Chapter 5
Longitudinal Studies into Science Learning: Methodological Issues

Russell Tytler

The Gold Standard for education research promotes randomized controlled trials (RCTs) that can produce generalizable knowledge claims across similar problems and situations. Unfortunately, the Gold Standard does not fully recognize the need for developmental research to better understand the problem space, formulate theory and approaches to teaching and learning, and formulate and pursue associated research questions. This developmental research has been a precursor to the development of interventions together with the necessary instrumentation and technologies required to fully investigate these through the more formal evaluative processes imagined by the Gold Standard. This chapter focuses on longitudinal studies that cover a continuum from such developmental research to research that uses control-experimental features to evaluate interventions. These studies attend to a set of issues dealing with developmental progressions and learning trajectories that require investigation over an extended period of time. It will be argued that these longitudinal studies of a variety of methodological types represent quality research in that rigorous design and implementation produce evidence-based claims. The chapter examines the nature of the relationship between evidence and claims in these studies, to show the possibility of building in control features every bit as strong as those in classic Gold Standard designs. Further, it will be argued that, given the complexity of learning pathways, a simplistic interpretation of RCTs conducted over the shorter term can be misleading in terms of both internal and external validity claims.

5.1 Background

There have been relatively few longitudinal studies of student learning in science, despite the fact that the gains sought for in education generally are long term and permanent (Arzi, 1988, 2004; White & Arzi, 2005). Increasingly, learning is
becoming understood as a complex process involving the interaction of many elements and the building of understandings gradually over the longer term, rather than the sequential imposition of specific conceptions. A sequence of reports by the US National Research Council (1999, 2005, 2007) based on neuroscience and cognitive science research emphasizes the complex interactions between prior knowledge, maturation, experience, and instruction. It is claimed that “to be successful in science, students need carefully structured experiences, instructional support from teachers, and opportunities for sustained engagement with the same set of ideas over weeks, months, and even years” (2007, p. 338). As with curriculum and teaching, these views imply the need for research into student learning that is long term; yet studies of this kind are rare since they are difficult to justify and maintain in a climate where research interests and personal circumstances are unpredictable, research grant funding is normally for a maximum of 3–5 years, and Ph.D. cycles are focused on bounded studies because of timescale issues.

White (1987, 2001) called for longitudinal studies tracing the emergence and development of conceptions. Studies of the development of student conceptions in different domains have almost all been cross-sectional in design and with patterns of growth established by comparing responses of different age students. These studies often involve a mix of qualitative and quantitative analyses with comparative counts of categories of response. The methodological problems with these cross-sectional studies are twofold: first, it is difficult to guarantee that the cohorts are identical in composition to make valid comparisons; and second, while broad patterns might emerge to chart general developmental principles, these cannot be translated to the learning and development pathways of individual students. Black and Simon (1992) argued, on the basis of the need to chart progression of children’s knowledge in science, that any proposal to explore progression “is hampered both by the lack of an effective theory of conceptual change and by the absence of substantial evidence about the changes in pupils’ ideas with time” (p. 48). Shymansky et al. (1993, 1997) described a complex pattern of conceptual gains and losses for teachers and students over separate interventions. In my own work (1998a, 1998b), a similar complexity of conceptual growth was shown over a 6-month period with understandings depending on context and explanations gradually becoming more consistent with time after the intervention ended.

These complexities in student learning call into question any evaluation of a short-term teaching intervention that does not acknowledge time-related growth or diminution in understanding. Long-term studies are needed to evaluate the effectiveness of teaching interventions in supporting student learning over the longer term. Shymansky, Yore, and Anderson’s (2004) study of a long-term, elementary schoolteacher, professional development program is an example of research that took this time factor seriously, both for exploring teacher change and investigating student attitudes and learning over the longer term. Yet most evaluations of teaching and learning interventions, either classroom sequences or large-scale programs are short term and do not trace ongoing benefits of short-term gains nor do they identify longer-term effects that may occur separately from those that are short term.