Chapter 36
Science Education in Rural Settings: Exploring the 'State of Play' Internationally

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The existence of the *Journal of Research in Rural Education, Education in Rural Australia, Rural Educator* and the *Rural Society Journal* reflects that rural education is a clearly defined area of research. Reviewing the articles represented in these publications highlights (a) a broad diversity of topics pertinent to the research area (see Arnold et al. 2005 for a recent synthesis) and (b) an apparent dichotomy around the focus of the research. For example, at one end of the spectrum, studies emphasise what Mary Jean Herzog and Robert Pittman (1995) refer to as a 'deficit model' of rural community and lifestyle as they explore the issues and challenges experienced by schools situated in these locations. Debra Holloway (2002) provides an extensive synthesis of this literature as she discusses the variety of concerns facing teachers working in rural communities in the USA. At the other extreme, research accentuates the high rate of success underpinning education and schooling in rural areas (Haller et al. 1993; Alspaugh and Harting 1995; Arnold 2001; D'Amico and Nelson 2000). Joyce Stern (1994) particularly acknowledges the early 'pioneering' role of rural teachers in the USA by implementing strategies around multi-grade teaching, cooperative learning, interdisciplinary studies, peer tutoring and block scheduling, which are now commonplace in classrooms across the globe.

This dichotomy is also evident in the science education literature, although the pool of available studies with a focus on rural settings is considerably fewer. The most recent publication by James Steve Oliver (2007) is a book chapter entitled *Rural Science Education* in which he addresses four broad aspects. First, he considers the many difficulties around defining 'rurality' and attempts to identify characteristics of rural schooling that are 'universal'. Second, he provides a historical perspective on research in science education from the 1960s to the 1990s that

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describes the condition of rural science teaching during the period. While focused predominantly on research conducted in the USA, the findings are pertinent to other countries facing similar challenges. Third, he outlines the Rural Systemic Initiative Movement in Science, Mathematics and Technology Education (RSI) in the USA and six drivers to use as "guideposts or standards about which the progress of systemic reform could be measured" (2008, p. 357). Finally, he discusses the ramifications and implications of these findings for teacher education programs. This is a critical component if educational authorities are to devise policy around the provision of challenging, relevant and opportune pre-service and in-service professional development to address the needs of rural science teachers.

The work of James Steve Oliver (2007) and others begins to unravel the apparent inconsistencies in the research data for rural settings. This chapter attempts to develop the area further by exploring the following questions. What is the extent of the impact of a rural location on student achievement in science internationally? What can we extrapolate from the existing research around rural education that helps to explain the dichotomy in the findings? Considering the research findings more holistically, what direction for science education in rural settings emerges for the future? Subsequently, rather than critique a range of individual research studies around science education in rural settings (given that this already exists), this chapter identifies the major themes emerging from this prior research and attempts to provide a broader and holistic perspective upon which to consider future directions.

Student Achievement in Rural Settings

In considering the research available around science education in rural locations, student achievement is often a prime area of focus. This is one area where inconsistencies in the data proliferate, with some studies suggesting that students in rural areas achieve more highly than their peers in urban centres (Fan and Chen 1999) while other research suggests that the reverse is the case (Canadian Council on Learning [CCL] 2006; Panizzon 2009). What is most interesting from a research perspective is when these discrepancies occur *within* the same country. For example, in the case of the USA, Frank Beck and Grant Shoffstall (2005) found that rural students in Illinois attained higher results for the Illinois Standards Achievement Test (ISAT) than their urban peers. Alternatively, Vincent Roscigno and Martha Crowley (2001) identified that students in rural areas exhibited lower levels of achievement than urban students using National Longitudinal Education Study (NELS) data. Clearly, one issue emerging here is that comparisons within or across countries are difficult given the lack of a common metric or standard upon which to base the evidence. This is complicated further by the alternative definitions of rurality used in particular studies (Kannapel and Young 1999 for the USA; Lyons et al. 2006 for Australia). However, data from the Programme for International Student Assessment addresses both issues and provides a common metric and consistency around a definition of 'rurality'. For PISA, geographical locations are defined solely around population size:

1. Village, hamlet or rural area with fewer than 3,000 people
2. Small town with between 3,000 and 15,000 people
3. Town with between 15,000 and 100,000 people
4. City with between 100,000 and 1,000,000 people
5. Close to centre of a city with over 1,000,000 people (OECD 2006)

To facilitate a comparison across participating countries, mean scores for science from PISA 2006 were reviewed along with their standard errors (*SE*). This measure expresses variation around the mean, with a lack of overlap of *SE*s suggesting significant differences between the individual values. Results of this analysis for selected countries are summarised in Table 36.1.

In reference to Table 36.1, three broad patterns in relation to location are identifiable including countries in which the:

- Mean score for rural students is considerably lower than urban students' scores
- Mean score for urban students is lowest when compared to all other locations
- Mean score variation across geographical locations is minimal, suggesting a high degree of homogeneity

Considering the first set of countries, the relatively low *SE*s across PISA categories for Australia, Canada and to a lesser extent New Zealand is indicative of potential significant differences. The extent of the 'rural versus urban' divide in student achievement for these countries is supported by research including Lyons et al. (2006) for Australia, the Canadian Council on Learning (2006) for Canada, with Panizzon (2009) reporting initial evidence of a gap in New Zealand. The data for Korea suggest a clear gap between the rural students (i.e. PISA categories 1–2) and students in more urbanised areas (i.e. PISA categories 4–5), even though the *SE*s are high for a number of these categories. Germany is interesting in that students in small towns and cities (i.e. PISA categories 2–4) achieved more highly than both highly rural and urban students (i.e. PISA categories 1 and 5, respectively). However, the high *SE*s for three of these categories indicate that the differences might not be significant, thereby explaining why this gap is not documented in the literature.

In contrast to this first group of countries, results for the UK and the USA suggest that rural students achieve higher mean scores than their urban peers. While little research is available to corroborate the results for the UK, as discussed earlier, there is considerable research data from the USA that provides conflicting results about student achievement according to geographical location. It is interesting to note that, in the USA, the highest mean score is for PISA category 3 representing centres with populations of 15,000–100,000 people. Clearly this raises the issue about how 'rural' is defined, which goes part of the way in explaining some the inconsistencies in the data for the USA. This aspect is discussed in detail later in the chapter.

The final pattern of countries including Denmark and Ireland suggests a high degree of homogeneity with minimal differences in the achievement of students in

Table 36.1 Patterns of science means for PISA 2006 based on geographical locations

Pattern across geographical location	Examples of countries	PISA category	*M*	SE
Rural mean score lowest across locations	Australia	1	502	8.01
		2	507	6.22
		3	518	4.22
		4	536	4.38
		5	536	4.57
	Canada	1	507	5.68
		2	539	4.21
		3	537	3.34
		4	539	4.01
		5	535	7.51
	Germany[a]	1	453	14.94
		2	516	7.73
		3	526	7.70
		4	521	13.61
		5	487	17.77
	Korea	1	469	16.18
		2	463	14.16
		3	505	10.90
		4	528	4.91
		5	527	5.68
	New Zealand	1	499	9.52
		2	518	11.08
		3	530	5.67
		4	545	4.93
		5	530	6.75
Urban mean score lowest across locations	UK	1	549	11.88
		2	528	5.69
		3	518	5.01
		4	503	7.72
		5	501	15.20
	USA	1	497	5.73
		2	485	6.67
		3	511	6.57
		4	486	12.72
		5	440	12.88
Minimal difference in mean scores across locations	Denmark	1	489	5.97
		2	495	5.45
		3	498	4.44
		4	496	11.27
		5	532	16.43
	Ireland	1	501	5.43
		2	512	4.90
		3	502	6.99
		4	513	13.23
		5	516	8.36

[a] Different pattern from other countries in the group

relation to location evident from the data. Hence, neither country is likely to be represented in the rural education literature, which does appear to be the case.

Subsequently, this broad analysis of data patterns indicates that the gap between the achievement of rural and urban students appears to be an international issue for a number of countries that participated in PISA 2006. However, other examples are evident in the literature with Adebowale Akande (1990) highlighting a gap for Nigerian students; Christine Liddell (1994) within the South African context; Harold Stevenson and colleagues (1990) for Peruvian students; and, finally, UNESCO (2003) for students in South American countries. Critically, only a small proportion of these countries is represented in the research literature.

In an attempt to explain this particular outcome, it is important to recognise the need for higher-level statistical analyses to ensure that confounding variables do not mask the impact of location. An excellent study that demonstrates the importance of statistical procedures being applied and implemented in this manner is provided by James Williams (2005) in a detailed study of PISA 2000 mathematics results. A number of the aspects raised by Williams are discussed in the following section.

Reflecting on Rural Science Education Findings

An audit of the science education research literature for rural settings highlights a wide diversity of topics impacting rural schools including teacher recruitment and retention (Holloway 2002), teacher subject knowledge (Carlsen and Monk 1992), teacher qualifications (CCL 2006), teacher preparation and the quality of ongoing professional development (Holloway 2001; Oliver 2007), accessibility to resources (Truscott and Truscott 2005) and teacher expectations of students (Gilbert and Yerrick 2001). Again, there are often contradictions about the extent to which these aspects impact on rural schools. To help explain some of these discrepancies, Wang Fan and Jin-Quan Chen (1999) highlight four potential limitations in relation to the research findings including: (a) inconsistent and unclear definitions of rurality; (b) the potential for ethnicity and the school sector to act as controlling variables; (c) issues around school selection and the research sample; and (d) socio-economic status (SES) as a confounding variable.

Potential Limitations of Previous Studies

1. *Definitions of rurality*. Implementation of different criteria across and within country comparisons make comparative studies meaningless because population size (OECD 2006; Stern 1994), school size (CCL 2006; Huang and Howley 1993; Simpson and Marek 1988) or the area served by a school (Liu and Brinlee 1983) are used to categorise rural and urban localities. Complicating this further, students live in what can be defined as urban locations but they choose to travel

to rural schools. This increased mobility makes it even more difficult to define 'rurality' (Gilbert and Yerrick 2001).

2. *Ethnicity and the school sector as controlling variables*. Fan and Chen (1999) suggest that ethnicity varies markedly across geographical locations, although, historically, there was greater homogeneity in rural areas (Nachtigal 1982). Given that links between ethnicity, poverty and socio-economic status are identifiable in the broader research literature, researchers suggest that ethnicity needs to be considered as a confounding variable in any analysis of rural settings (Biddle and Berliner 2002; Truscott and Truscott 2005). Similarly, few studies differentiate between public and private school sectors in their designs, even though significant differences in student achievement between the school sectors are evident in the research data (Fan and Chen 1999). This aspect is elaborated upon in relation to the research sample.
3. *School selection and research sample*. James Williams (2005) and James Oliver (2007) raise the issue of relying on convenience or local samples of schools that do not provide appropriate representation. In their view, most rural research merely incorporates rural schools because of convenience, with few research studies actually seeking to understand the 'rural-specific issues' relevant to the context. As quoted by Mary Jean Herzog in Topper Sherwood (2000, p. 161): 'People will do a study in a rural area and think this makes it a rural study; but they aren't necessarily the same thing'. This aspect was explored by Michael Arnold et al. (2005) through a detailed audit in which they filed studies into two possible categories. *Rural-specific studies* focused on issues in rural schools and were indicative of 66% of papers. In contrast, *rural-context studies* explored generic issues in rural school and accounted for 34% of the literature. Such representation is positive although Fan and Chen (1999) suggest that, without a non-rural setting for comparison in any rural study, it is impossible to discern generic teaching-related issues from those that are rural-specific. Importantly, comparative studies across urban and rural settings are rare in the science education literature.
4. *Socio-economic status (SES) as a confounding variable*. There is already a strong correlation demonstrated between student achievement and socio-economic status in the literature (CCL 2006; Howley 2003; Khattri et al. 1997; Williams 2005). In many countries (e.g. Australia) rural settings tend to have lower socio-economic status than urban areas so that any analysis that does not control for this variable hides the actual impact of locality on student achievement in science (Lyons et al. 2006). For example, in a large-scale study of rural Australian students in science, Diedre Young (1998) used multi-level modelling techniques to control for SES to highlight that students were not disadvantaged by location but by differences in relation to their self-concept. In her view, student variability in science achievement was influenced more at the level of student and classroom than by geographical location. To explain this result further, Williams (2002) suggests that, while Young (1998) considered community-level SES, it is critical to distinguish this from school-level SES, which is overlooked in the majority of research studies.

Attempting to Address These Research Limitations

A number of these limitations were addressed in a large-scale national study conducted in Australia around science, mathematics and information and communication technology (ICT) education (Lyons et al. 2006). The study consisted of five questionnaire surveys designed for primary teachers, secondary science, ICT and mathematics teachers and parents. Essentially, the science teacher surveys sought views around the availability of: (a) qualified science teachers in schools; (b) material resources and support needs; (c) accessibility of professional development; and (d) the availability of science learning experiences for students.

Schools in the study were categorised using the MCEETYA Schools Geographic Location Classification based upon population size and accessibility to a range of facilities and services to produce four main categories: Metropolitan Areas, Provincial Cities, Provincial Areas and Remote Areas (Jones 2004). Surveys for secondary science teacher were distributed to 1998 secondary departments or faculties (i.e. high schools) in all provincial area and remote area schools (i.e. rural schools) across Australia, along with a stratified random sample of 20% ($n = 291$) of metropolitan secondary departments. Responses were received from 580 secondary science teachers representing 334 secondary departments.

A number of analytical strategies were implemented including chi-squared tests on categorical data, principal components analysis on Likert Scale items, and MANCOVAs for comparing the component scores across various respondent categories (e.g. sex, indigenous populations). The MANCOVAs also controlled for the effects of school size and the socio-economic background of the school location. Some of the major findings were:

- Science teachers in different locations reported significant differences ($p < 0.001$) in the annual turnover rates of staff and the difficulty in filling vacant science teaching positions when compared with teachers in metropolitan schools.
- Science teachers in provincial cities and areas were twice as likely, while those in remote areas were four times as likely, as those in metropolitan areas to identify that it is 'very difficult' to fill vacant science teaching positions in their schools.
- Science teachers in provincial areas were twice as likely, and those in remote areas were about three times as likely, as those in metropolitan areas to teach a science subject for which they are not qualified.
- Science teachers in provincial and remote areas demonstrated a significantly ($p < 0.001$) higher unmet need than teachers in metropolitan areas for professional development opportunities that provide help with teaching targeted groups of students (e.g. gifted and talented, indigenous and special needs). In contrast, teachers in metropolitan schools had a lower level of unmet need for *every* professional development and resource item (e.g. laboratory consumables) included in the survey.

Incorporation of a representative sample of rural and non-rural schools in this study facilitated the comparisons necessary to identify significant differences between the needs and experiences of secondary science teachers across geographical locations in Australia. Strengthening the emergent findings from this study was the controlling of school size and socio-economic status, thereby addressing some of the limitations identified in previous research (Arnold et al. 2005; Fan and Chen 1999; Williams 2005). Another positive outcome of the study is that it provided an opportunity to compare the findings across secondary science, mathematics and ICT teachers given that similar but separate surveys were implemented with each group of teachers (see Lyons et al. 2006 for the full report).

However, one of the constraints of the national study was the focus around issues already evident in the literature (i.e. retention, resources, professional development). So, while it provides substantive evidence for Australian educational authorities about prevailing concerns around the teaching of science in rural settings when compared to other geographical locations, it did not allow other factors not yet identified in the literature to be investigated.

Clearly, much is known about the types of factors that influence the effectiveness of science teachers in rural communities, even though the data are somewhat inconsistent. The discussion of potential limitations of previous research goes some way in explaining some of these ambiguities but not all. Another key component to recognise is the diversity that exists among schools and communities that are designated as rural. For example, Mike Arnold (cited in Sherwood 2000, p. 161) suggests that 'there is poor "rural" and wealthy "rural". There's "rural" with no minorities, and "rural" with high minorities'. Similarly, Jerry Horn (1995, p. 3) states: '[T]he simple fact is that rural people, rural communities and rural conditions are so diverse that one can find evidence to support nearly any characterization'. Hence, it is recognition of this variation within rural settings that helps to explain further the discrepancies in the data around student achievement and the impact of schools in not only rural but also urban education. This component is explored in more detail in the final section of the chapter.

Future Directions for Rural Science Education Research

In 'stepping back' from the literature, alterative perspectives emerge that compel us to consider science education in rural settings in a more holistic fashion. Before exploring this avenue further, it is imperative to recognise what Alfred Schultz referred to as a 'life-world' (Schultz and Luckmann 1973) around rural communities that must be understood to appreciate the complex and highly dependent interactions that exist between rural schools and the communities in which they reside (Barley and Beesley 2007; Harmon et al. 2003; Howley et al. 2005). Critically, this life world is very different from that of an urban setting, which explains the importance of specific science education research for rural and urban settings. However, given this premise, it is possible to identify similarities across the two spheres that 'unifies the cause' (Truscott and Truscott 2005). For example, Howley et al. (2005, p. 3) suggest that:

> [r]ural education research simply must ask what sort of schooling rural kids are getting, why they are getting it, who benefits, who gets injured in the process, and by what mechanisms?

Surely, the same questions are pertinent to research around urban schooling? Perhaps finding an alternative way of conceiving the research area will help to overcome some of the difficulties experienced by researchers in their attempt to develop a coherent research framework around rural science education (Kannapel and DeYoung 1999; Lyons et al. 2006; Oliver 2007). As expressed by Topper Sherwood for the US context (2000, p. 164):

> Researchers have tried to establish a 'rural education research agenda' at least since 1984, but no effort seems to have been dynamic enough – or well funded enough to capture the research community as a whole. Successes in rural research have been as isolated as some rural communities.

Diane Truscott and Stephen Truscott (2005) provide a radical exemplification of an alternative lens by suggesting the replacement of the rural–urban antagonism with a 'high-need versus resource-rich school' perspective (p. 1). In their view there are four critical factors that impact on the quality of education received by students regardless of location.

1. *Catering for increasing diversity*. Truscott and Truscott note that, over the last decade, there has been an increase in ethnic and racial diversity in many rural communities in the USA as people migrate away from urban centres in search of work. Subsequently, there is no longer the ethnic homogeneity assumed in much of the early rural education literature (Nachtigal 1982).
2. *Overcoming childhood poverty*. One of the most ubiquitous challenges for all schools is that poverty is linked not only to ethnicity but also to lower student achievement and self-efficacy (Biddle and Berliner 2002; Teachman et al. 1997; Young 1998). Quite simply, 'poor children fare worse in school and are less likely to graduate from high school' (Truscott and Truscott 2005, p. 2). This statement is supported by research evidence that recognises poverty as an issue in both rural and urban schools, with traditional generalisations about the wealth of rural communities in the USA being no longer applicable (Michael Arnold cited in Sherwood 2000; Horn 1995).
3. *Lack of adequate financial resources*. Biddle and Berliner (2002) suggest that having inadequate resources aligns strongly with poverty because schools with a higher proportion of poor students often receive less government funding. While urban or metropolitan areas are known for poverty and a lack of adequate resourcing (Calabrese Barton 2007), Truscott and Truscott (2005) allude to the high levels of poverty in many rural communities in the USA where science teachers constantly struggle to obtain the funds needed to maintain school laboratories. Similar findings around resources emerged for research involving Australian secondary science teachers (Lyons et al. 2006).
4. *Recruiting and retraining 'good' quality teachers*. While often alluded to in relation to rural settings (Barrow and Burchett 2000; Holloway 2002), many urban schools also struggle to recruit and retain qualified science teachers (Calabrese Barton 2007).

Collectively, these factors encompass the notion of *equity* and the recognition that some schools, because of their clientele, geographical location, SES or community context, require more support if they are to provide their students with educational opportunities equivalent to those in the 'resource-rich schools' referred to by Truscott and Truscott (2005). Exploring this area further, Angela Calabrese Barton (2007) discusses an *equity metric* for science and mathematics developed by Jane Butler Kahle (1998) for implementation in urban schools. The resource-based indicators (e.g. course enrolment, quality of courses, teacher expectation, instructional quality, out-of-school experiences) used to assess the degree of equity in urban schools are equally appropriate for rural schools.

Similarly, Steve Oliver (2007) identifies six drivers guiding systemic reform in rural education in the USA that are relevant to schools in urban areas: (a) a standards-based curriculum; (b) consistent policies to ensure high-quality science education; (c) convergence of resources; (d) unification of stakeholders towards a common goal; (e) the need for quality evidence around student achievement; and (f) the basic need to improve the achievement of all students. Subsequently, these examples demonstrate that there is an opportunity to develop a coherent and high-quality research framework across high-need rural and urban schools that incorporates the broader contextual and community factors that impact on schools. The advantage of such a perspective is that it might attract the sustained interest of educational authorities and governments given the focus on a wider cross section of the student cohort. The central thesis presented here is captured succinctly in the following quote from Truscott and Truscott (2005, p. 5):

> The problems facing high-need urban and rural schools are long-standing, deep, and pervasive. The similarities that exist between urban and rural schools are pronounced, as both respond to day-to-day challenges brought on by the effects of poverty, insufficient school funding, and external socio-political demands. Short term fixes and abrupt changes in emphasis cannot succeed. Successfully addressing these problems will require sustained, multifaceted efforts that address many areas simultaneously and evolve continuously.

Conclusion

Evidence from PISA 2006 suggests that there are a number of countries experiencing issues around science education in rural settings. Care does need to be taken in using data sets of this type because of the complex interaction that confounding variables, such as socio-economic status, ethnicity and school size, play in masking differences in student achievement across geographical locations. Interestingly, the investigation of the rural–urban gap in student achievement has been a major focus for the USA, Canada and Australia, judging by its representation in the literature. While rural education research appears to have a well-grounded tradition, this is not the case for science education in rural settings, with studies appearing relatively scant, difficult to access, and often reporting contradictory findings. A major weakness in the research design of many of these studies is the lack of inclusion of both rural and urban schools, which is necessary for meaningful comparisons (Fan and Chen 1999; Williams 2005).

In conceptualising a future research agenda for science education in this area, alternative views are emerging in the literature. The predominant view is about 'stepping back' from the fine detail to focus on the factors shared across geographical locations that restrict and limit the educational opportunities of all students. In other words, we need to raise the issue of *equity* because the research already demonstrates that the main school variables affecting student achievement and learning in science generally include the quality of school facilities, availability of resources and equipment, teacher qualifications and experience, ongoing professional development, and availability of specialists for support and mentorship (Truscott and Truscott 2005). However, improving these factors requires considerable financial resources in densely populated urban areas as it does in sparsely populated rural areas. Framing a research agenda across geographical boundaries has a greater likelihood of attracting the attention of governments and educational authorities because of the broader socio-political implications.

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