Learning Research

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Over the past decade we have been learning how to research learning - in classroom settings and elsewhere. Research into learning in classroom settings is widely practised. Increasingly, research is addressing teaching and learning events in the workplace. Historically, the research methods employed to investigate learning have been refined and replaced as our image of learning and, consequently, the goal of our research has changed. The availability of new technologies offers researchers the capability to compile rich data sets with a level of complexity not previously possible. The analysis of such complex data sets poses a significant challenge. While new technological tools also offer the possibility of new forms of analysis (particularly of qualitative data), it is the sophistication of our theories and analytic frameworks that will determine whether we are able to utilise the potential of the new techniques. Central to the realization of this sophistication is the operationalization of the constructs with which our theories are expressed. This paper explores contemporary approaches to researching learning and some of the questions associated with this type of research.

Introduction: Operationalized Constructs

Within mathematics and science education, there are several contenders for the title of central construct: ability, learning, teaching, competence, mathematical (or scientific) meaning, problem solving, understanding, reflection, abstraction, negotiation, task, and activity, come readily to mind. The difficulty with such central constructs lies in their observation and recognition within overt social activity. In order to recognize "Learning", for instance, we must develop an operational definition, whether formally articulated by a researcher, or implicitly enacted by a teacher. To whom are the operational definitions of our constructs most important? Those responsible for research and for assessment and evaluation are the most obvious users of operational definitions, since these are the groups responsible for the investigation, the monitoring and the refinement of the constructs which drive the domain. It is the research perspective that provides the focus for this paper.

The observation of any social activity: (i) involves an act of selection on the part of the observer, and may omit elements (actions or contextual details) which the participants or another observer would see as significant (*selectivity*); (ii) distorts the phenomena being observed,through the presence of the observer or through the act of observation (*indeterminancy*); (iii) cannot claim to represent the meaning which the activity has for the observed participant(s), but only the meaning which the researcher has constructed for the activity (*subjectivity*); (iv) misrepresents the construct by dissociating it from other related constructs (*reductionism*) when the meaning of the activity resides in the dynamic interplay of the combination of constituent constructs (for example, ability, affect, achievement, and understanding); (v) misrepresents the construct by dissociating it from the contextual setting of its occurrence (*decontextualization*); (vi) accords a reality to the construct as "observable" which misrepresents the inferential chain by which the researcher builds a representation of the construct as "observed" from overt social actions, even though the construct may relate to an individual's cognitive processes (*reification*); and, (vii) focuses only on the "observed activity" without recognizing that this is itself only a part of a larger social event (the research activity) which has its own participants (observer and observed), context (immediate social setting and enfolding research setting), purpose (observed task and overarching research aims), actions (including those of the researcher), and consequences (*dissociation*).

In summary: the apparent utility of operational definitions masks several concerns about their use in research. In particular, the commitment by the researcher to a specific operational definition of a construct being studied might render the research insensitive to some of the associations or nuances of meaning which actually characterize the construct from the perspective of the respondent/subject/student. Recent developments in educational research (and in learning theory) have led to acceptance of the idiosyncratic and legitimate subjectivity of the research subjects in comparison with the spurious claims regarding the objectivity of the researcher, which characterised earlier research. As a consequence, the goal of research into learning undertaken in 'naturalistic' social settings is not the establishment of the legitimacy of competing claims regarding "what really happened", but rather the consideration of what can be learned from the comparison of the multiple stories compiled from the accounts of the various participants (including the researcher's account) in the social setting.

The need for the operationalization of constructs is not diminished by this change in goal. Instead, the acknowledgement of the relativist character of any account of social activity commits us to defining explicitly those terms we employ in the analysis and comparison of the various accounts, since we are no longer able to presume any specific (absolute) meaning, by implicit appeal to the authority of culture or the conventions of use.

> The question mark that postmodernism puts on the 'truth' of all discourse means only that all knowledge is contextual, not that all knowledge is false, nor that one cannot support the validity of one claim over another in a specific circumstance.
>
> (Scholle, 1992, p. 276)

The operational definition of the terms we employ in comparing the various accounts derive from our purpose and help to make that purpose explicit for the reader of our research account. Commitment to a particular operational definition should not be construed as a claim to truth, but rather as delimiting the field of discourse - the boundaries of our analysis - within which the viability of various accounts can be compared.

Approaches to Learning Research

The word "community" is much in vogue amongst educational theorists. Mathematical activity, like scientific activity, is engaged in by individuals as members of intersecting communities of discourse and practice. It is membership of a community of practice that defines the context and the purpose that an individual associates with a task. It is as a member of a community of discourse that an individual construes the meaning of a task and frames an appropriate response. Classrooms may be conceived as communities of learners, but these are only one of the many types of communities in which teaching and learning may occur. It may be that it is the community that defines 'meaningful' learning. And a community may be a family, a clerical team, a class, a maintenance crew, a congregation, or a nation.

It has been acknowledged for some time that teaching and learning are organized quite differently in school and workplace setttings (Becker, 1986; Collins, Brown & Newman, 1989; Hall & Stevens, 1995; Lave & Wenger, 1991; Resnick, 1987; Rogoff, 1990). Yet, the means by which teaching and learning are organized as ongoing practical activities within workplaces has received very little study. Studies of ethnomathematics and 'street mathematics' (Carraher, 1988) have documented the character of the mathematics of daily economic transaction, in ways that distinguish it from 'school mathematics' without necessarily contributing to our evolving model of learning, other than to underscore the situated character of all learning.

What form does learning take in classroom settings? This is perhaps the most obvious of the questions which might be the subject of educational research, yet it remains one of the least well answered. Recent attempts to study learning have taken two common forms: Clinical studies of one or two children in situations described as "Teaching Experiments" (for example, Schoenfeld, Smith & Arcavi, 1993; Steffe, 1993); and descriptive studies of mathematics classrooms, in which videotapes of classroom interactions have provided data for later analysis (for example, Cobb, Wood & Yackel, 1992). Such studies have as their focus the construction of a model of the process of learning mathematics. The work of Steffe, Cobb and their co-workers presume a constructivist model of learning and seek to both validate and elaborate such a model through their research. Schoenfeld's approach is more concerned with theory construction.

Steffe and Schoenfeld have restricted their study to the learning of individuals in quite tightly controlled situations involving few participants. The challenge confronted by Cobb and his colleagues and other such classroom-based research is the challenge presented by the complexity of the classroom as a research site; the interaction of social and personal variables in a setting over which the researcher can exert no control. While studies of the first type might be characterized as "experimental" or, at least, "clinical", studies of the second type have much in common with ethnographic studies of community behaviours. However, this second category of studies retains a focus on the learning of participant individuals, and depends to a large extent on inferences concerning cognitive process drawn from videotape data of overt social actions.

There are advantages and disadvantages to both approaches. Either experimental control is retained by creating a research context which does not resemble the classroom contexts to which the research will ultimately be applied, or commitment to a realistic social context leads to a lack of control over variables and a lack of opportunity for interaction with the learners while learning and consequently demands a high level of inference on the part of the researcher as to the thinking that actually occurred during an observed lesson.

Each approach is also characterized by a particular theoretical position and a particular purpose. The 'Teaching Experiment' has been variously interpreted and applied, and in its most clearly articulated form offers a distinct methodological alternative to either workplace or classroom research, since it accepts no obligation to mimic or to investigate society's 'naturally occurring' educational settings.

> The teaching experiment methodology is based on the assumption that students have a mathematical reality that is distinct from that of the researchers, and that the researchers, through interacting with the students, can come to understand that mathematics and how to engender changes in it in ways that seem appropriate and productive.
>
> (Steffe & Thompson, 1996, p. 23)

In identifying the purpose for their research, Steffe and Thompson articulate a reform agenda to be informed by Teaching Experiment research.

> It is our intention that the mathematics of students replace contemporary school mathematics. This is the main thrust of our work, and we want it to be understood in this way. We strive to specify the mathematical concepts and operations of students and to make those the conceptual foundations of school mathematics.
>
> (Steffe & Thompson, 1996, p. 2)

Schoenfeld and Clarke and their co-workers (Schoenfeld, Smith, & Arcavi, 1993; Clarke, 1996), while employing very different research techniques are similarly committed to the development of models by which the learning of mathematics might be represented in order to inform instruction. An exhaustive discussion of different approaches to researching learning is beyond the scope of this paper. The research methods and analytical techniques of Schoenfeld and Steffe exemplify the richness and diversity of the research endeavour in mathematics education. The remainder of this paper examines research in classrooms.

Classroom Research

Learning has been studied in many ways and in many settings. Classrooms are distinguished by being environments with the specific purpose of serving as sites for learning. Learning in classroom settings is no less situated than learning in other settings. This may seem an obvious assertion, but one consequence of the current enthusiasm for workplace learning could be an eroding of the status of the classroom as a setting for legitimate, meaningful mathematical activity. If the community is to continue to employ schools as the principal means by which young people are educated and enculturated into academic disciplines, then educational research must attend to the characteristics of the learning environments in such settings and to the processes by which learning occurs in classrooms. Many researchers have made the classroom the focus of their efforts (for example, Yackel & Cobb, 1993). There are certain characteristics of structure and purpose shared by all classrooms. Equally, each classroom presents a unique social setting, which facilitates and constrains the actions of all participants and the form of the consequent learning. Classroom research typically attempts to capture the characteristics of learning in one classroom in a form that will bear translation to other classrooms.

Early attempts to research learning in classrooms made extensive use of non-participant observation. The following excerpt from Bourke (1984) is representative of the reporting of data collection by observation.

> The observers used were all qualified teachers and were trained to use a low-inference classroom observation schedule . . . The observer was required to record, approximately every five seconds, the class grouping being used, the participants in each classroom interaction, and the nature of the interaction for a series of five minute periods during the lesson.
>
> (Bourke, 1984, 6)

Among the noteworthy observational techniques are Flanders' work on *Interaction Analysis*, (Amidon & Hough, 1967), and the *Systematic Classroom Analysis Notation (SCAN)* (Beeby, Burkhardt & Fraser, 1980). These techniques are typical of the observation schedules employed by non-participant observers. Researchers seeking naturalistic or ethnographic data have typically involved participant observers. That is, observational data is collected by researchers who are participant in the actions, events and contexts being studied.

Much of contemporary classroom research employs videotapes of classroom activity. The use of videotapes allows the exhaustive analysis of classroom activity at a level of detail which a classroom observer applying an observational code in real time could not hope to emulate. Videotape data provide a permanent record amenable to multiple analyses. However, to infer student thought processes and the significance of classroom events on the basis only of videotape data has been viewed as an unjustified extrapolation, and many researchers sought to supplement their videotapes with other sources of data. The resultant composite data sets were rich, complex and multi-faceted.

> Observational procedures included video recording, audio recordings of public and private student talk, continuous observations of individual case study student behaviours, and photographic records of student work. Our purpose was to create the fullest possible continuous record of each individual case study student's experience of the unit.
>
> (Alton-Lee & Nuthall, 1992, p.4)

Other researchers (Anthony, 1994; Clarke & Kessel, 1995) sought to minimize the need for researcher inference regarding student thought processes. Clarifying and corroborative data were provided by the students themselves in interview situations, where their accounts of the significance of classroom events and their associated thought processes could be reconstructed with the assisting prompt of the classroom video record. More detail regarding the rationale for this research technique can be found elsewhere (Clarke, in press; Clarke & Kessel, 1995).

The technique employed by Clarke and his co-workers provides an illustration of the use of currently available technology and can be outlined quite simply. One camera is directed at the teacher, while the other camera is focussed on a group of about four students. The teacher's utterances are recorded through a radio microphone and a single microphone was used to record the conversations of all four students. The two video images are mixed to produce a composite picture in whch the students occupy most of the screen with the teacher image superimposed in a corner of the screen. This combined image is recorded onto video-8 tape using a compact videorecorder attached to a laptop computer. The researcher, seated at the rear of the classrom, is able to listen simultaneously to both student conversations and teacher utterances and recorded field notes onto a word processing document on the computer using *CVideo* software (Rochelle, 1992). The field notes can be "time-tagged" to corresponding events in the video record. The field notes enable the researcher to document impressions of significant classroom episodes and learning events as well as provide reference markers for the subsequent interviewing of student subjects.

Students from the groups which had been videotaped are interviewed immediately after the lesson. The videotape record is used in the interview to stimulate student recall of classroom events. The use of the *CVideo* software enables the researcher to locate within the field notes reference to actions of the student which seem to be of significance either to the researcher or to the student. Having found a particular item in the word document, the software can be used to very quickly find the corresponding moment on the video record. This is then played back and discussed. The audio record of the interview provides a third source of data. A more detailed account of this research technique can be found in Clarke (in press) and Clarke and Kessell (1995).

Other researchers, notably Ball (1993, for example), have compiled sets of related data, including classroom videotapes, interviews and student work samples, and utilized available computer technology to synthesise a single complex interconnected data file. Such complex data files are amenable to multiple analyses, facilitating equally the investigation of particular behaviour types over many students or many lessons and the longitudinal study of an individual's learning. It is the analysis of such complex data sets that now presents the most significant challenge to learning researchers.

Analyzing Complex Data Sets

Research techniques, such as those outlined above, offer researchers richer, more complex sets of data than have ever been available before. The analysis of such complex data sets poses a significant challenge. One aspect of this challenge is the search for effective theoretical lenses through which to view the data.

Gore (1994) employed the work of Foucault (1977, 1980, for example) to carry out "a systematic multi-site study of the micro-level functioning of power relations" in classroom settings. Gore (1994) explicitly sought to "systematically examine the minute practices of classrooms." In this case, Foucault's writing on the subject of power relations formed the basis of a coding system. Gore stated explicitly that her research was not an ethnography, but, instead, applied a complex coding system to detailed descriptions of classroom events in order "to illuminate the mechanisms of schooling."

By way of contrast, Jungwirth (1991) identified a theoretical position which synthesised symbolic interactionism and ethnomethodology in her use of "microsociological approaches."

> These are based on the following assumptions: People construct subjective meanings for things but nevertheless arrive at a common reality and at a knowledge which is experienced as universally valid. The commonly accepted valid meanings are the result of social negotiation processes. As a consequence, social interaction establishes the reality to be analyzed.
> (Jungwirth, 1991, p. 266)

Another approach is the development of new methods for the schematic representation of data. Such schematic systems carry implicit theoretical meaning, since certain spatial associations and arrangements are allowed within the system while others are precluded. One example is Schoenfeld's recent use of such a schematic system to represent the shifts in teacher goals in the course of instruction (Schoenfeld, 1996).

> The basic idea is that a lesson can be parsed into large units corresponding to large-scale action plans, that these in turn can be parsed into smaller units (corresponding to smaller-scale action plans), and so on - down to the level of small linguistic chunks, on the order of a line or two of transcript.
> (Schoenfeld, 1996, p. 6)

As Feynman demonstrated in physics, a schematic system can be a powerful analytical tool; modelling relationships between key variables, embodying specific algorithms and suggesting further research questions and lines of investigation. Schoenfeld's scheme offers this sort of analytical power and could be applied with equal legitimacy to the analysis of shifts in student goals. An example of the application of this scheme for "A full parsing representing action plans and goals" is given in Figure 1.

> If you trace across horizontally, you can see that each chunk on the left (an action plan) contributes to at least one of the goals on the right. By looking at the "goal traces" on the right, we get a sense of which goals were addressed, how frequently and how intensively.
> (Schoenfeld, 1996, p. 9)

Clarke, Helme and Kessel (1996) have used the *NUD•IST* computer package to analyze the complex text files compiled from the synthesis of classroom videotape transcripts, observational field notes, and student interview transcripts. For example, text analysis can identify points at which the student's state of knowing demonstrably changes from uncertainty to comparative certainty or conviction. It may be that a student recounts a situation in which they came to "know" or to "understand" something related to the topic dealt with in the observed lesson. These accounts are also taken to constitute data regarding the process of coming to know.

In particular, any student use of the verbs, "know", "understand" or "learn" can be analysed in detail with regard to the subject and object of each verb's use. That is, what sort of things can be "known", "understood" or "learned"; what sort of experiences, events, images, or people appear to be associated with "learning", "understanding" or "coming to know"; and, who is it that "knows", "understands" or "learns" things? In this analysis, the software package *NUD•IST* (QSR, 1994) is employed to undertake a textual analysis of the frequency of association of terms such as those above in student classroom discourse and in student discussion of video-recorded classroom situations.

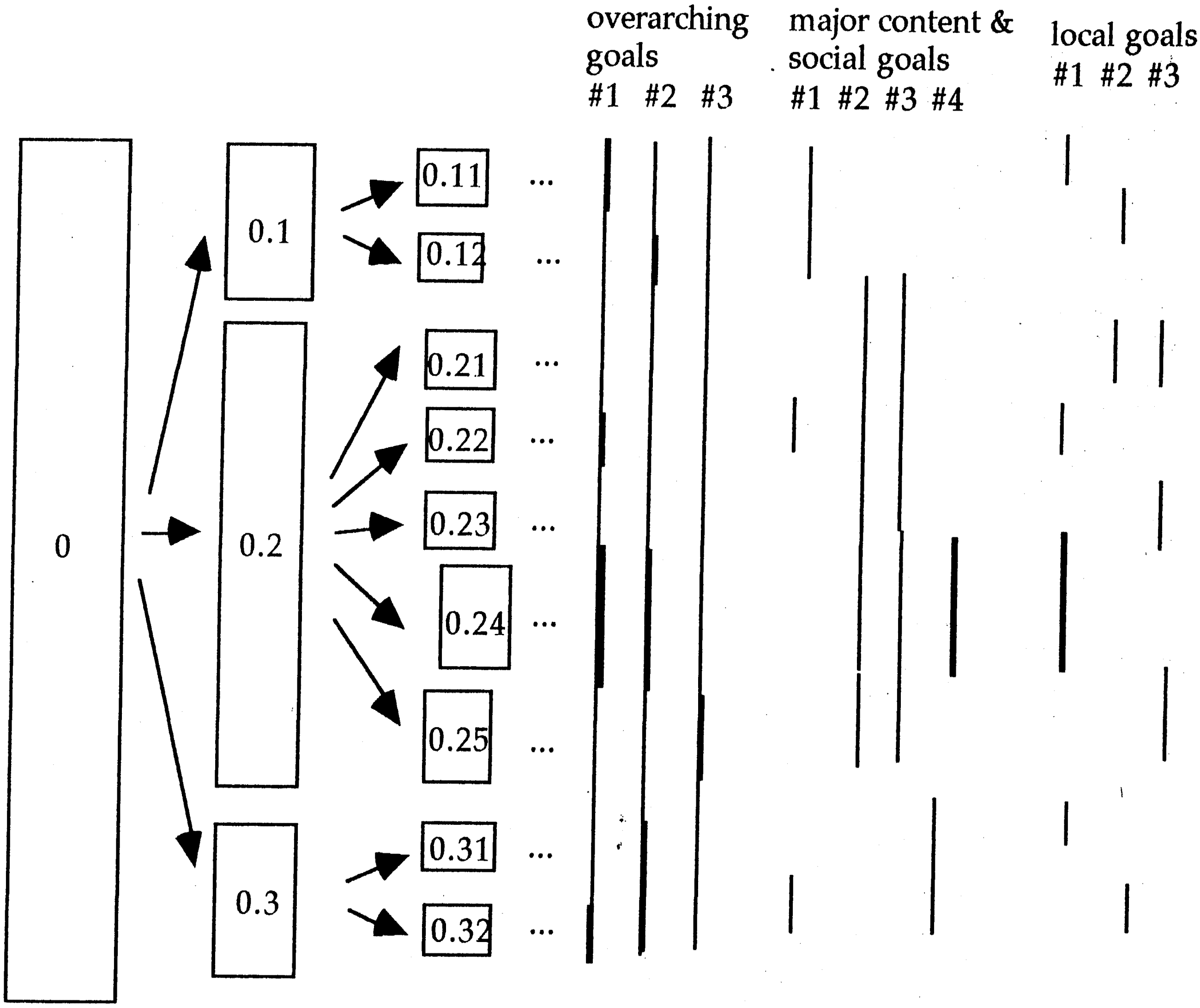

Figure 1

NUD•IST is fundamentally an indexing tool, which allows the cross referencing of particular terms or phrases. Central to its use in this type of research is the capability of *NUD•IST* to reveal clusters of related terms: related by common situation (textual or social situation), or by association with a common key term or referent. In addition, relationships can be identified between clusters of terms. *NUD•IST* facilitates the identification of the sort of "grounded key" discussed by Glaser and Strauss (1967). The search for the associations between textual elements, which appear to structure the process of coming to know, is a form of exploratory content analysis. Use of *NUD•IST* is intended to reveal structure within the learning process by identifying "nodes" of associated terms such as "know" and "understand". Structures emerge through the associations identified between these nodes. The use of an indexing tool such as *NUD•IST* offers a form of replicability not previously associated with conventional content analysis. As with any content analysis, the identification of "key terms" must derive from a clearly articulated theoretical position. Technological aids like *NUD•IST* offer the researcher a new capability to identify associative links within complex, qualitative data sets. The search for these associative links must be purposeful and theory-driven, otherwise we will witness the sort of random exploratory analysis that characterized some early applications of statistical techniques to educational data.

Conclusions

We continue to learn how to research learning. Our efforts to date have led to the development of a fascinating variety of research techniques and some distinct differences in methodology. The mathematics education research community is all the richer for this diversity. Technology has increased our ability to study the complexity of classroom and workplace learning, offering us the tools to synthesize different data types into data files of substantial complexity and interconnectedness. This capability is matched by the existence of analytical tools capable of demonstrating associative links in qualitative data with a level of replicability and rigour that was previously only associated with quantitative data.

Among the factors on which our success depends, one of the most important is our ability to define what it is that we are studying. And these definitions must be framed in terms that inform and structure our research. Education abounds with ill-defined terms. We must scrutinize the articulation of our theories to ensure that each construct has been appropriately situated both theoretically and operationally. The real advances in learning research will continue to come from the ingenuity and insight of individual researchers, who find new theories and new perspectives on the constructs at the heart of our discipline, and which inform our research efforts from design and data collection to analysis and interpretation. New representational schemes facilitate the interpretation of data, and new perspectives on research methodology provide a correspondence of subtlety and sophistication between our theories, our research techniques, our analytical tools, and the interpretation of our findings.

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