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TEACHING SCIENCE

Knowledge, Language, Pedagogy

Legitimation Code Theory

ROUTLEDGE

8

WIDENING ACCESS IN SCIENCE

Developing both knowledge and knowers

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Introduction

Historically universities served the interests of an élite few from the middle and upper classes of society. Thanks to the global economic and social justice drivers, massification of universities in the last century has resulted in major transformations across the higher education sector. A significant feature of this transformation has been greater diversity of the student body in terms of social and educational backgrounds. However, for many universities the fundamental 'culture' of teaching, learning and research has remained remarkably constant (Longden 2006), resulting in an inequitable system that favours certain social groups over others (Archer *et al.* 2003, Arum *et al.* 2012). Physical access without concomitant success is meaningless, and the emotional (Pym and Kapp 2011) and the financial toll (Council on Higher Education Report 2013) on individuals and families makes equity of outcomes an urgent moral imperative. The broader-scale implications of perpetuating a system with a grossly unequal distribution of power and access to educational, social and economic resources in any society add impetus to this imperative.

This chapter is particularly interested in access for success in the sciences. New scientific knowledge is constantly being developed and a typical pedagogic response in the higher education context has been to maintain the focus on knowledge but at the same time increase the volume and pacing of curriculum material. Muller (2015: 410) suggests this favours students from privileged educational backgrounds as they are 'better equipped by virtue of being educated in cognitively rich environments by better qualified teachers to respond to the increased volume of novel material'. There are, however, increasing calls from knowledge-based fields, such as the sciences and engineering, to consider ontological aspects of student 'becoming' and 'being' and agency in promoting learning (Barnett 2007, Dall'Alba and Barnacle 2007). In an in-depth study of student learning in engineering, Case (2013) makes an argument for student agency as a central part of engagement with, and learning of, requisite knowledge. As such, a student's social, cultural and educational background would strongly influence her/his engagement with a curriculum, and Case suggests that while engineering (or science) curricula must focus on the knowledge, there needs to be better accommodation of student identity development and agency. In short, she calls for more focus on both the knowledge and the knower.

The main question that this chapter addresses is how access for success can be enabled or constrained in a science curriculum.[1] To explore these issues, access for success is encapsulated in the term 'epistemological access' which Morrow (2009: 77) defines as learning 'how to become a participant in an academic practice' and that this requires learning 'the intrinsic disciplines and constitutive standards of the practice'. By invoking 'disciplines' and 'standards' of practice he is suggesting an underpinning framework, but his work does not provide the necessary analytical tools to unpack them. For this I turn to Legitimation Code Theory, which is a conceptual framework that provides a means for identifying the organizing principles that constitute curriculum practices. This chapter draws on a single case study of a higher education science access course that has been designed to accommodate students from traditionally less privileged education backgrounds. The findings suggest that the curriculum of the course involves two main bases for achievement, one which emphasizes the possession of knowledge, skills or procedures and another which emphasizes the need to be a particular kind of knower. Moreover, the course requires students to be the right kind of knower in order to then access the right kinds of knowledge. These findings are used to develop a conceptual model of epistemological access that could inform curriculum transformation processes in the sciences in this age of diversity and difference in higher education.

Conceptual and analytical framework

Legitimation Code Theory (LCT) is a conceptual framework that allows 'knowledge practices to be seen, their organizing principles to be conceptualized, and their effects to be explored' (Maton 2014: 3). The notion of legitimation is central to LCT: when actors engage in a practice, they are making a claim of legitimacy for the basis of that practice. What actors say or do can therefore be described as 'languages of legitimation', and the principles that underpin those practices are conceptualized as 'legitimation codes' (Maton 2016: 10). These codes represent the means by which success can be achieved in the practice. In this chapter, the knowledge practice that is the focus of our attention is the curriculum of an access course, and the legitimation codes that will help explore the role of constructions of knowledge and knowers in this curriculum are from the LCT dimension of Specialization (Maton 2014).

Specialization explores a set of organizing principles underlying practices as 'specialization codes'. These concepts begin from the simple point that practices are 'oriented towards something and by someone' (Maton 2016: 12), which highlights an analytic distinction: *epistemic relations* (ER) between practices and their object (that part of the world towards which they are oriented); and *social relations* (SR) between practices and their subject, author or actor (who is enacting the practices). The relative strengths of epistemic relations and social relations can vary from stronger (+) to weaker (–) along a continuum of strengths. Both refer to the basis of knowledge practices. For example, if your knowledge of environmental conditions (soil-type, nutrients, temperature, light conditions) promoting optimal growth of a particular plant was based on scientific knowledge, skills and procedures, it would represent stronger epistemic relations (ER+). In contrast, understanding that the plant grows best against the sunny wall of your house because it did when you tried it would represent relatively weaker epistemic relations (ER–): there is relatively less emphasis here on specialist knowledge, skills or procedures. Conversely, that experiential basis for deciding where to place your plant represents stronger social relations (SR+): it emphasizes your own experiences and opinions. The specialist scientific knowledge of optimal growth conditions downplays such personal opinions and experiences, representing weaker social relations (SR–). In identifying the relative strengths of epistemic relations and social relations, the *basis* upon which success in the practice is achieved is relevant as opposed to the sometimes more obvious *focus*. For example, student activities in a plant growth experiment may focus on recording plant size, leaf colour and flower production, but the basis for achievement in the final report may instead be the correct presentation of data.

By plotting the relative strengths of epistemic relations and social relations on a two-dimensional plane as in Figure 8.1, four principal codes are identified: knowledge codes, élite codes, knower codes and relativist codes (Maton 2014). When a practice has relatively strong epistemic relations and relatively weak social relations,

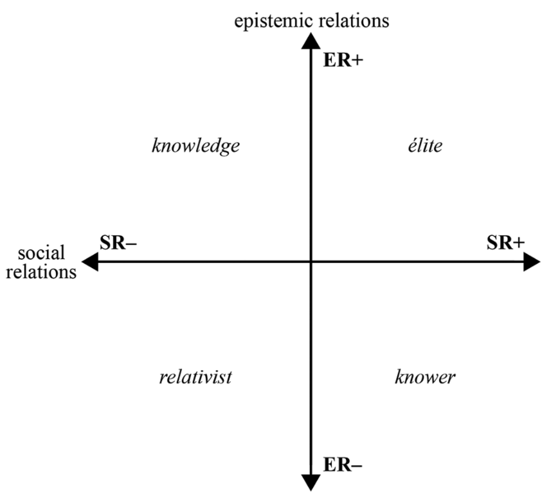

FIGURE 8.1 The specialization plane (Maton 2016: 12)

it legitimates a *knowledge code* (ER+, SR–). That is, the basis for specialization and legitimacy in the practice depends on possession of determinate and specialized knowledge and practices (ER+), and the attributes of knowers, such as their disposition and 'gaze', are downplayed (SR–). Science and science disciplines, such as physics and zoology, are typically considered to be dominated by knowledge codes. Educational practices characterized by a *knower code* (ER–, SR+) have relatively weak epistemic relations, but relatively strong social relations. Here, specialized knowledge is downplayed (ER–) and legitimacy is based on the disposition or 'gaze' of the knower (SR+). The humanities and many of their disciplines, such as sociology and anthropology, are often considered to be dominated by knower codes. Educational practices characterized by an élite code (ER+, SR+) have relatively stronger epistemic relations and relatively stronger social relations. In other words, both specialist knowledge and knower dispositions are equally valued. Professional levels of classical music, for example, require both depth of knowledge and personal talent – an élite code (Lamont and Maton 2008). Finally, practices characterized by a relativist code (ER–, SR–) have relatively weak epistemic relations and relatively weak social relations. Legitimacy here requires neither specialist knowledge nor knower dispositions. This is unlikely to be illustrated by subject areas in a specialized context such as education but can be found during periods of unfocused classroom activity or potentially during periods of 'brainstorming' when all ideas are welcomed.

It is worth emphasizing that these examples are simply illustrative: most sets of practices are likely to involve more than one code, and the particular code characterizing science, for example, depends on the context. While science is typically considered to be dominated by knowledge codes, in a specific classroom it may involve a range of codes, of which the dominant code may not be a knowledge code. Maton and Howard (2016), for example, found that a significant proportion of students' perceptions of secondary school science in New South Wales, Australia, exhibited a relativist code. The point is that these concepts enable us to explore these issues, rather than allocate subjects in advance to particular labels.

The specialization code exhibited by a curriculum may be expressed in explicit ways and therefore be obvious to participants, but may also be tacit, especially when underpinned by poorly articulated norms and values. Building on Bernstein's distinction between 'recognition' and 'realization' (2000), LCT suggests that for a student to be successful in a context they need to not only recognize its dominant code but must also be able to realize or enact practices that match that code. LCT therefore not only allows for identification and explicit articulation of the codes, but also opens up opportunity to see possible points of conflict. For example, if a science curriculum requires the use of empirical data to develop an argument, a knowledge code is being legitimated. However, if instead personal opinion is provided, the student is invoking a knower code. The resultant 'code clash' (Lamont and Maton 2008) can help explain poor student achievement. This study identifies specialization codes of a science course curriculum and invokes codes clashes to explain difficulties students have in their studies.

Context of study

Students' backgrounds

The study was located within a South African higher education science access programme. In order to enter any of the mainstream disciplines in science, students in the programme are required to pass three year-long foundation courses: Mathematical Foundations, Computer Skills for Science, and Introduction to Science Concepts and Methods (henceforth 'ISCM'). ISCM is the focus of this study. Because of a range of entrance selection criteria, students in the programme have achieved only slightly lower school marks than those entering mainstream directly, seldom have their home language as English, regularly require government funding to help pay for their tertiary studies, and attended poorly resourced and performing schools. They enter university with a range of literacy, numeracy and learning practices that are very different from the open-minded, analytical, creative, critical and independent approaches required when working with the high levels of conceptual knowledge in the sciences in higher education.

Study site

The purpose of ISCM, a multidisciplinary, integrated science foundation course, is to enable epistemological access to mainstream science by introducing students to scientific concepts, methods and literacies within the context of specific science disciplines, as well as through developing academic learning competencies and practices (Science Extended Studies Programme Review Report 2011). Currently ISCM draws on physics, chemistry, life sciences (human kinetics and ergonomics) and earth sciences (geology) for disciplinary input by mainstream staff from each of their respective disciplines. The focus in the two disciplinary lectures and one practical session per week is therefore on developing understanding of disciplinary concepts. Two permanently employed access programme lecturers facilitate the rest of the ten weekly contact periods, in what are termed 'literacies' pedagogic interactions.[2] While there is much overlap in the work of these two staff members, the 'language-related literacies' facilitator focuses mainly on reading and writing in the sciences. In contrast, the scientific-related literacies facilitator (myself) focuses on building foundational science concepts (such as spatial and temporal scales, hierarchies and connections, diversity) and procedures (such as working accurately and precisely, solving problems, working with empirical data) and considering how scientific knowledge is constructed. At least two of the weekly pedagogic interactions, particularly in the first semester, focus primarily on student learning in which strategies and approaches to learning are explicitly voiced, and appropriate practices related to student learning are modelled. As a coordinator of the course, I attend and observe or participate in all disciplinary interactions and some of the literacies interaction taught by my colleagues.

ISCM therefore has two main themes in its teaching: scientific and disciplinary concepts and methods; and student learning competencies. While these themes are often addressed separately in particular pedagogic interactions, the curriculum has been developed as a coherent whole and there is much integration across themes.

Methodology

The overall approach in the study was a single, in-depth case study. In order to surface the specialization codes that underpin the ISCM curriculum, data for epistemic relations and social relations analysis were obtained from course documents (handouts, resource materials, assessment tasks, student answers in assessment tasks), informal observations of pedagogic interactions, and interviews with four disciplinary and one literacies lecturer in which their perceptions of the purpose of ISCM were discussed. In order to bridge the gap between the empirical data and the abstract specialization concepts, a 'translation device' (Maton and Chen 2016) was developed through iterative movement between theory and data. In the original analysis, the strengths of epistemic relations and of social relations were examined independently of each other (Ellery 2017a, 2018) and thereafter specialization codes were identified (Ellery 2017b). What follows is the final code categorizations. In addition, in order to understand student response to codes, their answers in assessment tasks were analyzed and follow-up interviews with 17 volunteers of 47 students probed their approach to their studies (Ellery 2016, 2017b).

Specialization codes of ISCM

Because ISCM has an explicit dual focus of introducing students to disciplinary and scientific concepts, methods and literacies, as well as developing academic learning competencies and practices, two distinct codes were recognized: a *science-related knowledge code* and an *academic practices-related knower code*. These are now discussed in turn.

Science-related knowledge code

Since science and science disciplines are often associated with knowledge codes, it is not unexpected that such a code is highly visible in the ISCM curriculum. However, because the nature of the work done by the disciplinary and literacies lecturers in the course is so different, and because the strengths of epistemic relations for these two sets of work also vary, they are considered separately below.

Disciplinary epistemic relations and social relations

Evidence for the disciplinary component of the science-related knowledge code relates primarily to teaching done by mainstream disciplinary lecturers. Their focus on specialized and distinct concepts and procedures linked to their own disciplines, with little overlap between the work of the different lecturers, indicates relatively very strong epistemic relations (ER++). Table 8.1 outlines examples of disciplinary concepts identified in ISCM course documents, such as the geological processes of river formation, the concept of a mole in chemistry, the process of radioactive decay in physics, and factors that affect range of joint motion in human kinetics and ergonomics. Linking with these respective examples of disciplinary concepts, students are required to engage with specialized procedures such as plotting a river course on a topographic map, titrating a solution to determine molar concentration, calculating a radioactive decay constant and measuring range of joint motion using a goniometer. Assessment tasks that draw on these concepts and procedures consist of both low-order questions such as 'State the three main processes involved in river formation' and high-order questions such as 'Using a well-annotated diagram, explain the process of subduction in plate tectonics'.

While epistemic relations are strongly legitimated, social relations in the disciplinary component of the science-related knowledge code are not. Student dispositions, behavioural attributes and opinions are downplayed, representing weaker social relations (SR–). Typical examples, as indicated in Table 8.1, are where student opinion is sought on the effect of genetically modified organisms on the environment, or the use of nuclear energy as a form of energy generation, but students are judged on the coherence of their scientific argument, not on their opinion. Another example relates to the geological field trip in which the stated primary purpose is to enable 'careful, rigorous and systematic observation', which could represent stronger social relations linked to a particular way of working, but marks are allocated instead for correct identification of certain features and correct use of geological descriptors of rock characteristics, representing weaker social relations.

Scientific literacies epistemic relations and social relations

Evidence for the scientific literacies component of the science-related knowledge code relates mainly to work done by the two literacies lecturers. Since this work is underpinned by specialized science concepts, it represents stronger epistemic relations, but because many of the principles in this category can apply across a number of science disciplines, they are not as strong as the disciplinary-based category. Table 8.1 presents some examples of scientific literacies concepts that are visible in the ISCM course documentation. These include developing an understanding of how scientific knowledge is generated (for example through careful measurement and observation, inductively through looking for patterns in nature, deductively through generating hypotheses and conducting controlled experiments, and making predictions) as well as the basis upon which knowledge claims are made (for example, through using empirical data, recognizing the tentative nature of science, recognizing the idealization of many science laws, and knowing that understanding is often based on models of reality). Specialized procedures are closely linked to these concepts and relate to, among other things, designing and conducting experiments, developing coherent arguments, working with data (collecting, analysis, interpreting, presenting), writing scientifically and evaluating sources. In an independent research project, students are expected to design, conduct and present research in which they examine the effect of an environmental factor of their choice on plant growth. Most draw on home-based practices of growing plants, and their projects usually include the use of grey water or some form of organic waste. Assessment criteria for the proposal include such aspects as using an appropriate experimental design (taking into account randomization, replication and control of local conditions) and developing a logical argument (with the hypothesis being supported by information from the literature). These criteria represent stronger epistemic relations (ER+).

These scientific literacies concepts and procedures have relevance in the disciplinary work as well. For example, the principles of experimental design could apply equally in chemistry and human kinetics and ergonomics experiments. However, the analysis indicates that they are addressed initially in ISCM tutorials in fairly generic ways, and only later drawn on specifically in the disciplinary work.

In terms of social relations, the required dispositional attributes and values associated with this experimental work are closely linked to the specialized procedures. Students are expected to work in rigorous, reliable, accurate, precise, honest, curious, logical, analytical, critical and evaluative ways, all attributes required of scientists (Matthews 2015). While these attributes might at first glance suggest stronger social relations, they in fact represent weaker social relations (SR–): their *focus* may be knower attributes but their *basis* for achievement are the epistemic relations outlined above. For example, as indicated in Table 8.1, honesty in collecting and presentation of data is emphasized in tutorial discussions, but since this is difficult to ascertain students are instead awarded marks based solely on the presented outcomes of their experiment. Furthermore, students are generally expected to work objectively in the sciences, which means they must suspend personal biases and subjectivity in favour of what the empirical data tells them. This valuing of objectivity in the sciences therefore also represents weaker social relations (SR–).

Student response to the knowledge code

In terms of the science-related knowledge code, when students exhibit poor realization in the disciplinary component their answers are usually conceptually incorrect, too generalized or oversimplified (see Ellery 2017b). In other words, they recognize that a knowledge code is necessitated but are unable to produce the required cognitive or abstract standard. Similar code recognition but poor code realization is evident in the scientific literacies work and is usually linked to, amongst other things, students not being acceptably accurate or precise in their measurements, logical in their argument or objective in gathering their data. Therefore, although social relations are relatively weaker in this code, it appears that students need to pay some attention to the *valuing* of procedures as they influence being able to produce the requisite text. The student interviews indicate that educational background may play a role in poor realization of the science-related knowledge code at a university level. As one student commented:

TABLE 8.1 Specific translation device for knowledge code in ISCM (adapted from Ellery 2016, 2017a)

Code	*Indicators*		*Empirical evidence from observations, document analysis and staff interviews*	
Science-related knowledge code	Disciplinary component Disciplinary conceptual and procedural knowledge is emphasized while dispositions and opinions are downplayed	**ER++**	**Concepts** (from lecture handouts) Geology: processes of river formation Chemistry: concept of a mole Physics: process of radioactive decay HKE: factors that affect range of joint motion	**Procedures** (from practical handouts) Plot river course on topographic map Titrate a solution to determine molar concentration Calculate a decay constant. Measure range of joint motion using a goniometer
			Assessment (test): State main river formation processes; explain process of subduction in plate tectonics	
		SR–	**Dispositional attributes and opinions** **Assessment** (tutorial discussion): Opinion sought on nuclear energy as a form of energy generation, but answers need scientific base **Assessment** (field trip) Stated focus is careful, rigorous and systematic observation, but marks allocated for correct identification of geological features	
	Scientific literacies component Scientific literacies conceptual and procedural knowledge valued while dispositions and values are downplayed	**ER+**	**Concepts** (from tutorial handouts) How scientific knowledge is generated (measurement, observation, inductively, deductively, developing hypotheses, conducting experiments, making predictions) The basis upon which knowledge claims are made (use of empirical data and models of reality; recognizing tentative nature of science and idealization of laws)	**Procedures** (from tutorial handouts) Design and conduct experiments Develop coherent arguments Work with data Write scientifically Evaluate sources
			Assessment criteria in a proposal: Experimental design (principles of randomization, replication, control of conditions); Logical argument (hypothesis supported by literature)	
		SR–	**Dispositional attributes** Tutorial discussion: On the value of and need for honesty in reporting in experiment, but assessment criteria based on final outcome of experiment	

> I won't lie, it's the first subject that I can say it was quite difficult for me ... last year when I was doing my matric, I didn't see how deep is science, but in ISCM I saw how deep is science ... in terms of being critical and put your understanding towards your work.[3]
>
> (Kanelo)

Academic practices-related knower code

Epistemic relations and social relations

The second code legitimated in ISCM is an academic practices-related knower code. The term 'academic practices', which has social connotations and infers underpinning values as opposed to the more acontextual 'study skills', is used here to describe this work. It relates to what staff perceive to be the main purpose of the course: enabling students to become effective learners in a higher education science context. This purpose arises from a concern that once students leave the access programme and enter the mainstream, support for learning is either greatly reduced or non-existent. As one staff member stated in an interview: 'When they leave us students need to be able to get on with the job ... work on their own' (Lecturer 1). Since there are no underpinning specialized concepts, but instead students are required to engage in and develop learning practices appropriate for a higher education context, it embodies relatively weaker epistemic relations (ER–).

As indicated in Table 8.2, epistemic relations here are primarily procedural and linked to particular learning practices:

- organizational practices that relate to issues such as managing time and organizing notes;
- technical practices that are linked to their accessing information and taking good lecture notes from which they can learn;
- study practices that require students to prepare for and attend lectures, ask questions, review and consolidate work, practice calculations, and engage with and respond appropriately to feedback; and
- assessment techniques that include managing time in assessment and unpacking questions.

Working effectively in these academic practices is contingent on understanding the contextual 'rules', as outlined in Table 8.2. For example, in order to develop the practice of reviewing and consolidating lectures, students need to know that the ISCM context requires them to work constructively and independently outside class, otherwise it is unlikely they will be successful. Likewise, answering test questions effectively requires understanding that verbs of instruction (describe, explain, evaluate) determine the kind of answer, and that the supporting text and mark allocation signal the scope of answer required.

TABLE 8.2 Specific translation device for knower code in ISCM (adapted from Ellery 2016, 2018)

Code	*Indicators*		*Empirical evidence from observations, document analysis and staff interviews*	
Academic practices-related knower code	Dispositions and behavioural attributes for shaping own learning are emphasized and valued	**ER–**	**Contextual 'rules'** (from tutorial interactions) Organizing principles of library, Internet, textbooks, dictionary, words (suffix, prefix), learning context, assessment questions	**Procedures** (from tutorial handouts) Organizational practices: manage time, file notes Technical practices: access information and take lecture notes Study practices: prepare for and attend lectures, ask questions, review and consolidate work, practice calculations, work with feedback Assessment techniques: manage time, unpack questions
		SR+	**Dispositional attributes** Staff interview quotes: 'realising they don't know; study effectively and independently; developing deeper and better understanding; right kind of academic level; willingness to engage; active participation'	

It is through these academic practices that a particular kind of learner is being legitimated. In interviews, as indicated in Table 8.2, staff articulate the norms and values they perceive as necessary to become an effective learner in ISCM in particular and in a higher education context in general. All five staff interviewed spoke about learner independence. As one stated: '[They] need to become capable as students to study effectively and independently as we cannot always be here to support them' (Lecturer 5). In this regard another said: '[They should] not always rely on someone to teach them everything nor rely on someone to check whether they have understood' (Lecturer 1). Most staff emphasized the need for students to develop proper understanding. As one mentioned: 'It's not just surface content … it's about developing a deeper and better understanding … [they] cannot just rote learn all the time' (Lecturer 3). They also spoke about engaging at a higher level than at school. As one suggested: '[Staff] need to bring them to the right kind of academic level in terms of the scientific reasoning approach' (Lecturer 3). Most spoke about developing metacognitive, reflective and reflexive understanding. In this regard one stated: 'It's metacognitive thinking, you know. Realizing that they don't know what's going on, thinking about *how* they learn, and *what* they are going to learn, and *why* they are learning it' (Lecturer 2). Other aspects that staff spoke about were seeking help when needed, a willingness to engage and be challenged and active participation. In short, they view the academic practices work as engendering independence in learning and development of depth understanding, which is conceptualized here as students becoming and being *autonomous* learners. This invokes learners underpinned by relatively stronger social relations (SR+).

Autonomy in learning is enabled in ISCM through tutorial interactions in which appropriate learning practices such as preparatory reading for a topic, consolidating lectures and practical sessions, and active reflection on feedback for improvement, are supported and modelled in order that students can later do such activities independently of lecturer input. Outputs from these tutorial activities are not assessed directly, but many disciplinary and scientific literacies assessment tasks in ISCM are instead designed to not only assess knowledge of concepts and procedures but also to test autonomy in student engagement. Therefore, what may appear to be a question exhibiting distinctly stronger epistemic relations, such as the identification of a limiting reagent in chemistry, in fact has stronger learning-context social relations embedded in the task, based on how the topic has been addressed in class. If students have not heeded the cue to watch the necessary YouTube video, practiced calculating molar mass and number of moles and developed a proper understanding in order to answer a question that is phrased differently to that in class, it is highly unlikely that they will be successful in the task. In other words, the basis for achievement of the academic practices knower code is not measured directly, but rather indirectly through assessment tasks in the science-related knowledge code.

Student response to the knower code

When asked about poor performance in knowledge-code assessment tasks many students recognize the need to engage with their studies in particular ways, as demanded by the knower code, but are less successful at realizing such practice (see Ellery 2017b). In this regard students speak about the need to learn more: 'I just did not learn enough for this test, I will be honest' (Liwa). Along with insufficient engagement, how students engage is also an issue. Some appreciate the need to learn for understanding: 'I think I just did it [learning] for marks not for knowledge' (Khuselwa). Poor engagement often arises from a misreading of context requirements: 'I didn't know [learn] this because when she [the lecturer] answered that question she didn't spend a lot of time with it, she just browsed through it' (Anele). Students also recognize the need to practice technical tasks more: 'I understand the concept and method of calculating but I made a confusion in the test … I should practise more often to familiarize myself with the conversions' (Mbuyiselo).

In summary, students signal poor realization of the academic practices-related knower code in interviews when they speak of, amongst other things, ignoring difficult work, poor engagement with resources (including feedback), inconsistent study habits, reliance on rote learning and surface understanding, and dependence on an authority figure to direct their learning, which they acknowledge originates from their school contexts. These habits suggest unspecialized learning-context dispositions that exhibit weaker social relations (SR–). When combined with the weaker epistemic relations (ER–) of the generic procedures or skills being taught, this suggests that students enact this component of the course as a relativist code (ER–, SR–), instead of a knower code (ER–, SR+). There is thus a code clash for the learning context. Despite explicit articulation and strong support for the knower code in ISCM, students are not easily making the necessary shift. In this regard, students mention the challenge of changing entrenched study practices that have ensured success previously:

> I did well at school, very well, I was often first or close in my class ... my pattern was to study very hard just before tests – sometimes for hours ... [but here at university] I always run out of time 'coz there are tests and assignments and homework and stuff and it all takes too much time ... I guess I should be working more consistently like every day like you tell us [laughs].
>
> (Mandisa)

Epistemological access in ISCM

Figure 8.2 indicates that ISCM legitimates two distinct codes. In summary, the science-related knowledge code focuses mainly on students understanding of disciplinary and scientific concepts and procedures and forms the primary basis for success in ISCM. While the disciplinary and scientific literacies components can be plotted separately on the specialization code plane based on their different strengths of epistemic relations, they still form part of the same code in which epistemic relations are emphasized and social relations downplayed. The academic practices-related knower code focuses primarily on student learning and relates to students

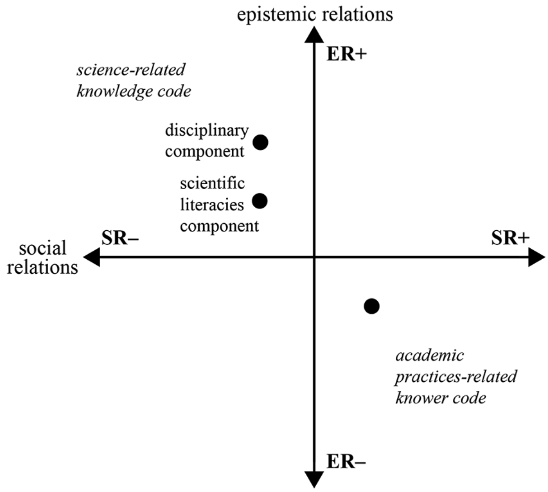

FIGURE 8.2 Specialization codes enacted in the ISCM course

becoming and being independent learners responsible for their own knowledge and understanding, which represents weaker epistemic relations and stronger social relations.

Because of the way the course and assessment practices are structured in ISCM, there is a close relationship between the two codes. In other words, if students do not work independently and develop deep understanding, as required by the academic practices-related knower code, they seldom can provide the depth that science answers require by the science-related knowledge code. This raises the key finding of this study that realizing the science-related knowledge code is contingent on students realizing the academic practices-related knower code. This hierarchy of access to these two codes has major implications for students' success and forms the basis for the more generalized conceptual model of epistemological access in the following section.

Epistemological access in higher education science

In serving its purpose of enabling access to the sciences ISCM has a dual focus of developing students' science knowledge as well as their dispositions as learners. ISCM is therefore unrepresentative of science higher education courses in general in that it has an explicit focus on developing students as learners through overt articulation, support, modelling and scaffolding of appropriate learning practices. However, many science-related higher education courses do, in fact, legitimate the kind of learner similar to that valued in ISCM (see Case 2013, Ellery 2017c). In other words, by working at a high volume and pace and addressing most concepts only once in class, they are legitimating a self-regulated learner who will work independently to ensure their own understanding. However, provision of support for such work is little or non-existent (Ellery 2017c). It appears that in current content-laden science-related curricula it is generally assumed that students will invoke learning approaches necessary for their success.

Since many science courses likely legitimate both a knowledge code (explicitly) and a knower code (implicitly), two levels of access are required for success in the sciences in general. The first level represents access to the specialized knowledge and procedures associated with stronger epistemic relations and is referred to as *science-context access*. This is the core of any science curriculum. However, since academic success is influenced by both the mastery of specialized knowledge *and* the 'capacity to be in control of one's own learning' (Edwards 2015: 14), access at the science-context level may well be constrained, as this study suggests, by poor access at the learning-context level. The focus here on becoming a particular kind of learner in a particular academic context is referred to as *learning-context access*. Without access at both levels, students are unlikely to be successful.

Access to two codes, with different strengths of epistemic relations and social relations, has implications for curriculum and pedagogy. The science context with its stronger epistemic relations poses certain structural constraints in any curriculum. To give an example, understanding the process of evolution as described in many higher education science curricula requires a prior understanding of base concepts such as the structure of DNA and the process of gene recombination. In contrast, the learning context with its stronger social relations demands a certain kind of learner as perceived relevant by staff. Aspects of the curriculum associated with the learning context are thus influenced by the purpose of the course and the values of the lecturers and are much more negotiable than those of the science context. In this regard, because ISCM is a science foundation course that is preparing students for success in the mainstream, an independent and self-regulated learner is legitimated. However, studies in engineering courses have shown that the ability to integrate multidisciplinary knowledge from a range of different contexts (Wolff and Luckett 2013) and the capacity to work with large volumes and at a high pace (Case 2013) may also (or instead) be key components of the learning context. Because there is more room to adjust expectations in learning-context aspects of the curriculum, I suggest this is where future effort needs to be focused to better accommodate students' backgrounds.

Prior educational experiences will influence access at both levels. Nonetheless, poor learning-context access in science-related disciplines is increasingly recognized as problematic (Adendorff and Lutz, 2009, Case 2013) and several studies have shown that prior educational experiences can limit uptake of, and access to, a new code (Hoadley 2007, Chen 2010, Pearce *et al.* 2015). It is suggested that the larger the articulation gap between secondary and higher education requirements, the more challenging the uptake (Scott 2012). The difficulty of changing dispositions and attitudes based on entrenched habits needs to be recognized, accommodated and supported in our educational practices (Pym and Kapp, 2011), without which certain groups of students will continue to be alienated and excluded from the system. From a social justice perspective, there is an obvious and urgent need to better support all students entering the higher sector today.

Conclusion

The contribution of this study, through enacting the concepts of specialization codes, has been the recognition of two levels of concern in a curriculum: the science (or disciplinary) context and the learning context. These two sets of concerns are always present in an educational field of practice, but empirical studies usually focus on either one or the other. By examining them together, these concepts allow a more holistic and nuanced analysis of curriculum and the different bases of achievement that are articulating within the educational context. As such, this approach offers the necessary subtleties to identify a key site of student difficulties with success – at the level of the learning-context knower. This highlights a somewhat unusual finding for education in the sciences, namely that learning-context social relations are key to enabling access to the highly valued science knowledge that will ensure success in academia. This emphasizes the need to significantly rethink science higher education to take into account methods for teaching both the knowledge of science and how students can be apprenticed into becoming science learners in a higher education context, thereby enabling epistemological access. This is particularly relevant for students whose prior socialization at home and school does not match well with expectations at university.

Notes

1 For the larger study to which this chapter relates, see Ellery (2016).
2 The literacies approach in ISCM is based on Street's (2006) ideological model that assumes there are multiple literacies and that these are acquired in socio-cultural contexts.
3 Pseudonyms are used for student quotes.

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