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Responding to the literacy load of science in monocultural contexts: *Preparation programs can change teacher classroom behavior*

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Abstract

Existing research about literacy within different subjects suggests that specialist language styles add an extra load to student learning. This has resulted in changes to centralized policy mandates in various jurisdictions, eliciting a variety of responses, including enthusiasm, agreement, compliance, neglect, subversion, and/or resistance. This mixed method study investigated whether 55 secondary school teachers from a culturally homogenous coastal region of Eastern Australia recognized literacy issues within science and their responses to such issues. There were three main findings. Firstly, only one third of participating mainstream science teachers accepted direct responsibility for helping their students deal with the literacy load of science, but most participating teachers recognized the literacy nature of more than half of the activities suggested to them. Secondly, participants teaching classes at several grade levels, and female participants, reported using a greater range of literacy activities in their science classes, and more clearly content-related activities were mentioned more frequently. Thirdly, participants who had completed a postgraduate teacher preparation program were more likely to express confidence in dealing with the literacy load of science and acceptance of responsibility for doing so. Time spent on literacy in teacher preparation programs appears to influence positive mainstream science teacher attitudes and practices in response to the literacy load of science. Study findings challenge conventional views of teacher recalcitrance, and they support the maintenance of policy and teacher preparation practices that encourage science teachers to respond productively to student literacy needs that have been identified by on-going research.

Keywords: *Disciplinary literacy, standards, science, language, policy, change*

INTRODUCTION

Past decades have seen increasing centralization in many educational jurisdictions, as explicit statements of mandatory standards provided a mechanism by which policy makers "attempt to align and create commonality across systems" (Lewis et al., 2020, p. 1). Such standards form frameworks for registration of schools receiving government funding within those jurisdictions and accreditation of institutions offering initial teacher education to support them. This process has provoked both productive criticism and outright resistance.

There have been calls for more emphasis on educational research to determine appropriate standards (Webster & Whelen, 2019), for closer liaison between government departments and initial teacher education providers (Ledger et al., 2020), and for more consideration of the interaction between the evaluator and the evaluated when standards are used in teacher registration and subsequent promotion (Barry et al., 2020). Against this background, changing student demographics encouraged some jurisdictions to mandate a literacy focus beyond subject English (eg., ACARA, 2023; Reid, 2005), but work on the limited impact of teacher preparation programs (Foss & Kleinsasser, 1996; Píšová, 2013) suggests that such policy-driven changes may have little influence.

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Research Objectives:

This paper is based on a study that sought to investigate the extent to which secondary teachers of science in a limited geographical area of Australia were cognizant of, and teaching to address, the literacy load inherent in their science classes.

1. To what extent are science teachers aware of the literacy demands inherent in their teaching and students' learning?
2. How do science teachers support their students in managing the literacy demands of science?
3. What aspects of teacher background influence attitudes and practices regarding scientific literacy?

LITERATURE REVIEW

Responses to change

Change happens at different levels and people have always responded to it in a variety of ways. At some times, in some places, some people implement changes as fully as they can. For example, the introduction of School-based Curriculum in New South Wales, after decades of curriculum defined by a single textbook, prompted enthusiasm in contemporary science teachers. This resulted in production of a wide range of innovative material in the 1970s, some based on international models, and some based on the best local practice developed under the previous, more detailed requirements. Teacher enthusiasm can be identified by the development of such resources.

Other people will attempt to implement policy without such enthusiasm. Many teachers agree with policy, declining to publicly oppose it, other than through ineffective private conversations. Such teachers will often make initial, limited attempts at policy implementation in their classrooms, but revert to local traditional practice in the face of any difficulty. Yet other people try to carry on without getting into trouble. Such teachers will apparently comply, altering their program documentation while leaving their classroom practice unchanged. Others ignore such changes entirely. Design and Technology documentation and classes in NSW remained essentially unchanged throughout the 1990s as their teachers neglected a new syllabus in the absence of pressure from an external examination. Some other people apparently comply, while undermining the process of change. Such teachers try to subvert unwelcome policy by complying themselves, while martialing parental and community resistance to it. Some people, or jurisdictions, actively resist change through public dispute and explicit professional non-compliance. Employers or government officials, policy makers, bureaucrats, managers, and workers are all likely to have different attitudes (Comber, 2012; Dilkes et al., 2014; Zimmerman, 2006) to such enthusiasm, agreement, compliance, neglect, subversion or resistance.

Bovey and Hede suggested that “resistance is a natural and normal response to change because change often involves going from the known to the unknown.” (2001, p.1) and asserted that individual resistance arises from unhelpful cognitive and affective personal characteristics. Their work, resting on classical psychoanalysis and the rational-emotive behavior therapy that emerged from it, suggests that resistance to organizational change varies between individuals based on irrational ideas, influencing both their perceptions of the change and their emotional response to it, which in turn influences their intention to resist the change. Like many instances of corporate psychology, this work assumes that the change itself is unproblematic and that it is being implemented through a clearly hierarchical organizational structure characterized by close managerial oversight, with power diminishing and responsibility increasing as one moves down the pyramid. Education is not so closely coupled. Varying and competing pressures may drive policy change; and teachers have acquired a reputation for recalcitrance.

More recent work on people’s responses to change was prompted by responses to the personal and professional impact of COVID-19 pandemic public health policies. If people already broadly agree with a change, information may encourage compliance; but if they do not see the reason for the change, information may be ineffective in changing their behavior (Xiao & Wong, 2020). Such combination of agreement and compliance into palpable acceptance depends on trust of the source(s) of information; identification with developers of the new policy; harmony between the information and group values; and ready comprehension of the information vehicle

(Philipp-Muller et al., 2022). The pandemic drastically reduced face-to-face teaching and prompted a rapid turn to on-line learning. Academics had little control over this change and it touched relationships that they saw as central to their personal responsibility for excellent work. On-line learning drew on skills that many did not possess and then apparently de-skilled them. Modern academics are relatively autonomous and this seemed to place such limited autonomy in jeopardy. All this provoked shifts in responses from mere (and temporary) compliance to more intense resistance (Laufer, 2023), exemplifying the impact of such drivers for changes in professional behavior.

This has implications for the present paper, as the presence of linguistically diverse students who have difficulty in understanding content that seems clear and simple to their teacher can encourage such teachers to accept responsibility for student literacy beyond subject English and seek out discipline-appropriate language resources. The absence of such diversity may mitigate enthusiasm for changing policy and, instead, encourage neglect or resistance. Classrooms have doors that, once closed, make close oversight of teacher practice very difficult.

Teaching has traditionally been loosely coupled, with policies being implemented by professionals trained within distinct traditions and largely trusted to operate within broad ethical standards as they apply the methods of those traditions. The whole range of responses, from enthusiasm to resistance, are apparent in teacher and jurisdictional response to many educational innovations and this has prompted on-going work on ways to encourage enthusiasm for productive change and reduce the likelihood of resistance. Teacher enthusiasm has long been recognized as central to successful innovation (Fullan & Hargreaves, 1992), as has been the negative impact of ineffective application of the wrong drivers for change (Fullan, 2011). Such ineffective attempts to improve conditions for student learning have been widely documented (see, for example, Edge et al., 2014), as have been situations where teacher recognition of the student needs driving policy change has led to more successful implementation (Khoboli et al., 2013; Zangmo et al., 2013).

The 'Bullock Report' (HMSO, 1975) initiated an international movement that advocated extension of responsibility for language learning beyond traditional language teaching and into other school subject areas. The policy, which was sometimes described as 'Language Across the Curriculum', rested on international work done in English for Specific Purposes (Swales, 1985) and initiated several decades of work by academic linguists (Fang, 2024; Shanahan & Shanahan, 2008; Swales, 1990). This work led some contemporary syllabi to urge science teachers to deal with issues beyond their ideas of science content within the programs they design and deliver for students, provoking tensions both in schools and within academic linguistics (Martin, 2000/2012).

Science teachers can feel inadequate in managing class work that includes high levels of uncertainty and opinion (Levinson, 2001) and they may consequently retreat into 'turf protection': "I teach science, leave me alone to do it, I don't have time to do anything else". Such attitudes are commonly encountered when teachers are asked to deal with language within their science classes (Davison & Ollerhead, 2018). Both workload and lack of recognition of widespread student challenge can discourage teachers from engaging with the literacy load of science. Careful and reasoned introduction of disciplinary literacy through professional development programs in culturally diverse schools can reduce resistance from all but the oldest teachers and schools, and from those teachers for whom the link between literacy in their subject an enhanced learning in that subject was not sufficiently clear (Glaeser et al., 2012). What happens in science classes within less culturally diverse schools?

Literacy load of science

Student difficulties with the language of their science textbooks have been recognized for a very long time. Contemporary science student difficulties prompted an early attempt to produce a formula for calculating the readability of text that was phrased in terms of the "vocabulary burden of textbooks" (Lively & Pressey, 1923, p. 389). A quick comparison, 50 years later, indicated that children entering British secondary schools encountered as many new words in their science textbook as they did in their preliminary French text (Evans, 1974). Technical words (such as oxide or alkali) are the most obvious features of such text, but semi-technical words (such as base or react) have common as well as technical meanings and may be even more problematic for a novice learner. More recent work has suggested extension of this earlier focus on vocabulary burden into a notion of a 'literacy load' that students encounter as they move into specialized varieties from a more general style of English.

Such 'general English' comprises that limited stock of very frequent words and structures that forms the minimum requirement for communication in restaurants and shopping centers in English-speaking contexts. This is the language style taught in most English as a Foreign Language classes and through their preliminary English language textbooks (such as Collins, 2015). However, there is also a wide range of specific styles that groups within English-speaking societies produce to communicate among themselves (O'Toole et al., 2012). Entering such communities is dependent on gaining control of their specialist language style, and that produces the literacy load of access to its products. Teachers often expect their classes to operate within such styles and students need to be able to read material written in versions of specific styles, if they are to access specialist learning material; as well as being able to write versions of the style that demonstrate such acquisition (Shanahan & Shanahan, 2017).

Various jurisdictions brought all this together at the turn of the century. For example, the Australian national curriculum document incorporated an explicit cross-curricular focus on literacy, at least partially driven by recognition of the challenges faced by migrant students from diverse linguo-cultural backgrounds (Reid, 2005; ACARA, 2012). However, concern was not restricted to students for whom English was an additional language or dialect. The associated General Capability for Literacy (ACARA, 2023) clearly extended this responsibility beyond teachers of subject English to classroom teachers of other subjects (Derewianka, 2012) and this was subsequently integrated into national teacher registration standards (AITSL, 2017).

Over the past decade, national policy has mandated Australian specialist teacher knowledge as including knowledge of the structure of language at word, clause, sentence, and text level, as well as of the meanings conveyed through those levels of language. As suggested at the end of the last section, mathematics and science teachers frequently resist such prompting because they see it as requiring time, experience, and knowledge that they lack, and recognize little impact on valued subject outcomes. However, rapid increases in classroom diversity can push such teachers beyond their comfort zones as they struggle to help apparently able students deal with language-based difficulties that their teachers did not anticipate.

The scientific style of English imposes a literacy load that causes problems for a wide variety of student groups, whether teachers recognize those problems as being communication-based or not. Figure 1 shows language test results for students reporting various languages spoken at home, based on cloze test results, where responses from 2606 students were coded as 'conceptually correct' if they maintained the meaning of the passage. The differences between the heritage language groups were statistically significant ($F = 19.96$, $p < 0.001$), which suggests that they are robust enough to allow further discussion. The monolingual group, which is often considered to be the default condition, does score higher than the mean for this large sample, but they were still unable to suggest conceptually correct entries for more than 40% of the random deletions. Further work suggested that they shared many of the same difficulties as their more culturally diverse classmates, although to a lesser extent.

Demographic changes initially alerted some specialist teachers, and those responsible for preparing them, to the differential learning load that specialist language styles were placing on groups of students, with subsequent recognition of the magnitude of the difficulties being faced by all students. Movement beyond the general style of English imposes a literacy load on all students.

This situation suggested an opportunity to examine the impact of policy change in the absence of daily classroom re-enforcement of the need for it. Such an examination is important because apparent classroom diversity seems to be diminishing locally and recognition of the demands of specialist styles may diminish with it, until the next demographic change. The intrinsic stylistic problems will remain and may continue to exclude those students who do not recognize their difficulties as coming from the literacy load of their subjects, rather than from their own shortcomings.

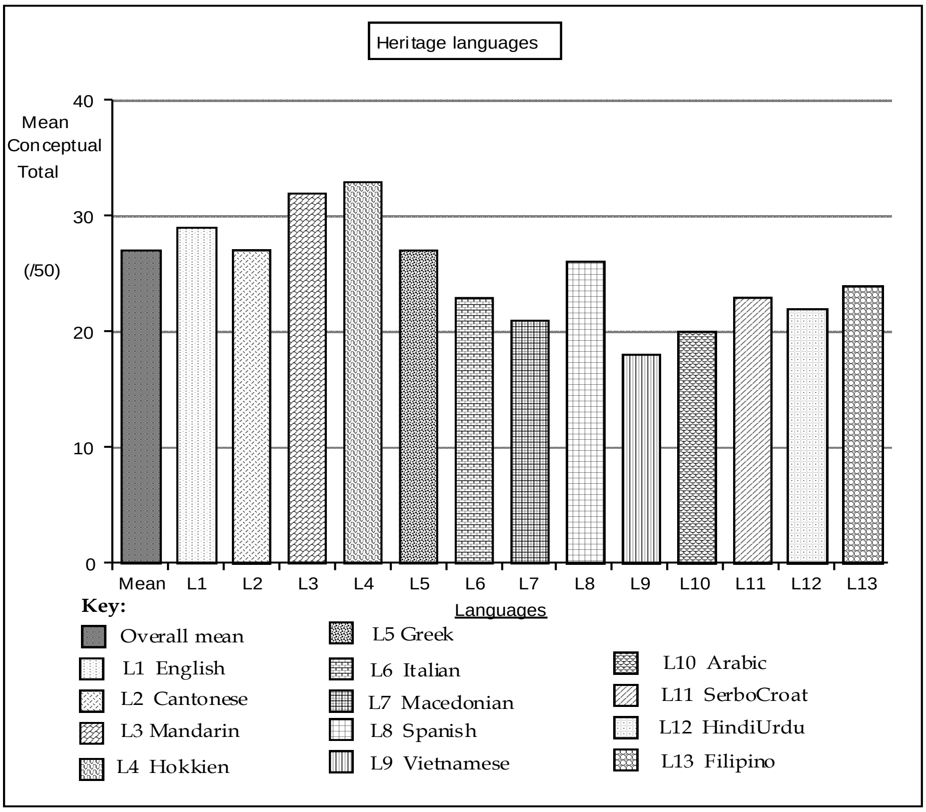


Figure 1 Comparative access to secondary science text (O'Toole & Laugesen, 2011, p.32)

RESERCH METHOD

The exploratory mixed method study (Creswell, 2009) on which this paper is based drew science teacher data from 12 secondary schools on Australia's east coast. These schools were in a confined geographical area with a relatively uniform population, and they represent what is often considered Australian 'mainstream' schooling: that is, classes composed of white, middle class and monolingual English-speaking pupils being managed by teachers from a similar background. The data on which this paper is based come from 14 interviews, followed by a survey with 41 responses, representing approximately half of the science teachers in the target area.

The interview sample included seven department heads, many of whom were trained during the initial controversy that followed the Bullock Report, but before the Australian Curriculum directly applied pressure for cross-curricular literacy development. They assumed their leadership roles after its impact was felt through school accreditation and teacher registration processes. Initial informal and wide-ranging discussions with two participants led to development of a protocol for subsequent semi-structured interviews where interviewees were prompted to discuss how they encouraged and managed student communication in their science classes. Interview transcripts were analyzed thematically (Braun & Clarke, 2012).

The general tenor of the interview transcripts reflected the focus on content and vocabulary found in earlier research on literacy. Transcripts also revealed reluctance to move beyond such concerns, representing the kind of resistance to dealing directly with the literacy load of science mentioned above. These qualitative data were instrumental in the development of the survey questionnaire, and this convergence of existing literature and our own qualitative data led us to expect that the later quantitative data would simply amplify the impression of recalcitrance.

The survey sample constituted a wider range of age, experience, role, and teacher preparation than did the interview sample, although most teachers surveyed were younger, less experienced, and more junior than the interviewees. They had been prepared to teach in a range of institutions, some close to the study location and others further away. Consequently, they had been exposed to a range of approaches to disciplinary literacy during teacher preparation. The survey consisted of 50 questions, of varying formats, that elicited demographics and participant recognition of the literacy component of common science activities (based on ACARA, 2012); perceptions of the locus of responsibility for literacy, and of the usefulness and duration of preparation for incorporating literacy in science teaching. Information regarding their personal literacy practices, and activities that they used in their own classes was also obtained.

These sections of the survey constituted conceptual scales for later analysis. Most scales satisfied conventional reliability assumptions, except for the questions dealing with personal literacy practices. Participating science teacher personal literacy was highly diverse, with approximately one third/two third splits between professional and non-professional reading and writing that were too inconsistent to be considered together.

Table 1. Conceptual scales within The Literacy Load of Science questionnaire

Scale	Probe	No. of Items	Reliability (Cronbach's α)	Mean (%)
Recognition of Literacy	*Do these science teachers **recognize** an activity as involving literacy?*	9	0.7	38
Response to Literacy Policy	*How do these teachers **respond** to teaching literacy in science classes?*	4	0.7	33
Preparation for Teaching Literacy	*How **prepared** do these teachers appear to be to teach literacy in science classes?*	3	0.8	47
Literacy Strategies	***How many** literacy teaching strategies do these teachers use in science classes?*	16	0.7	51

Table 1 describes the conceptual scales analyzed in this paper. The data in the final column represent summed participant responses, expressed in mean percentages to expedite comparison of the four scales. Application of multivariate tests through the General Linear Model suggests that the apparent mean differences are large enough to warrant further discussion (**F** = 115.515, ***p*** < 0.001).

This was a correlational study and many of its variables are categorical, rather than numeric, notwithstanding the use of comparative percentage scores on Table 1. Consequently, the non-parametric Pearson χ^2 test seemed appropriate for subsequent, sub-sample comparison purposes. Table 2 contains the interactions between participant background and survey response for which χ^2 was statistically significant, at the conventional $p < 0.05$ level.

FINDING AND DISCUSSION

Teacher, and jurisdictional, resistance to centrally mandated change can lead to cynicism regarding the likelihood of encouraging improvement in student learning and classroom diversity has seemed crucial in previous teacher recognition of the literacy load of science. Literature and teacher experience both suggest that problems with the language of science are not restricted to linguistically diverse students, although both experience and literature suggest that the presence of such students heightens teacher awareness of the literacy load. This sequential exploratory mixed methods study set out to investigate the perceptions and intentions of contemporary science teachers in a context where relatively homogenous classes would not provide such stimulation.

Preliminary interviews

The primary author interviewed 14 experienced science teachers in participating schools, at times of their own convenience, for between 35 and 40 minutes per interview.
Interview responses ranged from recognition of 'basic literacy',

> *"... to me, it's about reading and writing, it's being able to read and understand the meaning of the text as represented by the author".*

through focus on specific features of scientific English,

> *"The ability to use words appropriately, to use appropriate scientific words to describe phenomena, being able to construct sentences that make sense, correct spelling, correct use of words in the correct context."* … and …
>
> *"Being able to understand, analyze and access information from the forms that science is usually presented in …… Text, graphs, diagrams, flowcharts, maps, etc."*

to recognition of 'literacy' in its wider traditional sense:

> *"… it probably goes a bit deeper than that, so to be literate, I suppose that you'd need an understanding of the topic."* … and ...
>
> *"Literacy in the context of science is…… the ability for students to fathom their way through a world that has been pervasively impacted by science and technology."*

However, specific inquiries regarding how interviewees taught the literacy aspects of science yielded little detail, indicating that policy change may have made these experienced teachers more aware of literacy load without substantially changing in their classroom practice. They apparently *agreed with* the policy without *enthusiasm* for it, and consequently made minor, if any, changes to their classroom teaching. This suggested a focus on teacher intentions and reported actions in the wider survey. The mandatory nature of discipline-based literacy in this jurisdiction made a blunt refusal to engage with it in science classes unlikely, although the displacement of responsibility to Primary and English teachers that was evident in the survey data suggests local *resistance* (see Table 2).

The interview transcripts further illuminated tension between content and language requirements and exposed a range of teacher responses. All interviewees recognized the need to teach scientific vocabulary together with the text-types (Martin, 2000/2012) and the content of the topic, but fewer were aware of the need to move student writing beyond sentences to paragraphs and more complex passages.

"More than a paragraph, rarely, except for assignments – we might practice that once or twice a term, and then they got to do it for the assignment itself."

At one point in each interview, participants were asked whether they could assess change in literacy in their students and how they did this. Most of those interviewed responded with either a flat and definite "*NO!*", a vague reference to using national literacy test results, or a reference to a school-based program, in order of frequency. Unwillingness to assess suggests practical *neglect* of policy.

Subsequent survey

The final column of data in Table 1 suggest that, even in the absence of daily reinforcement, on average, these teachers recognized more than a third (38%) of the supposedly science activities that place literacy demands on their students and claimed a slightly lower proportion of the literacy-based responses suggested to them (33%). Their sense of preparation for such responses (47%) is apparently stronger than either recognition or response, and they claim to use around half of the literacy teaching strategies presented to them (51%). The reliability column and subsequent application of the General Linear Model suggest that the scales are adequately reliable and that the differences between them are large enough to allow such discussion.

These proportions are not large, but they are greater than either existing literature or the interview transcripts suggested that they would be, which raised the issue of differing responses by various groups within the study sample (see Table 2). There were 16 suggested activities and nine examples of literacy in science on the survey, so the 'Measures' column on that Table is split at less than, or greater than, half of this number. 'Recognition of Literacy' represents teacher perceptions of literacy load, while 'Range of Responses' represents teacher reported activities.

This teacher sample reflected a wider range of background variables than the interview sample but only the four of them appeared to influence participant attitudes and practices in a statistically significant way. Those significant interactions appear in Table 2. Neither participant age, experience, position, workload, degree, university attended, nor year of graduation made a difference great enough to warrant further comment. The final 'Mean %' column on Table 1 preserves information from the overall sample, for comparison purposes.

The information in Table 2 suggests that teachers who teach classes at two or three different grades, and female teachers, are more likely to report using a greater range of literacy activities in their science classes than those teaching either at a single grade, or across all four junior secondary grades. A subsequent planned contrast did not suggest an association between gender and range of classes taught.

Recognition of literacy activities does not present quite so clear a picture. Most participating teachers recognized the literacy nature of more than half of the activities suggested to them, although a higher proportion of teachers holding a higher degree recognized less than half. The task of 'correlating geological columns' was the least recognized literacy activity, while 'creating a food chain from text' was the most recognized. Teachers apparently have specific ideas on what literacy entails, with some forms acknowledged more than others. There seemed little clear pattern in these results though, with activities involving drawing, reading and a word equation being recognized more often than some requiring making tables or food webs.

Teacher preparation program structure is particularly interesting, with higher proportions of teachers who completed end-on Education programs expressing confidence to deal with literacy issues in science and recognizing a unique responsibility to do so. However, teachers in that group were less likely to recognize literacy activities according to our survey. A subsequent planned contrast supported suggestions that confidence in dealing with literacy issues was associated with a greater acceptance of responsibility to do so (χ^2 = 7.693; ***p*** = 0.021).

The data also suggested a composite dependent variable for subsequent analysis, based on aggregated measures of inferred teacher attitude and reported literacy-based class activities. Some of these teachers:

- appear more confident of their competence to teach literacy in science.
- appear to recognize more pupil activities that require such literacy.
- recognize their responsibility to do so, and
- report making use of a greater variety of literacy-related activities.

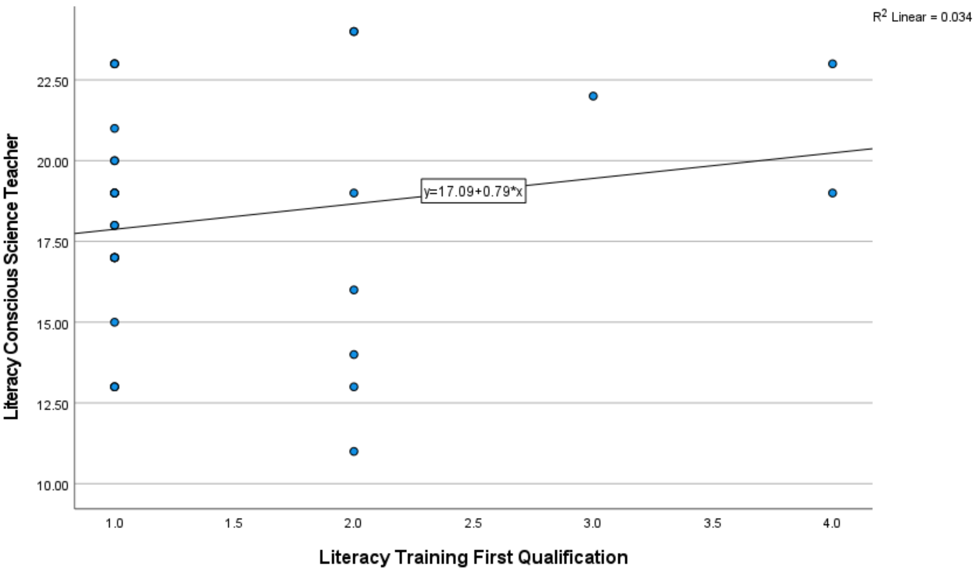
Such teachers demonstrate attitudes and practices regarding scientific literacy that represent the focus of this study. Positive attitudes towards literacy in science are indicated by acceptance of responsibility for literacy, recognition of literacy load, nomination of more strategies and confidence, and such professionals could be labelled 'Literacy Conscious Science Teachers' (see Figure 2).

Table 2. Participant Characteristics and Literacy Stance

Variable	Literacy Aspect	Characteristic	Measure	No.	%	Pearson χ^2	df	*p*
Gender	**Range of Responses** (n=16)	Male (n=21)	Use 8 or less literacy activities. Use 9 or more literacy activities.	13 8	***62*** ***38***	20.99	11	0.03
		Female (n=20)	Use 8 or less literacy activities. Use 9 or more literacy activities.	8 12	***40*** ***60***			
Range of classes		Only classes in 1 grade (n=9)	Use 8 or less literacy activities. Use 9 or more literacy activities	9 0	***100*** ***0***	72.16	44	0.01
		Classes in 2 grades (n=12)	Use 8 or less literacy activities. Use 9 or more literacy activities.	4 8	***33*** ***67***			
		Classes in 3 grades (n=13)	Use 8 or less literacy activities.	2 11	***15*** ***85***			

Variable	Literacy Aspect	Characteristic	Measure	No.	%	Pearson χ^2	df	p
			Use 9 or more literacy activities					
		Classes in 4 grades (n=4)	Use 8 or less literacy activities. Use 9 or more literacy activities	2 2	***50*** ***50***			
Highest Degree	**Recognition of Literacy** (n=9)	Bachelor's degree (n=33)	Recognize 4 or less literacy activities. Recognize 5 or more literacy activities.	5 28	***15*** ***85***	27.03	16	0.04
		Higher degree (n=7)	Recognize 4 or less literacy activities. Recognize 5 or more literacy activities.	3 4	***43*** ***57***			
Program Structure	**Confidence to Teach Literacy:**	Integrated (n=12)	Yes No	5 7	***42*** ***59***	5.22	1	0.02
		End-on (n=28)	Yes No	22 6	***79*** ***21***			
	Responsibility for Literacy in Science	Integrated (n=12)	Science Teacher Primary or English Teacher Primary and English Teacher	1 8 3	***8.3*** ***67*** ***25***	8.84	2	0.01
		End-on (n=28)	Science Teacher Primary or English Teacher Primary and English Teacher	14 6 8	***50*** ***21*** ***29***			

Following recoding, cross-tabulation of this derived variable against the wide range of background variables provided by this study suggested that the treatment of literacy issues in their first degree had a statistically significant impact on literacy practices of a 'Literacy Conscious Science Teacher', with a small to moderate effect size: χ^2 = 57.264; **df** = 36; ***p*** = 0.014 (< 0.05); R^2=0.034 (0.0196 < R^2 > 0.13).



Key:

Literacy Training First Qualification: Proportion of program reported:
(see Table 6.3): ***1***: 1-10%; ***2***: 11-20%; ***3***: 21-30%; ***4***: more than 30% of program.
Literacy Conscious Science Teacher: Composite variable (see above) representing a simple sum of counts of reported literacy strategies, recognized literacy strategies, acceptance of responsibility for literacy in science and confidence to do so. This produces a relative comparative scale from **11**: lowest count on all categories, to **24**: highest count.

Figure 2 The Impact of Literacy Preparation on Science Teacher Orientation

No other interactions between this derived variable and participant backgrounds were statistically significant. It appears that appropriate formal teacher preparation will increase teacher consciousness of the literacy load of science and encourage teacher enthusiasm to reduce that load.

CONCLUSION

Schooling systems can seem characterized by great inertia and both literature and experience provide evidence of teacher resistance to change. Education policy sometimes seems to have little impact on children's experience in classrooms.

Previous research suggests that when research responds to recognizable problems in their science classes, and curriculum adjusts to that research, and pedagogy provides approaches that teachers understand and apply, then those teachers may behave differently in their classrooms and laboratories. The findings of this project suggest that policy responding to substantial, but less immediately obvious, student difficulties may still be effective with sufficient support in teacher preparation programs. Teacher education programs need to emphasize a broad range of literacy in science activities and make this connection clear, particularly with regards to multiliteracies and multimodality of texts. All students experience the literacy load of secondary science, although its impact may be clearer in linguistically diverse contexts, and the information on Table 2 suggests that contemporary exposure to science classes at various levels may help teachers to recognize its impact on monolingual students.

When scientists first began to meet regularly and write for each other in English, Thomas Sprat advised a "close, naked, natural way of speaking" (1667/1958, p. 113) but the language of science has long ceased to have those characteristics. The load that such specialist language adds to student learning provides problems that are visible in many science classes. Students from diverse linguo-cultural backgrounds, and their teachers, are likely to distinguish between the impact of that literacy load and the conceptual demands of secondary school science. Students in less diverse contexts, where they share the local monolingual culture with their teachers, are more likely to interpret comprehension difficulties as arising from their own shortcomings, those of their teachers or the intrinsic difficulty of the subject. The literacy load of the subject can appear to fade in such contexts.

However, like the ditch that disappears as grass lengthens, that literacy load can still trip up an unwary hiker. Difficulties often arise from specialist styles, rather than student ignorance, teacher incompetence or disciplinary obscurantism. Underperforming students, incompetent teachers and difficult subjects all exist, but perhaps specialist language style should be considered before assigning such blame.

This paper suggests that policy can respond to converging research streams in ways that influence how science teachers are prepared for work in schools. The way that literacy issues were treated in the preparation of teachers who participated in this study seems to have influenced both their perceptions and their reported actions in contexts where that overgrown ditch may not have been so obvious (see Figure 2). If that is the case, it is reasonable to expect that the impact of changes in policy and preparation will be even greater for teachers facing more diverse classes.

Literacy courses are a challenging part of teacher preparation across the curriculum and for professional development. Poole's reporting of "*It's not our job*" (1995, p. 16) referred to infusion of values in science teaching but it is also reflected in the results of this study. Two thirds of the participating teachers were not conscious of the literacy load of their subject, but policy influence on teacher preparation and development has made a sufficient impact on enough teachers to influence student learning in more science classes than previous research appears to suggest. Maintenance of both policy pressure and teacher preparation support should continue to encourage expansion of science teacher recognition of the literacy load of their subject, with consequent improvements in secondary science student learning.

LIMITATION & FURTHER RESEARCH

The study on which this paper was based drew on participant indications of their attitudes to literacy load and reports of their actions in science classrooms. Such data sources are common in social and educational research, but they depend on the frankness and detail of participant contributions. Observations of teacher behavior in science classes and subsequent student achievement would be a useful extension to this work..

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