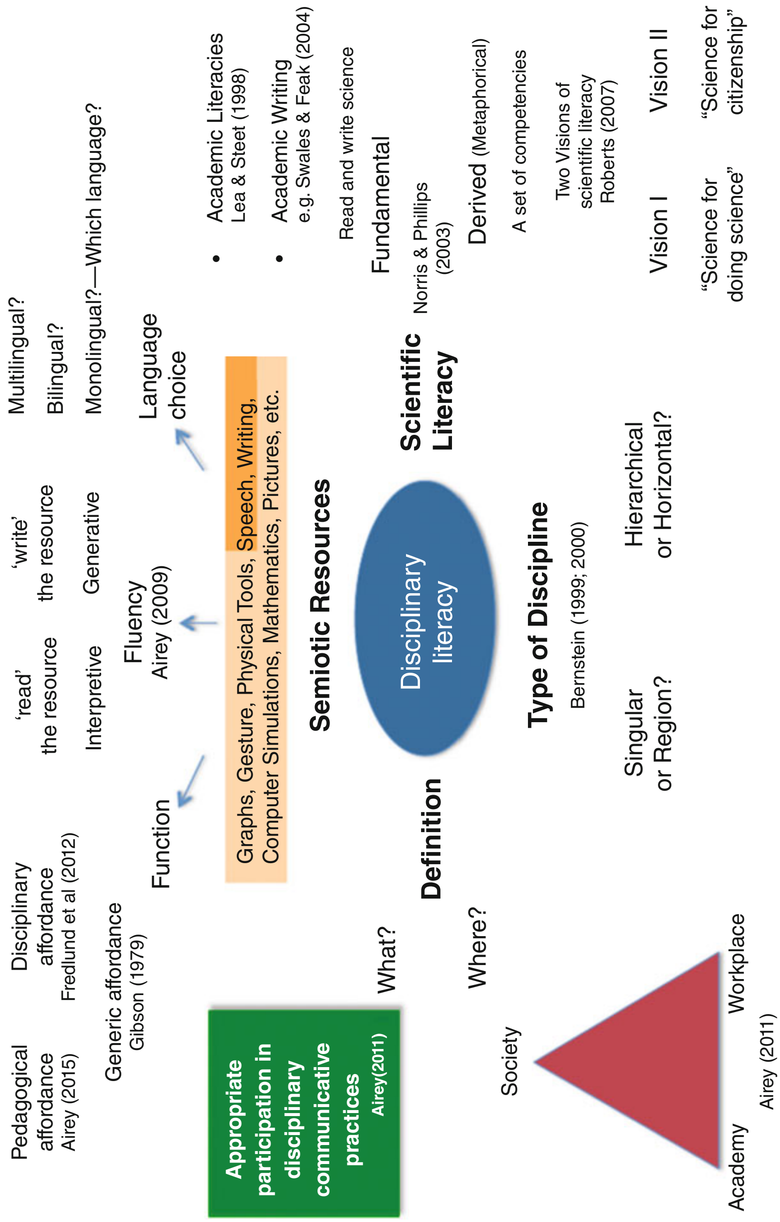

Fig. 21.4 Disciplinary literacy. Schematic diagram highlighting some of the aspects related to disciplinary literacy (adapted from Airey, 2013)

21.12 Using Disciplinary Literacy: An Empirical Study in University Physics

21.12.1 Data

The main data set used for this chapter is taken from a larger comparative research project where 30 university physics lecturers from a total of 9 universities in Sweden (4) and South Africa (5) described the disciplinary literacy goals they have for their students (Airey, 2012, 2013; Linder, Airey, Mayaba, & Webb, 2014). A disciplinary literacy discussion matrix (Airey, 2011b) was used as the basis for in-depth, semi-structured interviews (see Appendix A). All interviews were conducted in English and lasted approximately 60 minutes each. In the interviews, the lecturers were encouraged to talk about their disciplinary literacy goals for their undergraduate students, the site(s) in society that this disciplinary literacy is developed for, the semiotic resources they believe students need to learn to control and the type of control (interpretive or generative) that students need to develop. Ethical clearance for the study was not required for Sweden, but was applied for and granted in South Africa. In both countries participation in the study was voluntary with lecturers being selected on the basis of their involvement in some capacity with undergraduate physics. The anonymity of the lecturers was guaranteed and transcripts were only seen by the research team.

21.12.2 Methodology

The analysis drew on ideas from the phenomenographic research tradition by treating the interview transcripts as a single data set or 'pool of meaning' (Marton & Booth, 1997, p. 133). The aim was to understand the expressed disciplinary literacy goals of the physics lecturers interviewed.

Following the approach to qualitative data analysis advocated by Bogdan and Biklen (1992), iterative cycles were made through the data looking for patterns and key events. Each cycle resulted in loosely labeled categories that were often split up, renamed, or amalgamated in the next iteration. More background and details of the approach used can be found in Airey (2012).

21.12.3 Findings

Analysis of the 30 transcripts resulted in the identification of five themes with respect to the lecturers' disciplinary literacy goals.

1. Teaching physics is not the same thing as developing students' disciplinary literacy.
2. Disciplinary literacy in a wide range of semiotic resources is a necessary condition for learning physics.

3. Developing the necessary disciplinary literacy is not really the job of a physics teacher.
4. Some teachers were prepared to take responsibility for the development of certain aspects of students' disciplinary literacy.
5. The type of disciplinary literacy developed is focussed on the academy.

We will now present each of the themes illustrating them with quotes from the interviews.

1. Teaching physics is not the same thing as developing students' disciplinary literacy.

All the lecturers expressed a strong commitment that physics is independent of the semiotic resources used to construct it. For them, developing disciplinary literacy and teaching physics were quite separate things.

> These are tools, physics is something else. Physics is more than the sum of these tools it's the way physicists think about things—a shared reference of how to analyse things around you.
>
> Interviewer: Do you see yourself as a teacher of disciplinary Swedish for Physics?
>
> Lecturer: No, only in a very broad sense. Physics is a way of looking at nature and understanding things in simplified models. These other things are for presenting this way of thinking.
>
> Interviewer: So is your focus on scientific writing?
>
> Lecturer: No, you don't have time for that, there is content that you need to sort out.

This theme challenges contemporary thinking in education and linguistics. Halliday and Martin (1993, p. 9) for example insist that communicative practices are not some sort of passive reflection of *a priori* disciplinary knowledge, but rather are actively engaged in bringing knowledge into being. In science education, an even more radical stance has been taken by Wickman and Östman (2002), who insist that learning itself should be viewed as a form of discourse change.

Why, then, do lecturers view physics knowledge as separate from its representation? Here, we suggest that the hierarchical, integrated nature of physics knowledge leads to a belief that it will remain unaltered through processes of transduction between different semiotic resource systems. Thus, whilst Kuteeva and Airey (2014) have shown how there are strong preferences in physics for the use of one language—English—in the discipline, this is not a commitment to English *per se*, but rather a rational choice born out of a push towards standardization and the belief that physics is the same (and separate from) whichever language is used (see also discussion in Airey, 2012).

2. Disciplinary literacy in a wide range of semiotic resources is a necessary condition for learning physics.

All the lecturers in the study felt it was desirable that students develop disciplinary literacy in a range of semiotic resources in order to cope with their studies. In many ways this finding is unremarkable, with a number of researchers having commented on the wide range of semiotic systems needed for appropriate knowledge construction and communication in physics (Airey & Linder, 2009; Lemke, 1998; McDermott, 1990; Parodi, 2012). The following quote sums up this point:

> If you want to come out with an undergraduate degree in physics you will need to be able to interpret and use graphs, tables, diagrams and mathematics for an undergraduate degree in physics and then there is also the communication part of it which is the language. We work in English and so all the communication is in English. You need to be able to read the question and understand problems you know from reading. You need to write, to be able to communicate your answers. You need to be able to listen to the lecturers, you need to be able to speak in order to verbalise what problems there are with your answers.

The lecturers essentially reported that they would prefer students to develop disciplinary literacy in *all* the semiotic resources mentioned in the disciplinary literacy discussion matrix (see Appendix A).

3. Developing the necessary disciplinary literacy is not really the job of a physics teacher.

All physics lecturers expressed frustration at the level of disciplinary literacy of their students, feeling that they really should not have to work with the development of these skills:

> As a physicist I'm not there to solve the problem of the maths. They must be able to understand the maths sufficiently at that level and know why … I'm not there to teach maths, they must go to the maths department if they need to learn it.

> I cannot say that I test them or train them in English. Of course they can always come and ask me, but I don't think that I take responsibility for training them in English. I don't correct their work in English.

Northedge (2002) holds that the role of a university lecturer should be one of a discourse guide leading 'excursions' into disciplinary discourse. However, the physics lecturers interviewed in this study did not agree with this position.

4. Some teachers were prepared to take responsibility for the development of certain aspects of students' disciplinary literacy.

Nonetheless, some physics lecturers did say that the development of students' disciplinary literacy would be something that they would work with. In these cases, lecturers (grudgingly) took on Northedge's (2002) role of a discourse guide. This position was most common for mathematics which was seen as essential for an understanding of physics (See Airey, 2012, p. 75, for further discussion of this theme).

> Interviewer: Do you then have to spend time going back over the maths?

> Lecturer: Yes, what we do most of the time maybe he needs background on these topics. Differentials—you don't take it as granted that they know. Because of time constraints I invite them in their free time, then I brush up on the maths.

> So we would explain to them how to plot a graph, heading, labels—I mean our students don't know this! […] They don't know about scales so you see we would spend a lot of time explaining to them look why do we need a graph, why do we do this, so we would explain why we want them to do it in a particular way and then it takes a lot of practice and exercise to get better.

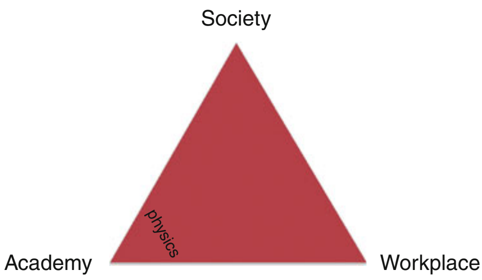

Fig. 21.5 The disciplinary literacy triangle for physics. The lecturers in the study situated their disciplinary literacy goals firmly within the academy

> The thing is that to be able to express it in a precise enough way you need mathematics. Language is more limited than mathematics in this case. So they need to use mathematics to see physics rather than language in this case.

5. The type of disciplinary literacy developed is focussed on the academy
The lecturers all report that they direct their teaching towards the academy, placing physics disciplinary literacy in the bottom left-hand corner of the disciplinary literacy triangle (Fig. 21.5).

> Interviewer: We are interested in how you decide on the learning goals for your students ….

> Lecturer: Physics has been around for a long time, you know it changes very slowly, anyway I would say that that is much given by the next level what you need to, to go on in physics

> What I teach, society doesn't really need to know—it would be nice if society knew and understood … but you don't have to know it.

21.13 Disciplinary Literacy Across Disciplines

The fundamental starting point for the conceptualization of disciplinary literacy presented in this chapter is that different disciplines emphasize the development of quite different communicative practices. Drawing on Bernstein (1999, 2000), Airey and Larsson (2014) suggest that it is differences in disciplinary knowledge structures that lead to these strikingly different disciplinary literacy goals. This could cause problems for inter-disciplinary work (see also argument in Airey, 2011b).

As we have argued, in physics, meaning is taken as agreed and unchanging across contexts (see discussion in Airey, 2012). This in turn leads to a commitment that physics itself is independent of the semiotic resources used to construct it. However, this argument is more difficult to uphold in the case of more horizontal knowledge structures where Bernstein (1999) suggests that development is actually driven by the creation of new 'languages' to describe the world around us. In the humanities meaning is contested and inextricably bound up with language. In extreme cases it has even been argued that meanings made in one language might be impossible to appropriately construe in another (Bennett, 2010).

In what follows, we present anecdotal evidence of this clash of disciplinary literacy goals using data from a study of physics teacher training (Larsson & Airey, 2014, 2015). First, the movement from the discipline of physics into teacher training entails a radical change in communicative practices:

> For me it was a shock to be thrown into an institution where you have to write essay-type exam questions. The students who had read History, Swedish, Social science, they passed these exams without any problems. For me the first time it was like ok, how do I do this? (School physics teacher)

Airey and Larsson (2014) show how different ideas about what counts as knowledge in the disciplines of physics and education have the potential to cause problems for trainee physics teachers. Students who are steeped in the epistemological commitments of a coherent, hierarchical, positivist, physics knowledge structure may experience the contingent nature of educational science as disjointed, incoherent and unscientific.

> These new values that they've included in the curriculum now—they don't seem so natural to me. There are competencies that I'm supposed to develop that can't be measured—it's silly! The whole thing falls like a house of cards because you just can't measure these things. (School physics teacher)

Here we see how a commitment to coherence and measurability (values of hierarchical physics) leads to the rejection of other forms of knowledge. This problem is compounded by the attitude of physics lecturers who insist that trainee physics teachers need the same experience as those reading for a physics degree:

> Interviewer: Do you have different goals for physicists and engineers?
>
> Lecturer: Yes, I suppose … but only slightly different.
>
> Interviewer: And for the teachers is it the same?
>
> Lecturer: Yes, I don't really distinguish between them. You need to understand physics to be able to teach it.

This quote also illustrates the inwardness of Bernstein's singulars (such as physics). This can be contrasted with the recontextualizing agenda of regions (such as education) where singulars are 'repackaged' for use in the society and workplace (Fig. 21.6).

In Fig. 21.7 we bring together Bernstein's two concepts of knowledge structure and disciplinary classification in one diagram. Singulars such as physics and history can have different knowledge structures, the same can be said of regions such as engineering and education. Here we see that that physics (hierarchical singular) and education (horizontal region) are diametrically opposed within Bernstein's two systems. This

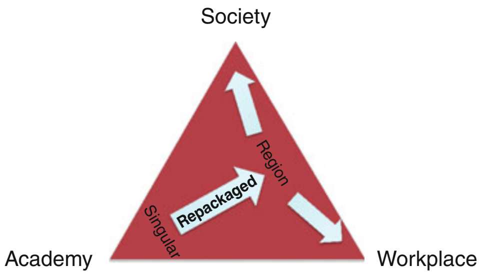

Fig. 21.6 Disciplinary categorization in the disciplinary literacy triangle. Singulars face inwards, developing disciplinary literacy for the academy, whilst regions face both inwards and outwards, recontextualizing singulars for use in society and the world of work

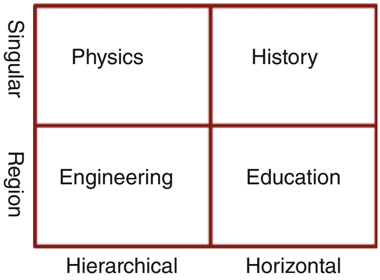

Fig. 21.7 Categorization of disciplines using Bernstein's (1999, 2000) constructs. Bernstein categorized physics as the singular with the most hierarchical knowledge structure of all. In the same diagram, education is categorized in a radically different manner—as a horizontal region (adapted from Airey & Larsson, 2014)

surely has consequences for the types of communicative practices that are valued in the two disciplines and the ease with which students can move between the two.

21.14 Conclusions

In this chapter we discussed the concept of disciplinary literacy and applied it to the goals of university physics lecturers. Lecturers reported that disciplinary literacy in a wide range of semiotic resources is a necessary condition for physics learning. However, the same lecturers do not view the development of this disciplinary literacy as their job. Although some lecturers were prepared to help students develop disciplinary literacy, all the lecturers interviewed believed that teaching physics is something that is separate from teaching disciplinary literacy. Here, Airey argues that:

> Until lecturers see their role as one of socialising students into the discourse of their discipline … [they] will continue to insist that they are not [teachers of disciplinary literacy] and that this should be a job for someone else. (Airey, 2011b, p. 50)

In the final section of this chapter we tentatively addressed the issue of disciplinary literacy across disciplines. Here, we suggest that the differences between the disciplinary literacy goals of physics and teacher training are an inevitable consequence of the differences between the two disciplines in terms of Bernstein's disciplinary classifications. Regions such as education always have to reformulate disciplinary literacy goals. Trainee physics teachers come from a singular with a strong disciplinary identity. This identity needs to be renegotiated into a teacher identity. As such we believe that teacher trainers should anticipate these issues and discuss them with their trainees. In particular, we suggest that some trainee teachers from disciplines with hierarchical knowledge structures may struggle to see the validity of other types of knowledge.

Our intention in this chapter has been to examine the disciplinary literacy goals of university physics lecturers. As such the concluding discussion of disciplinary literacy across disciplines has necessarily been tentative in nature. Going forward it would be interesting to apply the concept of disciplinary literacy to the analysis of other disciplines—particularly those with different combinations of Bernstein's classifications of hierarchical/horizontal and singular/region.

Appendix A

Disciplinary Literacy Discussion Matrix

This matrix contains some of the many representations used in physics (down the left hand side). Given the overloaded nature of many physics degrees, please tick the boxes that you think should be emphasized for students to master ***during an undergraduate physics degree course***.
Please do this with respect to ***where*** students need this physics representational skill (for physics, for the workplace or for participation in society in general).

		Where for?		
		Physics	Job	Society
Graphs	interpret			
	use			
Tables	interpret			
	use			
Diagrams	interpret			
	use			
Mathematics	interpret			
	use			
	interpret			
→ ______	use			
	interpret			
→ ______	use			
	interpret			
→ ______	use			
Language				
	Reading			
	Writing			
	Listening			
______	Speaking			
	Reading			
	Writing			
	Listening			
______	Speaking			
	Reading			
	Writing			
	Listening			
______	Speaking			

References

Airey, J. (2009). Science, language and literacy. Case studies of learning in Swedish University Physics. Acta Universitatis Upsaliensis. Uppsala Dissertations from the Faculty of Science and Technology, 81, Uppsala. Retrieved from http://publications.uu.se/theses/abstract.xsql?dbid=9547Accessed 27 April 2017.

Airey, J. (2011a). The disciplinary literacy discussion matrix: A heuristic tool for initiating collaboration in higher education. *Across the disciplines, 8*(3) Unpaginated.

Airey, J. (2011b). Initiating collaboration in higher education: Disciplinary literacy and the scholarship of teaching and learning. In *Dynamic content and language collaboration in higher education: Theory, research, and reflections* (pp. 57–65). Cape Town: Cape Peninsula University of Technology.

Airey, J. (2012). "I don't teach language." The linguistic attitudes of physics lecturers in Sweden. *AILA Review, 25*, 64–79.

Airey, J. (2013). Disciplinary literacy. In E. Lundqvist, L. Östman, & R. Säljö (Eds.), Scientific literacy–teori och praktik (pp. 41–58). Malmo: Gleerups.

Airey, J. (2015). Social semiotics in higher education: Examples from teaching and learning in undergraduate physics. In: SACF Singapore-Sweden excellence seminars, Swedish Foundation for International Cooperation in Research in Higher Education (STINT), 2015 (p. 103). Retrieved from urn:nbn:se:uu:diva-266049.

Airey, J., & Larsson, J. (2014). What knowledge do trainee physics teachers need to learn? Differences in the views of training staff. International Science Education Conference ISEC 2014, National Institute of Education, Singapore, 25–27 November 2014.

Airey, J., Lauridsen, K., Raisanen, A., Salö, L., & Schwach, V. (2017). The expansion of English medium instruction in the Nordic Countries. Can top-down university language policies encourage bottom-up disciplinary literacy goals? *Higher Education. 73*(4), 561–576. https://doi.org/10.1007/s10734-015-9950-2.

Airey, J., & Linder, C. (2008). Bilingual scientific literacy? The use of English in Swedish university science programmes. *Nordic Journal of English Studies, 7*(3), 145–161.

Airey, J., & Linder, C. (2009). A disciplinary discourse perspective on university science learning: Achieving fluency in a critical constellation of modes. Journal of Research in Science Teaching, 46(1), 27–49.

Airey, J., & Linder, C. (2011). Bilingual scientific literacy. In C. Linder, L. Östman, D. Roberts, P.-O. Wickman, G. Ericksen & A. MacKinnon (Eds.), *Exploring the landscape of scientific literacy* (pp. 106–124). London: Routledge.

Airey, J. & Linder, C. (2017) Social semiotics in university physics education. In D. Treagust, R. Duit & H. Fischer (Eds.), *Multiple representations in physics education*. (pp.95–122). Cham: Springer.

American Association of Physics Teachers (1996). Physics at the crossroads. Retrieved from http://www.aapt.org/Events/crossroads.cfm

Becher, T., & Trowler, P. (1989). *Academic tribes and territories*. Milton Keynes: Open University Press.

Bennett, K. (2010). Academic discourse in Portugal: A whole different ballgame? *Journal of English for Academic Purposes, 9*(1), 21–32.

Bernstein, B. (1999). Vertical and horizontal discourse: An essay. *British Journal of Sociology Education, 20*(2), 157–173.

Bernstein, B. (2000). *Pedagogy, symbolic control and identity: Theory, research and critique*. Lanham: Rowman and Littlefield.

Björk, L., & Räisänen, C. A. (2003). *Academic writing: A university writing course* (3rd ed.). Lund: Studentlitteratur.

Bogdan, R. C., & Biklen, S. R. (1992). *Qualitative research for education: An introduction to theory and methods*. Boston: Allyn and Bacon, Inc.

CHE-SAIP. (2013). Review of undergraduate physics education in public higher education institutions. Retrieved from http://www.saip.org.za/images/stories/documents/documents/Undergrad_Physics_Report_Final.pdf.

Duff, P. (2010, March). Language socialization into academic discourse communities. *Annual Review of Applied Linguistics, 30*, 169–192.

European Commission Expert Group (2007). *Science education now: A renewed pedagogy for the future of Europe*. Brussels: European Commission.

Forsman, J. (2015). Complexity theory and physics education research: The case of student retention in physics and related degree programmes. Digital comprehensive summaries of Uppsala dissertations from the Faculty of Science and Technology. Uppsala: Acta Universitatis Upsaliensis. Retrieved from http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A846064&dswid=-4668.

Fortanet-Gomez, I. (2013). *CLIL in higher education: Towards a multilingual language policy*. Bristol: Multilingual Matters.

Fredlund, T., Airey, J., & Linder, C. (2012). Exploring the role of physics representations: An illustrative example from students sharing knowledge about refraction. *European Journal of Physics, 33*, 657–666.

Fredlund, T., Airey, J., & Linder, C. (2015). Enhancing the possibilities for learning: Variation of disciplinary-relevant aspects in physics representations. *European Journal of Physics, 36* (5), 055001.

Fredlund, T., Linder, C., Airey, J., & Linder, A. (2014). Unpacking physics representations: Towards an appreciation of disciplinary affordance. *Physical Review Special Topics Physics Education Research*, 10, 020128.

Gee, J. P. (1991). What is literacy? In C. Mitchell & K. Weiler (Eds.), *Rewriting literacy: Culture and the discourse of the other* (pp. 3–11). New York: Bergin & Garvey.

Gibson, J. J. (1979). *The theory of affordances. The ecological approach to visual perception* (pp. 127–143). Boston: Houghton Miffin.

Halliday, M. A. K., & Martin, J. R. (1993). *Writing science: Literacy and discursive power*. London: The Falmer Press.

Hurd, P. D. H. (1958). Science literacy: Its meaning for American schools. *Educational Leadership, 16*, 13–16.

Ivanič, R. (1998). Writing and identity: The discoursal construction of identity in academic writing. Amsterdam: John Benjamins.

Johannsen, B. F. (2013). *Attrition and retention in university physics: A longitudinal qualitative study of the interaction between first year students and the study of physics*. Doctoral dissertation, University of Copenhagen, Faculty of Science, Department of Science Education.

Josephson, O. (2005). Parallellspråkighet [Parallel language use]. *Språkvård, 2005*(1), 3.

Kress, G., Jewitt, C., Ogborn, J., & Tsatsarelis, C. (2001). *Multimodal teaching and learning: The rhetorics of the science classroom*. London: Continuum.

Kuteeva, M., & Airey, J. (2014). Disciplinary differences in the use of English in higher education: Reflections on recent policy developments. *Higher Education 67*(5), 533–549.

Larsson, J., & Airey, J. (2014). Searching for stories: The training environment as a constituting factor in the professional identity work of future physics teachers. *British Educational Research Association Conference BERA 2014*, London, September 2014.

Larsson, J., & Airey, J. (2015). The “physics expert” discourse model – counterproductive for trainee physics teachers’ professional identity building? Paper presented at the 11th Conference of the European Science Education Research Association (ESERA), Helsinki, August 31 to September 4, 2015.

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education, 84*, 71–94.

Lea, M. R., & Street, B.V. (1998). Student writing in higher education: An academic literacies approach. *Studies in Higher Education, 23*(2), 157–172.

Lemke, J. L. (1998). Teaching all the languages of science: Words, symbols, images, and actions. Retrieved from http://academic.brooklyn.cuny.edu/education/jlemke/papers/barcelon.htm. Accessed 16 September 2005.

Lillis, T., & Scott, M. (2007). Defining academic literacies research: Issues of epistemology, ideology and strategy. *Journal of Applied Linguistics, 4*(4), 5–32.

Linder, A., Airey, J., Mayaba, N., & Webb, P. (2014). Fostering disciplinary literacy? South African physics lecturers' educational responses to their students' lack of representational competence. African Journal of Research in Mathematics, *Science and Technology Education, 18*(3), 242–252. https://doi.org/10.1080/10288457.2014.953294.

Martin, J. R. (2011). Bridging troubled waters: Interdisciplinarity and what makes it stick. In F. Christie & K. Maton (Eds.), *Disciplinarity* (pp. 35–61). London: Continuum International Publishing.

Marton, F., & Booth, S. (1997). *Learning and awareness*. Mahwah, NJ: Lawrence Erlbaum Associates.

Moje, E. B. (2007, March). Developing socially just subject-matter instruction: A review of the literature on disciplinary literacy teaching. *Review of Research in Education, 31*, 1–44.

McConachie, S., Hall, M., Resnick, L., Ravi, A. K., Bill, V. L., Bintz, J., & Taylor, J. A. (2006). Task, text, and talk: Literacy for all subjects. *Educational Leadership, 64*(2).

McDermott, L. (1990). A view from physics. In M. Gardner, J. G. Greeno, F. Reif, A. H. Schoenfeld, A. A. diSessa, & E. Stage (Eds.), *Toward a scientific practice of science education* (pp. 3–30). Hillsdale: Lawrence Erlbaum Associates.

National Research Council. (2013). *Adapting to a changing world — challenges and opportunities in undergraduate physics education*. Committee on undergraduate physics education research and implementation. Board on physics and astronomy division on engineering and physical sciences. Washington, DC: National Academies Press.

Nordic Educational Research Association. (2009). Literacy as worldmaking. *Congress of the Nordic Educational Research Association*. Retrieved from http://www.neracongress2009.com.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87*(2), 224–240.

Northedge, A. (2002). Organizing excursions into specialist discourse communities: A sociocultural account of university teaching. In G. Wells & G. Claxton (Eds.), Learning for life in the 21st century. *Sociocultural perspectives on the future of education* (pp. 252–264). Oxford: Blackwell Publishers.

Parodi, G. (2012) University genres and multisemiotic features: Accessing specialized knowledge through disciplinarity. *Fórum Linguístico, 9*(4), 259–282.

Phillipson, R. (2006). English, a cuckoo in the European higher education nest of languages. *European Journal of English Studies, 10*(1), 13–32.

Roberts, D. (2007). Scientific literacy/science literacy: Threats and opportunities. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 729–780). Mahwah: Lawrence Erlbaum Associates.

Seymour, E., & Hewitt, N. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder: Westview Press.

Shanahan, T., & Shanahan, C. (2012). What is disciplinary literacy and why does it matter? *Topics in Language Disorders, 32*(1), 7–18.

Swales, J. (1990). *Genre analysis: English in academic and research settings*. Cambridge: Cambridge University Press.

Swales, J., & Feak, C. (2004). *Academic writing for graduate students: Essential tasks and skills*. Ann Arbor: University of Michigan Press.

Tang, K. S. K., Ho, C., & Putra, G. B. S. (2016). Developing multimodal communication competencies: A case of disciplinary literacy focus in Singapore. In *Using multimodal representations to support learning in the science classroom* (pp. 135–158). Springer International Publishing.

UNESCO (2004). *The plurality of literacy and its implications for policies and programmes*. Paris: UNESCO.

UNESCO (1958). *Recommendations concerning the international standardization of educational statistics*. Paris, UNESCO.

Wickman, P.-O., & Östman, L. (2002). Learning as discourse change: A sociocultural mechanism. *Science Education, 86*(5), 601–623.