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Student Perceptions of the Learning Value of Biology 30 Projects Compared with Piagetian Cognitive Developmental Levels

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Student Perceptions of the Learning Value of Biology 30 Projects Compared with Piagetian Cognitive Developmental Levels submitted by J. W. Crowell in partial fulfilment of the requirements for the degree of Master in Education in Secondary Education.

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ABSTRACT

The purpose of the study was to determine if student perceptions of biology projects as a learning experience were related to student cognitive developmental levels as defined by Piaget. Specifically the study examined student perceptions of grade 12 biology projects to determine if:

1. Students who had attained a formal operational level of development were more satisfied with the project experience than concrete operational students.

2. Students who had attained a formal operational level of development perceived the biology project as a more significant learning experience than did concrete operational students.

3. More females or more males in the test sample had attained a formal operational level of development.

4. Male and female students differed in their perspectives of the biology project experience with respect to satisfaction and learning value.

The sample of 107 students from 7 rural schools surrounding Edmonton, Alberta, was chosen from schools where a teacher consented to cooperate with the study. All students had completed projects in the second semester of the 1982-83 school year and all sampling was done during the period April to June.

Three test instruments were used in the study. The Test of Logical Thinking, designed by Tobin and Capie, is a pencil and paper test used to determine the student's cognitive developmental level according to the theories of Piaget. The Student Perceptions Instrument, designed by the author, is a twenty-item questionnaire with a five-point Likert scale used to measure the student's satisfaction with the biology project and to provide information on the organization and structure of the project experience. The Inventory of Processes in Scientific Inquiry is a twenty-item questionnaire adapted from a list of processes of inquiry developed by Nay and associates. This instrument measured students' perceptions of process skills learned in the project experience and provided a sentence completion section to complement the quantitative responses to the questionnaires with written observations by the respondents. Further qualitative data were available from tape recorded interviews with randomly selected students from each study school.

Analysis of the data indicated that neither student satisfaction with the project experience nor students' perceptions of the value of the project d[illegible] the cognitive developmental level of the student (p [illegible] 0.05). The study also found no significant difference between male or female students with respect to the numbers of formal operational thinkers (p = 0.05).

While no significant differences were found between male and female students with respect to satisfaction or perceptions of the value of the biology project in total (p = 0.05), responses on several individual items on both the <u>Student Perceptions Instrument</u> and the <u>Inventory of Processes in Scientific Inquiry</u> were significantly different (p = 0.05) to suggest further study.

What was clearly evident from both the quantitative and qualitative data of the study is that satisfaction and value of the learning experience of a biology project are dependent on the level of inquiry allowed by the classroom teacher.

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TABLE OF CONTENTS

LIST OF TABLES

I. Introduction

A. Background

Many educators believe that science education should be a participatory activity. Students should be allowed and encouraged to become actively involved in investigations to explore many of the skills and techniques of scientific research and to pursue topics of personal interest in some depth. To this end the concept of student projects has been included in many science curricula, including the Biology 30 curriculum used in Alberta and the Northwest Territories.

Despite the official prescription in the curriculum guide and the philosophical commitment of planning committees and such service guides as the Biology Teachers' Handbook (BSCS, 1970) and the Student Project Handbook (Alberta Education, 1976), actual practice of student projects as a teaching methodology seems to be less than intended. The Biology Evaluation Report (Alberta Education, 1981) indicated a number of points related to Grade 12 Biology Projects:

a. While 74% of biology teachers who responded to an Alberta Education evaluation survey felt a project helped students achieve learning objectives that could not be achieved in other ways,

b. Only 57% of the responding teachers felt a project should be mandatory,

c. And currently, when projects are done, 53% take less than 10 hours to complete and 72% take 15 hours or less. This is appreciably less than the 25 hours indicated in the curriculum guide used up to September, 1984.

Rationale offered by respondents for not requiring student projects emphasized the logistics of management and organization, but comments included the following:

a. "Students are too immature; insufficient background to do an effective job."

b. "The choice of project is too difficult as students lack knowledge or background."

c. "Not capable of conducting independent research study...". (Alberta Education, 1981)

The comments above are included in the evaluation report as composites of many comments received from respondents. Each composite represented about 11% of the responses (n=146).

These data suggest an examination of the relationship between the cognitive developmental levels of biology students and the practice of biology projects is in order. Such a study could be conducted from a number of points of view but this study will examine the issue from the student's perspective.

B. Basic Assumptions

This study is based on certain assumptions of the nature of Biology 30 projects and measurement of Piagetian cognitive developmental levels, specifically:

a. A paper and pencil test can measure cognitive developmental levels.

b. Biology 30 projects involve a wider range of topics and include a greater possibility of student-generated problems than Biology 10 or 20 projects.

c. Biology 30 projects produce data.

d. The characteristics of formal thinking measured by the Test of Logical Thinking, such as controlling variables, are congruent with the levels of thinking required by a Biology 30 project.

C. Statement of the Problem

The purpose of this study is to determine if student perceptions of biology projects as a learning experience are related to student cognitive developmental levels as defined by Piaget.

D. Research Questions

The present study attempts to focus on the following research questions:

1. Do formal operational students express more satisfaction with the biology project experience than do concrete operational students? This question may be expressed as, are there relationships that exist between Piagetian cognitive developmental levels and student satisfaction with the learning experience of a biology project?

2. Do formal operational students perceive the biology project experience to have more learning value than do concrete operational students? This question may be expressed as, are there relationships that exist between Piagetian cognitive developmental levels and student perceptions of the value of biology projects as a learning experience?

3. Have more girls or more boys in the test sample attained a formal operational level? This question may be expressed as, are there relationships that exist between cognitive developmental level and gender?

4. Are there differences in the way male and

female students rate the project with respect to satisfaction and learning value? This question may be expressed as, are there relationships that exist between student perceptions of the learning experience of a Biology 30 project and gender?

E. Definition of terms

Piagetian Cognitive Developmental Levels

This will refer to the scores obtained on the Test of Logical Thinking (Tobin and Capie, 1981). These scores may be translated into categories that correspond to the following accepted definitions (Wadsworth, 1978):

a. Concrete operational

The student has attained reversibility and can solve conservation problems. Logical operations have developed and can be applied to concrete problems. The student cannot solve complex verbal problems.

b. Formal operations

The student logically solves all types of problems and thinks scientifically. The student can solve complex verbal problems.

Biology Project

This will refer to any learning experience designated by the subject's teacher to be a project under the Biology 30 curriculum.

Student Satisfaction

This will refer to student responses on selected items of a <u>Student Perceptions Instrument</u>. These items will assess the student's interest, enjoyment and approval of the biology project as a method of learning, with specific reference to teacher responses on an evaluation report (Alberta Education, 1981) which indicated that biology projects are a unique way for students:

a. to be motivated,

b. to learn to work with others,

c. to learn self-discipline,

d. to learn wise use of resources,

e. to have pride in one's work.

Student Perceptions of the Value of a Project

This will refer to student responses on selected items of an <u>Inventory of Processes in Scientific Inquiry</u>. These items will assess student agreement with teachers' opinions that biology projects are unique experiences that help students achieve learning objectives that cannot be achieved in other ways (Alberta Education, 1981); specifically:

a. "To become proficient in research techniques (such as) written communication reporting, oral communication, reading current scientific literature, reasoning, analysis, manipulation, (and) process skills.

b. "Teaches individual responsibility and applies scientific method, (and teaches) independent problem solving."

c. "Appreciation of scientific work."

d. "Reinforcement and/or extension of core material (and) exposure to many facets of biology."

e. "Helps develop organizational skills."

F. Hypotheses to be Tested

H1: There is no significant relationship between student satisfaction with a biology project (SPI) and cognitive developmental level (TOLT). (alpha=0.05)

H2: There is no significant relationship between cognitive development levels (TOLT) and student perceptions of the value of a biology project as a learning experience (IPSI).

(alpha=0.05)

H3: There are no significant relationships between cognitive developmental levels (TOLT) and gender. (alpha=0.05)

H4: There are no significant relationships between student perceptions of the learning experience of a Biology 30 project and gender. (alpha=0.05)

G. Delimitations of the Study

a. The study was restricted to those schools that completed Biology 30 projects in the second semester.

b. The study was restricted to schools in a 200 km radius of Edmonton, Alberta, excluding schools within the metropolitan boundaries of the City of Edmonton.

c. The sample was restricted to intact classes of Biology 30 students.

d. Due to such practical considerations as travel time and the conditions for cooperation from classroom teachers, the selection of subjects was non-random.

H. Limitations of the Study

a. Since the selection of subjects was non-random, results of this study may not be generalized beyond the sample.

b. Generalizability of the study results to Biology 10 or 20 is limited because of:

i. the rather more advanced nature of the projects usually attempted at the Biology 30 level, and

ii. the maturation of cognitive developmental levels from Grades 10 to 12.

I. Design of the Study

Selection of the Students

Schools outside a 200 km radius of the City of Edmonton were eliminated from a list of rural high school biology teachers in zones 2,3 and 4, as published by Alberta Education. Twenty schools were randomly selected from those remaining in the radius, following the procedures of Hopkins and Glass (1978). Schools were phoned in order of the random selection to solicit the co-operation of ten teachers with Biology 30 students who would complete projects in Semester II of the 1982-83 school year. The initial selection of twenty schools to obtain ten teachers was based on the personal assumption that as many as 50% of Biology 30 students in the province do not undertake a project.

In each school the test instruments were administered to intact classes of Biology 30 students.

In the event there were more than one class in a school, the choice of classes to be tested was decided by the cooperating teacher.

The Test Instruments

After the selection of subjects, students in each school received a battery of test instruments to measure student cognitive developmental levels and student perceptions.

Measurement of Piagetian Cognitive Developmental Levels

Measurement of the cognitive developmental levels of students used the Test of Logical Thinking (TOLT) (Appendix I) (Tobin and Capie, 1981). This instrument uses sets of two questions to measure formal thinking ability in five modes: proportional reasoning, controlling variables, combinatorial reasoning, probabilistic reasoning, and correlational reasoning. Students are shown the equipment relevant to each question set, then choose a correct response from a five-item multiple choice question. The student must also choose a correct explanation for his answer. If either the answer or the reason chosen are incorrect, the response is scored "0". The response is scored "1" if both the answer and the reason are correct.

The internal validity of the TOLT as reported by the authors is high (Tobin and Capie, 1980b) and its correlation with five clinical interview tasks following the protocols of Piaget and Inhelder (Inhelder and Piaget, 1958) is reported as high (alpha=0.80, $p<0.05$) (Tobin and Capie, 1980a).

The range of scores on TOLT is 0 to 10. Although the raw data will be used for analysis, comparison with the clinical interviews suggests scores of 1 and 4 correspond to transitional and formal operational stages respectively.

Determining Student Perceptions

Determination of student perceptions of the Biology 30 project used two instruments: the Student Perceptions Instrument (SPI) (Appendix II) and the Inventory of Processes in Scientific Inquiry (IPSI) (Appendix III).

The SPI is a twenty-item questionnaire with a five-point Likert scale developed by the author to measure student satisfaction and interest in the Biology 30 project.

The IPSI is a twenty-item questionnaire developed by the author to measure the student's perception of what he learned from the Biology 30 project. Modified from the work of Nay and Associates (Nay et al, 1971), the IPSI focuses on the cognitive domain, specifically process skills, identified by the author as important objectives for student inquiry-learning. These items were also considered to be congruent with the teachers' responses, to Alberta Education's evaluation of the Biology program, as processes unique to the project method.

The Interviews

After the administration of the test battery, the researcher asked students from the class, in order of random selection, to volunteer for a tape-recorded interview. Four students were chosen in this manner from each class to participate in a group discussion before the microphone. The intent was to provide an opportunity for students to express in more detail some of their perceptions of the experience of doing the projects. Transcripts of the recorded sessions (Appendix IV) were examined for the underlying themes in the discussions and these are reported in a later chapter.

J. Organization of the Remainder of the Study

The remainder of the study is described in the chapters that follow. Chapter Two reviews the literature related to the study, including an examination of the inquiry approach to teaching, research in science education in the Piagetian paradigm and criticism of educational research in the Piagetian paradigm.

Chapter Three describes the design of the study. Chapter Four summarizes the quantitative results of the study, while Chapter Five analyzes the responses of the students to the sentence completion questions of the IPSI and in the tape-recorded interviews. Chapter Six describes the summary, conclusions and recommendations of the study.

II. Review of the Literature

A. Science Education Research in the Piagetian Paradigm

In the early 1960's American educators discovered the theories of intellectual development of Jean Piaget. Piaget had actually begun his work in the middle 1920's in Geneva and at the time of his "discovery" in North America his reputation in Europe was solidly backed by more than forty years of research. In spite of th[illegible] start the interpretation of Piaget's concepts ha[illegible] resulted in the establishment of an extensive paradigm of educational research. Although Jean Piaget was neither a clinical psychologist nor an educator, the promoters of his theories have attempted to evaluate the classroom learning experience in light of his concepts of the development of thinking in the child.

Research in science education using the Piagetian paradigm has concentrated on three main areas (Chiappetta, 1976):

a. Reporting the developmental level of adolescents and young adults.

b. Showing the relationship between cognitive development and science achievement.

c. Discussing the research and its implications to science teaching at the secondary and college level.

Studies intended to assess the developmental levels of students have been undertaken by a number of researchers and Chiapetta has summarized the work of McKinnon and Renner in 1971, Lawson and Blake in 1974, Juraschek in 1974, and Chiappetta and Whitfield in 1974 (Chiapetta, 1976). Their general findings seem to indicate most adolescents and young adults have not attained the formal operational stage of cognitive development. The ranges reported for students at the concrete operational level were between 77 and 83.4% for junior high school students, 22 to 85.5% for high school students and 0 to 52% for college students (Chiappetta, 1976). These data illustrate a marked variation from the theoretical age of 15 to 16 years for formal operational thinking suggested by Piaget's studies.

Lawson and Blake, Sayre and Ball, Sheehan, and Chiappetta have all investigated the relationship between thought development and science achievement (Chiappetta, 1976). Their research subjects varied from junior high school students to science teachers and physical science to biology students. Generally, all researchers found that even the few students who were classified as formal operational tended to regress to intellectual functioning at the concrete level when dealing with science content. Although formal operational thinkers achieved higher grades on concrete topics than concrete operational students, the formal thinkers still failed to achieve high grades on formal concepts.

Continuing into the 1980's the research literature under the Piagetian paradigm has remained extensive. A survey of the Journal of Research in Science Education showed that 15 of the 70 articles published in 1980 were rooted in Piagetian concepts. Such titles as "The Sequence of Learning Cycle Activities in High School Chemistry" (Abraham et al, 1986); "A Review of Research on Formal Reasoning and Science Teaching" (Lawson, 1985); and "The Role of Physical Content in Piagetian Spatial Tasks: Sex Differences in Spatial Knowledge?" (Golbeck, 1986) illustrate some of the popular themes. These titles also illustrate the North American attempts to turn Piagetian concepts into a learning theory with proscribed methodologies for curriculum development and classroom instruction. Such themes and current research methods differ markedly from Piaget's original work. One of the reasons Piaget's concepts remained "unknown" in North America was his non-traditional research methods. Typically, experimental research on this continent has concentrated on testing of hypotheses, control of experimental variables and statistical analysis of data. Piaget, in contrast, developed a clinical-descriptive approach;. Children were presented with a task and were interviewed individually. Questions were carefully selected and the responses of the children were noted. Varying the questions to suit the individual responses, the researcher may have never treated any two subjects the same.

In contrast, many science education projects have developed paper and pencil tests to replace the labourious personal interview approaches of Piaget (Blake, 1980; Renner, 1977; Tobin and Capie, 1980a). Such tests allow researchers to sample complete classrooms or whole school systems. However such techniques which diverge widely from Piagetian methodology and such wide-spread adoption of the paradigm has given rise to some criticism.

B. Criticism of the Piagetian Orientation to Research

Hugh Munby has criticized the educational research community for adopting a Piagetian orientation to research without question; "if educational theory can offer little in the way of a syntactic structure, then novel theoretical approaches, such as that of Piaget, find their ways into schools and curriculum unchallenged by even a slight systematic question" (Munby, 1980, p. 127). While Munby does not criticize the validity of Piaget's theory itself, he does express concern that the immense committment to Piagetian oriented research should be questioned because:

1. It may not be appropriate to speak of developmental stages, and that this way of speaking may be inconsistent with our understanding of development.

2. The Piagetian research orientation is somewhat at odds with Piaget's own holistic and structuralistic view.

3. Stated implications of this research orientation could be in conflict.

Munby's first concern is that it is probably just as wrong to speak of discrete stages of cognitive development as it is to speak of a rainbow being composed of a series of distinct, separate colours. Just as there is no abrupt series of changes in physiological maturing from infant to adult, so there are no distinct stages in psychological growth.

"So the temptation exists to take things quite literally, to lose sight of the syntax, and to begin to award the notion of stages a status it does not deserve. And, within the science education context, it thus makes uncertain sense to construct science curricula and teaching strategies according to definitive stages and to what we might suppose that children can logically manipulate within those stages." (Munby, 1980, p.130)

Munby's second area of concern is the conflict between the inherent reductionist nature of research and the holistic view of Piaget's theory. The basic premise of research is that all events may be reduced to an explanation of the state of fundamental particles. But as Higginson (Munby, 1980) has noted:

"It has been estimated that in over half a century of work in the field Piaget has written the equivalent of fifty five-hundred-page books on child development. All too often this edifice is reduced to an oversimplified description of 'four stages' and educators scurry away to devise diagnostic tests and means for accelerating children through the stages. Hence one gets the ironic situation of having the holistic, constructive Piagetian position being interpreted in reductionistic terms with the major focus in application being on those activities children are <u>unable</u> to do." (p.132)

In summary, it is clearly evident that the Piagetian paradigm of science eduction research has stimulated research in science education into the evaluation of curricula and classroom instruction.

However the criticisms of Hugh Munby are important considerations for both researcher and classroom teacher. Specifically, the researcher must be aware of Piaget's holistic view of the conceptual development of the child. While the theories of cognitive development offer some insight into how the student interprets the classroom learning environment and such instruments as pencil and paper tests to assess cognitive development are important and useful for evaluating the student's thinking abilities, the researcher must be cautious to maintain the holistic view of the student.

C. A Rationale for Inquiry Learning in Biology Projects

The Project Method of instruction began in the early 1900's as a method of training agricultural students in the practical arts of farming (Bleeke, 1968). From this beginning "projects" developed into accepted curriculum content and classroom methodology with the work of W. H. Kilpatrick, D. Sneedan, C. Mann, and W. Whitman (Bleeke, 1968). The support for project work continued wlith J. Dewey (1938) and more recently E. Klinckman (1970) and M. Mayer (1978) have emphasized the use of projects in the BSCS Biology Teacher's Handbooks. In the recent past, in Alberta science curricula, the ethos of inquiry learning through student projects has been clearly supported (Alberta Education, 1976, 1984), yet there are some indications from L. D. Anderson (1972), the Biology Evaluation Report (Alberta Education, 1981) and personal observations of the author that many teachers are abandoning independent, student-centred, student-generated biology projects.

This section will attempt to offer a rationale for inquiry learning and show the support of certain psychological learning theories for inquiry teaching. Student projects will then be defined and the correlation between student projects and inquiry learning will be examined.

A rationale for inquiry learning

For many years science educators have agreed with J. Brunner (1961) that inquiry learning is an important element of science teaching. Some, such as J. Schwab (1962,1969) and F. J. Rutherford (1964) have argued that inquiry skills are not merely a methodological technique, but an integral part of the content of science instruction. Today, most science teachers would acknowledge the philosopical importance of inquiry as defined in the second edition of the Biology Teacher's Handbook (Klinckman, 1970):

> Enquiry is defined as a set of activities directed to solving an open number of related problems to which the pupil has as his principal focus a productive enterprise leading to increased understanding and application. (p. 27)

Despite the wide acceptance of the philosophy of inquiry, several researchers have noted a marked difference between theory and practice. M. Gardner (1979) has noted trends away from laboratory orientation to demonstrations and deskwork and away from subject matter to class control. DeRose (1979) relates the findings of a NSF study which shows that the teaching of inquiry is stifled by curriculums dominated by the textbook and even when teachers try inquiry techniques there are a number of barriers such as inadequate time blocks in the schedule, shared classrooms, and inadequate facilities which foster more passive text book oriented teaching styles. Hurd (1980) echoes DeRose's conclusions, pointing out that only 10% of laboratory assignments associated with the three most commonly used textbooks were judged to be inquiry based.

In a more recent study, W. Welch and associates (1981) compared the desired state of the domain of inquiry with actual status as evidenced by four studies of science education in the United States. (See Appendix V for complete comparison). Although the results of this analysis further illustrate the discrepancies between theory and practice, Welch and associates firmly maintain that:

> ...with regard to the content of science courses, we still agree that, not only knowledge of the products of scientific inquiry but also the development of skill in certain processes of scientific inquiry is important for many students. We also still believe that some items of knowledge regarding the nature of scientific inquiry should be a part of the conceptual baggage of all educated citizens. And we still believe that an important purpose of schooling is the development of general inquiry behaviors, which includes problem solving, decision making, and values clarification. (p. 44)

The third edition of the Biology Teacher's Handbook (Mayer, 1978) emphasizes that students should actively engage in their own learning. If they participate through inquiry learning, they are expected to manifest certain behaviours:

1. Students will show a natural curiosity about the living world with questions asking "how" and "why".

2. Students will participate freely in class discussions and express opinions and criticisms based on substantial evidence rather than on pure conjecture.

3. Students will show a willingness to subject

themselves to criticism and evaluation of others.

4. Because of their involvement with "doing science" students will develop a more realistic understanding of the nature of scientific endeavour and knowledge.

5. Students will learn to show confidence in their special abilities and satisfaction in the learning activity.

6. As contributing members of a group, students will respect the ideas of their peers and share and accept responsibility.

J. Nagalski (1980) would add that any modern curriculum should encourage students to develop the ability to think critically.

> If our students are to survive in and adapt to a swiftly changing social and technical world, they must have the ability to analyze information, to arrive at logical conclusions, and to act wisely based on these conclusions. They must, in other words, be creative and critical thinkers.....How do they get that way? Through learning methods based on inquiry. (p. 27)

A study by I. Rodriquez and L. J. Bethel (1983) is a good example of how such objectives expressed above can be achieved. They found participation in inquiry science lessons had an overall positive effect on oral communication and classification skills of Mexican

American bilinqual children.

The literature would suggest that a science educator should attempt to implement inquiry techniques in classroom learning. Failure to do so will mean that students will not be exposed to the three main themes of the domain of inquiry:

1. science process skills;
2. the nature of scientific inquiry; and
3. general inquiry processes (Welch et al, 1981).

Within the theme of science process skills Welch includes observing, measuring, seeing and seeking solutions to problems, interpreting data, generalizing, and building and testing theoretical models. A more detailed treatment and classroom guide to process skills may be found in the work of Nay and associates (1971).

Within the theme of the nature of scientific inquiry, the student should examine the epistemology of science and learn how science knowledge is embedded in the social and psychological contexts of a human enterprise (Kuhn 1970). Welch and associates' (1981) analysis indicates students do not recognize such characteristics as the tentativeness of scientific knowledge or the assumptions underlying scientific inquiry.

Within the theme of general inquiry Welch includes such strategies as uses of evidence, logical and analogical reasoning, clarification of values, decision-making, and safeguards and customs of inquiry.

To restrict inquiry learning in the student's environment is to deny the nature of science and to hamper the growth and development of personal communication, thinking and scientific process skills.

Biology projects as inquiry

What is a student project and how does it differ from a laboratory exercise or class field trip and how does a student project fulfill the objectives of inquiry learning?

Belanger and Jacknicke (1978) outline the historical development of the definition of a project, beginning with W. H. Kilpatrick's definition:

> We understand the term project to refer to any unit of purposeful experience, any instance of purposeful activity where the dominating purpose, as an inner urge, (1) fixes the aim of the action, (2) guides its process, and (3) furnishes its drive, its inner motivation. (p.3)

To this they add Huffmire's opinion that the project is a "problem upon which a student works" (p. 4) and Washton's emphasis on the project as an "individual" effort.

Bleeke (1968) quotes W. W. Charter's view that the project is "considered to be an act carried to completion in its natural setting and involving the solution of a relatively complex problem" and it is seen to be "an attempt to return to the concrete conditions of home education from the abstract isolation of the school" (p. 49-50). An important element is added by C. R. Mann when he emphasizes the compelling interest of the student to reach an understanding:

> A desire to understand the meaning and use of some fact, phenomenon, or experience. This leads to questions and problems. A conviction that it is worthwhile and possible to secure an understanding of the thing in question. This causes one to work with an impelling interest. The gathering from experience, books, and experiments of the needed information, and the application of this information to answer the question in hand. (Bleeke, 1968, p. 22)

Finally, the <u>Student Project Handbook (Biology)</u> (1976) summarizes its definition with "Projects imply a teaching-learning activity in which the student learns to learn on his own" (p .2)

For the purposes of this discussion the author favours the definition of K. Adderley and associates (1975):

> A project is a significant, practical unit of activity having educational value and aimed at

> one or more definite goals of understanding; involves investigation and solution of problems and, frequently, the use and manipulation of physical materials; planned and carried to completion by the pupils and teachers in a natural "real-life" manner. (p. 1)

Further, although not all projects will necessarily involve the manipulation of physical materials; all projects have the following characteristics (Adderley et al, 1975):

1. They involve the solution of a problem, often, though not necessarily, set by the student himself.

2. They involve initiative by the student or group of students, and necessitate a variety of educational activities.

3. They commonly result in an end product (thesis, dissertation, report, dossier, design plans, computer programme model, oral report).

4. Work often goes on for a considerable length of time though the time span may range from a single afternoon to three years.

5. Teaching staff are involved in an advisory, rather than an authoritarian, role at any or all of the stages -- initiation, conduct and conclusion.

For Adderley and associates, a project differs from a laboratory exercise or field trip in that the "outcome of an exercise is predicted by a tutor and is under his control whereas, in a project, the student is responsible for making decisions which affect what he does" (p. 1) The two central characteristics which distinquish projects from daily laboratory investigations seems to be the focus on student interest and student control in the project and the advisory-consultative role of the educator as opposed to the authoritarian role of the teacher or manual in the laboratory.

The student biology project would seem to be an appropriate opportunity for students to engage in inquiry learning. The student project would seem to be a logical method for achieving the philosophy of inquiry typified by Schwab (1962):

> The potential scientist needs exposure to the most completely open and unstructured versions of the enquiring curriculum. For him, the laboratory work which specifies neither problem nor method is the appropriate one. The classroom which rests most firmly on the uncertainties, doubts, and difficulties of firsthand reports of investigation is one most likely to evoke his competence and interest. It is through the activities of invention, analysis, and critical evaluation they afford that he can participate in and be conditioned to the vicissitudes of enquiry. (p. 190)

How well do student projects achieve inquiry objectives? There is no simple answer to this question since projects will vary with the capabilities of the students and the commitment of the teachers, but the effectiveness of any inquiry activity can be assessed using the model of Nay and associates (1970). M. Nay has defined the "level" of inquiry by the degree of structuring of the science activity and the amount of guidance provided by the teacher. A "low level" of inquiry is characterized by the teacher or instructional materials providing all instructions for the initiation of an investigation, collection and analysis of data, and conceptualization of the data. A "high level" of inquiry is characterized by a minimum of teacher direction and a maximum of student-initiated solutions to problems in the investigation. The analysis of data described in Chapter IV follows this pattern for classifying the level of inquiry found in the biology projects in this study.

Typically, the usual school "lab" is a confirmatory, illustrative type of highly structured activity calling for a low level of inquiry. While the daily lab activity need not be limited to a low level of inquiry and there is no guarantee that a teacher will not impose a similar degree of structure to student projects, the project mode offers the potential for a higher level of inquiry sparked by student motivation to study a topic of personal interest.

The rationale stressed so far for biology projects emphasizes that the student becomes more involved in his own learning, becomes more enthusiastic about the learning experience, develops certain scientific process skills and develops certain personal skills of communication, learns through a high level of inquiry and learns to inquire into the process of inquiry itself. Adderley et al (1975) would add that the project method offers four advantages:

1. Projects make the student responsible for his own education and promote a relationship of cooperation between teacher and student.

2. Projects provide the context for integration of different disciplines.

3. Projects permit students to look deeply into a field of knowledge.

4. Projects offer flexibility; students can pursue different interests and personal motivations.

Problems encountered in inquiry teaching and student projects

As noted earlier, Welch and associates (1981) describe a discrepancy between the philosophical support for inquiry teaching and the actual practice in the classroom. Welch quotes a study which estimates only 10% of class time is spent in inquiry teaching. Some teachers found inquiry approaches difficult to manage with equipment and supplies too difficult to get. Some considered inquiry too dangerous for poorly disciplined students. Many teachers felt inquiry was too confusing for all but the very bright students.

Some objections raised to inquiry learning in the Welch analysis focused on student and parent expectations of schooling. School was seen as a preparation for the next level; Junior High, High School or College. "Next year" knowledge was more highly valued than inquiry skills and inquiry methods were viewed as an inefficient method to acquire that knowledge.

While there were barriers raised to inquiry teaching by block time tables, poor facilities, and divergent goals of students, teachers, parents, and school administrators, the "greatest set of barriers to the teacher support of inquiry seems to be its perceived difficulty" (Welch et al, 1981, p. 40). Inadequate teacher preparation seems to be a major obstacle to high level inquiry in science education.

Objections to the inquiry approach and project work are not new. As early as 1917 W. H. Kilpatrick was replying to two objections raised against projects. To the charge that the project method was too slow, Kilpatrick replied that the attitude engendered in the student more than compensated for the slower pace. Second, project work was considered too haphazard in its approach to knowledge. Kilpatrick responded by saying that nothing was more haphazard than knowledge which lasts only to the time of examination (Bleeke, 1968).

Practical problems seemed to be the focus of teachers' responses to L. D. Anderson's study (1972). Rural teachers felt that "inadequate reference material" and "not enough project topics to give students" were serious problems. Urban techers tended to regard "lack of adequate space" and "insufficient biology background" as considerable problems for their environments. Written responses included:

Rural

Teacher load is too great to supervise projects properly.
A semester is too short to do a project properly.

> The carrying out of projects becomes very difficult in large classes.
>
> Urban
>
> It is almost impossible for a teacher to supervise several classes of students doing projects and do it properly.
> Students and teacher are continually frustrated by lack of time, materials and space.
> Projects cause teachers extra work so they cannot spend time with pupil problems of a more basic nature.
> Pupils have never been taught basic logic; therefore deductive research is not done well.
> Present financial and physical limitations coupled with large class sizes make carrying out projects difficult. In urban centres it places ridiculous demands on teacher and student ingenuity and time. There are many more basic and relevant things which could be done in schools. (p. 41-42)

In a study conducted ten years after Anderson's, similar problems were still listed by teachers in the Biology Evaluation Report (1981). The three most often mentioned problems were:

> Lack of materials, limited facilities, poor storage
>
> Time factor
>
> Students are too immature; insufficient background to do an effective job. (p. 11)

Adderley and associates summarized the main advantages and disadvantages of the student projects (see Appendix V) and concluded that the chief problem was the difficulty of assessment. Essentially, does the teacher assess the end project against some absolute criterion of scientific research or measure the individual student's progress and evaluate the personal growth of each student? Adderley et al feel the assessment process, regardless of criteria, may offset the benefits of feedback and cooperation between student and teacher.

III. Experimental Procedures and Design

A. Introduction

The study used three test instruments and recorded interviews to collect data on Piagetian cognitive developmental levels and student perceptions of the learning experience of Biology 30 Student Projects.

The development of the three test instruments is discussed in this chapter as well as the statistical and analytical techniques used to analyze the data are discussed.

B. The Sample

Subjects were drawn from intact Biology 30 classes which were completing biology projects in the second semester of the 1982-83 school year in seven rural Alberta schools. The schools were determined by random selection of twenty high schools in a two-hundred kilometre radius of Edmonton, Alberta. Biology 30 teachers in these schools were contacted by phone to solicit their cooperation with the study. Nine teachers volunteered to participate. One school was used as a pilot, since students had already completed their projects in the previous fall semester, to check and improve the test instruments. One school was eventually rejected when the class time available was found to be inadequate for the study. The results which follow in Chapter IV represent the data collected in the remaining seven rural schools. The total number sampled was 110, but any student born prior to 1960 was eliminated from the data calculations, resulting in a final sample population of 107. Table I indicates the age and gender composition of the final sample population. Note that the mean age of 18.5 would be within the expected age range for grade 12 students in the late spring.

Table I

Age and Gender Data

for

Sample Population

Males	47
Females	60
Age Range	17 to 22
Mean Age	18.5

Most of the schools were located in towns of populations around 1200 to 5000 and the "typical" school could be characterized as having a high school population of approximately 150 students in a school which included grades 1 to 12. Class sizes were small, ranging from 2 to 25.

C. Instrumentation

The Test of Logical Thinking (TOLT), the Student Perceptions Instrument (SPI) and the Inventory of Processes in Scientific Inquiry (IPSI) were administered to students to obtain the quantitative data collected in this study. The sentence completion portion of the IPSI and the tape recorded interviews sampled the study population for qualitative data on the biology project process.

In the eighty minutes used to administer the battery of three tests to each biology 30 class, the first test given was the Test of Logical Thinking. The original test instrument designed by Tobin and Capie (1981) was modified only by the substitution of the word "mass" for the word "weight" to correspond to the SI conventions used in Alberta Education science curricula. Guidelines for administering the instrument were provided by the test authors. Before beginning the test students were given a short demonstration of a swinging pendulum made with a piece of string and several large washers. They were told this would relate to questions on the test.

In accordance with the guidelines the students were advised when to begin each question. Three minutes per question were allowed for questions one through eight inclusive, and six minutes per question were allowed for questions nine and ten. Students could work ahead, but were advised not to do so. At the end of each alloted time period students were advised to begin the next question. Total administration time was 40 minutes. To score the student responses for questions one to eight, a value of 1 was given if both the answer and the reason were correct, while a value of 0 was given if either the answer or the reason was wrong. Questions nine and ten were given a value of 1 if all possible combinations were given correctly and a value of 0 if there was any error in the answer. The scores for the ten questions were summed to give a student's score in the range 0 to 10.

The Student Perceptions Instrument was administered to students as the second test in the series. This questionnaire used Likert scales to obtain first basic data such as name, date, gender and organizational information on the structure of the project process and then sampled student opinion on the value of the project experience. Initially students were lead through the information section of the SPI with definitions given for each of the organizational categories as follows:

1. Group Size:

(a) Individual: The student worked on the project by herself.

(b) Small Group: The student worked on the project as a member of a group of two, three or four. None of the classes studied used gro[illegible] larger than four.

(c) [illegible]: The project was carried out centred [illegible] a problem being examined by the whole class. Initially this definition was intended to include the possibility of small groups of students executing specific tasks to contribute to a joint problem. In practice, the author found "class" projects centred on one problem statement with all students doing the same tasks at the same time.

2. Statement of the Problem:

(a) Me: The student was instructed to indicate this response if the problem conception was essentially her own. The instructions indicated that teacher input to modify the problem statement was expected but that the idea was the student's own.

(b) Together: The student was instructed to indicate this response if the problem statement was the result of consultation with one or more partners in the project. This response was tied to the "small group" response above.

(c) Teacher: Regardless of how many people participated in the project, this response was used to indicate the teacher provided the student with the topic and theme of the project.

3. Time:

Students were instructed to estimate the total number of hours spent on all aspects of the project. The time was to include all library research, experimental setup, data collection and analysis, and final report writeup.

4. Project Mark:

Students were asked to indicate what mark they felt they should receive on their project work. In most cases the students had not yet received their project marks from the teacher. In at least one class they knew the grade awarded by the teacher but were advised to still follow the guideline of <u>their</u> estimation of the project grade.

5. Course Grade:

Again students were asked to give their estimate of the final grade they would receive for the Biology 30 course. The pilot students were the only group who knew their final results since they had finished the course in the previous semester, but their data was not included in the analysis detailed in Chapter 4.

6. Percentage of Time Spent on Project Activities:

Students were advised to estimate how much of their time was spent in the project on four possible categories:

experiments
literature research
collection of specimens
model construction

Model construction was defined as the production of any structure or working apparatus to represent a biological structure, organ or process or to simulate a physical process described in the project. Some students, for instance, produced simulations of solar heated structures, while one student mounted a beaver pelt and reconstructed the animal's skeleton.

7. Students were given approximately five minutes to describe their project in a very few sentences. They were encouraged to define the problem examined and the hypothesis formulated. These summaries were used along with the numerical data from items one to six above to judge the organizational categories and the level of inquiry referred to in Chapter IV.

Following the description and completion of the information section of the SPI, which usually took about 10 minutes, students were advised to complete the questionnaire section of the instrument. It was emphasized they were to indicate their personal opinion. As with the instructions to all phases of the testing procedure students were advised that at no time would their responses be shown to their subject teacher or school administration.

Students never asked any questions while completing the 20 questions of the SPI, which usually took about 6 to 8 minutes.

The 20 items of the SPI were written by the author and all reflect value judgements on the value of the biology project as a learning experience. Some items were suggested by the Biology Evaluation Report (Alberta Education, 1981), such as question #7, "The biology project was the most interesting academic activity I have done in high school", which comes from a student response quoted in the survey. A question like #14, "The biology project allowed me to explore in detail something in the class that caught my interest" comes from the opinion of teachers in the 1981 survey that this is one of the educational values of individual student research.

Other SPI items were designed to test assumptions the author has held about the value of project learning. These include:

1. Projects are frustrating to do but give the student a sense of achievement and self-confidence when the student perserves and completes the task.

2. Projects should be stored in the school library or the biology classroom as examples and models for future students.

3. It is possible for students to do original research that educates the teacher as well as the student.

4. The project should be an opportunity for

the student to exercise decisions that affect his own education and should provide the opportunity for the student to view the natural consequences of his decisions.

Some items were also suggested by the basic definition of a project given by Adderley et al (1975):

> "A project is a significant, practical unit of activity having educational value and aimed at one or more definite goals of understanding; involves investigation and solution of problems and, frequently, the use and manipulation of physical materials; planned and carried to completion by the pupils and teachers in a natural 'real-life' manner."

This definition contributed to such questions as #14 "The biology project allowed me to explore in detail something in the class that caught my interest."

Adderley further characterizes a project as involving "initiative by the student" where the "teaching staff are involved in an advisory, rather than an authoritarian, role at any or all of the stages -- initiation, conduct and conclusion". This definition suggested questionnaire items that focused on students' perceptions of the degree of control they exercised in the project experience, such as question #5, "I was allowed to make my own decisions in the biology project".

Finally, some questions were included to see if students counted the project experience as a valuable or useful exercise, hence questions such as #20, "The biology project was a waste of my time" or question #16, "I feel what I learned in the project was worth the effort".

Students responded to the twenty items on the SPI by indicating their choice of "Strongly Agree", "Agree", "Disagree", or "Strongly Disagree". The completed questionnaires were later scored with a value of 4 assigned to "Strongly Agree" down to a value of 1 assigned to "Strongly Disagree". For questions #10 and #20 where the logic of the question was the reverse of the others in the set, the values assigned were reversed since a response of "Strongly Disagree" to the question "The biology project was a waste of my time." was considered to be a positive response. The scores for the twenty items were summed to give a student's total score in the range 20 to 80. A high total score was considered to indicate a high degree of student satisfaction with the project experience while a low total score was taken as an indication of little satisfaction with the project approach to learning.

The Inventory of Processes in Scientific Inquiry was the third and final test administered to students

(See Appendix III for a copy of the instrument). This instrument was adapted by the author from an extensive list of processes developed by Nay and associates (1971). From the many listed by Nay the author chose twenty items felt to be most pertinent to the grade 12 biology project. Students were asked to indicate on a three-point scale to what degree they felt the process had been learned in their project from "Not Learned Well" to "Learned Well". A fourth choice was provided indicating this item was "Not Applicable" to the student's experience with that particular project. It soon became apparent as the sampling progressed that the "NA" category was used by students to indicate "Not Done" or "Not Used".

The items were scored upon completion by assigning a value of 1 to "Not Learned Well" through to a value of 3 for "Learned Well", with a value of 0 assigned to "NA". The individual scores for the twenty items were summed for each student to give a total score. The range of possible totals was from 0 to 60. A high total score was taken as a measure of a high level of inquiry as perceived by the student. A low total score was taken to indicate few processes of scientific inquiry were perceived by the student to have been included in the biology project learning experience.

The sentence completion section on the last page of the IPSI instrument was an attempt to collect some qualitative impressions of what it means to do a project. All items were designed by the author and centred around these main themes:

1. What are the most difficult stages of a project?

2. How can a teacher help in the project process?

3. What did the student think she learned?

4. Did the student perceive any resources that would have improved the project process?

Analysis of the student responses to these items is provided in Chapter V.

D. Data Collection

Seven classes of Biology 30, exclusive of the pilot group, from school jurisdictions surrounding the city of Edmonton participated in the study. The distribution by gender was already given in Table I.

The tests were administered by appointment with the cooperating teachers during the period from mid-April to late June. This was near or at the end of the second semester of the school year. All students participating in the study had just completed or were near completion of the project in that semester.

All tests were administered by the researcher in a single 80-minute session with the cooperating teacher absent. The tests were administered in the order:

Test of Logical Thinking

Student Perceptions Instrument

Inventory of Processes in Scientific Inquiry

All students completed all test items within the time allotted. Students recorded their responses directly on the test instruments. The researcher scored the responses directly onto the test instruments. The scores were then transcribed by a keypunch operator onto keypunch cards for batch analysis by Amdahl computer at the University of Alberta, Computing Services Division.

The raw scores for all the test items were used in the analysis of data.

The qualitative data provided by the sentence completion exercise was summarized under each question by the researcher who then analyzed the responses for re-occurring words, phrases and themes.

In a similar manner the data from the tape recorded interviews was reviewed both for re-occurring themes and for unique student perceptions. A verbatim transcript of one interview was produced to provide a detailed example of this type of data.

E. Statistical Procedures

All statistical procedures used in this study were taken from Norman H. Nie et al, Statistical Package for the Social Sciences (SPSS) (1975) and executed on the Amdahl computer of the University of Alberta.

Frequencies were generated for all items on each test instrument and for gender and birthdate data and these may be found in the appropriate appendix for each test instrument.

For all other analysis of the quantitative data Pearson Correlations were used.

IV. Results and Discussion

A. Introduction

This chapter discusses the results of the statistical analysis of the quantitative data obtained from the three test instruments: the Student Perceptions Instrument (SPI), the Inventory of Processes in Scientific Inquiry (IPSI) and the Test of Logical Thinking (TOLT). The first section considers the distribution of concrete versus formal operational subjects found in the study as determined by the TOLT. The next four sections deal with the relationships between Piagetian cognitive developmental levels and student perceptions of their satisfaction with the biology 30 project and the value of the project experience, cognitive developmental level and gender, and student perceptions of the biology project and gender.

The remaining two sections of the chapter discuss the relationships between biology 30 projects and the level of inquiry found in the projects and the organizational structures of the project.

B. Piagetian Cognitive Developmental Levels and the Study Subjects

Chiapetta notes that a number of studies intended to assess the developmental levels of students have been undertaken by several researchers such as McKinnon and Renner in 1971, Lawson and Blake in 1974, Juraschek in 1974, and Chiappetta and Whitfield in 1974 (Chiappetta, 1976). Their general findings seem to indicate most adolescents and young adults have not attained the formal operational stage of cognitive development. The ranges reported for students at the concrete operational level were between 77 to 83.4% for junior high school students, 22 to 85.8% for high school students and 0 to 52% for college students (Chiappetta, 1976). These data illustrate a marked variation from the theoretical age of 15 to 16 years for formal operational thinking suggested by Piaget's studies.

In contrast to the above data this study found 87% of the students in the grade 12 classes sampled were found to be formal operational thinkers as determined by the TOLT (Table II).

C. Piagetian Cognitive Developmental Levels and Student Satisfaction with a Biology Project

To examine the relationship between cognitive developmental level and student perceptions of satisfaction with the biology 30 project a crosstabulation of TOLT scores with SPI scores was employed. According to the manual for the TOLT a total score of 4 or more would correspond to a formal operational level. The data were therefore sorted into two ranges, 0 to 3 and 4 to 10, which were interpreted as concrete operational and formal operational stages, respectively. For the SPI frequency distribution the author choose to organize each student's total score into four ranges: 0 to 20, 21 to 40, 41 to 60, and 61 to 80. Table II below shows the frequency distribution obtained.

Since the SPI measures student satisfaction with the project experience, progressively higher total scores were interpreted as progressively higher degress of satisfaction. Results in Table II show that both concrete and formational operational students indicated a high degree of satisfaction with the biology project.

Table II

Crosstabulations of TOLT by SPI

n (%)

		SPI TOTALS				
		0-20	21-40	41-60	61-80	Totals
T	0-1	0	0	6	8	14
O	(Concrete)	(0)	(0)	(5.6)	(7.5)	(13.1)
L						
T	4-10	0	5	68	20	93
	(Formal)	(0)	(4.7)	(63.5)	(18.7)	(86.9)
	Totals	0	5	74	28	107
		(0)	(4.7)	(69.2)	(26.2)	(100.0)

Chi Square = 8.3 Significance = 0.02

Table III continues to examine the relationship between cognitive developmental level (TOLT) and student satisfaction (SPI), but, whereas Table II examined total SPI scores, Table III examines those specific SPI items which showed significant correlations ($p = 0.05$) with cognitive developmental level.

Table III

Correlations of Student Perceptions of Project Satisfaction (SPI) with Cognitive Developmental Level (TOLT) ($p = 0.05$)

SPI ITEM	CORRELATIONS
The biology project was the most interesting academic activity I have done in high school.	-0.29
I worked hard on my project.	-0.20
My teacher learned something about biology from my project.	-0.22

Only three SPI items showed significant correlations with TOLT scores.' On all these items the negative correlations indicate students with higher TOLT scores ascribe less positive feelings about particular aspects of the value of the project. It is interesting to note the negative correlation of the first item: "The biology project was the most interesting academic activity I have done in high school". This item was included in the SPI since it was a direct quote given on the Biology Evaluation Report (Alberta Education, 1981). This opinion expressed by a student impressed the report authors and was offered as one rationale for retaining biology projects.

It is also worth noting that students with high TOLT scores tended to think that a teacher would not learn any biology from their project efforts.

D. Piagetian Cognitive Developmental Levels and Student Perceptions of the Value of Biology Projects

Table IV examines the relationship between cognitive developmental level (TOLT) and individual items respresentative of inquiry processes (IPSI).

Table IV

Pearson Correlations of Cognitive Developmental Level (TOLT) with Inventory of Processes in Scientific Inquiry (IPSI) ($p = 0.05$)

IPSI ITEMS	CORRELATIONS
"In my biology project I learned some of the following skills:"	
How to make predictions.	-0.18
How to make an hypothesis.	-0.17
How to obtain semi-quantitative and quantitative data by measuring, reading scales, calibrating, counting objects or events, estimating or approximating.	-0.18

The three correlations which were significant (p = 0.05) were all negative. Students operating at a formal operational level did not perceive that the project experience had taught them to perform three important inquiry processes: how to make predictions, how to form an hypothesis, and how to quantify data.

E. Piagetian Cognitive Developmental Levels and Gender

Analysis of TOLT scores versus gender of the student indicates there is no-significant difference between the cognitive developmental levels of a student and the gender of the student. (p = 0.05)

F. Student Perceptions of the Biology Project and Gender

Table V examines the relationships between the gender of the student and student satisfaction with the project (SPI). For the purposes of the data analyses male students were assigned a value of 1 and female students a value of 2. Positive correlations are then interpreted to indicate a greater preference for test items by female students.

Table V

Pearson Correlations of Gender*

with

Student Perceptions of Project Satisfaction (SPI)

(p = 0.05)

SPI ITEMS	CORRELATIONS
I found the biology project to be an interesting way to learn.	0.17
I would like to see my project report kept in the school library.	0.19
I worked hard on my project.	0.24
It is possible for a student to do original research that produces new science knowledge.	0.24
I think the project approach to learning taught me some things that were not included in the regular class lessons.	0.18

*. Male = 1, Female = 2

Generally, the results in Table V show that female students indicate more satisfaction with the biology project than did the males. Given the present concern in science education for encouraging girls to remain in science and math courses it is significant to note that girls found the biology project an interesting way to learn; with some learnings which were not included in regular classes; to a degree of satisfaction where the students felt the project report should be preserved in the school library.

Table VI continues to examine if there are different perceptions of the project experience based on gender by examining the relationships between gender and the processes of inquiry learned in the project (IPSI).

Table VI

Pearson Correlations of Gender*

with

Student Perceptions of Processes of Inquiry

Learned in the Biology Project (IPSI)

(p = 0.05)

IPSI ITEMS	CORRELATIONS
In my biology project I learned:	
How to devise a method for recording data.	0.24
How to do field work and/or perform an experiment.	0.16
How to record data.	0.22
How to represent my data with graphs, charts, maps, diagrams photographs, or films.	0.17

* Male = 1 Female = 2

Female students in the sample felt more positive about the learning value of the project in the key area of recording experimental data. Perhaps even more significant, again in light of the concern over involving girls in science education, the female students felt positive about learning how to do field studies and experiments.

G. Student Perceptions of the Biology Project and Project Organization

The types of student projects encountered in the study are summarized in Table VII. The high percentage of projects devoted to human physiology reflects the emphasis of this topic in the Biology 30 curriculum. Projects which were classified as "contemporary issues" included: wind energy, sewage treatment, solar energy, smoking as a pollutant, artificial and natural food preservatives, reforestation, and eutrophication. For the CAI/Genetics project the teacher asked groups of students to produce a computer program to demonstrate protein synthesis and the action of the DNA molecule. None of the projects involved field trips, although one teacher related an incident where two students were locked into the University of Alberta library late one night while searching for references for their ecology project! There was little evidence that students consulted any community resources such as local public health nurses, fish and game personnel or other biological sciences occupations.

Table VII

Types of Biology 30 Projects

Found in Seven Rural Alberta Schools

Type of Project	Number of Students	%
Human Physiology	29	27
Contemporary Issues	22	20
Human Disease	25	23
CAI/Genetics	11	10
Ecology	5	5
Plant Physiology	5	5
Cell Physiology	3	3
Nutrition	2	2
Embryology	1	1
Reproduction	1	1
Psychology	1	1
Animal Physiology	1	1
Taxonomy	1	1

n = 107

Table VIII shows the organization of Biology 30 projects found in the study. Data for this analysis was provided by each student on the first pages of the SPI instrument. Table VIII summarizes the frequencies found in the student projects for three organizational criteria:

1. Group size: Students were asked to indicate if they did their poject alone, as a member of a small group of two or three students or as a participant in a class-centred project. The author found no small groups of more than two students, so "small group" could actually be interpeted as "pairs".

2. Problem formulation: Students were asked to indicate if the problem for their project was formulated by themselves, formulated in consultation with other members of a small group, or provided by the teacher.

3. Number of hours: Students were asked to indicate the total number of hours required to complete the project. Students were instructed that this time included all planning and report writing time.

Table VIII

Organization of Biology 30 Projects in the Study

Categories	Percentage of Students (Number of students)
Group size:	
Individuals	39% (42)
Small group	38% (40)
Class	23% (25)
Problem formulated by:	
Student	21% (23)
With partners	18% (19)
Teacher	61% (61)
Number of hours to complete project:	
5	10% (11)
10	39% (42)
15	20% (21)
20	6% (7)
25	6% (6)
Over 25	19% (20)

Approximately 1/4 of the projects were conducted by the class as a whole. The remainder of the projects were divided almost equally between individual efforts and small group projects. Although not reflected in the above table the majority of the small groups were partnerships of two students.

Most problems were defined by the teacher; only about 40% were defined by the student, either alone or in consultation with group partners.

While the curriculum at the time of the study prescribed 25 hours for the project in Biology 30, approximately 50% of the projects sampled were completed in 10 hours or less. Only 1 project in 5 required more than 25 hours. Although not indicated in the above table, most projects were done in about a two-week period.

Table IX indicates the distribution of time in the Biology 30 project according to categories which the researcher determined could be elements of most biology projects. Students were asked to indicate the percentage of time spent on the four categories of activity. The numbers in each column represent the number of students who indicated the proportion of time spent in each category.

Table IX

Proportions of Time Spent On Some Project Activities

Activity	Percentage of Project			
	0-25	26-50	51-75	76-100
Students determined the project was composed of:				
Experiments	82	18	6	1
Literature Research	24	27	34	22
Model Construction	94	4	8	1
Collection of Specimens	105	1	1	0

N = 107

Table IX clearly indicates a very small percentage of the time spent on the projects was used for collection of data from experimentation. Only 7 students (7% of the sample) indicated they spent more than 50% of the time on experiments. Only 2 students spent any time on collection of specimens and 94 (88%) indicated they spent less than 25% of the time on model construction. By far the majority of student projects concentrated on literature research. More than half the projects (56 respondents) spent more than 50% of the project time on literature research. This strong emphasis in student projects on library research shows some interesting correlations in Table X with IPSI items.

Table X examines the relationships between the elements of project organization found the in the study and the items of the Inventory of Processes in Scientific Inquiry (IPSI).

Table X

Correlations of Project Organization with

the Inventory of Processes in Scientific Inquiry

($p=0.05$)

Inventory Category	Time	Problem	Expts.	Literature Research
How to state a problem for study.	0.21	-0.35	0.23	-0.20
How to read Science Journals for information.				
How to consult people with science knowledge.			0.39	
How to make predictions.	0.28	0.22	0.43	-0.27
How to make an hypothesis.	0.22		0.45	-0.31
How to define the independent, dependent and controlled variables.	0.19		0.32	-0.25
How to define the procedure and work out the sequence of steps for the procedure.			0.38	-0.39
How to identify the needed equipment, materials and techniques.	0.25		0.35	-0.28
How to identify safety precautions.				
How to devise a method for recording data.	0.20		0.37	-0.42

Table X continued

Inventory Category	Time	Problem	Expts.	Literature Research
How to collect, construct and set up apparatus or equipment.	0.23		0.42	-0.41
How to do field work and/or perform an experiment.	0.31		0.[illegible]	-0.35
How to record data.			0.41	-0.34
How to obtain semi-quantitative and quantitative data.			0.25	-0.25
How to gather specimens.				
How to represent my data with graphs, charts, maps, diagrams, photos, or films.	0.24		0.19	
How to do simple calculations with data.	-0.25	0.31		
How to use statistics to analyze data.				-0.20
How to compare data with initial assumptions, predictions, hypotheses.				
How to express data in the form of a mathematical relationship.				
IPSI TOTAL SCORE	0.20		0.52	-0.37

N=107

The data in Table X indicates a positive relationship exists between the amount of time spent on the project and students' perceptions of how well they learned the processes of scientific inquiry listed on the IPSI. Generally, teachers who encouraged inquiry learning allowed students more time to complete their projects. Learning inquiry process skills is therefore not simply a function of time, but a function of the greater amount of time allowed by inquiry-interested teachers for students to complete self-directed projects.

Correlations of IPSI items with the column labelled "Problem" are easily understood if one remembers that for analysis purposes, student-chosen problems were assigned a value of 1 and teacher-centred problems were assigned a value of 3. Therefore, the data indicate that student responses indicate a negative correlation between learning to state a problem for study and teacher-chosen topics. It is interesting to note that students responses seem to indicate that projects chosen by the teacher tend to strengthen student's ability to make predictions and their ability to do simple calculations from data.

There are a number of positive correlations between processes of scientific inquiry and the amount of experimentation included in the projects. As the amount of experimentation increased in the projects, students indicated a higher level of learning for many of the IPSI items. Particularly important are the strong correlations between experimentation and students' perceived ability to make predictions and formulate hypotheses. According to students, including experimentation as a major element in the project enhances the learning of these two key elements of the scientific process. Students also indicate strong correlations between experimentation and such practical skills as setting up apparatus, doing field work and recording data.

According to students' responses an emphasis on literature research in a project does not contribute to the learning of scientific process skills such as those listed on the IPSI. Literature projects do not strengthen any of the inquiry skills such as hypothesis formation, prediction testing, or manipulating data.

H. Biology 30 Projects and the Level of Inquiry

Students were given an opportunity on the test instruments (SPI, page 2) to describe the nature and extent of the their biology 30 projects. From these descriptions and discussions with the cooperating teachers the researcher classified all projects in the study according to the level of inquiry following the model of Schwab as modified by Herron (1971). Table XI indicates the classification scheme used and Table XII indicates the levels of inquiry found.

Table XI

The Level of Inquiry

As Determined by the

Schwab-Herron Model

Level of Inquiry	Problems	Ways & Means	Answers
0	Given	Given	Given
1	Given	Given	Open
2	Given	Open	Open
3	Open	Open	Open

"Given" = Given by teacher.

"Open" = Open to the student to formulate.

Table XII

Level of Inquiry in Biology 30 Projects

of Seven Rural Alberta Schools

		Level of Inquiry			
		0	1	2	3
Students	%	24	39	1	36
	n	(25)	(42)	(1)	(39)
Schools	%	14	43	0	43
	n	(1)	(3)	(0)	(3)

n=107 students

n= 7 schools

The table clearly shows a low level of inquiry as defined by the Schwab-Herron model in 57% of the schools. Still, 43% of the schools followed student projects with a very open level of inquiry. There seems to be fairly close to an even split between schools where the teachers retain control over essentially all of the project elements and those schools where teachers relinquish control entirely to the students. Unfortunatsely the majority of the students, 63%, were in the schools with the lowest level of inquiry.

Further, following the Schwab-Herron model, Table

XIII examines the relationship between the level of inquiry and student satisfaction with the project (SPI).

Table XIII

Pearson Correlations of Level of Inquiry with Significant Items of Student Perceptions Instrument ($p = 0.05$)

SPI Item	Correlations
I would like to do another biology project.	-0.45
I was proud of my project.	0.36
I felt I did a better job of the project than I usually do with the regular biology labs we do in class.	0.30
I was allowed to make my own decisions in the biology project.	0.55
I worked hard on my project.	0.26
I would like to be able to make my own decisions in a biology project.	0.40
I found the biology project to be frustrating.	-0.19
I felt I had produced something that was my own work when I finished the project.	0.43
Doing a biology project has made me think about a career in science.	-0.25

Positive correlations appeared between the level of inquiry and six SPI items. Students who had been allowed to pursue projects classified as very "open" by the Schwab-Herron model indicated satisfaction and pride with the project. Not only was the experience satisfying, but it seemed to be less frustrating. It is interesting to note, that despite this satisfaction, the more open-ended the investigation, the less likely the student wanted to do another project. Students in open projects seemed also to be less inclined to consider the experience as an indication of future careers.

Finally, Table XIV examines the relationships that exist between the level of inquiry and students' perceptions of the processes in scientific inquiry learned in the biology project.

Table XIV

Pearson Correlations of Level of Inquiry with

Inventory of Processes in Scientific Inquiry

($p = 0.05$)

IPSI Items	Correlations
In my biology project I learned some of the following skills:	
How to state a problem for study.	0.42
How to make predictions.	0.32
How to make an hypothesis.	0.20
How to define the independent, dependent and controlled variables.	0.25
How to define the procedure and work out the sequence of steps for the procedure.	0.26
How to identify the needed equipment, materials and techniques.	0.38
How to do field work and/or perform an experiment.	0.28
How to do simple calculations with data.	-0.41
How to express data in the form of a mathematical relationship.	-0.22

As the level of inquiry increases, so does the level of learning of certain processes in scientific inquiry, according to student responses. Negative correlations are obtained only for quantitative manipulations of data. According to students, the degree to which such key processes as indicated in the table are learned increases as the degree of openness of inquiry increases. This is very much in keeping with the expected outcomes of inquiry learning.

V. Student Perceptions and the Project Experience

A. Introduction

The primary purpose of the study was to examine the biology project experience from the perspective of the student. To that end the test instruments were designed to quantitatively evaluate student's opinions on the value of the experience. The data in Chapter IV examined those opinions using statistical means. However, the study was never intended to rely solely on numerical data and statistical techniques. It was considered important to provide some "voice" to the sample subjects and to obtain specific opinions from students on this learning experience. This chapter first examines student responses to the sentence completion section of the IPSI. These responses were collated by question and analyzed for any reoccurring themes and ideas. The ten sentences have been grouped below into categories for reporting in this chapter.

The second section of this chapter focuses on the taped interviews conducted with randomly selected students from six of the schools sampled. A complete transcript of one interview is given as an example in Appendix IV.

B. A Summary of Sentence Completion

The ten sentence completion items (Appendix III) were sorted into five categories, labelled: interest, frustration, teacher's role, learning, and summary. These categories were specific themes suggested before the design of the test instrument. "Interest" and "frustration" were clearly themes in the written responses of biology teachers in the Biology Evaluation Report (Alberta Eduction, 1981). Asking students to comment on the "teacher's role" and the "learning" they perceived in the project work reflects the organizational point of view of a classroom teacher interested in developing better strategies for the teaching experience. The "summary" category was added to the test items to see how students would summarize the project experience.

For each category the frequency of response is expressed as a percentage in brackets. Assigning a particular student response to the category was a subjective decision of the author. No attempt was made to categorize all student responses for a particular sentence, so only the major categories are summarized below and the percentages indicated for a category will not add to 100%.

1. Interest

Only the first test item is summarized under this heading. The IPSI item read, "The most interesting part of the project was...."

Surprisingly one of the first words to emerge as one surveys the responses to this item is the theme of reading (3%). For instance, one student replied "...reading up about genetic mutation". There seemed to be genuine satisfaction with the literature searches for information, although note the references below under "frustration". A second student wrote, "...reading through material and finding out things I did not know". This response also illustrates a second major theme, that of finding out (8%). For some students "finding out" reflects a sense of discovery: "...finding out about something I didn't really know very much about", and, "...finding consequences of acid rain". For others the "finding out" perhaps meant realizing relationships in a new and more meaningful context; "...finding out the amount of importance the stomach was and the causes of stomach diseases", and "...finding out the function or role of the organ in the body. The enzyme and hormones it secreted". These last two topics, course content for Biology 30, take on new meaning for the students through the project experience.

The third major theme, learning (21%), is an extension of the second. It is a specific word used by more than 20% of the respondents as they described a variety of "interesting" experiences: "...leanning new things about stuff you thought you had already known", "...the learning to make deoisions in a scientific manner", and "...learning how complicated and exact the human brain is". Some saw future potential in this learning; "...learning so I could possibly set up my own home in solar heating". Others again saw the learning in terms of realizing relationships between isolated groups of facts; "...learning about body systems, how each one works independently and also how they all worked together. When you see how digestion works you begin to appreciate your body alittle more".

The fourth theme, doing (30%), was by far the most common student response. Students found it interesting to perform specific tasks associated with their project. These activities cover the range of practical experiences usually found in biology classes: "...collecting specimens", "...the demonstration", "...the experiments", and "...model construction". A very clear favourite was dissection: "...a dissection of the eye (subject of my report)", "...the dissection of the heart", and "...the skinning and actual taking out special organs, also putting it back together". A few of the activities suggested, while possible in many biology classrooms, are probably more likely to occur in the context of a project. Some students reported: "...doing a survey", "...when I went on a field trip to observe the processing from canola seed to crude vegetable oil", and "...going to a professional and asking questions".

Several minor themes were suggested when only two or three student responses focussed on the same idea, but from an educator's point of view they were significant. For instance, a few students found the checking of their predictions to be the most interesting part of the project: "...comparing results to the predictions" and "...seeing if my model would work". These two responses represent very strongly the potential for inquiry learning possible in projects.

It is gratifying from a science educator's point of view to see student responses indicate that reading, learning, finding out, and doing a variety of types of activities can stimulate interest and that students seemed to enjoy working through themes consistent with educators' goals.

2. Frustration

Students find biology projects a considerable source of frustration, especially as the level of inquiry increases. They are left more to their own resources and must solve a number of problems related to planning their time, organizing equipment, collecting reference material, and motivating themselves to complete the project. Two items on the IPSI were intended to sample student opinion on what they considered to be the most important elements that caused frustration in their projects. The first question, "The most difficult part...", asked students to identify the elements which merely caused some problems. The second item, "I almost gave up when...", provided an opportunity to respond to incidents or circumstances which raised frustration to a critical point with respect to the project's completion.

Practical problems (19%) presented the most difficulty for most students. For some the problem was simply mastering a technique: "...weighing the kittens", "...identifying the form of mold cells", "putting the feet together and cleaning the small bones making sure not to lose any", and "...trying to recognize certain solutions". One student lamented a condition many researchers will recognize; "...people who did not answer truthfully"!

Writing (15%) the report was mentioned almost as often as practical problems as a source of difficulty. While for some the problem was not meeting minimum expectations, "...making it long enough"; for others, writing the report presented the researcher's dilemma, "...limiting my topic down to make an 8 page report". Most of the responses under this theme were succinct, "...writing it down"; with no clear indication as to why this was a problem. Whether the act of writing was a problem of poor communication skills or a question of available time and motivation is not clear.

Perhaps some of the difficulty of the report writing is reflected in the next major theme of organizing the information (12%). The process of synthesizing and summarizing the data into a unified presentation was expressed in several ways: "...compiling the information", "...condensing all the information", "...getting my notes in order and trying to figure out what they mean", and "...coming up with conclusions and stating what we found out".

Several students seemed to have difficulty right from the beginning. For some it was a question of motivation, "...getting started and interested in the project". For others it was the very real problem of what question to pursue, "...finding or coming up with an experiment or project that was relavent (sic), could be done in the lab and that some other Bio. 30 class hadn't done for the past six years". This problem of choosing a topic is further explored in the student responses during the taped interviews discussed below.

Finding information (10%) was certainly a source of difficulty to many students: "...finding data on the project that was at a high school level" and "...getting the information because the information from one book to another isn't consistent". Both of these comments suggest an important role for the biology teacher in the project activity. Note below that several students comment on how the teacher can and should help with reference material. The second comment reflects the adolescent's wish to see the world strictly in colours of black and white. The tentativeness of scientific knowledge and the importance of conflicting theories confuses and disturbs teenagers. Educating students to the nature of scientific knowledge is an important role for the science educator.

A few students found terminology (5%) difficult: "...learning all the terms and applying them properly".

Only three students indicated teacher's expectations (2%) created difficulty, "...understanding what the teacher wanted".

The greatest difficulty for students in the biology project was clearly the practical problems of weighing, identifying, calculating, dissecting, and experimenting. Almost as important were the problems of summarizing the data and writing the report. For fewer students, finding a suitable topic and the relevant information was the source of their frustration.

Some students will give up if the frustration is unresolved and becomes so overwhelming that the project is abandoned. The second IPSI item in this category explored the circumstances students identified as almost insurmountable.

A significant number of students (14%) indicated they never felt like giving up on the project while another 31% indicated the question was "not applicable" or left this item blank.

For students who almost gave up the biggest source of frustration was again practical problems (16%). Some of these seem to be the result of inexperience; "...I exposed all the pictures of the project" and "...I had an experiment to do and the directions from the booklet were beyond comprehension. Everyting (sic) had to be changed to metric and percentage solutions had to be made up. I didn't know how". Some problems seem to be the result of inadequate resources; "...after having just chosen the project I liked most, I thought our school was not equipped with some of the materials I needed". Plants seem to give particular problems; "...our plants died the first time" and "...our first set of oats had died that were to be used for our experiment". There is wide scope here for the teacher to facilitate the experience for the student. By helping the student to adjust the project topic to existing school and community resources and by supervising the care of plant and animal materials the teacher can ease the student's frustration without diminishing the learning experience of dealing with the practical problems.

A second problem which provided great frustration was <u>information</u> (9%) that was too difficult or difficult to find. "...I could not get the information I wanted" was a frequent complaint. Just as common was the comment, "...the textbooks did not make any sense because they were written in a high form of language and it was hard for some one with no knowledge of the organ to understand what they were saying".

A few students found the <u>volume of work</u> (5%) to be daunting; "...I had to read 52 pages in a lab book" or "...I saw piles of notes that had to be organized". A few had similar thoughts but expressed them in terms of the time required to do the project; "...there were major assignments from other courses, all requiring completion in the same time space".

While a significant number of students did not feel the problems encountered in the project were sufficient to cause them to quit, those who felt extreme frustration with the experience cited practical problems, the scarcity and complexity of the information, the volume of work required and the time required for the project, as major stumbling blocks for completion of the project.

3. Learning

Three IPSI items were summarized under the category of "learning". One specifically asked, "I learned...". Two more, "I wish..." and "I could have done a better job...", were interpreted to imply the student could evaluate the experience and could suggest improvements.

In response to the first IPSI sentence, students clearly indicated they felt they had learned facts and concepts (51%). Responses commonly suggested: "...the physical dangers of marijuana and the history of its use" and "something about what cancer is and how it starts and some of how it can be treated". Some thought the knowledge gained supplemented or reinforced the classroom learning, such as, "...additional information about the subject matter which added my understanding of the subject". A large number (16%) specifically referred to learning more about parts of the human body: "...a lot about the brain, its evolution, parts and functions", "...much about how the heart works and the causes and effects of diseases of the heart" and "...that the digestive system is very important in our bodies. Without the small intestine we would not digest our food properly". Such an emphasis on human physiology is not surprising since this is the major theme of the Grade 12 biology course.

After content, the second most significant response concerned the learning of values (8%). For instance, "...from my project the seriousness of acid rain, which I feel everybody should be made more aware of" reflects the position the student has learned to take as a result of the project experience. Several of the projects covered broad issues such as the extinction of animals and the effect of pollution in the environment. The values learned in the study of such complex issues may be seen in these two responses: "...about the problems of extinction and ways to solve it. And how man can benefit from preserving the species on earth" and "...a lot about guidelines and why things are done for certin reasons. - to usually help the environment, not hinder it". Another response was shorter, but still reflected a value learned, "...to quit smoking"!

A small number identified processes of science as significant learnings: "...that experiments help to understand a concept by providing a concrete example" and "...that our hypothesis was correct". One student discovered "...that scientific experiments do not always go the way you have planned them"!

When asked to complete the sentence "I wish..." the response was clear, more time (26%). Time was obviously a major consideration because when asked to complete the sentence, "I could have done a better job...", again the majority replied, if they had more time (40%). Some said, "...we would have had more time, and we could have gone in more depth, and greater detail". For many the issue of time was tied closely to the problem of finding suitable resources: "...if I would have consulted more references & spent more time on the project". But, for many the wish was for an earlier start. The following comment was common: "...I would have started earlier than I did". One student illustrated a common problem found in a project if plants are used, "...I would have started a bit earlier so I would have had more time to write and I wish I would have planted my plants earlier so they could have died".

Some students wished they could have obtained more data (6%): "...that I would have had more specimen available, and more snapshots from the farm to display the different growth stages from spring to fall" and "...the people we wrote letters to asking for information would have been more helpful - we didn't get any replies".

A few students wished for more freedom of choice (5%): "...I could have had more input into what I was going to do for a project" and "...we could do more on our own".

About 14% of the students indicated dissatisfaction with the project. Some thought no project (4%) should be required at all. Many wished for a more interesting (6%) topic, while a few felt the teacher's expectations or the project specifications (4%) were either too strict or not clearly defined.

It was interesting to note how many students felt there should be more project opportunities (4%) in school: "...more schools would do projects like this". As well, the same number of students felt others should benefit (4%) from the same knowledge they found in their project, "...I could influence people what loud noises can do to their ears" and "...other people would quit (smoking) also".

Only a few students felt they could have done a better job of the project with more resources (6%). These resources included: "...if I could have talked to people who knew a lot about leukemia"; specimens, "...if I could have had more specimen available", and "...if we would have had the proper chemicals at school".

Finally, a few students gained some insights into their own skills and felt they could have done a better job if they had been more self-motivated (8%): "...if I could let my imagination go. (ie. create more personal interest)" and "...in doing my homework and gathering pertinant information. Being a fairly vigorous individual I feel a little disappointed in my laziness".

4. Teacher's Role

The IPSI item, "The teacher helped most...", encouraged students to offer their views on the teacher's role in the biology project. The most common response to this item indicated the teacher plays an important part in finding information (13%), "The teacher helped us to find information. If he saw something that pertained to our project he gave it to us.". Often the information needed interpretation, such as "...when we couldn't find the information ourselves, or when we didn't understand it" and "...in getting further information that made the technical stuff a little easier to understand".

The teacher also seemed to play an important role in clarifying (11%) the project process for the student, "...with different routes to take with our project", "...with analysis of graphs" and "...in discussing the terms used and explaining diagrams and facts on cancer".

Of course the teacher was often instrumental in helping with the experimental setup (8%) , "...when we needed help with instruments and procedures we were unfamiliar with", "...with dissection and finding references" and "...with the dissolved oxygen tests". Several students noted in particular that the teacher helped mix the appropriate solutions. "...with the percentage solutions. He explained to show to get the percentage we needed and what the percentage meant" was a typical response on this theme.

A few students felt the teacher had been most helpful with defining the topic for the project investigation. One student noted "...with developing our project so it would suit our needs", while another responded, "...helping me to find a workable topic from very little idea".

Students' perceptions of how the teacher helped most in the project experience seem to fit exactly the role of the science educator in inquiry learning: to guide the student in defining an appropriate topic for study; to assist in finding information related to the topic of inquiry and to interpret the information at a level appropriate to the student's understanding; and to assist in the practical problems of equipment manipulation to investigate the problem.

5. Student Suggestions

The IPSI item, "It would have been helpful..." explores student suggestions for conditions which would favour biology projects.

The most common response of students was to suggest more time (12%), "... if we had more class time" and "...if we could have had more time to go deeper into the project". The second most common theme found in the student's replys centred on better library and equipment resources. Such responses as, "...to have a more extensive library area, and more equipment - specimens" and "...if we had more facilities and supplies to do more things, as in slides etc. and to be able to do more experiments", illustrate students' thoughts on this subject.

Third, students felt more information (9%) would have been helpful. "...if I would of had more information and also been able to talk to a doctor about the different heart diseases" typically mentions this third theme and also refers to a fourth, the desired availability of resource persons (7%). Several students would like to have talked to knowledgeable people about their project, as mentioned by this student, "...to visit the Cross Cancer Clinic in Edmonton or the U of A Hospital to see the equipment used in treatments & speak to people involved either as physicians or patients".

The last major theme was suggested by this response, "...to have more free rein". Independence (5%) was clearly the intent of this student's reply, "...if the project (topic) was one chosen on my own & out of my special interest".

Students reiterated the themes of more time, more information and better resources when asked to comment on what conditions would have been helpful for their projects. They also suggested contact with resource people and some control over choosing their own topics would have contributed positively to the learning experience.

6. Summation

The final item on the IPSI sentence completion section asked students to reflect on the biology 30 project and offer some concluding statement by completing the sentence, "In summary, I would say the Biology 30 project...". Tabulating the responses showed 58% of the students felt the project was "worthwhile", 26% felt the project was a "moderate success" or "OK", while only 16% indicated a negative response such as the project was "a waste of time".

Several of the comments favourable to the project were very positive and indicate that students appreciated this method of learning:

> "...that I did was very interesting for my own personal benefit. I learned things that I would not have learned from other sources or free interest. I hope the information I gathered will be helpful to me in the future."

> "...is a great necesity (sic) for young people to take a step into a world unknown to them. Practical learning stays in one's mind easier & longer than 'classroom' learning does."

> "...is good to get you thinking and concentrating on a certain area. It lets you get yourself to ask questions and lets you think better and try to understand things more clearly."

> "...was good for learning about our body and also good for teaching us writing skills."

> "...is a very important part of learning and training yourself to work without

supervision."

> "...is a very good way of learning something more so than in the classroom. It enables you to get away from the actual books, and I found it fun and interesting!!!"

Many more examples such as these could be quoted to illustrate students' approval of the biology project and their perceptions of the skills and values learned through the experience.

It is interesting to note that many of the negative respondents shared the view of this student, "...isn't that good of an idea unless you are planning on a biological career. The in-depth study you have to do doesn't really apply to the average person.". The students' perception was that the project was a waste of time unless the student was a future career biologist.

C. Taped Interviews

To provide another opportunity for students to express their views of the Biology 30 projects, interviews were recorded in six of the schools visited. Students were selected at random from the class list of each school; approached by the cooperating teacher and asked if they would consent to the interview. An attempt was made to have a group of four students present for each interview, although one class had only two students. A complete transcript of one interview is provided as an example in Appendix IV.

While the questions varied somewhat with each interview depending on group dynamics and the types of projects completed, five essential questions were the focus for each session:

1. Could you please describe your project?
2. How did you choose your topic or problem?
3. What do you think you learned from the project?
4. What was the most frustrating part?
5. What advice would you give me as a teacher since I intend to assign projects to my students?

Student responses to the first two questions repeated information already mentioned in this study in previous chapters. Table VII describes the types of projects found in the study and Table VIII indicates that more than 60% of the topics were chosen by the teacher. However, two important observations may be made from the way students answered these questions.

First, when the topic for study had been chosen by students, either singly or as a member of a group, students had very little difficulty describing the project. Typically, a student presented a description in logical steps outlining the problem, the procedure followed to assess the problem, some of the findings and some of the conclusions the student had reached. On the other hand, if the problem had been chosen by the teacher and especially if the project was being conducted by the whole class, students had only a vaque idea of what the problem assignment involved. The procedure was uncertain. The purpose was not clearly understood. The student's individual contribution to the whole class puzzle was not clear. In short, students pursuing a problem of their own understood far more clearly the process and the intent of the project.

Second, students spoke with more enthusiasm and conviction about projects that followed their own interests. If the teacher chose the project topic and if the project involved a large group, the student was likely to feel removed from personal involvement and tended to be far more critical of projects in general and less enthusiastic about this method of learning.

The third question eventually raised in all interviews asked students what they felt they had learned. Not suprisingly, all students focused on the specific content of their project. For instance, several thought they now knew what caused certain types of cancer. Another felt she now knew how to piece together the bones of a small mammal. No student volunteered a response which suggested inquiry process skills or values had been a significant learning.

When asked what presented the most frustration in the project experience, students again reflected many of the themes mentioned above: complex terminology, lack of literature resources, report writing, and for some, practical problems such as finding the right glue or mixing solutions. Again there was a clear difference in students' responses to this frustration depending on who chose the topic. If the teacher chose the topic, frustration contributed to the negative feelings students had about the experience. If the student chose the topic, the frustration, especially those from practical problems, seemed to be solved by revising the technique or as in the case below, by analyzing possible avenues for further research. In the following excerpts (Appendix IV), the student had expressed some concern througout the interview that her plants did not die as expected when she tried to simulate acid rain:

> Researcher: What for you, Jill, was the most frustrating part?
>
> Jill: I don't really know. Ah..Ah.. I guess when my experiments didn't work out, not like I wanted them to.
> (Several lines are deleted here.)
>
> Researcher: Have you satisfied yourself that

you maybe have a guess as to why they didn't die as fast? Have you got some sort of....

Jill: Yeh, I read a whole bunch of reasons why and I'm positive that, you know, I'm pretty sure why they didn't die.

Researcher: So, in reality in one sense the experiment has at least helped you to...obviously you hadn't thought of those reasons before you started the experiment. But the experiment at least showed you had to think of those reasons, so can you see that you have learned at least something?

Jill: Yep. Plus I can see that conditions must be a lot worse than I thought. I mean I..if mine was quite a low, um, molar concentration and yet they say, oh, don't worry, you know, I......it must have to be quite concentrated or else it wouldn't leave the damage that it has.

What had been initially a frustration for this student became the focus for further reading and for the formation of several hypotheses to possibly explain her observations.

One final observation about students' responses on the theme of frustration. While students in all interviews seemed to have only a vaque idea of how the project would be evaluated, more students in projects chosen by the teacher mentioned this as a source of frustration. The general confusion over the purpose and process of group projects and teacher-centred projects seemed to focus on a concern for how the student would receive a grade.

From the researcher's point of view the last question, which asked students to provide advice, was the most important. Generally, all respondents had opinions to express on this question and the opinions centred on one suggestion:

> Basically, just make sure each student [illegible] something they are interested in. Because it they are interested in it they are going to work a lot more harder at it and the harder the work they are doing the better... (Appendix IV)

This same theme was repeated interview after interview - let students chose their own topic. When asked how a teacher could help students who have great difficulty doing just that, students frequently suggested the teacher provide a list of possible topic ideas and allow students to choose from that list. Students felt the list idea was only second best to choosing your own topic, but they acknowledged some students would need it.

With such a consistent message in each interview, could students who were following a teacher-chosen project define an area of interest for their own study? Essentially just that question was asked during one session. Note the following four responses:

> Frank: (Pause) Probably go out and study more of the wildlife or something. The actual going out and looking at stuff. We didn't do much of that in other grades.

Lorna: Maybe some handicap, like multiple sclerosis or something...There are people around here that have it or have had it. You hear about it on TV so much and about the pills and stuff they have to take. Things like that. I was just wondering what they think causes it and things.

Linda: I would study more on reproduction, like, not so much how it happens, but how you become - human. How you turn out and stuff like that.

Researcher: I think the words you are groping for are "growth and development". Not so much how you are born, but how you turn into the person you are, because of your genes - and - anything else?

Linda: Yes, how other stimulus can affect the way you developed, like, mothers who smoke or drink, or, just outside stimulus, how it affects the development.

Leonora: I think I would do a certain kind of horses cause in the white stallions they are born black and turn whiter every year and when they come 15 they die usually of cancer. And it is just in the one breed and they believe it's because of melanocytes in the skin. It decreases, the melanin, in the system, so the horses become lighter, but they are more susceptible to the sun's rays and the sun causes the cancer. So I think I would be interested in finding out about that.

Researcher: You breed horses or raise horses do you?

Leonora: Yes.

In the space of only a very few minutes each student had outlined a topic for possible study based on personal interests. None of the students, to be sure, had defined a clear statement of the problem to be studied, but with a teachers help the project could develop the necessary definition for a Biology 30 level of investigation.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. Introduction

In this chapter a brief summary of the study will be presented. This will be followed by the researcher's decisions with respect to the study hypotheses. Both quantitative data and qualitative observations of students in the sentence completion items and taped interview sessions suggested certain topics beyond the scope of the original hypotheses. These topics will also be discussed with a view to formulating several recommendations at the conclusion of this chapter.

B. Summary

The study was intended to examine grade 12 biology projects to determine if:

1. a relationship exists between Piagetian cognitive developmental levels and student satisfaction with the project
2. a relationship exists between Piagetian cognitive developmental levels and student perceptions of the value of the project as a learning experience
3. a relationship exists between cognitive development level and gender

4. a relationship exists between student perceptions of the project and gender.

The sample of 107 students from 7 rural schools surrounding Edmonton, Alberta, was chosen by randoming selecting schools for contact and then visiting those schools were a cooperating teacher consented to the study. All students had completed projects in the second semester of the 1982-83 school year and all sampling was done during the period April to June, 1983.

Three test instruments were used in the study. The Test of Logical Thinking (TOLT) designed by Tobin and Capie (1981) is a pencil and paper test used to determine the student's cognitive developmental level according to the theories of Piaget. The test is a series of five pairs of questions which measure formal thinking ability in five areas: proportional reasoning, controlling variables, combinatorial reasoning, probabilistic reasoning, and correlational reasoning. The range of scores was from 0 to 10, with a score of 0 to 3 interpreted as a concrete operational level and a score of 4 or more interpreted as a formal operational level. The Student Perceptions Instrument (SPI) is a twenty-item questionnaire with a five-point Likert scale used to measure the students' satisfaction with the biology project. The SPI also provided sections for determining how the project was organized in terms of problem definition, time spent, and percentage of time spent on typical project activities: experimentation, literature research, model construction, and collection of specimens. The <u>Inventory of Processes in Scientific Inquiry</u> (IPSI) was a twenty-item questionnaire adapted from a list of processes of inquiry developed by Nay and associates (1971). The instrument measures students' perceptions of process skills learned in the project experience and provides a sentence completion section to complement the quantitative responses to the questionnaire, with written observations by the respondents. The IPSI items chosen reflected the author's opinion of the most important process skills that should be found in biology projects. Student reponses to the IPSI items were intended to reflect students' opinions of how well they thought those process skills had been learned during the project experience.

To examine the relationships postulated in the hypotheses the quantitative data from the TOLT, SPI and IPSI were examined statistically for any significant correlations. Crosstabulations of TOLT with SPI and IPSI items and with gender were also examined. Further to the quantitative analyses, student responses to the sentence completion items on the IPSI were examined for reoccuring themes. Tape recorded interviews with students from the sample group were also analyzed for comments and observations pertinent to study questions.

C. Conclusions

The following conclusions may be drawn with respect to the study hypotheses:

H_1: There is no significant relationship between student satisfaction with a biology project (SPI) and cognitive developmental level (TOLT) ($p = 0.05$).

Decision: Hypothesis accepted.

H_2: There is no significant relationship between cognitive developmental levels (TOLT) and student perceptions of the value of a biology project as a learning experience (IPSI) ($p = 0.05$).

Decision: Hypothesis accepted.

H_3: There are no significant relationships between cognitive developmental levels (TOLT) and gender ($p = 0.05$).

Decision: Hypothesis accepted.

H_4: There are no significant relationships between student perceptions of the learning experience of a Biology 30 project and gender ($p = 0.05$).

Decision: Hypothesis accepted.

It is a conclusion of this study that student satisfaction with a biology project does not depend on the student's cognitive developmental level.

It is a conclusion of this study that the value of a biology project, as perceived by students, does not depend on the student's cognitive developmental level.

These conclusions are supported by the repeated observation that students identified as concrete operational, according to the TOLT scores, gave evidence in their responses to the sentence completion items and during taped interviews of well-designed, inquiry-effective projects. There is no basis for assuming students must reach a formal operational stage of development before undertaking an independent inquiry a part of a grade 12 biology course.

This study also concludes there is no significant difference between male and female students in terms of cognitive developmental levels (p = 0.05)

The decision to accept hypothesis 4 was difficult. While total SPI and IPSI scores compared with gender showed no significant relationships, individual items on both test instruments showed significant correlations. Girls expressed more positive responses to:

1. The biology project was an interesting way to learn.
2. The project report should be kept in the school library.
3. It is possible for a student to do original research that produces new scientific knowledge.
4. The project approach to learning taught some things not included in the regular class lessons.

Girls' responses were also more positive than boys' when indicating how well the following process skills had been learned:

1. How to devise a method for recording data.
2. How to do field work and/or perform an experiment.

3. How to record data.

4. How to represent data with graphs, charts, maps, diagrams, photographs, or films.

Hypothesis 4 was held tenable on the basis of no significant correlations were detected between the total scores for each test instrument and gender, in spite of significant correlations for the individual items mentioned above. It is the conclusion of this study that there is no difference in the perception of male and female students of the value of biology projects as a learning experience. This seems to be consistent with the results of Rakov (1985) who found there was very little difference in the overall prediction of inquiry skill for males and females.

The researcher acknowledges that due to the limitations of this study, these conclusions may not be generalized beyond the study sample.

What is clearly evident from the study data, both qualitative and quantitative, is that the satisfaction and value of the learning experience of a biology project are dependent on factors not hypothesized before the study. Student responses for both satisfaction and their perceptions of the skills learned in the project depend directly on the level of inquiry allowed by the classroom teacher. If the level of inquiry is high, student satisfaction is high. If the level of inquiry is high, students' responses indicate they feel they learn many process skills well.

Analyses of the students' responses to the sentence completion items and students' comments during the taped interviews suggest several practical considerations for the classroom teacher attempting biology projects:

1. Students want to be able to control the decisions in their project, especially, to be able to choose their own topic for study.

2. The role of the teacher is to facilitate, not direct. Students need assistance with finding relevant resource materials, both texts and appropriate community resource people. Students also need guidance when faced with practical problems requiring skills not yet learned or mastered.

3. If the level of inquiry is high, students are more confident of the goals of the project experience and experience less frustration when faced with practical problems.

D. Recommendations for Further Research

Several observations during this study have suggested areas for further investigation:

1. While there was no significant relationship between gender and total scores on the two instruments measuring students' perceptions of the satisfaction and learning value of a project experience, there was some evidence to suggest an inquiry approach to learning elicits favourable reactions from female students. It is suggested there be further research into female students' attitudes to inquiry learning and self-directed projects.

2. Since student responses indicate a clear relationship between the level of inquiry and the value of a project experience, it is necessary to study methods of instruction for student-teachers that develop positive attitudes to inquiry-based student projects.

3. This study has examined only students' perceptions of what they felt they had learned in the project experience. It has not tested specific process skills to determine the actual achievement levels of students and related that achievement to cognitive development. It is suggested that further research is needed to examine the relationship between cognitive developmental levels and student competence with the process inquiry skills needed for an independent study project.

4. Welch and associates mention that the greatest

obstacle to projects seems to be teacher's perception of the difficulty of projects. It is suggested that research is required to develop effective strategies for administering independent projects, especially to develop methods of project evaluation.

E. Personal Reflections

Review of this study has lead the author to reflect on three important ideas.

1. The Significance of Correlations

While this study included the use of statistical analyses of quantitative data to investigate the hypotheses, a prudent reader might well question whether this approach always is the best for the study of learning situations in the classroom. It is well known that correlations may be shown to be significant, yet is the information really "meaningful". Tables III and IV illustrate this point very well. In Table III, the item, "The biology project was the most interesting academic activity I have done in high school" is not really a valid question given the many and varied experiences in a wide range of subjects over twelve years of schooling. Similarly, "I worked hard on my project" should probably be ignored since it is a highly subjective and very relative question.

Table IV contains three significant correlations, all negative, relating cognitive developmental levels with processes in inquiry. Would a more in-depth comparison of the student interviews and sentence completion data with the IPSI responses still support this quantitative analysis? If only inquiry based projects were analyzed and the TOLT scores of those students used for analysis, would these correlations still be the same? Such questions can and should be raised about any correlational approach to the classroom situation.

2. The Positive Nature of Frustration

It will be ~~no sur~~prise to the classroom teacher that this study found students experience considerable frustration doing a biology project, but this should in no way imply that frustration is a negative quality. Too many teachers avoid projects because they feel students will become frustrated and yet encountering frustration is an integral part of any science research or everyday life. To paraphrase a quote attributed to Sir Frederick Banting, scientific investigation is not the activity of a quiet, ordered mind, but the efforts of a deeply troubled and agitated mind to bring some resolution or order to its unsettled state.

Two recent studies have reflected on the role of frustration in the classroom. Valerie Oldham (1982), studied the problems students had with the very difficult subject of tissue respiration and concluded that experiencing difficulty is an integral part of the search for self:

> Through our encounter with difficulty, life gives us the opportunity to reach beyond our limits, to show both others and ourselves who and what we truly are. (p. 108)

Raymond Nadeau (1984) investigated student attitudes and skill development during an inquiry approach to teaching grade 12 Chemistry using a series of eleven experiments. He found that while students expressed difficulty with mathematical calculations and writing a series of three reports for each laboratory activity: design, observations and final results; students consistently described the process as challenging, interesting and enjoyable.

The role of the classroom teacher should not be to minimize difficulty for the student, but to help the student develop a positive approach to coping with frustration in the subject material and classroom activities and to carefully assist with appropriate teaching strategies when the student's abilities or knowledge are inadequate for the task.

3. The Teacher's Role in Biology Projects

The types of biology projects possible vary, including not only the classic empirical approach, but also case studies, literature reviews, and environmental problem investigations, so the teaching strategies required are also varied. Which strategies work best for each teacher will also depend on their own skills and training, but the following suggestions are offered to teachers interested in encouraging individual student projects in their classrooms. These suggestions are in addition to the general role defined on page 97 of this study.

a. Start student projects early. This study found that typically student projects were done during the last weeks of school, when exams and other assignment deadlines were most pressing. Announce the start of projects on the first day of class, giving the general administrative details such as group size and final deadline.

b. Provide students with a check-list to break the project down into manageable "bites". Specific items on the list will again vary according to project type and teaching strategies, but suggested "bites" may include:

i. A Project Proposal which need not contain a detailed procedure, but should have a clear, concise statement of the problem to be investigated and a list of any unique pieces of equipment beyond the usual laboratory beakers and test-tubes. Defining a clear statement of purpose is perhaps the most difficult part of any study and it is vitally important that at this stage the teacher examine each proposal carefully. Problem statements which are too broadly defined or very vaque should be discussed with the student to help her refine and narrow the number of variables or questions to be examined.

The short list of unusual materials has the double benefit of requiring the student to put some thought into how the project will investigate the question posed and will alert the teacher to unrealistic expectations.

ii. A Reading List should be required some time after the approval of the Project Proposal and very early in the semester. This provides the student with some background to the study and also alerts both student and teacher to a project topic for which there is no information. This Reading List would probably not be regarded as the final and total literature review, but emphasizes the need to work at the project steadily and continuously.

iii. For an experimental project the list might also include: writing a procedure, assembling all equipment, performing the first set of tests, revising the procedure, final series of tests, analysis of data, consultations with local professionals, writing the report, writing the bibliography.

Whatever elements find their way into the check-list, the key issue is to start early and break the project into manageable sections.

c. Many useful and easily understood statistical analysis programs exist for microprocessors. Not all projects will yield quantitative data, but those that do will benefit from providing the student with the opportunity to use the school's computers as a meaningful tool for her research.

d. Allow students to choose their own project topics based on their own interests. This was a strong recommendation from the student interviews, but there will be those who seem completely unable to define a project proposal after considerable time. For these students the teacher must resist the urge to provide a complete project problem. Often a series of dialogues between teacher and student will produce something that may not be entirely the student's, but neither is it entirely the teacher's idea.

e. Encourage students to consult with local resource people in the appropriate professions. Every community has doctors, nurses, dentists, hospital lab technicians, foresters, agricultural representatives, fish and wildlife officers, and veterinarians. These people usually welcome students' interest in their professions. This study found that few students utilized these valuable community resources.

f. Finally, talk to each student often. It helps if the teacher keeps her own anecdotal records and attempts to see each student very briefly in a regular rota. The contact need only be brief, but the teacher can foresee problems and the student can feel encouraged to continue.

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Appendix I

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Student Perceptions Instrument

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Name: ______________________ 1-3

School: ______________________

Date: __________

Male: ① Female: ② 4

The purpose of the following questions is to give the researcher some information about the type of project you did in Biology 30. Please shade in the circle that is appropriate as the instructions are given for each questions. Please wait for the instructions. 5-6

1. Group Size: 7

Individual	Small Group	Class
①	②	③

2. The "problem": 8

Me	Together	Teacher
①	②	③

3. Time: 9

Less	5	10	15	20	25	More
①	②	③	④	⑤	⑥	⑦

4. Project Mark: 10

0-49%	50-59%	60-69%	70-79%	80-100%
①	②	③	④	⑤

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5. Course Grade: 11

0-49%	50-59%	60-69%	70-79%	80-100%
①	②	③	④	⑤

6. Percentage of time spent in the project on:

(a) Experiments: 12

0%		25%		50%		75%		100%
⓪	①	②	③	④	⑤	⑥	⑦	⑧

(b) Literature Research: 13

0%		25%		50%		75%		100%
⓪	①	②	③	④	⑤	⑥	⑦	⑧

(c) Model Construction: 14

0%		25%		50%		75%		100%
⓪	①	②	③	④	⑤	⑥	⑦	⑧

(d) Collection of Specimens: 15

0%		25%		50%		75%		100%
⓪	①	②	③	④	⑤	⑥	⑦	⑧

7. In the space below or on the back of this page, please write a short description of your Biology 30 project. Try to be brief, but include your problem or the main purpose of your project and the main conclusion or result of your efforts.

The purpose of the following questions is to give the researcher some information about how satisfied you were with the Biology 30 project. Did you enjoy the project? Did you find it interesting?

DIRECTIONS:

1. Work through the paper quickly. Often the first answer that pops into your head is the best answer.

2. Do not just circle your answer, blot out the letter completely.

   For example: SD ● A SA

3. Choose the answer which best describes how you feel about the statement:

   SD - Strongly Disagree
   D - Disagree
   A - Agree
   SA - Strongly Agree

SPI
Page 4

	Strongly Disagree	Disagree	Agree	Strongly Agree	FOR OFFICE USE ONLY
	SD	D	A	SA	
1. I found the biology project to be an interesting way to learn.	SD	D	A	SA	21
2. I would like to do another biology project.	SD	D	A	SA	22
3. I was proud of my project.	SD	D	A	SA	23
4. I felt I did a better job of the project than I usually do with the regular biology labs we do in class.	SD	D	A	SA	24
5. I was allowed to make my own decisions in the biology project.	SD	D	A	SA	25
6. I would like to see my project report kept in the school library.	SD	D	A	SA	26
7. The biology project was the most interesting academic activity I have done in high school.	SD	D	A	SA	27

	Strongly Disagree SD	Disagree D	Agree A	Strongly Agree SA	FOR OFFICE USE ONLY
8. I worked hard on my project.	SD	D	A	SA	28
9. I would like to be able to make my own decisions in a biology project.	SD	D	A	SA	29
10. I found the biology project to be frustrating.	SD	D	A	SA	*30
11. It is possible for a student to do original research that produces new science knowledge.	SD	D	A	SA	31
12. The project should be compulsory for Biology 30.	SD	D	A	SA	32
13. I felt I had produced something that was my own work when I finished the project.	SD	D	A	SA	33

SPI
Page 6

	Strongly Disagree SD	Disagree D	Agree A	Strongly Agree SA	FOR OFFICE USE ONLY
14. The biology project allowed me to explore in detail something in the class that caught my interest.	SD	D	A	SA	34
15. Learning to perservere and work through difficult assignments like the project is an important part of my learning.	SD	D	A	SA	35
16. I feel what I learned in the project was worth the effort.	SD	D	A	SA	36
17. I think the project approach to learning taught me some things that were not included in the regular class lessons.	SD	D	A	SA	37
18. Doing a biology project has made me think about a career in science.	SD	D	A	SA	38

	Strongly Disagree	Disagree	Agree	Strongly Agree	FOR OFFICE USE ONLY
	SD	D	A	SA	
19. My teacher learned something about biology from my project.	SD	D	A	SA	39
20. The biology project was a waste of my time.	SD	D	A	SA	*40

Percentage of Student Responses

on

Student Perceptions Instrument

Item No.		Strongly Disagree 1	Disagree 2	Agree 3	Strongly Agree 4	x	S.D.
1		0.9	14.0	63.6	21.5	3.1	0.6
2		10.3	35.5	46.7	7.5	2.5	0.8
3		1.9	15.0	63.6	19.6	3.0	0.7
4		2.8	35.5	37.4	24.3	2.8	0.8
5		1.9	16.8	55.1	26.2	3.1	0.7
6		22.4	50.5	27.1	0	2.0	0.7
7		30.8	50.5	15.9	2.8	1.9	0.8
8		0.9	20.6	59.8	18.7	3.0	0.7
9		0	3.7	57.9	38.3	3.3	0.6
10		3.7	32.7	54.2	9.3	2.7	0.7
11	1.9*	5.6	30.8	57.9	3.7	2.6	0.7
12	0.9*	5.6	26.2	52.3	15.0	2.7	0.8
13		2.8	25.2	56.1	15.9	2.9	0.7
14		5.6	21.5	56.1	16.8	2.8	0.8
15		1.9	11.2	57.9	29.0	3.1	0.7
16	0.9*	0.9	15.0	55.1	28.0	3.1	0.7
17		2.8	9.3	66.4	21.5	3.1	0.6
18		24.3	50.5	18.7	6.5	2.1	0.8
19		12.1	48.6	37.4	1.9	2.3	0.7
20	1.9*	4.7	9.3	44.9	39.3	3.2	0.9

*Students responded in some manner other than indicated in the instructions, e.g. circling two responses for one item or indicating a point half-way between two response categories.

n=107

Reliability coefficient, alpha = 0.86

Appendix III

Inventory of Processes in Scientific Inquiry

Name: ______________________________

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1 - 3

The following questions ask you what you think you learned by doing a biology project. Look at the following list of skills very carefully. Please shade the number or letters which best describe how well you learned the skill in your Biology 30 project.

Shade over "1" if you used the skill in your project, but you do not think you learned it well.

Shade over "3" if you used the skill in your project, and you think you learned the skill very well.

Shade over "NA" if you do not think the skill was necessary for your project. For example, if you built a model, then "representing my data with graphs" is probably "NA".

IPSI
Page 2

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In my biology project I learned some of the following skills:	Not learned Well		Learned well		For office use only
1. How to state a problem for study.	1	2	3	NA	43
2. How to read science journals for information.	1	2	3	NA	44
3. How to consult people with science knowledge.	1	2	3	NA	45
4. How to make predictions.	1	2	3	NA	46
5. How to make an hypothesis.	1	2	3	NA	47
6. How to define the independent, dependent and controlled variables.	1	2	3	NA	48
7. How to define the procedure and work out the sequence of steps for the procedure.	1	2	3	NA	49

		Not learned well		Learned well		FOR OFFICE USE ONLY
8.	How to identify the needed equipment, materials and techniques.	1	2	3	NA	50
9.	How to identify safety precautions.	1	2	3	NA	51
10.	How to devise a method for recording data.	1	2	3	NA	52
11.	How to collect, construct and set up apparatus or equipment.	1	2	3	NA	53
12.	How to do field work and/or perform an experiment.	1	2	3	NA	54
13.	How to record data.	1	2	3	NA	55
14.	How to obtain semi-quantitative and quantative data by measuring, reading scales, calibrating, counting objects or events, estimating or approximating.	1	2	3	NA	56

	Not learned well		Learned well		FOR OFFICE USE ONLY
15. How to gather specimens.	1	2	3	NA	57
16. How to represent my data with graphs, charts, maps, diagrams, photographs, or films.	1	2	3	NA	58
17. How to do simple calculations with data.	1	2	3	NA	59
18. How to use statistics to analyze data.	1	2	3	NA	60
19. How to compare the data with initial assumptions, predictions and hypotheses.	1	2	3	NA	61
20. How to express data in the form of a mathematical relationship.	1	2	3	NA	62

Name: ______________________________

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Here is an opportunity for you to describe in your own words some of your feelings and impressions of the Biology 30 project.

1. The most interesting part of the project was...

2. The most difficult part of the project was...

3. I almost gave up when...

4. The teacher helped most...

5. I learned...

6. I wish...

7. It would have been helpful...

8. Working with a group...

9. I could have done a better job...

10. In summary, I would say the Biology 30 project...

Percentage of Student Responses

on

Inventory of Processes in Scientific Inquiry

Item No.	Not Applicable 0	Not Learned Well 1	2	Learned Well 3	x	S.D.
1	18.7	14.0	47.7	19.6	1.7	1.0
2	46.7	12.1	20.6	20.6	1.2	1.2
3	44.9	13.1	25.2	16.8	1.1	1.2
4	40.2	2.8	29.9	27.1	1.4	1.3
5	33.6	5.6	37.4	23.4	1.5	1.2
6	55.1	2.8	26.2	15.9	1.0	1.2
7	45.8	3.7	19.6	30.8	1.4	1.3
8	39.3	7.5	21.5	31.8	1.5	1.3
9	62.6	3.7	19.6	14.0	0.9	1.2
10	34.6	8.4	26.2	30.8	1.5	1.3
11	57.0	6.5	12.1	24.3	1.0	1.3
12	41.1	2.8	30.8	25.2	1.4	1.3
13	30.8	4.7	31.8	32.7	1.7	1.2
14	61.7	1.9	19.6	16.8	0.9	1.2
15	67.3	8.4	15.0	9.3	0.7	1.0
16	33.6	7.5	35.5	23.4	1.5	1.2
17	54.2	1.9	30.8	13.1	1.0	1.2
18	46.7	3.7	29.0	20.6	1.2	1.2
19	38.3	6.5	33.6	21.5	1.4	1.2
20	66.4	5.6	19.6	8.4	0.7	1.1

n=107

Reliability coefficient, alpha = 0.83

Appendix IV

The following is provided as an example of a complete transcipt of one interview session held with four students after the administration of the test battery.

Researcher (R): I think that the first question I would like to ask then is to just take a minute and go round the table and ask you to tell me what your project was about and that gives me some sense of what you're doing. And if I can get your first name first of all...

Dave (D1): My name is Dave. (R: David)

R: OK, what was your project about?

D1: It was aboaut endangered species and problems that...are the rates and the causes that have made it come to, you know, what it is at today and I looked at some of the things they have now, using the, you know, preventing it from happending and I also used other ways in which we can prevent, like better ways and so on, that they don't have; well I guess they've started them, but they're not complete. (R: UmHm) That's about it.

R: OK. And your name?

Dave (D2): Dave number 2.

R: Dave number 2. OK. And what was your...

D2: Ah, mine was related to baseball pitcher's injuries like tendons and various things like that.

R: Mr. J (class's teacher) was mentioning a little bit about your project.

D2: And what I did, I did some sort of analyze the shoulder and the elbow for its parts. And from there I took three or four of the major injuries, like pulled tendons...strained muscles and went into like how they're repaired and how to prevent them from happening to yourself and various exercises for strengthening things like that.

(Hmm)

R: OK. And you are....

Jill (J): Jill

R: Jill. And what was your project, Jill?

J: Ummm...I took the effects and the causes of acid rain and whether there's and then the problem...you can't really do anything about because we don't have any government support. Cause the government would rather side with the corporations that are producing the pollutants than side with the environmentalists and stuff like that. That's what I did.

R: OK. And you are....

Christina (C): I'm Christina.

R: And your project?

C: OK. My project was dealing with Canola which is a vegetable oil seed grown quite frequently in this area. And I went in to see why it's adapted to this area, why it is so frequently grown and also arranged a processing plant, went to a crushing plant and I saw the whole process (Hmm) (inaudible)

R: Umm. You know that I was orginally from Saskatchewan and at Tisdale which is just east of Saskatoon, they grow a lot of Canola and they grow.. have a lot of honey bees. And they petitioned the post office to have their cancellation stamp read, "The land of rape and honey". (Some laughter). Needless to say the Post Office wasn't going for that at all.

OK. You all seem to have done different projects. You all did them by yourselves? (Heads nodded 'yes'). Like without working in another group? OK. I suppose two things I would want to know in general ways would be: Did you enjoy it? And what did you think you learned out of it? And... let me go back to you for a minute, Jill. Did you do andy experiments with your...(J: Yes) OK What do you think you learned by doing the experiments?

J: That my plants didn't die. (R: They didn't die.) No. Ah I should have used, I learned what I should have did;. I think they would have died if I would have started a bit earlier and if I would have used mo[illegible] concentrated acid. And stuff like that, but I think even too the potting soil I used might have been low for, low sulphur content [illegible] someth[illegible] that and they were just....cause in some places when acid rain falls it supplies nutrients that are needed by the soil. (R: UmHm) Some way some of that sulphur content in the sulphuric acid was needed by the soil and stuff, or else the plant was just really hardy, I guess. Sulphuric acid.

R: You used sulphuric acid and mixed it with water to put on your plant?

J: Yes. and I did like I did my plants and one was control plant and I put four teaspoons in like every three days...and even if I were to put them in every day but I thought no, no, no. Dennis, like the lab technician, said, "Don't worry they'll die, they'll die, real quick. Don't worry about it." Alright, you know, I had them planted for quite a while.

R: Your plants didn't die, which presumably you expected them to...

J: Well, one shoot died (R:Umm) on one (inaudible) plants, but that was it.

R: Are you disappointed that they didn't die?

J: No. No. No. But I know what really happens...like, Um...They should have been a bit more dead. (laughter)

R: Um. OK. A couple of things that come to mind and maybe some of the others could think about it. Did you have problems.....or difficulty choosing a problem to study?

J: Unuh (i.e. 'no')

R: So this sort of appealed to you right off the bat and it came to you easily.

J: Umum (i.e. 'yes')

R: (Turning to D2) Was that pretty well true, I think that was true of yours, ah, with your shoulder question. Ah, (turning to D1) what about yours? (inaudible from D1) You had to struggle through it?

D1: I didn't know what to do, right, I just looked through magazines and that and saw something about species in Russsia or something, like the magazine (indistinquishable) and I just thought, ah, I wrote down about three topics and I asked Mr. J what he thought would be a good one and he said that that one would be accepted.

R: Was your problem easy to come up with, Christina?

C: ~~Yes~~, I think so because I'm, I've always been involved in agriculture and that's what I'm interested in and that's what I'm going in for education wise and this was, ah, just one small project that, ah, I learned a lot from it, working on it.

R: So, basically, most of you had no problems at all, even you (turning to D1) really, um,...got..

D1: Well, it wasn't to hard to find it once, you know, but I didn't know, like I had, I didn't have an idea until I started looking through the magazines.

R: Were you all interested in your projects? Did any of you have any problems, sort of, well, I gotta do this.. and ...cause I found that with some students they eventually come up with a question because I keep pushin them and they do it because I keep pushin them...ahmm...Did you find that the thing sorta got tiring after a while or did you still maintain your interest in it?

D2: I think if its really a topic your're interested in you wouldn't have that problem, like I've done other projects where I was too lazy to go out and try to look for a topic I wanted to do I just wanted to get it over with..so I forced myself to take any topic that's in my brain and did a sort of slack job ot it, rather than the topic I chose this time. I was interested and sort of just kept with it and I ran out of time (R: Hmmhm). And I wish I had more time I would give..sort of improved it.

R: To go back to yours for a minute, Jill, as an example. You said that....the plants didn't do quite what you expected and you feel in a way that you did not really represent the way acid rain actually works. (J: Hmm)..Uhmm...Would you do much changing of your procedure all the way through or did you just come up with one procedure, do it and that was it?

J: Jus one procedure.

R: Would that you had more time, would you want to go back and revise it and try it a different way?

J: Yep...I would...well, I talked it over with D too later and...probably...he said to spray the leaves...with the sulphuric acid and I would have added acid every day to give them, you know, acid everday, um, added acid every day.

R: Hmhm. What about yours, Dave #1, was your project such that you could see other things you would want to do with it, are there things you would want to explore if you had more time?

Dl: I'n know, if your interest, the reading and that was kind of interesting when I was doing it, but...I got started early and it just came to wha..what I..I have out (door opened and interview was interrupted briefly) you know, probably if I would have gone a little bit, my little bit, um, over on the time that maybe I would have looked into more things, but in the end it was mostly like I had a certain amount of time..and..(R:

Umhm)..get it done, but ah, there really was..I got a good book from the library there was..and some magazines and that was....kind of interesting.

R: What about your project, did you see other ways it could go?

C: Ah...Well, there was one part that I did, I actually grew some Canola plants under artificial conditions at home, and, ah..they didn't grow as they usu/normally does under normal conditions out in the field..and I think also like my soil was quite there were some procedures that I would have if I would have had enough time I would have redone them. As it was now I sort of ran out of time, cause you hard I didn't have enough time to start another, a new experiment with the (undecipherable) and also, em..also I wanted to do an extensive interview with different farmers and like growers (R: Umum) and see the reasons why they grew Canola, but that's another aspect I ran out of time again.

R: But there are other things that you would like (C: Yes) to have done if there was time.

C: Yes, definitely.

R: See...ah, it seems to me that, if you choose a project which is interesting it will be something that you could sort of go in several different directions and you might not be really satisfied that you ever completed the thing...Another question that comes to mind is, what was the most difficult, the most frustrating part of the project? Maybe if we ask you first (turning to D2).

D2: Mine was like all the medical terms involved like you know trying to like read (unintelligible) didn't make sense to me because I wasn't too aware of those big medical terms so I had to read further into it an then I'd understand it but then trying to put down on paper bacame a bit...like I.. I'm not really good at expressing myself on paper so that's the hardest part of the whole project was revising all the reading to sort of a standard that other people could understand...they were big long words.

R: Do you find that in..in..you really have to know what the term means in order to express it in simple terms. (D2; Yeh)

R: What for you, Jill, was the most frustrating part?

J: I don't really know. Ah..Ah.. I guess when my experiments didn't work out, not like I wanted them to. (R: Umhm) I think the best part of the whole thing was that all the information I found related to Canada instead of the United States and Western Canada too, and that was like really good because usually every book you find its all the States and hardly any...hardly anything (indistinquishable).

R: Something that occurs to me,..you sound almost as if your experiment was a failure..I think of..hm;..I think if we were to play a game where I say, okay, I am thinking of a number between one and a hundred. What's the best question to ask to narrow it down?

R: Anybody.

D1: Is it over fifty?

R: Okay. So, is it over fifty. Now, if I say "no"...have you failed?

J: No.

R: Okay, You have got just as much information as if I had said "yes". And one of the things that you should maybe think about with your results is, okay, they didn't do what you expected them to do. Was there something else that you maybe could have learned out of that. Did you get something positive out of that that maybe you haven't seen or wasn't as important to you as you may have thought of.

J: Ahh...probably with the research I did though, you know, like, just the case studies that I read there was some stuff that goes on, like, I just expect, I guess I did expect them to die faster. Especially with D's reassurance too, the lab technician.

R: Have you satisfied yourself that you maybe have a guess as to why they didn't die as fast? Have you got some sort of...

J: Yeh, I read a whole bunch of reasons why and I'm positive that, you know, I'm pretty sure why they didn't die.

R: So, in really in one sense the experiment has at least helped you to...obviously you hadn't thought of those reasons before you started the experiment. (J: No) But the experiment at least showed you had to think of those reasons, so can you see that you have learned at least something?

J: Yep. Plus I can see that conditions must be a lot worse than I thought. I mean I..if mine was quite a low, um, molar concentration and yet they say, oh, don't worry, you know, I (unintelligible)....it must have to be quite concentrated or else it wouldn't leave the damage that it has.

R: So, it makes you think that it's really more of a problem than they actually make out because of its causing the damage it means a very high concentration.

R: What about you, what was the most frustrating part?

D1: I don't know, maybe, re-explaining, like kind of all the writing, it comes across an idea or something and you want to..you know, put it in your own words or something but you can't because he knows more about it than you do. I came across tht quite a bit, or I would anyway. In this book, you know, we have...a lot, er, there will be maybe pages long or something and I don't want to write a big page long idea or something. To try and summarize or whatever I found was pretty hard cause obviously he knows a lot more about it than you do and...that would be about the hardest thing, I'd say.

R: Something that occurs to me you might be interested in, ahm, maybe you know about it already, but Alberta Fish and Wildlife has something they call Conservation and Education Extension branch and they provide a number of posters and they also have a brochure series, including a little pamphlet on endangered species in Alberta. And so...I don't have the exact address with me today, but you might be able to track that down...it's a series of brochures from Alberta Fish and Wildlife, their Education Conservation Extension branch in Edmonton.

Dl: I didn't go into like, any really, examples of....well I went into some, but most of the project was on like; like every species, of all the species that were in the....and the rate that they're...kind of....becoming extinct...in the book, the one book that I had had a rate of one per year or something like that for now and he said that it could get up to as high as one per day in a few years of all species, like not just animals. Plants and all organisms. So I didn't go completely right into any main one thing, I don't know, is that what those pamphlets are?

R: I imagine they would be specific species (Dl: yeh) and about them. But you know, if you are interested, I just thought I would let you know.

R: Christina, what was the most frustrating part?

C: I think it was just simply putting all this information I had together...(unintelligible).

R: You've all produced something and you've laid it on the teacher's desk. Would you want that to be kept in the library for future generations of students to look at? How about you Christina?

C: I don't know.......I don't think that anybody else would be interested. (She laughs.) If you....(laughing) that's sort of the way I look at it. It was something that I did for my own personal benefit, no one else. It wasn't really anything that I did for other people to look at, just for my own personal benefit. That's what I feel.

R: Jill?

J: I feel a little more I would so much if I um...I know I could have done a way better job than what I did. I thought I did a pretty good job, but....not exactly what I should have. I mean, if it would have been <u>right</u> to my satisfaction maybe I wouldn't mind it, but....not the way it's lying right now.

R: Rick (an error in the student's name)

D2: Same lines. If I sort of did some more improvements then maybe...

D1: (Unintelligible)

R: OK, let's look at another question. Supposing I was your teacher and now that you know about biology projects....you want....I told you I w[illegible] make my students next year do biology pro[illegible] advice would you give me to make it, not easie[illegible] next year's students, but make it [illegible]er learning experience for next year's students?

D2: Basically, just make sure each student finds something they are interested in. Because if they are interested in it they are going to work a lot more harder at it and the harder the work they are doing the better...like...some teachers I found they give categories. The categories...right there you have a mental block against each project. So you go down to the library and take out a book and do it like that.

R: (to D2) For you it was easy to, or relatively easy to come up with something, um, Dave here (D1) is saying he had to search a little harder, um...

D2: Oh I had to search just as hard. Cause there isn't that much material on it. Sure you've got your basic shoulder anatomy and stuff, like it's packed with books and that, but when you get into like sports injuries, like especially baseball it is very hard to find.

R: Well, what I was thinking of was that you at least had the topic (D2: Oh yeh). That was the point. Okay.

I find students have problems coming up with things that interest them, you know. How can I make that easier for them and how can I help, sort of, them to..to... I don't want to exactly lead them to a problem, but how can I help them sort it out for themselves without laying out the categories - which you said you don't like?

D1: I guess if you want to do it that way, then just... better tell them pick your own topics from the ones that you know... some will do (unintelligible) and some won't..you know, it's hard to, you can't just. I don't know if there is any way that you really could help them besides, you know, telling them, "okay, you do this, you do this, you do this, if you don't want to do that". So, probably the only thing you could do, I guess, give them time early in the year to...you know, you are going to have to do this project and outline the key...we had to have our outlines in quite a bit before the paper was due, a few months, probably two months before, so right at break, so it's halfway through the course, so it still leaves you a fair amount of time to do the work and maybe if some are having problems then, maybe you could help those ones.

J: Yeh...I was just going to suggest...one thing, you people are really against giving different topics, but like, a wide range of maybe thirty or forty different topics and I'm sure that there's going to be one that appeals to every student. There has to be. Because I think a lot of the problems, ah, sort of goes back to what...you think somehow you can't see anything that appeals to you, you know. You really, you worry about what you are going to do about it. And then you might see one that sounds real interesting. You know, if you see something.

R: One student, ah, a student I was asking this question, "How do you choose a project?". And they felt that part of their problem was that they had this idea it has to be scientific and..."my little question about the shoulder isn't really scientific. It isn't big enough. It isn't a real earth shattering discovery isn't going to come out of it". Did you ever feel any of that kind of sense of "well my project isn't really worth anything because it's not scientific. It's not very big"?

J: ...Umm, a little bit. The most important thing is to stay away from something too broad. If the subject's too broad then you just drown yourself. You'll start and then you'll lose your way around. It...it...for somebody to find a topic I think it's good to find something really specific.

R: Okay, so....

J: Maybe what you can do is say give them a list of about four things or something like...you know, give them a paper saying this is what students in Alberta write about and give a big long list and I'm sure they can give themselves all kinds of work...

R: Something they do find helpful is I tend to lay out last year's projects (unintelligible) and so students get a sense...it's interesting they can get a sense too of what is good and what is bad as a project. I don't put marks on the pieces of paper that are out on the desk...and that helps.

OK, supposing now that the students have got their project, ah, topic. They have defined their problem, again what advice can you give me, ah, how can I help you do your project?

J: Get excited about it. (General laughter) Like, when you get excited then they get excited too, a bit, maybe, probably.

D1: Yeh, (unintelligible)....well basically you just have to show interest and offer encouragement...maybe sort of keep on asking him how it's comin...

D2: Yeh, if you keep asking then I find, you know, if the teacher keeps asking me lots of stuff about it then you tell him all along, then you don't wanna, you're scared you might let him down so you make sure you...put in a fair amount of work or something, you know. As long as the teacher knows what you're doing and everything. It's not as if just you say you are going to do this and then a few months later get the paper and nothing is said in between or something then, I don't know. If you've been talking to the teacher all along then you feel that you're going to let him down if you don't....(unintelligible)...I don't want the teacher to think that I did it less than I said or something, that's you know....

C: I think also the teacher should be able to help with finding resources, like you say, giving suggestions that maybe you could talk to so and so about information regarding this and, ah, sort of help along that line too.

R: I know that you (indicating J) said that you talked to some people about your particular project, what about the rest of you did you have an opportunity to consult other people besides the teacher?

D2: Yeh I talked, like ah, to my pitching coach and even sometime with doctors in the area of sports injuries, which was pretty good. And they showed me some equipment they used and stuff like that.

R: Did you find that they were reasonably receptive to you or did they say, "Ah, it's a high school kid wanting to know about..."

D2: Well, most of the people I did talk to I knew before, so that helped right there.

I guess they sort of took interest like, he's interested in my area of work, so they sort of gave me a special tour of everything. They helped me, like they gave me some extra information which..right off the press so to speak.

R: I found that basically if my students go ask someone they are more than happy to share their interest...it sort of breaks up the monotony of their day.

J: Another good thing to do is to encourage them to do field work too. Like do something or (unintelligible).

It gets them more involved in the project than just reading it out of a book. That sort of brings it closer to let you examine your own, like, your certain specimens in this area or something like that and you have to go out...and that's a great study.

R: OK, one last...perhaps one last question. What should I not allow students to do for projects?

(Long silence)

J: Broad topics.

R: Broad topics?

J: Yeh. I remember last year for my biology project the first essay I'd ever had to write like that, sort of, I just picked the whole topic "plants" - like no (one) plant, just "plants", you know, and it was like ridiculous, you know, but my teacher didn't say anything and I wasn't even like writing my essay for him...he said, "Oh, put a bibliography". I didn't even know what that was, you know. So he didn't have it, but...I don't know - stay away from broad topics.

C: I think that there should be some sort of field work, or something besides the library research included in the project. I think so.

(Short silence)

R: Any other don'ts?

(Silence)

R: OK. Any questions that you want to ask? You've gone through all those tests I gave you, anything strike you now...

D2: What is this for? You putting out a book on projects?

R: No, well..

D2: Is it like a teaching aid or something?

R: Well, what I'm doing is, hmm, I'm doing thesis research. I have to do my field work and in essence it is very much like a project. I have to come up with a problem, something that interests me. I have to come up with a statement of the problem. I have to come up with an hypothesis. I have to go out and collect data. I have to then come to some sort of conclusion.

My hypothesis is that the kinds of projects that you do; the kind of satisfaction you get out of it; the kinds of things you think you learn from these projects relate to your problem solving abilities. Now that first blue test was sort of, hm, various problem solving strategies -- and in essence I am sort of saying if you can't figure out how to control the variables on a pendulum then you would probably have difficulty figuring out how to control variables in a biology project. I don't know, I could be proven entirely wrong. You know I haven't got much information at the moment, but at the moment the only information I've got says there is no relationship. So I am very much like your project (turning to J) in that it's not...the plants aren't dying. (laughter)

But what I will do is, ah, it will take me all of May and June to collect data, like this, from about 8 or 9 schools, like yours. And then I have to sit down through the winter and try and tie together what I've found with what other literature says about the whole problem and then write a thesis and it isn't exactly a book, but it will come out to 150 to 200 pages. Something like that.

But it's pretty much like yours, yours came out thick without too much effort because you usually have your statement of the problem and your hypothesis and you've got your literature. You've got your diagrams and all that jazz. Ah, it's very much analogous to the kind of thing that you've done already. Which is good for me because I had to go through the same kinds of things like finding something that wasn't so broad that it would take me 5 years and several thousand dollars to do. But also something which was of interest and importance to me.

C: So what you might be saying then is, are you sort of going to come up with a statement for or against ....(end of the tape)
(The tape was turned over and started again after a few minutes.)

J: Not every kid is going to get so interested they're going to learn from their biology project, but the kids that to, I mean the kids that learn will be able to do real well (at university).

C: I think a lot of them ..(unintelligible)

R: OK, any more questions?

D2: I think the major point I would like to get across is that I see the project as my own work and the less that teacher tries to relate it to school assignments the better, like the harder I'll work at it. Like when you have your set categories and right away you start thinking this is classroom material, which it is, like if it has to do with the school...well my own work would be a better project.

R: If there are not more questions I would like to thank you for your time and I appreciated your comments and I will try not to reduce you to computer numbers.

Thank you very much.

Appendix V

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for

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Appendix VI

RAW DATA

COLUMN LABELS

For the purpose of computer analysis the following columns and code assignments were given to the data for the table included.

Column	Code
1-3	A three digit student number
4	Gender: 1=male 2=female
5-6	TOLT total score: Range 0 to 10
7	Group Size: 1=individual 2=small group 3=class
8	The "Problem": 1=student 2=together 3=teacher
9	Time required to complete the project (hours): 1=less than 5 2=5 3=10 4=15 5=20 6=25 7=more than 25

10 Project mark, estimated by student:

[illegible] 2=50-59% 3=60-69%

4=70-79% 5=80-100%

11 Biology course grade, estimated

by the student:

1=0-49% 2=50-59% 3=60-69%

4=70-79% 5=80-100%

Columns 12 to 15, inclusive used the following scale of % to indicate the amount of time spent in the project:

0=0% 1=0-24% 2=25%

3=26-49% 4=50% 5=51-74%

6=75% 7=76-99% 8=100%

12 Experiments

13 Literature Research

14 Model Construction

15 Collection of Specimens

16-20 Blank

21-40 SPI items:

1= Strongly Disagree

2= Disagree

3= Agree

4= Strongly Agree

40-42	Blank
43-62	IPSI items: 0= Not Applicable 1= Not Learned Well 2= Learned 3= Learned Well
63-64	Blank
65-70	Age: YYMMDD
71-80	TOLT data: 0 = incorrect 1 = correct

End of file