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Frameworks for Disciplinary Literacy

Summary

This final issue of the volume on disciplinary literacy reviews the literature on what disciplinary literacy means in terms of the desired behaviour and skills that students must develop. The issue looks at various attempts to draw up a general framework of such behaviours to be used by all disciplines or a set of multiple such frameworks to cover different disciplines. It then looks at the four broad discipline areas identified by McArthur (2012) – science, mathematics, the social sciences and the arts and humanities – and the teaching principles that teachers should use in each. There are commonalities that could indicate that it may be possible to have a single framework of what disciplinary literacy might mean in terms of teacher skills across the disciplines. However, there also appear to be some differences across disciplines that may make it more difficult to fit everything into a single framework. It is also noted that much of the research so far has examined to what extent current classrooms conform to a certain model of disciplinary literacy. There is now a need to look at how far particular models promote required student outcomes. Finally, the review reports the views of researchers regarding the need for professional support for teachers from all levels of the education service, including principals and training institutions. Teachers, too, need to work together in professional learning communities to provide the needed mutual support.

Introduction

Previous issues of this volume of the ELIS Research Digest have looked at different aspects of disciplinary literacy, reviewing the growing amount of literature that emphasizes the importance of developing disciplinary literacy skills among the student population. The term 'disciplinary literacy' (or 'subject literacy') refers to more than the basic general literacy skills of being able to decipher written text and being able to write a text. Disciplinary literacy includes learning to think, listen, speak, read and write in the way subject specialists do, i.e. to think and communicate in the way they do. This may include text (spoken or written) but it can also include pictures, diagrams, formulae and video, i.e. any aid to communication that may be used by specialists.

For teachers and educationists, this leads to a new set of questions. What skills and behaviours constitute student disciplinary literacy? How do we help our students develop disciplinary literacy? What kind of classroom environments will help our students develop those literacy skills? Will such classrooms vary by subject area or will the requirements be the same for all? This issue of the ELIS Research Digest will review what the literature says about these questions. In particular, it will note any guidelines, frameworks or sets of guiding principles that could help educationists, including classroom teachers of both language and content subjects, to understand what needs to be done to help students develop the literacy skills necessary to communicate in subject areas. In the next section, it will look at the literature that attempts to describe what the literacy skills required of students might be. In a subsequent section, it will look at how the literature suggests teachers can develop classroom environments in which students can be helped to develop those skills.

Developing frameworks of disciplinary literacy skills for students

In the USA, the Common Core State Standards have provided a ready source of descriptions of the skills that students need to master by the end of school. One such guide to the standards, *Framework for English Language Proficiency Development Standards corresponding to the Common*

Core State Standards and the Next Generation Science Standards (Council of Chief State School Officers, 2012) provides details of the expected language competencies of students vis-à-vis the Common Core State Standards and the Next Generation Science Standards (from now on referred to as 'the standards') in three disciplines – English language arts, mathematics and science. (It is expected that educators from other subject areas will use these guides as models for drawing up their own frameworks of standards.)

The writers of the Framework (Council of Chief State School Officers, 2012) pointed to the increased demands on language built into the standards. As a result, they repeatedly emphasized the need for students to develop their language skills in combination with their learning in the subject areas. This required language varied according to subject and needed to be learnt in combination with other ways of presenting concepts such as with mathematical symbols, for example. The writers noted that, in the early grades, the students' language would not be precise but as the students progressed through the grades, they learnt to be increasingly precise. In science, students needed to read, write, view and visually represent as they learnt scientific models and concepts. In the process of developing these skills, they needed to listen to others, present and defend their ideas and develop shared conclusions. The writers suggested that the language used in class would be different from everyday language. However, it would not be the same as that of expert scientists either although it would grow closer to the latter as the students progressed up the grades.

For each of the three subject areas, the Framework (Council of Chief State School Officers, 2012) first listed the required standards and then analysed the related embedded analytical tasks and receptive and productive language functions. For example, for the mathematical practice, 'Construct viable arguments and critique the reasoning of others', one of the analytical tasks was 'Justify conclusions, communicate them to others, and respond to counterarguments'. One of the related receptive language functions was 'Comprehend … (q)uestions and critiques using words or other representations' (Council of Chief State School Officers, 2012, p. 22). Finally, one of the related productive language functions was 'Critique or support explanations or designs offered by others'.

Lee, Quinn, and Valdes (2013) examined the Framework (Council of Chief State School Officers, 2012) and illustrated how there were commonalities across and differences between the requirements of the subject areas considered. They illustrated these with a diagram in which they demonstrated that certain required skills were common to all the three subject areas. For example, in science, mathematics and English language arts, there were references in all three to engaging in arguments using evidence. However, there were also skills specific to each of the subject areas, such as making sense of problems and persevering in solving them in mathematics, planning and carrying out investigations in science and demonstrating independence in reading complex texts in English language arts (Lee, Quinn, and Valdes, 2013, p. 3).

The focus of the Framework (Council of Chief State School Officers, 2012) was very much on student competencies, the first of the expected teacher concerns mentioned in the Introduction to this issue of the Digest. The following sections look at what the literature is saying about possible frameworks that can help teachers help their students, the second issue mentioned.

Frameworks for helping students

The task of helping students with disciplinary literacy may not be simple, however. Sfard (2001) noted that there was often a gap between research results and their possible application in classrooms. Ametller, Leach, and Scott (2007) also pointed out that there could be difficulties using insights from educational research to help in the design of actual teaching programmes as the research dealt with large grain (general) principles as opposed to the fine grain details that teachers needed to consider when preparing their teaching. The large grain research thus did not help with the fine grain decisions of everyday teaching. However, it was essential that the effort be made to reconcile the two as otherwise the research effort would be wasted and teaching would suffer from the lack of input from scholarly research. Ametller et al. (2007) indicated that the fine grain tools they had developed for teachers were informed by evidence from research and advocated that more such research evidence-informed (REI) approaches to subject teaching design should be developed.

Baker et al. (2008) noted that it would be difficult to measure the effectiveness of any new strategies without some measure of how far teachers had been able to implement them, i.e. the fidelity with which the strategies had been followed. They developed an instrument for doing this for science teaching. This will be discussed further below.

DiCerbo, Anstrom, Baker, and Rivera (2014) reviewed the literature regarding the need for English Language Learners (ELL's) to understand the language used in subject content areas. While the needs of the ELL's were the focus of the study, they felt that much of what they covered could be applied to any student who had had little prior contact with what they referred to as Academic English, i.e. 'the language used in school to help students acquire and use knowledge' (DiCerbo et al., 2014, p. 446). For students to learn, they needed help to gain competence in that language. It was not that the students lacked language; they were not language deficit. However, they did need assistance to learn the language variety of the school and how it could be used.

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DiCerbo et al. (2014) noted that Academic English (AE) could be differentiated from social (everyday) English, the language the students would be more familiar with, at three levels: vocabulary, grammar and discourse. Even within the school, the language of communication between students and teachers regarding general matters, such as classroom organization, would be different from the language that dealt with subject content. Furthermore, language could vary even then with, for example, the language used in preparation for a presentation being different from the more formal language of the actual presentation.

DiCerbo et al. (2014) noted that the *Framework for English Language Proficiency Development Standards corresponding to the Common Core State Standards and the Next Generation Science Standards* (Council of Chief State School Officers, 2012) indicated a growing consensus on what the features of AE were. However, they claimed, research still did not provide a definitive answer as to whether AE could be taught and, if it could, what the best ways of teaching it were. Suggestions that subject content teacher trainees should be given a better understanding of the language demands of their subjects had not been universally welcomed as this would add further burdens to an already busy training programme. However, one alternative possibility, it was suggested, was to build language features into the curriculum.

There were a number of techniques that teachers could use to help students. DiCerbo et al. (2014) suggested that the balance of talk between teachers and students should be shifted towards the students. Teachers should use follow-up questions to student answers, non-evaluative listening, instructional modelling and challenges to students to produce longer utterances. One way of giving students the chance to practise decontextualized discourse was to ask them to explain to the class something they alone knew about. In this, they could be helped by the teacher asking questions that encouraged the students to use 'expanded discourse'. In terms of writing, opportunities to prepare longer written texts could help students rehearse the skills they needed.

The research quoted by DiCerbo et al. (2014) focused primarily on academic language (AE) functions, such as functions involving asking and answering questions, explaining cause and effect and persuading. To help the students cope with these functions, teachers needed to support students in understanding and using them as well as the related vocabulary and grammar. This was true even of subjects such as mathematics as the literature had shown that language, including grammar, was important in solving mathematics problems. There was, however, a tendency for teachers of all subjects to focus simply on the vocabulary related to content. One way of helping students was for teachers to model their own use of language in the process of solving mathematics problems, for example.

McConachie et al. (2006) suggested that disciplinary literacy was based on the idea that students could only gain a deep understanding of a discipline (or subject) by using the habits of thinking, talking and writing found in that discipline. It was important to remember that literacy was not a separate area that the teachers had to set aside time to deal with. It was an important part of the teaching of content. This belief would affect the work of many teachers in the four main discipline areas of science, mathematics, history and English language arts.

McConachie et al. (2006) proposed a framework for disciplinary literacy that contained five principles. The first principle was that knowledge and thinking should go hand in hand, that is, in order for students to develop the complex knowledge of a discipline, they needed opportunities to read, think, talk and write about the concepts following modelling by the teacher. The second principle was that learning was an apprenticeship, through which students learnt the thinking and methods of the discipline such as knowing the criteria for a good scientifically oriented question, i.e. that it started with 'what' or 'how' and included something that could be measured and compared. Initially, students could use simple vocabulary but over time would learn the specialized terms. The third principle was that teachers mentored the students by designing lessons that made explicit disciplinary approaches by, for example, asking students to provide evidence in support of their ideas. The fourth principle was that instruction and assessment drove each other. Teachers monitored student discussion, questions, etc. as part of formative assessment that would allow them to adjust the lessons according to student needs. The fifth and final principle was that classroom culture socialized intelligence in that, in such classrooms, teachers treated students as thinkers, readers and writers who could take risks, solve problems and be responsible for their own learning.

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In the book edited by McConachie and Petrosky (2010), there was again an emphasis on the four core academic areas with separate chapters on history, mathematics, science and English language arts. In her chapter on disciplinary literacy, McConachie (2010), although she listed nine principles as the foundational tools of disciplinary literacy, emphasized the same five principles listed in McConachie et al. (2006) detailed above. She also stated that the foundational model for disciplinary literacy was 'diagonal learning'. In this model, the horizontal axis represented 'Growth in habits of thinking' used in the particular discipline while the vertical axis represented 'Growth in content knowledge' of the same discipline. The diagonal between these two axes represented learning that combined growth along both axes at the same time – students learnt new content as they learnt new ways of thinking and vice versa.

Reflecting the four core academic areas mentioned by McConachie et al. (2006), McArthur (2012) also suggested that there were four broad discipline areas: science; mathematics; social sciences (including history); and the arts and humanities (including English language arts). (See also Moje, 2007.) Each had its own knowledge structure and ways of thinking, its own language and its own ways of looking at the world. For example, science used an empirical approach combined with logic to investigate the world. He pointed out the disciplines were different in terms of their text structure; their technical vocabulary; their unique grammatical functions; and their lexical density (the relative frequency of content-related vocabulary).

The sections below review work on disciplinary literacy in each of the four areas identified by McConachie et al. (2006) and McArthur (2012) with the third represented by history and the fourth by English language arts. Through this review, some of the similarities and differences between subjects and writers can be noted.

Disciplinary literacy in science

Chin (2006) looked at the traditional triadic dialogue of Initiation (by the teacher), Response (by the student) and Follow-up (by the teacher) or IRF as used by two teachers in their science classes in Singapore. While the IRF dialogue had often been criticized as limiting student roles to giving short, factual responses to teacher questions, Chin (2006) found that teachers were able to foster some discussion and student thinking when they incorporated a number of techniques within the IRF exchange. First, the teachers avoided immediate positive or negative evaluations. Second, they acknowledged the students' contributions. Third, they restated (or revoiced) student responses confirming that they (the teachers) had understood and ensuring that the whole class could hear. Fourth, the teachers' subsequent questions built on students' earlier responses and stimulated use of various cognitive processes. Based on these observations, Chin (2006) drew up a table illustrating possible F moves in response to student responses within the IRF framework. Using these techniques, teachers could lead students into various cognitive processes such as hypothesizing, predicting, and explaining. Chin (2006) did point out, however, the need to be aware that some students found any direct challenges threatening and such challenges might cause them to avoid making any contributions.

Ametller et al. (2007) noted that research had shown that science learners' explanations of phenomena were often quite different from accepted scientific explanations. There was also evidence that learner explanations were fairly consistent across cultures and were resistant to the teaching of the correct scientific explanations. Ametller et al. (2007) looked into this using an approach influenced by Vygotsky (1978) who believed that higher mental functioning was influenced by the learner's social settings.

Ametller et al. (2007) started from the idea that scientific explanations were developed through the social discourse of scientists. In a similar way, learners' alternative explanations were developed through their social discourse. They further suggested that thought and language were not separate, but that language was the tool through which thoughts were first developed within a social setting before being internalized by the individual. The authors suggested that the process of internalization by an individual was extremely important. Students might start with their own ideas concerning certain phenomena based on their everyday social setting. In order for the students to understand the scientific explanations they were to subsequently learn, they needed to process them through talk and make them part of their own ideas and thinking.

Ametller et al. (2007) looked at the fine grain decisions in teaching science with regard to content and pedagogy: for example, deciding which details should be taught and in what order. They offered two tools to help with these decisions. The first, learning demands, delineated what scientific explanations needed to be learnt and how these might be different from everyday explanations of the phenomenon in focus. The second, the communicative approach, referred to how teachers interacted with students in order to develop scientific ideas described in terms of two dimensions: authoritative/ dialogic and interactive/ non-interactive. (This use of 'communicative approach' should not be confused with the term used in language teaching as described in Richards & Rodgers, 2001.) In authoritative mode, the teacher presented the school/ scientific view. In the dialogic mode, the teacher and/ or students talked about differing views. In a non-interactive section, the speaker (teacher or student) presented in a monologue whereas, in an interactive session, some discussion took place.

These two dimensions formed a matrix. Where a particular teaching section lay within the matrix depended on the teaching intent. For example, where the intent was to raise a question in students' minds such as why a light bulb lit instantly and no time was needed for the electricity to travel from the power source to the bulb, the section would be dialogic and interactive. Later, when the teacher summarized why this was the case, the session was more likely to be authoritative and non-interactive. An analysis of the classroom talk would allow an assessment of how far the communicative approach at any time supported the teaching purposes. The authors suggested that this fine grain approach to lesson preparation or analysis would help teachers in a way that research focusing on large grain issues could not.

Ametller et al. (2007) believed that, just as the language of school science developed in the discourse of practitioners (science teachers, curriculum designers or textbook writers), so the language of other subjects developed in the discourse between practitioners in those subjects and, thus, the same general approach could be adopted. However, each subject was likely to have its own set of language and learning demands to consider. They believed that the evidence showed that research evidence-informed teaching of the type they advocated would result in students having a better conceptual understanding. While teachers had choices of how to present within their classrooms, there was a need for them to take into consideration the 'learning demands' of their subjects (such as, in science, the difficulty students had in conceptualizing an electric circuit as a system) and then to offer analogies that would help them.

As mentioned earlier, Baker et al. (2008) developed an instrument to evaluate how far teachers were implementing the strategies that were thought necessary to foster a science classroom discourse community. This was part of a programme, The Communication in Science Inquiry Project, that saw talking and writing as central to the learning of science while at the same time noting that it was essential to teaching effectiveness that the teacher have good content knowledge.

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The Discourse in Inquiry Science Classrooms (DiISC) instrument was to be used by trained researchers and was designed to measure the teacher's use of certain strategies. The instrument consisted of five sets of instructional strategies that made up five scales:

- Inquiry
- Oral Discourse
- Writing
- Academic Language Development
- Learning Principles

Like many of the researchers discussed here, Baker et al. (2008) felt that the fostering of a classroom discourse community was essential to the learning of science. Their focus was on assessing prior understandings, linking facts to conceptual frameworks, metacognitive monitoring, setting performance expectations and providing formative and summative feedback, all learning principles also described in Bransford, Brown, and Cocking (2000).

Each of the scales was made up of a set of processes that could be checked for by an observer. For example, the Inquiry scale included the following processes:

- Engaging with scientifically oriented questions.
- Giving priority to evidence, which allows students to develop and evaluate explanations that address scientifically oriented questions.
- Formulating explanations from evidence to address scientifically oriented questions.
- Evaluating explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Communicating and justifying proposed explanations.

The authors explained that the instrument had gone through four drafts before the final version. The first draft was based on a review of research results. Later drafts were based on input from teachers, administrators, language experts, etc. The instrument results were also compared with the results of a survey of 187 students regarding their science lessons. A correlation of .80 had been achieved.

The authors stressed that no single lesson could cover all the strategies listed in the instrument. Similarly, no single class observation could be a full measure of the strategies employed by a teacher. Thus, when a researcher used the instrument to look at teaching, the observation programme would need to cover a series of lessons or units rather than just single lessons or units.

Bintz and Moore (2007) proposed a similar instrument, the Interdisciplinary Curriculum Framework. This framework had three central elements: content, learning process and pedagogy. It had six 'curricular engagements': text clusters; learning strategies; hands-on engagements; representing and reporting on data; multidisciplinary learning extensions; and assessment for and assessment of learning with the latter an important tool for helping the teacher support learning, reflection and differentiation. The important difference was that whereas Baker et al. (2008) were proposing a finely-designed instrument for research into science teaching, Bintz and Moore (2007) were proposing an interdisciplinary curriculum guide to teachers on how they could support students in learning the literacy skills in the different subjects. The broad similarities, however, might point to the possibility of developing a detailed guide for teachers to use in developing their lessons.

Mercer, Dawes, and Staarman (2009) noted that despite research indicating the need for teachers to consider how they could encourage learning through their talk with students, evidence indicated that closed questions that demanded little input from students still dominated the world's classrooms. (A survey of UK teachers found they emphasized student politeness and 'good grammar' more than anything else.)

Mercer et al. (2009) analysed the talk of two primary teachers teaching science in UK classrooms. (The two were from a larger sample of 12, all of whom had expressed an interest in dialogic teaching.) They found the amount of talk of the two teachers was not that different (85% and 88% of all the words spoken in the class) and the types of questions they asked were very similar. The authors felt there were some subtle differences that could have been important for teaching. (For example, both teachers allowed students to work in groups but only one allowed the discussion to last more than one or two minutes.) Despite these differences, neither teacher stimulated the kind of 'dialogic/ interactive' discussion that would have allowed students to make lengthy contributions. In addition, neither picked up on student contributions to advance their lessons or to be discussed in any detail. The authors concluded that even teachers who showed interest in dialogic teaching might need reassurances that it was an effective way of teaching science and might need to be made more aware of the importance of their own contributions to classroom talk.

Spiegel, Bintz, Taylor, Landes, and Jordan (2010) noted that there were more published disciplinary literacy materials for teaching science than for other areas of the curriculum. As a result, science teachers were in a better position to focus on their own teaching. They described two lessons taught by two teachers who were introducing disciplinary literacy approaches into their classrooms. The first teacher focused on two essential features of science disciplinary literacy: the students developing scientifically oriented questions and using the evidence to develop and evaluate explanations in response to those questions. In doing so, she used moves from Accountable Talk, a list of moves developed at the University of Pittsburgh. The authors noted that the talk and writing in the classroom (in groups or in whole class discussion) provided the teacher with formative assessment opportunities that could help her respond to the needs of individual students.

In the second lesson Spiegel et al. (2010) described, the teacher focused more on the three remaining essential features: students formulating explanations from evidence, evaluating their explanations against alternative explanations and communicating their proposed explanations. Getting the groups to select relevant data, develop explanations and then compare their explanations to those of other groups before going back to refine their explanations resulted in the students having a much more robust understanding of what a scientific approach entailed.

While Carpenter (2011) was writing with regard to courses on academic writing in the disciplines that are not the focus of this Digest, his suggestion that scientific literacy was a layered combination of a number of interrelated literacies might be useful in highlighting the complexity of subject/ disciplinary literacy in subject classrooms as well. He suggested that there were four literacies involved:

- Communicative literacy. This referred to the understanding that writing (and presumably speaking) was about communicating with an audience. Thus, students would not be helped by the mechanical application of a set of rules. They needed to learn to respond to the purpose, audience and context of their writing while being fully aware of the conventions of their subject areas.
- Graphical literacy. Students needed to learn the purposes of the different graphical representations and how they could be used to summarize complex sets of data or concepts that would otherwise be difficult to explain briefly in words.
- Technological literacy. Students had to learn how to use technology not only in the laboratory but also as a tool for communication. It

was important, for example, that they learnt how to look for articles on relevant scientific topics using databases on the Internet. They also needed to learn how to use word processing and graphic software to produce the reports they would need to prepare.

- Sociocultural literacy. The students needed to learn how to work with others in the production of reports and to take into account the different audiences for their reports whether they were scientists, other experts or a general audience.

These literacies cover the same kinds of student skills discussed in an earlier section of this issue. The important point that Carpenter (2011) made was that he believed that these literacies could and should be taught in a layered way, i.e. integrated into assignments so that the students learnt different literacies in combination. He emphasized that learning literacy rules without a context did not help as this could lead to the mechanical application of those rules in inappropriate ways. He felt that students could be helped to understand by being asked to analyse scientific texts and the reasons for the way they had been written.

Students must be involved in their own learning, solving problems, discussing questions and working in groups so as to learn together scientific thinking and talk in interesting ways.

Cook and Deaton (2012) felt that science teaching had focused too much on teaching facts that had little connection or application to the children's lives. In order to promote science literacy and better understanding of science, the authors felt students must be involved in their own learning, solving problems, discussing questions and working in groups so as to learn together scientific thinking and talk in interesting ways. The authors suggested a case study approach in which students were required to collect, sort and analyse information from different sources, consider a variety of opinions, and come up with alternative solutions to locally relevant issues, weighing the costs and benefits. The emphasis was on providing relevance for the students and giving them opportunities to voice their own views with suitable support from the evidence they had collected. There was also an emphasis on making the learning socially meaningful. According to Cook and Deaton (2012), a good case study was relevant to the students, presented a challenging problem with a number of possible solutions, encouraged discussion and cooperation among the students, had a human 'empathy' angle and was relevant to the subject curriculum.

Although his article focused on English language learners, Bergman (2013) suggested that all students could benefit from the sheltered instruction approach he described. The approach had a lot in common with science inquiry but also emphasized the need to look at language needs in drawing up lesson plans. He suggested adding into the actual lessons many of the features advocated by other writers reviewed in this issue. These included giving clear expected lesson outcomes at the start of lessons without giving 'the answer' to the inquiry that would be part of the lesson; drawing on students' prior experience; providing opportunities for student-student interaction; and the teacher modelling the thinking and talking.

Lee et al. (2013) believed that, with support, students could learn the language skills for science within the subject lessons as they learnt the science. When preparing models of concepts and processes, students needed to read, write, view and visually represent their ideas. They had to talk and listen as they discussed their hypotheses with others. The authors believed that students should be heard no matter what their language skills were and they should be encouraged to speak and to listen to each other to create meanings. In this way, they would learn the subject while becoming more sophisticated language users.

Lee et al. (2013) suggested that teachers could use four principles to encourage this kind of talk: problematize the content; give the students authority; make sure students were accountable to others and the subject for their ideas; and provide relevant resources. Further, the teacher could help with the subject language by making it explicit and showing that it was a tool to talk about the subject and not something to replace everyday language, i.e. a tool that the students as learners of the subjects would develop over time.

Disciplinary literacy in mathematics

In looking at the learning of mathematics, Sfard (2001) proposed 'thinking-as-communication' as a theoretical base from which to work. The idea was that thinking was a form of communication – internal communication with oneself.

From this position, Sfard (2001) went on to discuss learning mathematics as an initiation into mathematical discourse, i.e. to a special form of discourse. Often, the rules of this discourse were not explicitly taught but were learnt 'on the run'. In any discourse situation, participants came with their own sets of rules and understandings and it was through the discourse that adjustments were made between the participants. Some of the participants, such as teachers, were more authoritative and would have greater influence on how the rules developed. The less authoritative, in this case the students, would then learn new rules of communication and thought. However, this process did not always go well and teachers needed to be ready to assist.

Bakker and Hoffmann (2005) looked at a class of students aged 12 to 13 years in a Dutch school as they learned to use graphical representations of data. They concluded that students initially needed to make their own diagrams (or graphs) but then move towards the conventional, experimenting as they did. In the process, they needed to be stimulated to reflect on what they were doing. In the classroom they studied, Bakker and Hoffmann (2005) found that this occurred most commonly in whole-class discussions when the teacher and students discussed the students' graphs and what was represented. In this latter stage, students learnt to talk about abstractions such as the 'majority' and to be more precise in their speech (and thus in their thinking). The graphic and diagrammatic representations could then be used to help students to conceptualize and predict (such as what would happen to a graph if the heights of an older set of students were plotted). Using various graphical representations of the same data could help students see the common structures underlying those representations. In this way, diagrams and talk worked together to help student learning and understanding.

Anthony and Walshaw (2009) collected the principles for teaching mathematics from across the research literature and developed a set of ten principles that should be found in an effective mathematics classroom. These ten principles formed a framework for a teacher's classroom approach. The authors' focus was on effective pedagogy within a community of practice in the classroom which was part of a larger, changing network that included the school and the home. The students' individual and collective knowledge evolved within the dynamics of that learning community. The ten principles together were designed to encourage such a community of learning.

The first principle, an ethic of care, related to teachers caring about student engagement and managing student expectations and obligations with regard to who could speak when and what listeners should do. Students should be confident enough in their own skills to be able to consider the ideas of others and deal with any mathematical challenges they might face as a result.

The second principle, arranging for learning, recognized that the effective teacher provided opportunities for students to learn individually and together. The authors suggested that students sometimes needed time on their own in order to think more deeply about ideas. At other times, they needed to work with other students so that they could share and thus reinforce what they had learnt. Teachers needed to establish the proper student role behaviours such as listening to others, providing support for ideas, etc.

The third principle, building on student thinking, involved teachers in understanding the students' level and the common ways in which students at that stage of learning interpreted the principles being taught. This necessitated teachers monitoring the skills of the students through their talk and writing. This could be done through discussion that focused on known areas of difficulty such as the relationships between fractions, decimals, percentages and proportions.

The fourth principle, mathematical communication, emphasized the need for teachers to model the communication of mathematical concepts through speaking, writing and concrete representations so that students learnt the mathematical conventions. The authors suggested that revoicing could be a useful technique for teachers allowing them to take student ideas, check the assumptions behind them, negotiate meaning with the students and move on to new ideas or concepts.

The fifth principle, mathematical language, focused on the need to teach students the mathematical language required. The authors suggested that teachers might need to help students with particular language aspects such as the use of prepositions that might be unusual to the students in certain contexts. On occasions, the teachers might find it useful to initially use language the students were more familiar with to achieve understanding while continuing with the eventual aim of getting students to use the subject related language.

The sixth principle, assessment for learning, involved teachers collecting information on what students knew, how they learnt and what they were interested in as part of the everyday activities of the classroom. The questions being asked by teachers and students were an important source of such information.

The seventh principle, worthwhile mathematical tasks, emphasized the need to select tasks that helped students see how mathematics was relevant to real world issues such as work, leisure and home and how mathematics related to other subjects. Moreover, the tasks should be more than practising algorithms; students needed to be challenged to understand the mathematical concepts.

The eighth principle, making connections, related to students being encouraged to see how different aspects were linked and come up with alternative solutions to problems. The classroom atmosphere should support students trying out alternative solutions to complex problems, explaining their thinking, and listening to the thinking of other students.

The ninth principle, tools and representations, related to teachers using a range of modes to help students understand. These included the number system and algebraic symbols but also included analogies, stories and technology. While doing so, the teacher needed to take care that the students truly understood the teaching aids, such as number lines and tens-frames, that were being used.

The tenth principle, teacher knowledge and learning, focused on the need for teachers to have a good grounding in mathematics and in how students learnt in order to be able to clearly explain to students and, at the same time, challenge them to learn more. Teachers needed to be aware of what students were likely to find difficult so that they could prepare to help.

Anthony and Walshaw (2009) emphasized that their concept was of teaching as part of a systems network. Their idea was thus not to prescribe the actual detailed practice but to emphasize pedagogical practice leading to student outcomes.

Bill and Jamar (2010) described a mathematics lesson comparing two long-distance calling plans to illustrate learning on the diagonal proposed by McConachie (2010). (See p. 75 of this issue.) They showed how the lesson was designed to give practice in mathematical ways of thinking at the same time as the students learned the content. As the topic related directly to students' out-of-school experiences, there was the added value that students could relate the lesson to their own lives.

While teachers could go to outside courses to learn the theory, they needed to be given time at school to work with other teachers to reflect on their teaching and develop their approaches.

The authors argued that critical thinking was not a skill that could be learnt independently of content and then used across the curriculum. Critical thinking had to be learnt and applied in specific content. The learning was a type of apprenticeship.

Bill and Jamar (2010) went on to suggest that the support of principals was important in helping teachers learn the techniques and approaches that were needed in disciplinary literacy classrooms. While teachers could go to outside courses to learn the theory, they needed to be given time at school to work with other teachers to reflect on their teaching and develop their approaches. Principals could support the learning further by using non-evaluative observations to discuss with teachers their implementation of the approach and ways that the principals could further support them.

Disciplinary literacy in social sciences

As in much of the available literature, this issue of the Digest will take history as representative of the social sciences. In fact, it is difficult to find any work on other disciplines. This could be an area of future work.

Mandell (2008) offered a framework for history that gave history teachers a quick way to check whether their lessons were covering the required aspects of historical inquiry. She defined 'historical literacy as an understanding of what history "is" and what historians "do"' (Mandell, 2008, p. 55). She felt that teachers should be proficient in the language of history so that they could use effective approaches to teach this to their students. They needed to learn the skills, processes and concepts used by historians. Their students were to learn that history was not a set of facts but a way of thinking about the past. She suggested there were three steps:

- Asking questions about the past.
- Collating sources and evaluating the evidence.
- Drawing conclusions based on the evidence to answer the questions.

Asking the right questions was an important first step. To encourage students, teachers could start sessions with relevant questions, a task that could be handed over to students over time. In the discussion, students needed to be trained to provide supporting evidence for their views. Over time, they should be able to weigh the significance of their evidence.

Damico, Baildon, Exter, and Guo (2009) pointed out that the approach to history had recently changed. Previously, histories had often been considered to be objective texts with clear distinctions between fact and opinion. More recent approaches to history had emphasized that histories inevitably included the personal biases and views of the historian writer. They pointed out that active, expert readers employed various strategies while they read such as asking questions, thinking about the importance of an item, and synthesizing the content with prior knowledge. Among students too, prior views and background could affect their understanding of the histories they read and it was important for teachers to help them discuss, compare and contrast the cultural backgrounds they brought with them when approaching different historical texts.

Ravi (2010) showed how the five principles advocated by McConachie et al. (2006) could be realized in the history classroom by describing a unit on immigration into the USA. The unit started with students listing reasons for immigration based on their own personal knowledge or experience. From that base, the teacher introduced a source text for the students to identify the reasons for the immigration of an individual. In this way, in increments, the students learnt to ask the kind of questions historians ask, to develop conclusions and to give evidence for their views. The teacher used classwork and group work to monitor student progress and to make adjustments to the unit.

Disciplinary literacy in the arts and humanities

The academic area of the arts and humanities is grossly underrepresented in the literature on disciplinary literacy with only English language arts being covered. Thus, this discipline will be taken as representative here although it is possible that many will question how representative one discipline can be of the rest in this broad area.

Petrosky, McConachie, and Mihalakis (2010) noted that the typical English language arts lesson continued to be IRF dominated instruction that emphasized information transmission and rote learning. Such classes were dominated by a focus on details of language, word and sentence structure. They used an example of a teacher discussion and a lesson case study to show how the five principles of disciplinary literacy suggested by McConachie et al. (2006) could be applied in an English language arts lesson. They felt that the past two decades of curriculum development had wrongly focused on simplifying reading materials and teaching approaches in order to help those weak in reading. Instead, they thought the focus should be on developing a disciplinary literacy approach that would allow the students to learn to deal with texts with increasing sophistication. Teachers could encourage students to analyse texts on their own with the teachers modelling the approach when needed.

Petrosky et al. (2010) indicated that, for the proposed changes in teaching to take place, principals had to be aware of the work teachers needed to do to develop the necessary skills in collaboration with their colleagues and to lend their support in every way including providing time for them to continue their study of disciplinary literacy. They felt the changes would not be sustainable if teachers did not reflect on their teaching together with colleagues.

In the same vein, Park (2013) thought teacher reflection important and thus looked at the understanding of disciplinary literacy in literature held by a group of pre-service teachers in a small college in the USA. She noted that the two theoretical frameworks which she used in her study both emphasized that the difficulties students might have in learning did not necessarily indicate any language deficit. It was more likely that it was related to them meeting an unfamiliar type of discourse as each discipline had its own way of knowing, using language, thinking and even believing. Park (2013) noted that, in English literature, there were a number of different approaches and, thus, discourse possibilities, such as those of the formalists and reader-response theorists. Her study looked at how the pre-service teachers dealt with these differences in the belief that it was important that teachers should reflect on the different discourse approaches in their discipline in preparation to helping their students.

The question was what would be counted as misreading a text and who it was who should decide what a valid reader response was.

Among the group of pre-service teachers in her study, Park (2013) found that disciplinary reading represented a number of different approaches and tasks. For example, reading could mean paying close attention to the language and form of the text. On the other hand, it could refer to looking at the social and cultural aspects built into the particular text so that the readers could better understand themselves and the human condition. It could also involve literary criticism, knowing how to talk about literary theory, or interpreting texts. While many of the pre-service teachers acknowledged that there were a number of different and valid approaches, some were critical of other approaches. For example, some felt that a close analysis of the language of a text led to a myopic view of the text and they very much favoured a focus on the content and its meaning for life. Even those who advocated close reading of texts had different views regarding its purpose: some believed that it would help students learn the craft of writing while others emphasized the approach as a way for the reader to better understand their personal responses to the text.

Just as the pre-service teachers had different beliefs regarding the role of literature in schools, they had varied approaches to teaching. However, there were some common themes such as the importance of frequent practice with multiple texts including with those from popular culture as well as with canonical texts, perhaps asking students to explain what they saw as literary texts, and asking for their reasons in order to force them to think about the issue.

A second theme related to engaging in dialogue in class about the purposes of studying English. In the dialogue, students and the teacher could share their beliefs and hopes through the examination of literary texts.

One area perceived by the pre-service teachers as potentially difficult was balancing having students express their views and interpretations regarding particular texts against the possibility that not all interpretations would be regarded as acceptable by literature experts. The question was what would be counted as misreading a text and who it was who should decide what a valid reader response was.

Conclusion

This issue of the ELIS Research Digest has scanned the literature for possible ideas to include in disciplinary literacy frameworks that might provide teachers and educators generally with help in understanding the issues involved in disciplinary literacy. There are two areas that can be considered. First, what are the student skills or behaviours that constitute disciplinary literacy and how do they vary across disciplines? Second, what kind of teacher behaviour and classroom environments help in the development of students' disciplinary literacy?

As indicated in the early sections, there is a growing set of guides in the USA as to what constitutes disciplinary literacy in terms of student outcomes as a result of the need of states to conform to the new Common Core State Standards. These guides could be used as a basis for working on similar guides that could be used in Singapore classrooms.

In the later sections, the focus was on what teachers could do to help students and on what kind of classroom environments could help. In this area, there are a number of studies that have come up with different guides but there is a lot in common across them all. Essentially, they all indicate that we must first start from where the students are. This means we need to listen to them talk and read what they write. We must then help them to learn the concepts and language of the subject. Based on principles advocated by Vygotsky (1978), we can only do this in a social setting in which students learn together with knowledgeable others – their teacher and other students.

This review found a situation very similar to that described by Howe and Abedin (2013). They reviewed the literature on classroom dialogue from the forty years beginning in 1970 using a fairly broad definition of dialogue that included written forms that were not face-to-face such as on the computer. They found that, where the subject context of a study was indicated, the most common subject was science followed by mathematics (much as was found in the preparation of this digest). They also found that studies often implied values such as the need for a shift from teacher talk to student talk but none laid out clearly what best practice their findings were being judged against. The writers suggested that the model-based assessment that was often used was suitable for estimating how closely a teacher applied the model but it did not help identify its effectiveness. That could only be done through a target-based assessment that looked at the results obtained. They suggested that research should perhaps now focus on quantitative studies to determine which forms of dialogic organization would be beneficial. It was important for teachers to know how large any benefits might be so that they could determine whether the extra effort in implementing such methods was cost effective. In their review of the article, Mercer and Dawes (2014) agreed with this position.

Howe and Abedin (2013) found that not a lot had changed over the forty years from 1970. The IRF structure still dominated the classroom. One difficulty teachers had in encouraging increased exploratory talk in class was judging the correct timing and technique for introducing the 'expert' view when students were unable to get there on their own. A further difficulty related to balancing the time between class discussion, which was useful for checking student thinking, and forming small groups that would increase the talking time for individual students. Moreover, they found that students had difficulties learning how to challenge each other's views. There was also a problem of student attitude towards discussion, which some students saw as fun but not real learning. Interestingly, the research reported that teachers were not able to scaffold student learning very well as they were not able to see what the students' misunderstandings were.

Perhaps the most important way to bring about a change towards a clearer focus on disciplinary literacy is through a focus on teacher professional learning. McConachie and Apodaca (2010) stressed the need for the whole education system to support the development of disciplinary literacy education among teachers. They suggested that district education officers needed to work with principals, who, in turn, needed to work with teachers. All, district education officers, principals and teachers, needed to learn the principles of disciplinary literacy so that they could provide the necessary support. Teachers needed to work together in Professional Learning Communities that looked at their own and others' teaching in a non-evaluative way focusing instead on how the teaching helped students learn.

In an example of raising teacher awareness, McArthur (2012) reported on a course for pre-service teachers from different disciplines in which they were shown that not all reading was equal. Each of them chose a text from their own discipline and then paired with someone from a different discipline to discuss how they read their own text, subsequently comparing this with how they read a text from their partner's discipline. The exercise helped them understand the importance of prior knowledge in the reading of text. Applying this to their teaching, they understood how students might need help to cope with texts from different disciplines with which they were not familiar.

Another potential source of teacher support would be a guiding framework of what disciplinary literacy entails for both students and teachers. There is probably still some way to go before a full set of frameworks for disciplinary literacy can be prepared. However, we do have models of target student behaviours, including that of Lee et al. (2013) that shows the overlap between three disciplines. (See p. 73 of this issue.) We also have a number of studies in science and mathematics. We still need to have more in the social sciences and the arts and humanities covering a wider range of subjects so that we can more satisfactorily build up a representative set of frameworks.

Another question to be answered is whether there can be one framework that covers all subjects or whether there is a need for separate ones for each subject. McConachie and Petrosky (2010) indicated that they believed it was not possible to have a single framework covering all four core academic areas. Instead, they suggested the five principles they offered (McConachie et al., 2006) could be used across the academic areas as a general framework but could be interpreted differently for each of the areas in terms of what they meant for student and teacher behaviour. Research may prove this to be the most suitable compromise.

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