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ABSTRACT

In this paper progress made in the systematic study of science classrooms is examined. Discussion centers on research studies related to three questions: (1) What is the nature of the environment in science classrooms? (2) What inputs to the classroom influence the environment? and (3) What environmental characteristics are related to student outcomes? The reviewer concludes that methodologically and conceptually sound classroom research is far from commonplace and that much classroom research is done because it can be done, not because it is related to the most important or the most basic issues. An 18-item bibliography is included. (PEB)

# SOMEWHERE OVER THE RAINBOW--SYSTEMATIC STUDIES OF THE ENVIRONMENT OF SCIENCE CLASSROOMS

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## Introduction

Ever since our extensive tours of the cemeteries of New Orleans last January, my five-year-old son Paul has developed an intense interest in burial plots. While driving past the Champaign-Urbana cemetery recently he asked, "Daddy, why don't tombs have windows in them?" Somewhat taken aback I inquired, "Whatever for?" "Well Daddy, I'd like to see the skeletons inside."

There are many reasons why those interested in those educational tombs we call classrooms should want to remove the shroud which has so long surrounded them. As the accountability movement gathers force, we can expect administrators once more to enter classrooms in a hunt for skeletons. At long last, researchers are directing their attention to classroom phenomena. For far too long, researchers have looked for consistent relationships between what is put into the "black box" of the classroom and what comes out without looking at what happens inside the "black box." Not surprisingly, the results have rarely been consistent, meaningful, or useful.

Systematic attempts to determine what goes on inside classrooms are based on the belief that the study of classrooms is an essential link in a research chain leading to an understanding of, and ultimately perhaps, to the improvement of, teaching. The research sets out to answer questions of the type:

1. What is the nature of the environment in science classrooms?
2. What inputs to the classroom influence the environment?
3. What environmental characteristics are related to student outcomes?

In this paper an attempt will be made to examine the progress made thus far.

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1. What is the nature of the environment in science classrooms?

There have been literally dozens of studies in which the behavior of teachers and/or pupils in science classrooms has been observed and classified. After a decade of intensive study[1], a good deal is now known about what goes on inside science classrooms. We find, for example, that the teacher is the dominant actor in not only the older style science programs but also in most of the "new" curricula of the 1960's. In these classrooms, most of the time the teacher is interacting with a target pupil while the rest of the class observes. A quite different pattern of interaction seems to characterize classrooms using programs like ISCS and the Australian Science Education Project. In this classroom, students are busy experimenting, interaction with one another, reading, and recording data. At any instant, 20 or more interactions among teacher, pupils, and materials may occur simultaneously--all dealing with something quite different.

Uncertainty still exists as to the underlying dimensions of classroom interaction. Instead of trying to determine how classroom behaviors are cross linked, we have tended to waste away our energies on the development of new schemes for analyzing classroom interaction. At least 120 such schemes are in existence. The bulk of these have been developed with little regard for others in the field, a narrow conception of reliability, a lack of underlying theoretical or empirical basis, and a scant concern for construct, prediction or any other type of validity. More often than not, the constructs measured represent little more than vague, simplistic molar variables of the good guy-bad guy variety. The time has come to venture beyond i/d ratios.

The adequacy of our measures of classroom environments depends as much on the comprehensiveness, reliance and consistency of the conceptual framework we employ, as the thoroughness, skill, and care taken in collecting data. Yet only 15 of the 73 category systems described in "Mirrors of Behavior" were found by

Rosenshine and Furst[2] to have an explicit theoretical or empirical base. However, there is much more to an adequate conceptual framework than a well-explicated theoretical position. The educational relevance of variables derived from sociological, communication and psychological theories and even from models of teaching must be established empirically. Furthermore, some variables of critical importance in science teaching may have no counterparts in the theoretical literature. There is always a place for the invention of constructs by sensitive observers.

To be comprehensive, description must encompass three facets of the classroom: cognitive, affective, and organizational. In "Mirrors for Behavior," Simon and Boyer[3] indicate the extent to which available systems cover these facets. Only a handful of systems attempt to capture the complexities of the classroom. Even among these, there are some notable gaps. There is more to the cognitive side of science classrooms than the use of multiple levels of questioning. What about the structure, clarity, density and accuracy of the information being transmitted? There are some promising thrusts in this direction as Koran[4] has already indicated, but much remains to be done. Even coding schemes developed expressly for the purpose of studying science classrooms[3] contain few categories which have proven value in studying the strategies teachers use to develop scientific concepts, attitudes, skills and interests. On the organizational side, the study of such variables as teacher "momentum," "with-it-ness" and "wait-time"[5,6] ought not be ignored--especially in studying laboratory environments.

While there is a chance that we will bypass some critical environmental variables, the danger of being overwhelmed by too many classroom variables is even more acute. At this stage of our understanding, the goal of parsimony can be better accomplished by using empirical techniques (e.g., factor analyses) for combining variables than by resorting to armchair abstraction. One noteworthy effort in this direction has been the approach adopted by Soar[7] in a study of Project Follow Through Programs. Four observational systems were used. First, the data obtained from these were reduced by a factor analysis procedure. Then analysis of variance was used to determine whether the factors discriminated across programs, and finally, factors were correlated with measures of class residual gain. Science education researchers could, by pooling their efforts, follow Soar's lead.

Like the Pace and Stern instruments for measuring college environments, the Learning Environment Inventory, developed by the Harvard Project Physics evaluation team[8] utilizes student perceptions of the classroom environment. In developing the instrument, the authors have been concerned with the internal consistency, stability, construct validity and predictive validity of the 15 environmental factors measured.

The HPP evaluation studies have provided us with a very clear picture of Project Physics classrooms as viewed by students. Since then the instrument has been used in studying the environment of other science classrooms. For instance, Tisher and Power[9] have used the LEI along with other questionnaire instruments and observational measures to determine the nature of the environment of Australian Science Education Project classrooms. While a good deal of congruence between student perceptions and observational measures of the same classroom exists, discrepancies and areas where no relationships were detected. The Tisher and Power study suggests that <u>both</u> direct observation and student perceptions have a place in determining the nature of classroom environments.

2. What inputs to the classroom influence the environment?

A classroom environment is the result of a series of interactions over a period of time of a unique mix of persons (a teacher and a group of pupils), a physical setting, and a set of curriculum materials. National, community, and school environmental pressures ensure that classroom environments are not too different--there are definite limits within which classrooms are permitted to vary. The broader environmental context in which classrooms operate has a subtlety but yet a strong realism about it. Like a mist, environments cannot be touched; but individuals cannot stay long in them without being thoroughly soaked. And teachers and students have been soaked long enough in school environments to give them a distinctive odor. But, individuals, classroom settings, and curriculum materials do vary--and these variations lead to variations in the environment of classrooms.

That the science curriculum used, can, and does affect the classroom environment has already been alluded to. But what is it about ISCS and ASEP which makes the environments of classes using them similar to one another and distinct from that of classes using conventional programs? Why did the new curricula of the 1960's have so little affect on classroom environments? What changes in teacher-student interaction can be expected to flow from the introduction of more socially responsive science programs (e.g., IAC Chemistry), and from programs based on the mastery-learning model?

Frankly, the detailed linking of variations in curricula with variations in classroom environments in well designed studies has barely begun. In the absence of precise information about the differences between Project Physics and PSSC, we can only guess as to why the HPP classroom environment is perceived by students to be less difficult but higher on diversity and environment than the PSSC environment.[10] We can use content analysis techniques to determine how science curriculum units differ. We can determine the nature of the differences between classroom environments when units which vary markedly in, say, social content are used. And the results would be useful to curriculum developers, science superintendents and teachers.

General structural properties of the classroom group (the size and permanency of the group; its homogeneity with respect to sex, race, ability; seating arrangements) do seem to affect the classroom climate. Welch[10] reports that larger physics classes tend to be more formal, impersonal and diverse. The environment of physics classes comprising many achievement-oriented students tends to be seen by such students as satisfying, difficult and frictionless. Science teachers are concerned about national and school policies which affect the structural properties of their classrooms, since these in turn affect the classroom environment and outcomes. Perhaps the time has come for us to begin to work with teachers rather than on them.

Generally variations in teacher age, sex, experience, science qualifications, and personality account for little of the variances in environments (or outcomes). While the amount of preservice training does not seem to be an important determinant of the clasrroom environment, training teachers to use specific strategies can lead to changes, some of which may surprise us. For instance, Evgelston [11] found that the laboratory climate of teachers trained to use inductive methods displayed more goal direction but was less satisfying, less intimate, more apathetic and more disorganized than that of teachers using traditional methods. Some mini-courses and self-observational instruments have proceeded to have desirable lasting effects on teacher behavior, an encouraging result. But, as has happened in the development of observational instruments, there has been much mindless duplication of effort. There are over 20 higher level questioning packages alone. The time has come to determine which package is most effective in producing the desired transfer effect, and whether the resultant changes in teacher behavior are reflected in student achievement.

The impact of a science program on a classroom depends on the interaction between the values of the teacher and those of the program. Power and Tisher[12] found greater task relevant activity and enjoyment in classrooms taught by teachers with values congruent with those of ASEP staff than in classes whose teachers had dissonant values. Both experience and research suggest that curriculum developers and curriculum implementers need to take into account the values and background of the teachers who will use the materials. Failure to do so in the past has limited the effectiveness of curriculum reform movements.

3. What environmental characteristics are related to student outcomes?

Many researchers have attempted to classify classroom behaviors and to relate measures based on their classifications to measures of pupil growth. Others have sought correlations between student perceptions of the classroom environment and outcomes. The extensive reviews of Rosenshire[13] suggest that clarity, variability, enthusiasm and task-orientation generally are positively associated with mean achievement gains. Associations have also been found between apathy, friction, warmth, and inquiry orientation on the one hand, and student interest and attitude towards science on the other. However, as Rosenshire and Furst[14] have been quick to point out: "The research on teaching in natural settings to date has tended to be chaotic, unorganized, and self-serving."

On the basis of the evidence obtained thus far it is difficult to make unequivocal statements about the effects of any particular teaching strategy or environmental condition. It is tempting to try to explain away the disappointing results of these studies by pointing to their very serious measurement, methodological and conceptual flaws. But if one takes the results of the Coleman Report, Project Talent and the IEA Maths Study at face value, the possibility that schools and science teachers do not make much difference cannot be ignored. There are several good reasons why schools, and presumably teachers, should account for so little of the variance in achievement in these studies. The studies were correlational, they used standardized tests of kinds that are relatively uninfluenced by teacher's efforts, and the teacher variables used were teacher characteristics not teacher behaviors. The IEA Science Study[15], while suffering from some of these deficiences, did set out to give teacher's a fairer trial. In this study, learning conditions accounted for 15-18 percent of the variance in achievement.

Maybe the results of classroom research are disappointing. Maybe variations in teaching and classroom environments are only marginally related to achievement. But it does not follow that the search for potent classroom variables should be abandoned. On the contrary, classrooms are too pervasive and significant a phenomenon to ignore. If the picture obtained to date is confusing and ambiguous, then our attempts to come to grips with the realities of classroom life must become increasingly sophisticated, sensitive and ingenious.

We have at our disposal the means to become increasingly sophisticated. Our attention has been alerted to many of the deficiencies which have plagued classroom research. Reference has already been made to improve the measurement problem. At the methodological level, subjects have not been assigned at random to treatments; critical variables like the opportunity to learn and course content have not been controlled; inappropriate units and methods of analyses have been used; and criterion measures have often lacked content validity. In the race to churn out papers and Ph.D.'s, the descriptive-correlational experimental research loop which has been propcsed so often, is still rarely followed. This is not to say that no further descriptive-correlational studies are needed. Indeed they are.

Most classroom research to date has been conducted in teacher-centered classrooms. It is not surprising, therefore, to find that the vim, vigor and business-like manner displayed by the teachers are associated with student achievement. Whether these same behaviors facilitate learning in ASEP, ISCS, IAC or ES classrooms is a moot point. Furthermore, behaviors rare in conventional science classrooms may be commonplace in new programs. New behaviors, new settings and neglected outcomes can be the focus of descriptive-correlation stud 's.

One hidden defect of the vast bulk of classroom studies is that they are based on the assumption that a direct link exists teacher behavior and student achievement. Almost forty years have passed since Lewin stressed the need to consider all the properties of the person and his environment in accou.. ..ng for human behavior. Nevertheless, many classroom studies implicitly assume that a direct link exists between an isolated teacher behavior on the one hand, and some change in students on the other. Admittedly, a number of investigators have recognized that the one pattern of teacher behavior may not provide the optimal growth conditions for all students. While the study of the differential effects of selected properties of the classroom environment on groups of students does represent a step in the right direction, classroom studies must display a far greater sensitivity to nuances of communication patterns occurring in classrooms than they have to date. As Mitchell[16] has argued, methods employed in classroom interaction research must become conceptually and statistically multivariate in approach if damage is not to be done to the data and to the reality that data reflect. By and large, observational studies fall far short of the criteria proposed by Mitchell: conceptualization of research problems in multivariate terms that accurately reflect the complexity of both persons and classroom environments has been the exception rather than the rule.

One further limitation of most studies of the classroom is that in focussing on the common experiences of all students, what happens to individuals has been ignored. While students can and do learn vicariously, their academic and social success is also dependent on the nature and frequency of direct interactions with the teacher, other students and curriculum materials. What and how much is learned depends on the total pattern of interactions between the cognitive, motivational and personality traits the individual brings to the classroom, and the input messages received.

It is believed that further progress towards understanding the complex phenomena of the classroom can be expected only if classroom studies are based on research models which take into account the total pattern of interactions between individual students and their learning environments. As science programs become more individualized, the need to discover how input, environmental and outcome variables are related at both the classroom and the individual level becomes increasingly urgent.

Power[17] developed and tested a multivariate model for predicting instructional outcomes based on the assumption that the latter, in part, are determined by what the student is like and what happens to him as an individual in a science classroom. The interrelationships among measures of the characteristics of the student, his interactive behavior and a variety of outcomes were explored. Four distinct combinations of student and environmental variables which appear to represent "syndromes" were detected. Each syndrome is closely associated with a distinct outcome condition, not all of which are desirable. It seems that the environment of the typical conventional science classroom is such that academic and social success is guaranteed only for students who are bright, achievement-oriented and initially science sophisticated. Whether we can design classroom environments better equipped to facilitate the development of other types of students is a question that only systematic research can resolve.

Using the LEI, Anderson[18] has examined the effects of the total classroom environment on individual learning in Project Physics classrooms. His results also suggest that classroom climate has significant effects on learning, and that there are wide differences in these effects for students differing in ability and sex. Classroom intimacy, for example, is positively related to learning for high ability girls and has negative effects for girls of lower ability.

Ingenious multivariate studies based on carefully developed theoretical models can do much to help us paint the broad picture, a picture which more limited correlational studies have muddied rather than clarified. The broad picture envisaged should indicate which input and environmental variables (acting singly and in interaction with student variables) are most closely associated with the science achievement and attitudes of classes and of the individuals in them.

We still need ingenious, broadly conceived multivariate studies set in real classrooms. But such studies merely indicate where to dig--they do not yield gold. The leads offered must be followed up in more tightly controlled, experimental studies. Only experimentation can provide us with unambiguous results as to causal relationships and only experimentation allows us to study the affects of environmental conditions not commonly found in existing science classrooms.

Conclusion

From time to time we need to step back and critically analyse our efforts. If the analysis undertaken is accurate, it would appear that methodologically and conceptually sound classroom research is far from commonplace. Surely if systematic research into the mysteries of classrooms means anything, it does not mean "quick returns in research-based platitudes."

Much of what we do in classroom research is done because it can be done, and not because it is related to the most important or the most basic issues. The discovery of ways to study classroom environments which yield results of significance to science education, is a difficult enterprise. It requires more than sophisticated instruments and ingenious techniques: critical and creative thinking about the nature of classroom environments, their origins and effects, are needed as well.

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