THE DEVELOPMENT OF SIMULATION-GAMES TO TEACH EVOLUTION TO YOUNG CHILDREN.

by

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ABSTRACT.

This study comprises an attempt to validate two simulation-games designed to teach concepts concerned with the theory of organic evolution to children in the nine to eleven age range. The author discusses the nature of simulation-games and their value in the learning situation, and describes the attempts of other writers to evaluate simulation-games at both cognitive and affective levels. He outlines the development of two games, and describes their evaluation using an illuminative approach consisting of four different assessment procedures. Cognitive gains are measured by written responses to multiple-choice questions. A change of attitude towards the whole area of natural history is investigated in a similar way. A form of interactional schedule, designed specifically for this experiment, is used to gauge pupil involvement. Teachers' opinions of the two games are obtained by means of a questionnaire. Cognitive and affective changes are assessed within the context of a Solomon three way quasi-experimental design. The results, presented separately for each game, indicate significant gains in terms of the pupils' knowledge and their ability to apply this to new situations, but only minimal changes in attitude are evident. Girls are found to learn more from the games than boys, and brighter pupils score higher than their duller counterparts at both pre- and post-test stages. The author suggests that success in simulation-games is likely to be related to the personality and attitude of the individual participants and may well be game- and situation-specific.

CONTENTS.

LIST OF ILLUSTRATIONS.

Figures illustrating the results of tests for "The Dinosaur Game".

Chapter One.

THE NATURE AND VALUE OF SIMULATION-GAMES.

The development of simulation-games as tools to assist the education of schoolchildren is a recent innovation; spanning only the last two decades. During this period a great deal has been taken on trust, and only spasmodic efforts to quantify the effectiveness of simulation-games have been evident. The science of gaming is, as yet, without a "coherent theoretical perspective which may allow the anatomy of representation to be systematically examined" (Rogers [79]).

The difficulties which underpin any effort to develop a generalised framework within which research might progress are difficulties based on diversity. Within the area subsumed by the term "simulation-games" are military training devices, "in-house" exercises for the development of catering managers, computer-based sixth form geography projects, and board and card games to assist seven-year olds to master simple mathematical relationships. It is not surprising that attempts to design validational techniques have been based on situation specific criteria. Even definitions attempting to restrict the field of activity of this new discipline have been couched in such general terms that they carry little real meaning.

Writing in 1974, Clark Abt [1] described a game as: "an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context". Whereas Abt's definition would include the interactions of two angry motorists who had met in the middle of a narrow bridge, it is difficult to apply to snakes and ladders, for the players cannot be thought of as "decision-makers", except in the most limited sense.

To this extent, Abt's earlier definition, quoted in Boocock and Schild [10], is more satisfactory:

A game is "any contest (play) among adversaries (players) operating under constraints (rules) for an objective (winning, victory or pay-off)".

The notion of what is, and what is not, a simulation is somewhat less elusive. Guetzkow, writing in 1963, [44] considered a simulation to be "an operating representation of central features of reality". A rather broader view is taken by Hartman [47], who defines simulation as "the development and use of models for the study of the dynamics of existing or hypothesised systems".

Ellington, Addinall and Percival [35], who provide an excellent up-to-date review of the development of games in science education, consider that an activity must possess four characteristics for it to be regarded as a simulation-game:

1. It must involve overt competition of some sort, either between players (as in whist or tennis) or between an individual and the "game system" (as in patience or golf).
2. It must have rules limiting the number of alternative courses of action open to the players.
3. It must represent a real situation.
4. It must be operational in the sense of constituting an ongoing process.

The extent to which a simulation-game needs to model "reality", as opposed to Hartman's "hypothesised systems" is debatable. One could argue that computer-based studies of population dynamics within colonies of breeding fruit flies rely on hypothetical models based on theoretical tendencies evident in laboratories, rather than models of real (in the sense of being natural) situations. For some simulation-games developed within the framework of science education, extrapolation and prediction beyond the "real" data in hand are fundamental characteristics.

For the purposes of this work we shall be concerned only with simulation-games as they are used in schools, and shall therefore define them in the narrower sense as those instructional devices which communicate skills, concepts and knowledge by means of working models of reality.

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The dramatic upsurge in interest in the use of simulation-games in education is based on a clear correspondence between recent trends in the development of educational thinking, and specific characteristics of gaming as a pedagogical technique.

Firstly, the employment of simulation-games involves the pupils in an <u>active</u> form of learning. An enormous volume of literature supports the notion of the pupil as an active participant in the learning process, making meaning of his experiences. Let us suffice with a quotation from Piaget (from "Jean Piaget: Notes on Learning" by Frank G. Jennings, Saturday Review May 20th 1967).

"Knowledge is not a copy of reality. To know an object, to know an event, is not simply to look at it and make a mental copy, or image, of it. To know an object is to act on it. To know is to modify, to transform the object, and to understand the way the object is constructed .... Anything is only understood to the extent that it is reinvented".

Simulation-gaming is one of several teaching methods which place "an emphasis on experiencing as opposed to simply being taught" (Adams [2]).

A second characteristic of simulation-games is that they are fundamentally dynamic, in the sense of being well suited to examining situations that change. During the last few decades, a shift of emphasis has been evident in schools, away from the teaching of a static, fact-orientated curriculum, towards one based on flexibility of thinking and responsive adaptation. (See Taylor and Walford [91]).

As well as being dynamic, simulation-games derive power due to the feeling of reality which they inject into the classroom. A number of writers have questioned the relevance of much of what is taught in schools. Rarely has this been put more strongly than by Louis Arnaud Reid [71].

"Some simple learning and skill aside, few of us, unless professionally required to do so, could or would wish to recover from the discard into which our minds have thrust it much of the truck on which we and our teachers spend effort, energy and patience at school."

The reality of the simulation-game, of course, is a protected reality. Real-world decisions are taken in a risk-free environment, at minimal cost to the participants.

Many simulation-games relate ideas from widely different subject areas, and serve the function of enabling the participants to integrate concepts into holistic models of the world. This is in line with those trends in education, rooted in the work of the Gestalt Psychologists, which resist the narrowness of over-specialisation. Ellington, Addinall and Percival [35] comment on the function of simulation-games as concept-integrating devices within science education.

They argue that exercises which require their participants to examine technological problems from other than a strictly scientific point of view, are particularly valuable in this respect. They cite the work of Reid [73] in particular, who has studied the development of a social awareness of science in thirteen and fourteen-year-old students. Reid restricted himself to an examination of the historical, domestic, industrial, economic and socio-moral implications of the O-grade chemistry syllabus.

A fifth and most favourable characteristic, which simulation-games share with certain other teaching methods, is that they encourage the proper and extensive use of language as a tool for intellectual growth. The relationship between language and thought has been explored elsewhere (see, for instance, Vygotsky). There is a considerable weight of evidence suggesting that the development of thought might be restricted by insufficient language practice. The notion that a deficiency of language practice is evident in schools is well expressed by Britton, in Barnes et al [7].

"It is not that there is too much language, but that it is not fulfilling its functions as an instrument of learning. Rather, language is seen as an instrument of teaching."

The most immediately evident advantage which the teacher will experience when working with simulation-games is the increased motivation of the pupils. Many writers give accounts of a heightened interest and excitement in learning exhibited by the pupils. (eg. Taylor and Walford [91]). All simulation-games involve a competitive element: sometimes this competition is staged between the individual players, sometimes between teams of participants, and sometimes between each player and the system of the game which underpins the rule structure. At least some of the excitement evident in pupils who are learning by means of simulation-games seems to be rooted in the stimulus and challenge of competition. Just what level of arousal will produce an optimum performance will relate to other factors, and will vary from pupil to pupil, but some degree of arousal is essential, and simulation-games serve not only to arouse, but also to maintain, the interest of their participants.

Many claims have been made for the cognitive benefits which accrue to pupils taking part in simulation-games. Very often the participants must select and organise their own data, recognising the most relevant, and dismissing the trivial. They may need to invent strategies and plan alternatives. They may learn to handle relationships with others, developing empathy through role awareness, and improve interpersonal strategies whilst learning to co-operate with others. Some authors even go so far as to claim that simulation-games may extend a person's belief in his ability to control his environment. (eg. Constance Seidner in Dukes and Seidner [30]). Certainly, a wide range of cognitive skills can be developed by the sensitive use of simulation-games, though it would be unrealistic to expect that any particular game would fulfil all of these ambitions.

It will be as well to conclude our introductory examination of the potential contribution of simulation-games by examining one further area: the pupil teacher relationship.

The traditional view of the teacher as the fountain of wisdom has gradually given way to that of the teacher as an "adaptive interventionist" (Roebuck [78]) who creates learning opportunities and manages learning resources. Simulation-games change the social conditions of learning, by reducing the role differences between teachers and taught, and ensuring that the pupil takes some responsibility for his own learning and for the assessment of his own progress. The "personalisation" of the pupil-teacher relationship is likely to improve it, for both can view the other in a better light, and self-fulfilling prophecy effects may further enhance this development.

It would, of course, be dangerous to over-emphasize the new role of teacher as co-learner in the simulation-game situation. Nancy Glandon [41] has written of the teacher as game director, who has access to the rules of the simulation-game, the secret knowledge which keeps them in a position of real authority. To some extent the simulation-games in classrooms are also simulations of classroom life which teach the same rules and obedience towards those in authority.

In education, like everything else, fashions change. Particular teaching methods become the focus of attention of the educational press, and then fade as others take their place.

However, it is relatively rare for such substantial and broad-based support to be given to a particular pedagogical style. It is appropriate for us now to consider how well supported by empirical investigations these claims for simulation-games really are.

CHAPTER TWO.

EVALUATION IN SIMULATION-GAMES.

Within the social sciences the notion of evaluation is not a new one. Since the time of Comte the value of observation and reason, in place of metaphysical speculation, has underpinned much of the progress which has been made. Rapid advances in the natural sciences, based on observation of controlled experiments, have taken place during the one hundred and fifty years which have followed Comte's "Cours de Philosophic Positive". It is not surprising in this context that during the first half of this century studies of man's behaviour were based on the sort of methodology and analysis which had been developed in the natural sciences. When we look at the investigations of learning by the behavioural psychologists, or the large-scale studies of the social correlates of reading effectiveness, we are looking at empirically-based and normative attempts to quantify differences between the variables apparent in particular social situations. These attempts are designed according to procedures which have evolved in the fields of natural science. They represent sincere attempts at objective analysis. The researcher intends to detach himself, and his preconceptions, from the situation under scrutiny, and to take measurements and make comparisons which may be termed "facts", and which may therefore be generalised to other similar situations.

During the 1960's early attempts at the evaluation of simulation-games proceeded on these traditional scientific lines. Boocock and Schild [10] state:

"Ideally the research design for a comparison study would be a version of the classical experimental design in which the control group or groups would be taught the same subject matter covered in the game by one or more alternative methods."

This form of empirical investigation has received much criticism. Megarry [61] writes:

"To expect to be able to hold constant all the other input variables so as to be able to attribute any change in output variable to the difference in treatment suggests either colossal faith or a degree of naivety about what variables are important."

Backed by a most coherent and persuasive argument, Megarry argues that the assumptions which underpin comparative evaluation techniques have little credibility in the world of the classroom. She goes on to suggest that experiments are seldom really "controlled" since there are numerous variables, such as teacher effectiveness, and pupil attitude towards the classroom context, which fall dangerously beyond the scope of the experimenter's data.

In place of what has, somewhat scathingly become known as the "agricultural paradigm" a number of other approaches to evaluation have developed. Megarry [61] lists eight models, based on techniques developed in other disciplines such as social anthropology, psychiatry and economics. The attention of most authors has been focussed on the particular empirical approach frequently referred to as "illuminative evaluation". This proceeds by means of small sample studies, taking account of the wider context in which the educational programmes are to function. Data are gathered from a number of sources by a number of methods, thus "illuminating" the situation.

The use of a broad-based and multi-faceted method of enquiry is especially apt for the evaluation of simulation-games, since, as Walford pointed out in 1975 [94]:

1. They usually involve complex mixtures of cognitive and affective intention, and these are not easily specified.
2. They are essentially open-ended, and therefore unpredictable in outcome.

Thus, the protagonsists of the illuminative paradigm (such as Bloomer [9] and Parlett and Hamilton [65]) have abandoned the narrow criteria of success which they see operating in conventional evaluation. They prefer, rather, a holistic and flexible approach. The latter authors say of illuminative evaluation that:

"the task is to provide a comprehensive understanding of the complex notions surrounding the problem", and that "its primary concern is description and interpretation rather than measurement and preduction."

It is to be hoped that any detailed description and sensitive interpretation of social events would, to some extent, be able to be generalised, and thus form the basis for, at least tentative, predictions. After all, the social life of both the researcher and his subjects depends on their ability to generate hypotheses and make predictions as to how people will behave. It is not enough, in modern society, to stand back, like some Taoist philosopher, and passively observe all that goes on around us. We must observe, describe, interpret and compare, in order to generalise and predict.

The greatest danger brought about by the germination of the new paradigms of evaluation is that, in striving to seek academic respectability, their champions may brush aside all that has gone before. As Parsons [66] so neatly puts it: "We should (not) be trying to re-invent the wheel, and there are very real dangers in importing the spokes alone."

In the same article he states:

"Certainly it can be detrimental to the conduct of the research to enter the field in the grips of a particular theoretical model, through which the attention is directed to certain issues and problems rather than allowing these to be generated through close analysis of the practical scene; but to enter the field in ignorance of the accumulated wealth of conceptual and theoretical schemes available is culpable. One can begin with the necessary openness and receptivity, holding constricting assumptions and pre-suppositions in check, but having already assembled on the sidelines resources, in terms of available theoretical orientations, which might prove useful in making sense of the situation being investigated."

What is required is an open-minded and self-critical assessment of the needs of each particular research problem. The evaluation of an elementary school mathematics game will demand different techniques to those employed for assessments of the effectiveness of a role-playing exercise for college students. A simulation-game can only be evaluated in terms of its aims, and they in turn will relate to the target population of subjects for whom the game is intended, and the situation in which the game is enacted. Different strategies may need to be employed to tease out the effectiveness of a particular simulation-game with children whose ages, abilities or situations are themselves different. Again, the methods of empirical research appropriate to the validation of a game in terms of specific cognitive objectives will not necessarily be the same as those which attempt to quantify its motivational power. Although the cost in terms of reduced comparisons between individual evaluative studies may be a serious loss, the gains derived through the development of specifically-designed research criteria are gains in accuracy and sensitivity which are well worth pursuing.

SIMULATION-GAMES AND INFORMATION ACQUISITION.

The performance of simulation-games as vehicles to teach information has been disappointing. Reviewing 22 studies which compared games with other educational techniques, Pierfy [69] reports that the accumulated evidence suggests that they are no more effective than conventional classroom instruction with reference to the rapidity of learning or the amount of information which the students acquire. A good number of other authors have come to the same conclusions. (eg Tansey [89], Boocock and Schild [10], Ellington, Addinall and Percival [35]). Indeed, the confidence of the last-mentioned is so shaken by these findings that they recommend that

"it is not advocated that they be employed as a main, front-line teaching technique, but rather as a complement and

support to traditional methods."
They go on to explain that the two ways in which they can be used in the teaching of science are "for reinforcing basic facts and principles" and "for developing laboratory skills". A humble role indeed, for a method for which so many claims have been made.

A more detailed examination of the literature reveals that the situation is much more complex than this. There are a number of studies which indicate that significant gains have been made by students using simulation-games. DeNike [26] reports research by Emery and Enger [36] who found that a computer simulation-game that was used to teach introductory economics was significantly related to gains in student achievement. Baker (in Boocock and Schild [10]) compared two classes who had studied a unit of work on pre-Civil War America. One class used a simulation-game approach, while the control group were taught by other methods. He reports that the experimental group outperformed the control by a substantial margin on content tests.

A number of researchers have reported significant improvements in specific cognitive areas, which have accrued to students participating in simulation-games. For instance, Curry and Brooks [22] and Johnson and Euler [50] report better retention by students using the game "Life Career". Keach and Pierfy [51], using a programmed text as a control group to reduce novelty effects, found significant improvements in retention by the experimental group at the delayed post-test stage. Fletcher [37] found that 5th graders improved significantly in their ability to read compass directions on a map after ten plays of "Caribou Hunt" - though after ten plays, we would hope so. Edwards, DeVries and Snyder [32] provide evidence that seventh grade students who played the game "Equations" in teams, scored significantly higher than a control group taught by "traditional methods" on achievement tests measuring general arithmetic skills, as well as skills specific to the games. Allen, Allen and Miller [3] provide further evidence in relation to a similar game, "Wff 'n' Proof".

There are plenty of negative results in the literature too. Szafran and Mandolini [88] are plainly optimistic when they write:

"The advantage of simulation-games in facilitating concept recognition is said to lie in their ability to present concepts as visible holistic entities rather than as ideas which can only be described in a linear, piecemeal manner through the vehicle of the written or spoken word. Simulation-games provide immediate and dynamic referents for the concept and allow the student to see the concept in interaction with other aspects of the .....system."

However, they report later in the same paper that the exposure of university sociology students to a simulation-game, "Simsoc", had no significant impact on their examination scores, and did not have any significant effect on their ability to recognise sociological concepts embedded in non-sociological written accounts.

Again, in a major study involving seventy two schools, Baker, Herman and Yeh [6] report that "the observed use of puzzles, games and to a lesser extent, audio-visual devices appear negatively related to pupil performance".

A doctoral dissertation by Wentworth (1972) is reported in DeNike [26] in which the use of the simulation-game "Marketplace" is shown to produce a significant retardation of student learning of economics.

SIMULATION-GAMES AND AFFECTIVE CHANGES.

The research concerned with the evaluation of affective outcomes - changes in attitudes and interests - is centred around two distinct areas. There are a small number of studies which examine changes in attitude towards the concept area upon which the game focusses, and a rather larger amount of empirical investigation of the attitude of the participants towards the game situation itself - the game's motivational power.

Seidner, in Dukes and Seidner [30] quite rightly states that the evidence relating to attitudes (in the former sense) is complex. Some simulations bring about changes of attitude, although these changes may be short-lived. In a critical analysis of simulation-game research Reiser and Gurlach [74] suggest that simulation-games are not a very effective instructional method in terms of attitude change. They comment that the research designs used in much empirical work are grossly inadequate.

A study by DeKock [25] indicated that a significant change of racial attitudes, using Krathwohl's taxonomy of attitude change, was brought about by use of the simulation-game, "Sunshine". An investigation by Vogel [93] revealed that sixth-grade students participating in "City Council" displayed significantly more positive attitudes of political efficacy when compared to a control group.

However, Livingston[58] reports finding no significant increase in interest in politics in junior high school students who played "Democracy" for two class periods. He also points out that junior high school students who played "Trade and Develop" for two class periods expressed no more interest in learning tasks related to the subject of the game and performed no better at them than students who did not play the game.

Like the research related to cognitive outcomes, the empirical findings relating to the effects of games on participants' attitudes towards the games subject content, are conflicting and difficult to reconcile. We shall return to this problem a little later.

The evidence that simulation-games significantly motivate students to join in with their activities is altogether more persuasive:

Brenenstuhl [11], using an adapted form of the Needs-Satisfaction Questionnaire (Porter and Lawler 1968) with college students, claims that the experimental group who worked with a computer-based simulation found the experience "really interesting" and were significantly "less dissatisfied" than the control group.

In summarising the work of The John Hopkins Games Program, Livingston [58] states that the most consistent finding of research with games in classrooms is:

"that students prefer games to other classroom activities. That finding holds true for students from elementary school through high school and for both simulation and non-simulation-games".

This conclusion is based largely on self-reporting techniques, although Karen Cohen [16] also noted lower absence rates among students whose courses included simulation-games, and Allen, Allen and Miller [3] reported no "drop-outs" from a summer programme in which simulation-games featured, compared with a previous average drop-out rate of 14%.

Teacher response has also been shown to be favourable. In a study by Sprague and Shirts [85], using two thousand five hundred pupils in seventeen schools,some thirty teachers were asked to rate a simulation exercise, and responded very enthusiastically. In the same study, some 93% of the junior high school pupils, and 75% of the older students, rated the simulation favourably.

Some evidence that simulation-games improve interpersonal skills is also provided in the literature. Devries and Edwards [27] report that students using the game "Equations" in teams (as opposed to working individually) perceived the task as less difficult and more satisfying, and worked co-operatively. A study by Seidner in 1971 reported in Dukes and Seidner [30] in which third grade boys, of mixed ethnical origin, and from both integrated and segregated environments, played co-operative games, revealed some degree of integration of black and white pupils.

An absence of racial patterns was evident in sociograms completed after the gaming sessions, and this was backed up by observed changes in attitude of the participants. Research undertaken by Percival and reported in Ellington, Addinall and Percival [35] includes an analysis of tape-recordings of discussions between participants in the interactive case study entitled "Proteins as Human Food". The analysis demonstrated quite clearly that all six members of each of the groups studied had made a significant contribution to the discussion, with no individual member spending less than 10% of the total time communicating. It is worth stressing that "Proteins as Human Food" is a case-study, rather than a simulation-game, and that one of its principal objectives is the improvement of communication skills.

SIMULATION-GAMES AND SCIENCE EDUCATION.

Very few of the published attempts to validate simulation-games concern games in the science area. Indeed, most of the science games which are available have not been evaluated at all, and, but for the work which has been carried out at The Universities of Aberdeen and Glasgow, no large-scale attempts to validate science games have been undertaken in the British Isles. Ellington, Addinall and Percival [35] provide a systematic and descriptive summary of evaluative research of science games.

One or two researchers have attempted to evaluate games developed by other workers. Ellington, Addinall and Percival mention Vaughan [92] and Millar [63] in this connection. Vaughan's evaluation was carried out with two chemistry-based card games, with one class of students. Millar examined the opinions of Australian trainee teachers concerning the value of "The Power Station Game". They also discuss in detail large-scale programmes of evaluation exercises which have been carried out in Scotland. The work by Hadden [45] and Reid [73] are especially important in this area. They are concerned with the all-round evaluation of simulation-games, and similar teaching exercises, developed to teach chemistry to C.S.E. pupils in Scottish Secondary Schools. Whilst their work is of considerable importance within the field of developing stimulating materials for the C.S.E. and "O" level Chemistry syllabuses it is less relevant to the needs of a study such as this. Whereas Haddon and Reid based their conclusions largely on answers to questionnaire-type material, the present author seriously doubts both the validity and reliability of "self-report" techniques with younger children.

Very little of the evaluative work carried out in schools has involved children of the middle school (9-13) age range. Workers such as Dean (1978) [24] and Kraft (1977) [53] who have reviewed a number of mathematics games for use with children at the upper end of primary schools, limit their attention to descriptions of their observed experiences of the games' use. A review of simulation-game research at the elementary level by Bagley [4] contains mention of only three studies. Jan Spencer [84] lists and briefly describes some one hundred and fifty science games. Many of these are American, and quite a number are not commercially available. Only some four or five impinge on the area of the effect of natural factors on animal survival. Those which are commercially available, and which conern themselves with teaching concepts related to organic evolution, do not appear to have been rigorously examined at all. "Extinction: The Game of Ecology", which is a board game developed by Dr. Stephen Hubbell of the University of Iowa for students of fourteen years and over, seems a very well designed game with much to commend it. In reply to questions concerning validation, the Carolina Biological Supply Company, who market the game, reassure enquirers that "Extinction is consumer tested - over 10,000 copies of the original version have been sold". Much the same claim could be made for rubber models of King Kong. "Predator", a food chain game based on a pack of cards, and marketed by Ampersand Press of Oakland, California, has similar credentials. Several of the games mentioned in Gibbs [39], such as those of Urban Systems Incorporated, have disappeared into oblivion, without having been subjected to the rigours of objective examination.

The research described in the forthcoming pages hangs, somewhat tenuously, in a contextual vacuum, and leans precariously on a literature that is both diffuse and distanced from its aims and origins.

The enormous difficulties in generalising from the diverse literature of experimentation, which has formed the basis of this review, derive from several component problems which are worthy of our attention. Perhaps the most significant variable which may intervene in serious attempts to generalise from findings in simulation-game research is the nature and quality of the exercise under consideration. Under the wing of publications such as the SAGSET journal (that is, The Journal of the Society for Academic Gaming and Simulation in Education and Training) are descriptions of a wide variety of exercises, some of which are simulation-games, some non-simulation games, some role-playing exercises, others case-studies. The organisation of these different teaching and learning methods are based on different premises, and attempt to achieve their aims from different starting points. They are therefore very difficult to compare. The differences of quality of the various exercises, their depth, their realism and the sharpness of their focus, serve to exacerbate this problem.

A second variable, which serves to confound the transfer of experience gained by previous research, is that of the different nature of the population of participants of each particular study. The majority of evaluative investigations have taken place in the United States of America, and the bulk of these with the captive college audiences to which the researchers had most immediate access. It would be naive to assume that a simulation-game would be equally reliable with different age ranges, or different abilities of player. Indeed, recent research, discussed in detail later, is clearly demonstrating that simulation-games are differentially effective according to the personality-type of their participants.

Game effectiveness is also a function of game presenter skill. A study carried out by Schriesheim and quoted by Remus [75] examines the motivation of business game participants.

Students receiving three different treatments were compared:

a) A group who were taught a business simulation-game by an enthusiastic instructor.

b) A group taught the same game by a neutral instructor.

c) A control group taught without the simulation-game.

Schriesheim found that the students belonging to group a) were significantly more highly motivated than those in both groups b) and c), and that the motivation of the students of group b) was not significantly different from c). Remus goes on to analyse errors of interpretation which may arise as a result of uncontrolled teacher variables, viz:

1. Teacher A is a more effective teacher than Teacher B.
2. Teacher A has high (or low) expectations of teaching material.
3. A novelty effect influences both teacher and pupils.
4. Teacher A has prepared the subject in ways other than specified as experimental differences.
5. Selection variables (such as place and time) affect Teacher A differently to Teacher B.

The relationship between teacher characteristics and components of game effectiveness has also been demonstrated by Baker [5] (on learning); by Livingston [56] (on attitude change); and Inbar [49] (on enjoyment).

Further problems which reduce the external validity of simulation-game research relate to the experimental techniques themselves. Very often the research designs used in empirical studies have been shown to be inadequate (see, for instance "Research on simulation-games in education: a critical analysis" by Reiser and Gerlach [74]. The quality of the testing materials may preclude the possibility of firm conclusions being drawn (Pierfy [69]). The type of statistics which are used may be inappropriate, and hence lead to inaccurate conclusions (Cronbach [21]). Further discussion of the crucial area of experimental design, and of the factors which jeopardise validity, follows in Chapter Three.

CHAPTER THREE.

METHODOLOGY.

EARLY DEVELOPMENT OF THE GAMES.

The two games described in detail in this chapter were designed by the author, in response to a need expressed by science teachers at his school, as a means of teaching the underlying principles of organic evolution to children in the first year (ie. nine and ten-year-olds).

These children were studying the development of life on Earth as a year-based project, and it seemed greatly advantageous to them to know something of evolutionary theory. However, although ideas such as the nature of predator-prey relationships, and the relationship between survival of a species and its adaptation to its environment, may be of inestimable value, they are extremely complex and elusive. The problem was one of presenting these abstract concepts to children who were, in the main, only operating comfortably at a concrete level.

Three games were developed: "Hide and Hunt" a role-playing game to explore predator-prey relationships; "The Dinosaur Game" a board game based on the survival, and ultimate extinction, of Dinosaurs; and a card game to teach the principle of inheriting genetic changes. The games were designed to be used with whole classes of children, that is, any manageable number from twelve to forty. The other principal constraint was that they should be within the capabilities of fairly able nine and ten-year-olds. (The school enjoyed the sort of catchment area which yields few children with learning difficulties).

One of these games, the game of inheritance, fell by the wayside. It was found that most children did not make the cognitive leap from the game to the phenomenon which it represented. The discussion, which, in all three games, takes the form of a series of analogies drawn between the game and the situation it simulates, had to be so tightly structured in

"The Inheritance Game" to include relevant terms and information, that the activity was almost relegated to being an afterthought. To a limited extent the play served a number of separate functions: it livened-up the learning context; it provided a physical referent for complex concepts. On the other hand, for some children it became a distracting element, in the sense that they devoted their energy - quite naturally - to "playing the game", and tended to lose sight of its symbolic significance.

To a lesser extent, this problem of translation from the game context to the natural situation was a problem with "The Dinosaur Game" too. The children always played with great enthusiasm, but were much less inspired by the demand to form analogies. However, because its content was more immediately familiar and its realism rather more compelling, "The Dinosaur Game" has withstood the test of repeated use with different groups of children, whereas "The Inheritance Game" did not.

The two remaining games then, were developed in the author's own school. Trials with small numbers of pupils out of school hours were used to monitor the effect of manipulating various game structure variables - for instance, the size of the board, and the initial population size in "The Dinosaur Game"; and the type of ancilliary apparatus that could feasibly be used in "Hide and Hunt". These initial playings of the games were crucial times of sensitive assessment and experimentation. A combination of intuition, discussion with colleagues and trial and error progress, led to the fine tuning of the (then three) games in preparation for their use as teaching instruments in the "Life on Earth" project.

At this stage in the games' development no pre- or post-tests had been devised, apart from the continual forms of assessment which were being used by members of the first year staff. It was after their initial use, and, subjectively speaking, the considerable success of two of the games, that attempts to measure their effectiveness were undertaken, separate from that of the other teaching strategies which made up the project. The "success" of the games at this stage was based entirely on the response of the children. They obviously enjoyed the games, and seemed to grasp the underlying concepts. The first year staff stated that the games supported the project work, and enabled the children to understand some of the ideas which were being presented elsewhere, by other methods.

PILOT TRIALS.

It was at this point that the author approached the headteacher of another 9-13 middle school in the same town, and negotiated an opportunity to try out the two games "Hide and Hunt" and "The Dinosaur Game" with pupils who did not know him. The opportunity to work in someone else's school was a valuable one, removing some of the hitherto uncontrolled experimental variables. Now the author, as game teacher, had no special knowledge of the children which might enable him to organise the learning more sensitively, to improve the games' apparent effectiveness. Nor did the children pay him the special attention which they pay to their own headmaster.

At this second school the evolutionary content matter of the games was not related to other studies being carried out with the classes at that time. The games did not comprise one facet of an integrated project, as at the author's school, nor were they alluded to in the science lessons during the period whilst the games were being taught. Partly for this reason, partly because the general level of ability was lower at the second school, and partly because the teaching was to take place near the beginning of an academic year (October 1980), it was decided to teach "Hide and Hunt" to second year children (ie. 10-year-olds) and "The Dinosaur Game", with its difficult and specialised reading vocabulary, to children at the beginning of their third year (ie. 11-year-olds).

One class of second year children was available for one single and one double lesson, where lessons were thirty five minutes long. In addition, one class of third year children was available for two double lessons. The first double "third year" lesson and the single "second year" lesson fell in the week beginning 27th October. The remaining lessons were a fortnight later. Since the games require at least two lessons playing time, very little time was left for any testing. It was therefore decided to compose post-tests for each of the games, and to administer these during the last of the lessons available with each class. Although it would also have been desirable to use pre-tests at this stage, it was just not practicable, and despite their absence the trial nevertheless provided an opportunity for the investigation of the games under more stringently controlled conditions than previous examination at the author's school.

These early post-tests comprised questions which examined specific cognitive skills. They consisted of a number of direct questions which were designed to test for specific concepts, and also some interpretive exercises, developed to examine whether the children could apply the concepts to new situations. All questions were derived directly from the statement of aims, which itself preceded the construction of each game. The necessity of this particular 'horse preceding its cart' has been stressed elsewhere (see Stadsklev's [86] notes on constructing a good game). Some of the questions presented to the children were in the form of statements which required the child to respond in his own words; others took a multiple choice form.

Additionally, the teacher of the two classes was asked to fill in a questionnaire, which was designed to give some structure to the sort of comments which had been made by the staff at the author's school. Copies of this questionnaire appear as Appendix 1. Unlike many of the empirical investigations reported in the literature (eg. Dowdeswell and Bailey [28]; Butcher [14]) the players comments on the game were not solicited in this way. The author shares the view expressed by Cronbach[21], who, in turn, quotes Strong [87] and Kuder [54] as providing evidence that, whereas the interests of people more than seventeen years old are stable over many years, predictions based on interest schedules are not recommended before the age of fourteen or fifteen. Gronlund [43] expresses a similar caution towards the interpretation of self-report data in general, and plainly this uneasiness becomes greater the younger the subjects are.

These pilot trials, whilst not providing substantial validational support for the two games, nevertheless were of considerable value to the later development of the experiment in several distinct ways:

They exposed the shortcomings of the test instruments themselves. For instance, certain of the questions had proved to be ambiguous, and the pupils were misled by distractors which were too subtle. In other cases certain distractors were not chosen at all, were therefore of no value, and were subsequently replaced by others. In later versions of the test most of the questions which required the children to respond in their own words were replaced by multiple choice alternatives. Some of the former type of questions had proved to be very difficult to mark. For instance, question five of the test associated with the game "Hide and Hunt" originally stated:

> "In any place there is a balance between the numbers of different types of animals. Name two different things which affect this balance."

The author had naively hoped for references to the availability of food, and to the birth-rate of the animal types involved. As well as these answers, he received quite sensible comments about the incidence of disease and the activities of man, concepts which arose from somewhere beyond the immediate sphere of influence of the game itself.

As well as various modifications to the cognitive measures outlined so far, it became obvious from the pilot trials that some gauge of children's attitude to natural history in general was needed, and in addition, some measure of the motivational level achieved by playing the game. Instruments subsequently designed to measure these possible changes of state are described later in this chapter.

To a lesser extent, the content of the games themselves was modified as a result of the experiences of the pilot trials. The choice of distractors in the interpretive exercises for "Hide and Hunt" revealed a certain amount of confusion about the stability of food preferences of animal species. This had come about as a result of ill-defined teaching in the game itself. The appropriate discussion session was modified.

Before examining the nature of the experimental design which was subsequently adopted for the main empirical investigation, it will be as well to review the principal structures and procedures of the two games, as they were at the time of the main experiment.

HIDE AND HUNT.

AIM.

To teach the nature of predator-prey relationships.

CONCEPTS.

1. That prey exhibit a variety of behavioural characteristics (eg. camouflage, agility, flocking) and that these have survival value.
2. That predators are adapted to out-manoeuvre their prey.
3. That many animals act out a dual role as hunter and hunted.
4. That there is competition between individuals of a species for the same environmental resources, and that among them the best adapted will survive.
5. That in the predator-prey relationship chance factors often play a significant role.
6. That in any environment there is an equilibrium between the numbers of predators and prey and that this balance is affected by fertility and availability of food.

STRUCTURE.

"Hide and Hunt" consists of a series of six games which take place in a school hall or other open situation over a total period of two or three separate thirty minute lessons. They are designed to be carried out within the normal teaching organisation of the school, that is with whole class groups of thirty or thirty-five children with one teacher. Certain children need to be distinguishable from the rest, by means of coloured bands or shirts, or by carrying a distinctive object such as a large ball. After playing each game a few times the children group around the teacher, who relates what has happened in the game to the relationships between predators and their prey.

GAME ONE.

PLAY: Predators (say, 3) try to catch prey (the rest) who run about the hall to avoid them. The predators touch their prey to capture them. The prey, who are then supposed dead, lie still. Some children may evade capture by hiding behind apparatus, by remaining still, or climbing ladders etc. This simple game will last seconds rather than minutes, and would be repeated several times with different children acting as predators, and with a short discussion following each playing.

DISCUSSION: The discussion sessions can open with the teacher asking what strategies the children adopted to evade capture. The survival value of these various evasion measures in the wild can be stressed. Attention may be drawn to:

a) concealment, camouflage.
b) speed and agility.
c) moving beyond the area of operation of the predator. (The equivalent of the bird flying away from the cat may be the child climbing a rope to get out of the reach of a less agile child who had been chosen to be predator).
d) cataleptic behaviour - pretending to be dead.
e) the significance of chance in predation. (The children will often say that they were unlucky).

f) the starvation of predators which do not catch prey.

Examples of predator-prey relationships familiar to the children should be brought into the discussion wherever possible. For instance, game one can be thought of as a cat/mouse or a cat/bird relationship. It is always useful to generalise beyond this. If the children can be helped to see that the same principles apply to the relationship between a shark and a cod, or a wasp and a cranefly, then they are more likely to be able to apply these concepts universally. They should be encouraged to think up their own examples.

GAME TWO.

PLAY. The predators are restricted to certain areas of the hall (marked off with benches or ropes). The prey have to enter these areas to gain food tokens (represented by bean bags, balls or similar). Those children who gain tokens are judged to have survived. Children caught lie still.

DISCUSSION. Attention may be drawn to:

a) The confusion effect gained by flocking. Antelopes often escape the attention of lions in this way. Many birds, fish and insects also flock or swarm.
b) The competition for food between members of one species. Some children will jostle their colleagues for tokens. The notion that the range of food taken by each species of animal is strictly limited is introduced here. If there is a shortage of flying insects the orb-spiders will starve; they are not capable of eating plants instead.
c) The effect of increasing the number of predators. The teacher may ask, "What will happen if we play the game again with more lions (or spiders or ladybirds, or whatever)? "The children's hypotheses will be discussed and tried out in a replay of the game.

d) The effect of changing the size of the guarded area. The teacher might ask, "If we increase (or decrease) the size of the area which the predators are guarding, how will this affect the game?"

These last two points, c and d, are of particular significance. The numerical relationship between the predators and their prey in any habitat is crucial, and changes in the numbers of one will directly affect the other. The size of the area patrolled by the predator is also of vital importance. One needs only to ponder the vulnerability of the mammals at an East African water-hole.

GAME THREE.

PLAY: Variations on games one and two can be played where the prey are handicapped in some way so as to make rapid movement impossible (eg. some must jump, some crawl, some carry cumbersome object, others are not allowed to climb, etc.).

DISCUSSION: The real difference between species and the physical "superiority" of their predators can be stressed. Different types of defensive movement can be evaluated. Again, many examples spring to mind. Compare the performance of a fox and a rabbit, or an eagle and a rabbit, or a sparrow and a butterfly. Children who are caught early in the game will be frustrated by their handicap, and will tell you, "It's not fair." This is the very point which their teacher would wish to make.

GAME FOUR.

PLAY: The children are divided into three groups - a large group of prey, a group of five or six predators, and one or two children acting as predators of these five or six. Thus the one or two category 'A' children try to catch the half dozen category 'B' whilst they, in turn, are chasing the remainder (category 'C').

DISCUSSION: Game four exposes the dual role which many animals play as both predators and prey. The conflict experienced by category 'B' children should be explored and emphasised. The actual number of children in each group is, once more, crucial, and it is recommended that the game is played several times with different numbers. The teacher should ask questions like, "What happens if we increase the number of category 'B' children?"

GAME FIVE.

PLAY: Game four can be extended by the introduction of prey handicapping (described in game three). Category 'A' predators might be required to stand still and count to twenty when they have caught someone. The "lion" is having a rest after his meal......

DISCUSSION: The children can usefully be asked what could be done to the numbers to make the game last longer.

GAME SIX.

PLAY: Instead of standing still or lying down, the children who are caught queue on opposite sides of the hall. The easiest way to organise this is to have them sit on a bench, if they are available. Periodically numbers of the captured children are released. For instance, one category 'B' and two category 'C' children re-join the game every fifteen seconds. Thus the game is self-perpetuating.

DISCUSSION: The idea that communities of animals exist in a fairly stable balance, in terms of their population size relative to that of their predators, can be investigated here. An opportunity should be sought to replay the game several times, varying the numbers of children alotted to each category, and also any handicaps imposed on them. The children should be asked to suggest appropriate changes, so that eventually a stage will be reached when the population is regenerating itself as fast as it is being captured. The idea that a predator never kills off its prey can be explored, and the relationship between the fecundity of a species and the feeding of its predators is thus exposed.

During the discussion sessions the teacher forges the link between the game and the reality which it represents. This link is not, in any way, a product of the game itself. It is drawn to the pupil's attention by carefully selected questions and answers. However, the cognitive leap - the insight - must be made by the pupil. His "eureka" comes from within him and cannot be placed there, however well-intending his instructor. However, the concrete and active qualities of this game help to create an atmosphere where young children can make this very difficult "cognitive jump" from the tangible to the abstract.

THE DINOSAUR GAME.

AIM. To illustrate the main principles of organic evolution.

CONCEPTS.

1. To show that the survival of a species depends on its adaptation to its environment.

2. To teach that variations occur in succeeding generations in a random way.

3. To show that some of these variations represent successful changes, whilst others lead to extinction.

4. To illustrate that there is competition between species for the same environmental resources.

5. To provide the children with an opportunity to use the specialised vocabulary appropriate to elementary discussions of organic evolution.

STRUCTURE. The game is played by groups of four to six children who sit around a board. Each player is given ten counters of a specific colour, representing the last ten thousand individuals of a species of dinosaur on the verge of extinction. Before commencing play each pupil opts to play the role of either a carnivore or a herbivore throughout the game. Players should be encouraged to picture a particular dinosaur species with which they are familiar. At the beginning of the game one player, who has been elected as dealer for his group, gives out four cards to each of the players, himself included. The cards, which are illustrated in figure 1, describe particular characteristics of the dinosaurs, and control their progress on a journey around the board (a reduced size version of which is shown in figure 2).

The aim of the game is to move one's dinosaur as far along the board as possible, each square passed symbolising its survival for a million years. The players continually change their cards throughout the game, and so are presented with an opportunity to adapt to the changing conditions of the board as they progress along it. The environment represented by each board square becomes progressively more hostile as the journey through time continues, and only those species of dinosaur which successfully adapt and maintain stable or expanding populations will be likely to survive.

PLAY: Play begins on the dealer's left and passes from player to player, until reaching the dealer again. Each player, in turn, places one counter on the start and exposes his four cards. He reads out aloud and subsequently obeys, the instructions given on them. The cards should be exposed as a group of four, and the resulting move should be made as a result of the combination of the instructions contained. Thus, if two of the cards state "MOVE ON ONE SQUARE", one card requires the player to "MOVE ON TWO SQUARES" and the remaining card a "MOVE BACK ONE SQUARE", then the player places his counter on the square three squares ahead of his present position, and ignores the squares in between. The movement of the counter may result in further instructions to the player being given on the board. These instructions are obeyed at the beginning of the next turn, when the player's new hand is revealed. It is important that

Fig (i) Details of a pack of 48 cards for use with "The Dinosaur Game".

Two cards - You tend to feed on your own young. MOVE BACK 1 SQUARE

One card - Your power of sight is very weak. MOVE BACK 1 SQUARE.

Five cards - You now lay more eggs. MOVE ON 2 SQUARES.

Two cards - You can survive for long periods in water. MOVE ON 1 SQUARE.

One card - You are poor at defending yourself. MOVE BACK 1 SQUARE.

Two cards - You are good at controlling your body temperature. YOUR POPULATION INCREASES BY 1000.

Four cards - You are able to eat many different foods. MOVE ON 1 SQUARE.

Two cards - A large number of your eggs fail to hatch. LOSE 1000 SPECIMENS AND MOVE BACK 1 SQUARE.

Three cards - You are well camouflaged. MOVE ON 1 SQUARE.

Five cards - You are able to swim.

Two cards - You have become more intelligent. MOVE ON 1 SQUARE.

One card - You get skin diseases very easily. LOSE 1000 SPECIMENS.

Two cards - You are able to move at great speed. MOVE ON 2 SQUARES.

Two cards - You tend to eat poisonous foods. MOVE BACK 1 SQUARE.

Four cards - You are good at conserving water and can resist drought. MOVE ON 1 SQUARE.

One card - You are becoming too heavy. MOVE FORWARD 1 LESS THAN INSTRUCTED, OR STAND STILL.

One card - You have developed a keen sense of smell. MOVE ON 1 SQUARE.

Two cards - You are fed upon by other Dinosaurs. LOSE 1000 SPECIMENS AND MOVE BACK 1 SQUARE.

Six cards - You have become resistant to many diseases. MOVE ON 1 SQUARE

Fig (ii) Reduced copy of the board used with "The Dinosaur Game".

1 START HERE	2	3 Plant food is abundant. Herbivores move to square 5.	4	5	6	7 Small animals are abundant. Carnivores move to square 9.	8
16 Land flooded.	15	14	13 Food shortage. Unless you eat many different foods lose 1000 specimens.	12	11	10	9
17 Do not proceed unless you can survive in water.	18	19	20	21	22	23 Diseases abundant. Do not proceed unless resistant.	24
32	31 Volcanic activity. Lose 1000 specimens if you do not move at great speed or are intelligent.	30	29	28	27 Food shortage. Unless you eat many different foods lose 1000 specimens.	26	25
33 Diseases abundant. Do not proceed unless resistent.	34	35 Drought. Do not proceed unless you are well adapted.	36	37	38	39 Shortage of plants. Herbivores lose 1000 specimens.	40
48 Shortage of small animals. Carnivores lose 1000 specimens.	47	46	45 Small mammals are feeding on your eggs. Lose 2000 specimens if you cannot lay more eggs.	44	43	42	41
49 Very cold weather sets in. Lose 1000 specimens if you cannot conserve heat.	50	51	52	53 Your predators are becoming faster. Lose 1000 specimens if you are not well camouflaged.	54	55	56 You are competing with mammals for food. Lose 2000 specimens.
64	63	62 Changes in plant life mean less food. Herbivores lose 1000 specimens.	61	60 Your prey is cleverer than you. Carnivores lose 1000 specimens.	59	58	57

this procedure is stressed during the playing of the game. Leaving the interpretation of board-based instructions to the next turn enables "dinosaurs" to "adapt" to the environmental changes which they represent.

At the end of each round of play the players shuffle their cards and offer them face down to the dealer, who exchanges two, selected at random. Thus the characteristics of the dinosaurs continually change. Gradually, as play progresses, the stock of the various dinosaur species dwindles, though it is unlikely that any will actually become extinct (having no more counters) within a period of thirty or forty minutes play.

DISCUSSION: An initial session of about fifteen minutes or so is essential, during which the teacher explains the rules of the game to the whole class. The author has found that the use of an overhead projector transparency of the board is a valuable aid for this puprose. During this initial explanatory session the special vocabulary of words such as "predator", "abundant", "carnivore" etc. should be introduced. It is perhaps worth reminding the reader that the game was developed for children who had already begun to master this vocabulary, and it is only in attempting to use the game in isolation that difficulties with some of the language might be experienced. It is useful during the pre-play discussion to read out the characteristics described on some of the cards, and some of the environmental changes listed on the board, and to ask the children questions about whether or not they might prove to be advantageous, and why.

During the session of play it is most valuable to discuss with groups at each board just what is happening, in evolutionary terms. One of the key concepts to reinforce in this way is that of adaptation. Questions like those following will greatly reinforce the principles involved....

"Has your dinosaur managed to adapt to the flooding? How has it adapted?"

"Has anybody's dinosaur not moved forwards recently? In what way is it badly adapted to life at the time?"

and "Is there anyone whose dinosaur population is now more than 10,000? What is it about your dinosaur which has caused the population to increase?"

Again, during the play itself, the teacher may find it worthwhile to ask the whole class which dinosaur has survived the longest, and why that was, or which dinosaur had the lowest population, and so on. It is also as well to ensure that each child is reading the instructions on his cards aloud, aided by other members of the group if necessary. This translation of the written instructions into oral form greatly improves the rate at which the children become familiar with the terms involved.

A short class discussion at the end of a playing session of about forty minutes or so, will also serve the purpose of forging a link between the game and the reality it represents. The teacher may ask more general questions, such as:

"Why did dinosaurs die out?"

"What sort of dinosaurs would be likely to survive the longest?"

"Can you think of some ways in which sharks (or gulls, or ground beetles etc.) are adapted to surviving today?"

and "Can you think of any way in which butterflies (or tortoises, or rabbits etc.) are poorly adapted to the conditions of life on Earth? What will prevent them from conquering the globe?"

EXPERIMENTAL DESIGN.

The final form of the experiment arose from the desire to improve the quality of the test instruments, both in terms of their validity and their scope, and to embed them in a sound research design. This design was selected to incorporate a multi-faceted approach to the evaluation, so that assessments could be established on as many variables as possible.

The most significant practical constraint was the size and nature of the sample. The experiment was carried out using some two hundred and forty children within two year groups of one nine to thirteen middle school (a third middle school, in the same town). To what extent the sample is a representative sub-set of all eleven and twelve-year-old children, or all British children of that age, or only the children of that age in that town, is impossible to determine without repeating the experiment many times elsewhere. The school was selected because it was a neighbouring school and was available, rather than because of any specific characteristic of its pupils. Indeed its catchment area comprised of roughly equal mixture of both private and council housing, so that in terms of its social mixture it was not unlike many other urban schools.

A Solomon three-group design was used (Solomon 1949 [83]) which provides the researcher with a means of assessing possible interactive effects due to the pretest. The basic model may be summarised thus:

	PRETEST	TREATMENT	POST-TEST
EXPERIMENTAL GROUP.	YES	YES	YES
CONTROL GROUP 1.	YES	NO	YES
CONTROL GROUP 2.	NO	YES	YES

The rationale of this design is based on the argument that increases observed in the experimental group which are significantly greater than those apparent in control group one might be attributable not only to the treatment which the experimental group have received, but also to the sensitisation which they experienced by having a pre-test. It could properly be suggested that this sensitisation ensured that the experimental group were aptly disposed towards the treatment, and that their attitude change played a significant part in the treatment's success. On the other hand, the existence of control group two permits a comparison between their post-test performance and that of the experimental group. If there is no significant difference, but yet still a significant difference between control groups one and two, in the appropriate direction, then the researcher may feel confident that sensitisation due to the pre-test did not play a significant part.

A fuller exposition of the three-group Solomon design is given in Kerlinger [52], who holds it in high regard, remarking that "in most respects they (ie. the three and four group designs proposed by Solomon) are the strongest designs."

Since four mixed ability classes were available to be taught each of the two games (ie. four second-year classes were available to play "Hide and Hunt" and four third-year classes to play "The Dinosaur Game") the author decided to place two classes in each experimental group and one each in control groups one and two, all classes being selected from their group of four at random.

Each class of children, in addition to being available for pre- and post-tests, was available for one double period, ie. a lesson of one hour duration. All six of these lessons fell within the same week.

One of the principal problems of educational research, pointed out in very certain terms by Campbell and Stanley [15], is that concerned with bias inadvertently introduced at the sampling stage. Plainly, if the sample is sufficiently large, a random sampling of the whole population is much more satisfactory than the use of matched groups. The difficulty of non-random methods derives from the probability that the groups which are being compared may not be similar in any really precise way. The use of pre-tests with both experimental and control groups in this research was a deliberate attempt to control for bias at the sampling stage. However, the lack of randomised sample selection procedures reduces the essence of this empirical investigation to a quasi-experiment, in Campbell and Stanley's terms, with a corresponding loss of external validity. However, the use of a non-equivalent group design as part of a non-randomised quasi-experiment was the only practical possibility open, and it is the author's contention that the careful control of a number of the other sources of loss of validity has reduced this seepage considerably.

Campbell and Stanley make the point:

"The more numerous and independent the ways in which the experimental effect is demonstrated, the less numerous and less plausible any single rival invalidating hypothesis becomes."

In line with their thesis, the effectiveness of the two games was assessed in various ways: A multiple choice written test of knowledge was presented to the children, together with some interpretive exercises, designed to assess the pupil's skill in applying the concepts embedded in the games to a new context. Both the written tests and interpretive exercises were carefully designed during the "tuning" stage of the pilot trials, in order to reduce ambiguities and eliminate weak distractors. The children were also given multiple choice questions to assess whether the hour's exposure to the game increased their interest in the area of natural history generally. The teachers, two of whom observed each game, were asked to complete a questionnaire which examined how effective they felt it had been. This non-participant observation was reinforced by the completion of a simple interaction schedule by an independent observer (actually a mature student on teaching practice) who was present for a single session of each game. The observer rated the behaviour of two children selected at random by her at the beginning of the lesson. None of the children were known to her previously. The schedule required her to record at ten second intervals whether the particular pupils were involved with the task in hand, or distracted by an event outside the task. Full details of these various tests comprise Appendix One.

An excellent and very full analysis of threats to valid inference in experimental design is given by Cook and Campbell [20].

They examine empirical methods in the light of four types of validity, viz: internal validity, construct validity, external validity and statistical conclusion validity. We shall examine each of these threats in turn, pausing to discuss the strategies adopted to overcome them.

INTERNAL VALIDITY.

Two related threats to the internal validity of an experiment are history and maturation. "History" refers to the unknown effects of the various extraneous experiences which have confronted the test population between pre- and post-tests. "Maturation" refers to the gradual development of the biological and psychological processes of the subjects during a given period of time. Whilst these two confounding effects are not possible to control in the normal school situation they were reduced to a minimum in this research by separating pre- and post-tests by a period of only two weeks.

The effect which Cook and Campbell refer to as "testing" describes the improvement which results from repeated exposure to particular testing materials. "Instrumentation" refers to a change in the measuring instruments which are in use during the experiment. The choice of a Solomon design, as described earlier, was a deliberate ploy to isolate the effect of "testing". To control variables resulting from changes in test instruments identical tests were used at both pre- and post-test stages. The principal problem of using the same test, as opposed to parallel forms, is the practice it gives the participants. However, as indicated, the Solomon design was developed to isolate this. Not only were the test instruments the same at both pre- and post-test stages, the same observer was used for both games, and the games were taught under identical, and tightly controlled conditions - a point which we shall pick up later on .

Cook and Campbell warn against the bias introduced by statistical regression, a tendency for low pre-test scores to improve, and for high pre-test scores to do worse, at the post-test stage, due to extraneous factors, such as health. In a reasonably large sample it is likely that these influences will cancel each other out.

Several other sources of variance, which might confound attempts to establish internal validity, are highlighted by Cook and Campbell. The dangers inherent in non-random selection have been discussed already. The factor of mortality - in this case pupils' absences - was controlled by eliminating the particular children from the experiment. The "diffusion of treatments" effect, brought about by the children of one class discussing the testing or teaching with others, for instance, cannot be ruled out as a contaminating effect in this design. It seems unlikely that children of this age would learn a great deal from their peers in this way, though quite possible that a warmer response set could be engendered in later experimental groups. A great deal of communication of the concepts embedded in the game would be illuminated by significant gains shown by the principle control group - control group one.

CONSTRUCT VALIDITY.

Cook and Campbell refer to the confounding of cause and effect brought about by incidental variables. They give examples where changes in the dependent variable are induced by causes other than the independent variable under investigation. Placebo, Hawthorne and novelty effects are suitable examples of these factors. In the context of this experiment, any stimulus to learning arising from the novelty or variety of a new and exciting learning experience is exactly what we are looking for anyway. Far from condemning it to the ranks of an experimental artefact, we can properly elevate it as one of the beneficial characteristics of the teaching method we are examining. The author assumes here that teachers who recognise the value of simulation-games will be astute enough to use them to complement other teaching methods, rather than to ram them ad nauseam down the throats of their unlucky charges.

Within the context of this experimental design the author decided that he would be the person to actually teach the games. Consequently the twelve thirty minute lessons devoted to learning about and playing the games were planned and controlled by the author. This duplication of roles, as game designer, game-teacher and game evaluator, seems, on the surface, to be fraught with hazards. Perhaps some of the observed effects might be attributable to particular qualities of the author's interaction with the class, rather than features of the games themselves. This would be very difficult to establish without repeating the experiment a good number of times in different contexts with different game-teachers. Undoubtedly some would find the experience more rewarding than others. Within the limitations of this experiment such luxuries were not possible and the author decided that the games could be most suitably promoted by the person who originated them.

One particularly potent source of confusion cited by Cook and Campbell is hypothesis guessing. The subjects in an experiment attempt to guess what it is that the researcher requires, rather than give sincerely self-generated answers. Rating scales completed by young school children, or other groups of people under pressure within a status-based context, are particularly vulnerable to this form of bias, and, as indicated previously, they were therefore rejected as a possible means of providing validational evidence within this research.

EXTERNAL VALIDITY.

The external validity of a piece of research is the extent to which it is reasonable to generalise from the sample population to the greater population to which the experiment has addressed itself. Cook and Campbell list three different types of threat to external validity, viz selection, setting and history.

"Selection" refers to the sampling strategies which have been chosen. "Setting" refers to the context of the experiment, in terms of such variables as the place where the experiment is held, the number of subjects in the group etc. "History" denotes the effect of time of the experiment, for example, the time of day, the time of school term, or the time of year.

The limitations imposed by non-random sampling have already been discussed on page thirty-six. The extent to which the particular context of this experiment is a generalisable context is very difficult to determine. The tone of that particular school, the general attitude of its pupils towards visitors, and even the precise choice of teaching area may all play their part. The difficulty of quantifying these effects without considerable replication of the experiment under differing conditions cannot be over-emphasised.

Some improvement in external validity of samples of reasonable size can be obtained by the analysis and comparison of the performance of sub-groups of the sample. In this work boys and girls have been examined separately, and three ability bands: those children who were able and good at science; an intermediate group; and those experiencing frequent difficulties who were poor at science (as assessed by their science teachers) were also compared.

One threat to external, and probably internal, validity which crops up in validational studies within educational settings is the nature of the activity which the experimental activity replaces. "Hide and Hunt" played in the school hall, may be a very stimulating way of spending a science lesson, but on the other hand, if it is played in that same hall instead of a P.E. lesson, then the whole experience may be regarded by the children in a different light. All the pre-testing, game play and post-testing for both "Hide and Hunt" and "The Dinosaur Game" were undertaken in normal science lesson time.

Whether or not an hour's play is an adequate length of teaching time for these games may also be situation - and teacher - related. Had the games been played for twice as long then corresponding post-test scores may have been higher. The choice of an hour was based on a consensus view of four science teachers consulted that an hour was the sort of length of time which they would expect to spend on these concepts if they were dealing with them by another method.

STATISTICAL CONCLUSION VALIDITY.

There are a number of distinct ways in which the inappropriate use of statistical measures and the sloppy supervision of testing procedures can affect the validity of empirical work.

Cook and Campbell describe random irrelevancies in the experimental setting and the reliability of treatment implementation. As mentioned earlier, the author acted as game teacher to all the groups. The testing, on the other hand, was delegated to the teacher who normally taught science to that group. Both pre- and post-tests were supervised in the same room by the same teacher in the identical period on the same day - but two weeks apart. The furniture was organised in the same way and the methods of supervising the tests was identical. The questions were all read aloud by the teacher (so that weak readers would not be penalised) and the children recorded their answers one question at a time.

Validity may be further threatened by low statistical power of particular statistical measures applied to the data, and by the violation of the assumptions of those measures. The significance of the improvement in scores between pre- and post-tests was assessed by means of the Wilcoxon Matched-pairs Signed-ranks test. The comparison of the performance of the experimental and control groups was carried out by means of a Mann-Whitney U Test. A fuller discussion of the rationale behind the choice of these tests, based on arguments advanced by Siegal [82], follows in Chapter Four.

A final source of error cited by Cook and Campbell is unreliability of the measures themselves. All the tests used in this research were designed by the author. The cognitive tests were based entirely on the statement of aims which precedes each game description. To this extent these tests have content validity. However, in Gronlund's [43], terms they lack criterion-related validity. They were examined by two science teachers before use, who felt that the tests were the sorts of instruments which they would be happy to use in order to examine knowledge and skills in this concept area. However, no correlation can be offered between performance on the cognitive tests and other objective measures of competence.

The attitude/interest test was similarly constructed. A further possible source of error, the socially-desirable response, at the post-test stage, was introduced here. Pupils who played the game may have attempted to gain their teacher's favour by giving particular answers. Three safeguards were built into the experimental design:

a) All tests were anonymous. Only the sex and ability group were coded onto the papers.

b) All tests were administered by the normal science teachers in a standardised way. These teachers had no vested interest in the outcome of the experiment.

c) The questions were not the straightforward "Did you enjoy the game?" type. The intended affective outcomes of the game were embedded more deeply in the question content.

Pupil motivation was measured by an interaction schedule, again designed by the author. The non-participant observer, a trainee teacher, had simply to record with an oblique whether or not the pupil was involved in the task. By avoiding rating scales it was hoped that some of the biases implicit in more verbally-based procedures would be avoided. Some type of generosity error, or its opposite, may have occurred, though, again, the data were collected by someone with no real axe to grind.

Copies of all of these tests appear as Appendix One.

CHAPTER FOUR.

RESULTS.

Four different types of test were used as part of the evaluation procedure for each game. Although the testing methods were similar for both games, the results of each could in no way affect the other. They will therefore be presented separately.

"HIDE AND HUNT": COGNITIVE TEST.

This test consisted of seven items, of which five were designed to test retention of information, and two were interpretative exercises, aimed to assess the pupils' ability to apply the principles learned to new situations. All but the first question were in multiple-choice form. Two of the questions in the first section consisted of two parts. Both of the interpretative exercises consisted of three parts.

Since the tests had been completed anonymously to reduce the likelihood of hypothesis guessing, it was not possible to make direct comparisons between pre- and post-test scores for individual children. This, in turn, meant that it was not possible to use 't' tests or other statistics based on standard deviations. Instead, the percentage of children obtaining the correct answer was calculated for each question at both pre- and post-test stage. These percentages were compared using The Wilcoxon Matched-Pairs Signed-Ranks Test, the rationale of which is to make comparisons between the rank position of the different pairs of scores. Siegal [82] describes the power-efficiency of the Wilcoxon test as being some 95.5% compared with the 't' test. This relatively small loss of power is largely associated with the quality of data required. The researcher needs to have ordinal information not only within pairs, but also concerning the differences between pairs, that is, data are available as "an ordered metric scale".

For the purposes of a sensitive examination of the data the papers were coded B1, B2, B3, G1, G2 or G3 according to whether the test was being taken by a boy or a girl, and whether the pupil concerned was:

1. an able scientist expected to do well.
2. an "average" scientist, in the sense of falling between categories 1 and 3.
3. someone who experienced frequent difficulties in science and who was expected to do badly.

The results of the Wilcoxon Matched-Pairs Signed-Ranks Test are shown in Fig (iii).

Fig iii. Comparison of pre- and post-test scores for year two children using Wilcoxon Matched-Pairs Signed-Ranks Test.

CATEGORY	Sample	T+	T-	z-Score	Significance Level (p=)
Control Group	32/30	30	61	1.083	0.140
Expt. Group	93/90	1	90	3.109	0.001
Boys	48/48	3	63	2.672	0.004
Girls	45/42	2	89	3.040	0.001
Bright Chn.	23/28	12	79	2.342	0.010
Average Chn.	50/37	2	89	3.040	0.001
Dull Chn.	20/25	6	60	2.402	0.008
Bright Boys	7/11	25	66	1.433	0.076
Average Boys	29/22	7	84	2.691	0.004
Dull Boys	12/15	17.5	73.5	1.958	0.024
Bright Girls	16/17	11	80	2.412	0.008
Average Girls	21/15	5	86	2.830	0.002
Dull Girls	8/10	8	83	2.624	0.004

The principal comparison, between the control group and the experimental group as a whole, is a significant one. Whereas the z-score for the control group reflects only a small gain in the raw scores, and is not statistically significant, the z-score for the experimental group is significant at the 0.001% level. The gains shown by the girls are also significant at the 0.001% level. Gains shown by the boys are not quite as dramatic, being tempered somewhat by a rather mediocre gain by the brightest boys. This may in part be due to the relatively small sample, seven boys only at pre-test, who were joined by four others for the teaching and post-test phase, who may have scored less well. Further distortion derives from particularly high pre-test scores for certain questions. In Question Six, an interpretative exercise described overleaf, all seven boys correctly selected choice C at the pre-test stage, whereas in the post-test only six (of eleven boys) opted for it. This effectively reduces the percentage of children obtaining the right answer from 100% to 54.5%. The gain by the "dull" boys is significant at the 0.05% level. All other gains are significant at a minimum level of 0.01%.

The use of the Wilcoxon Matched-Pairs Signed-Ranks Test assumes that the items of the test can properly be added together to give a meaningful overall score. The cognitive tests used to evaluate the two games were designed in such a way that this was the case. Although the different questions tap an understanding of different concepts taught by the game, these concepts are clearly inter-related, in the way that items of a mathematics test are inter-related, and can properly be regarded as parts of a tangible whole - a general competence in the area of knowledge taught by the game. However, a detailed analysis of improvement of scores for each sub-group of children for each particular question has also been carried out and appears in Appendix Two.

This item-by-item analysis provides a much clearer indication of the merits and shortcomings of the game. Certain concepts have been put across with considerable effect, though with others it is rather less so. The scores at pre-test, the base upon which the game operates, also exhibit considerable differences. An example may illustrate this variance:

Question six took the following form:

You collect a number of ground beetles, which normally eat small insects, and put them in a large glass jar. You feed them with pieces of meat and fish left over from dinner and put water in the jar regularly. After keeping them for four weeks, when there are 20 of them, you go away on holiday for a month, leaving them without food or water.

Tick the three most likely things to have happened when you came back.

(a) There are now 80 ground beetles because some of them had young.

(b) There are still 20 ground beetles because this particular type of beetle lays eggs which do not hatch.

(c) There are 5 ground beetles left. The others have been eaten by them.

(d) The beetles had become diseased and have all died.

(e) Some beetles had been eaten. The rest have died from lack of water.

(f) Only those beetles which could run quickly had survived.

(g) The beetles had changed their diet and survived by eating the soil in the jar.

The three "correct" answers are indicated (c), (d) and (e). At the pre-test stage 65.6% of the experimental group chose statement (c), 51.6% selected (d) and as many as 73.1% opted for (e). These high pre-test scores imply that many of the children were already familiar with the concepts concerned. At post-test 83.3% of the experimental group chose (c) and some

85.6% chose (e). It is assumed that this distinct improvement came about as a result of the one hour exposure to "Hide and Hunt". However, only 46.7% of the experimental group chose answer (d) in the post-test. This slightly depressed score seems to have been brought about by choices of a few children who at pre-test selected answers (c), (d) and (g), or (d), (e) and (g), but at post-test preferred (c), (e) and (g). They had dropped answer (d) in favour of one of the other correct answers, whilst holding tight to misconception (g). Nearly a third of the children opted for distractor (g) in the post-test. To some extent distractor (g) was badly designed, for whilst providing an attractive answer to the children, it was based on a concept that was not actually taught by the game. Each distractor had, of course, been examined at the pilot trial stage of the development of the game, but had been scrutinized in terms of its selection by a different group of children, with different experiential backgrounds, and, apparently, different misconceptions.

Further comparisons between the experimental and control groups were made by means of the Mann-Whitney-U-Test. Siegel[82] writes of this test as "one of the most powerful of the non-parametric tests". He describes its power-efficiency as approaching 95.5% with reasonable samples, and recommends the Mann-Whitney-U-Test as "an excellent alternative to the 't' test". No significant difference was evident between the experimental and control groups at the pre-test stage ($U = 72$; $z = 0.064$), but comparisons of the post-test scores yield a U score of 45.5 and a z-score of 2.064 ($p < 0.019$ - significance at the 5% level).

The extent to which the experimental group were "sensitised" by the experience of a pre-test may be examined by comparing their mean post-test scores with those of control group two, a class of children who experienced the game without having been exposed to a pre-test. A table of mean scores for each question appears as Fig (iv).

Fig (iv). A comparison of mean post-test scores expressed as the percentage of children obtaining the correct answer, for the experimental group and control group two (no pre-test).

Question.	Experimental Group.	Control Group Two.	Hypothesised Gain Due To Pre-Test.
1	67.0	76.5	- 9.5
2a	66.1	79.4	-13.3
2b	73.2	52.9	+20.3
3	67.9	58.8	+ 9.1
4	50.0	67.6	-17.6
5a	67.9	70.6	- 2.7
5b	85.7	64.7	+21.0
6a	82.1	85.3	- 3.2
6b	51.8	38.2	+13.6
6c	85.7	85.3	- 0.4
7a	62.5	64.7	- 2.2
7b	71.4	58.9	+12.5
7c	66.1	67.6	- 1.5
Overall Mean.	69.0	66.9	+ 2.1

Although there is an overall mean gain of some 2% by children who took the pre-test, the general picture is one of considerable inconsistency. Separate analyses for boys (fig.v) and girls (fig.vi) present a similar picture.

Fig (v). A comparison of mean post-test scores, expressed as the percentage of children obtaining the correct answer, for the boys of the experimental group and control group two.

Question.	Experimental Group.	Control Group Two.	Hypothesised Gain Due to Pre-Test.
1	68.3	83.3	-15.0
2a	60.0	83.3	-23.3
2b	70.0	44.4	+25.6
3	66.7	66.7	Nil
4	40.0	66.7	-26.7
5a	63.3	66.7	- 3.4
5b	90.0	55.6	+34.4
6a	76.7	83.3	- 6.6
6b	53.3	33.3	+20.0
6c	83.3	88.9	- 5.6
7a	66.7	55.6	+11.1
7b	73.3	50.0	+23.3
7c	66.7	55.6	+11.1
Overall Mean.	67.6	64.1	+ 3.5

Fig (vi). A comparison of mean post-test scores, expressed as the percentage of children obtaining the correct answer, for the girls of the experimental group and control group two.

Question.	Experimental Group.	Control Group Two.	Hypothesised Gain Due to Pre-Test.
1	65.4	68.8	- 3.4
2a	73.1	75.0	- 1.9
2b	76.9	62.5	+14.4
3	69.2	50.0	+19.2
4	61.5	68.8	- 7.3
5a	73.1	75.0	- 1.9
5b	80.8	75.0	+ 5.8
6a	88.5	87.5	+ 1.0
6b	50.0	43.8	+ 6.2
6c	88.5	81.3	+ 7.2
7a	57.7	75.0	-17.3
7b	69.2	68.8	+ 0.4
7c	65.4	81.3	-15.9
Overall Mean.	70.7	70.2	+ 0.5

To make the assumption that the 2% variance is a result of the effects of a pre-test would be naive. It is only too obvious that the initial differences between the classes is too great for effective partialling out of more sensitive variables. For a persuasive demonstration of sensitization by a pre-test, the gain of the experimental group over the no-pre-test control group would have to be significantly greater than the measured differences between the individual classes at pre-test. This is just not so. The pre-test scores of the two "experimental" second-year classes are shown in fig (vii).

Fig (vii). A comparison of mean pre-test scores, expressed as the percentage of children obtaining the correct answer, for the two classes comprising the experimental group.

Question.	Class A	Class B	A - B
1	50.0	33.1	+16.9
2a	33.3	35.5	- 2.2
2b	66.7	51.6	+15.1
3	53.3	38.7	+14.6
4	36.7	29.0	+ 7.7
5a	30.0	51.6	-21.6
5b	36.7	29.0	+ 7.7
6a	66.7	58.1	+ 8.6
6b	66.7	32.3	+34.4
6c	73.3	74.2	- 0.9
7a	53.3	54.8	- 1.5
7b	76.7	54.8	+21.9
7c	56.7	71.0	-14.3
Overall Mean.	53.9	47.2	+ 6.7

The knowledge of evolutionary theory possessed by each of the two experimental groups prior to the experiment is obviously not the same. Similarly, the control group starts from a basis which is different to the mean experimental score. Examination of the scores reveals a pre-test mean of 55.2%, and a post-test mean of 57.3% for the control group against which backcloth gains by the children who were taught the game assume even greater significance.

The various classes which acted as subjects for this experiment were not "matched" except in the limited sense that they were mixed ability classes within the normal school setting. Inter-class differences in ability undoubtedly have a clouding effect in research of this sort, but the obvious convenience of using a class-unit-based form of cluster sampling proved to be a necessary ingredient of this research design. The limitations of non-matched group comparisons would be much more serious had they been associated with a comparative evaluation model rather than one which is in essence, illuminative. It was the writer's intention to demonstrate gains by children who played the games, and to demonstrate these by means of a variety of empirical techniques, rather than to make broad comparisons with other teaching methods. It is only when he sought to examine the effects of the pre-test that sensitive comparisons between the groups needed to be made.

It is the author's contention that, within the context of illuminative research, it is the intra-group differences which are the key element. This within-group variance is what makes teaching such a challenging, and yet rewarding, experience. A summary of broad intra-group differences appears as fig. (viii).

Comparisons between the pre-test scores of boys and girls, both within the ability-related sub-groups and as a whole, reveal no surprising differences. However, at the post-test stage the girls' scores show a consistently greater improvement. This difference is not sufficiently great to merit the label "significant" in a statistical sense (post-test Mann-Whitney U=63; z=1.106 compared with pre-test U=79; z=-0.28) but nonetheless is an interesting trend.

Fig. (viii) A comparison of the pre- and post-test scores, expressed as the percentage of children obtaining the correct answer, for the various sub-groups of children under investigation.

Category.	Sample.	Pre-test.	Post-test.	Gain.
Control Group	32/30	55.2	57.3	2.1
Experimental Group	93/90	52.0	68.0	16.0
Boys	48/48	51.2	65.7	14.5
Girls	45/42	52.8	70.3	17.5
Bright Children	23/38	61.7	75.6	13.9
Average Children	50/37	49.7	66.6	16.9
Dull Children	20/25	46.2	61.0	14.8
Bright Boys	7/11	61.3	72.6	11.3
Average Boys	29/22	50.8	65.5	14.7
Dull Boys	12/15	46.5	60.8	14.3
Bright Girls	16/17	62.1	77.6	15.5
Average Girls	21/15	48.4	68.1	19.7
Dull Girls	8/10	45.7	61.3	15.6

Comparisons between bright and dull children show tendencies which lie in the predicted direction. The mean percentage score for bright children was 61.7% at pre-test, and 75.6% at post-test compared with 46.2% at pre-test and 61.0% at post-test for the dull children. However, question five presents us with a curious anomaly:

5. In any place there is a balance between the numbers of different types of animals. Tick the two things which are most likely to affect this balance.

- (a) The amount of food.
- (b) The intelligence of the animals.
- (c) The rate at which the animals have young.
- (d) The weakness of the prey.
- (e) The speed at which they move.

Question five is a highly abstracted and difficult question for children of ten. To some extent it is a key question, in the sense that it focuses on a fundamental principle of predator-prey relationships - that the size of a population of any species of animal is dependent on its fecundity and its food availability. At the pre-test stage 39.1% of the bright children (n=23) selected choice (a) and 34.8% opted for choice (c). However, 50% of the so-called "dull" group (n=20) chose (a), and 45% chose (c) at the same stage. In the post-test, as would be anticipated, the position was reversed in the sense that 89.3% of the bright children (n=28), but (only) 64% of the dull children (n=25), chose (c). However, while 64.3% of the "more able" group selected choice (a), some 80% of their "less able" counterparts made that selection! A detailed examination of the choice distractors reveals no obvious difference in the patterns of the two groups. It was not that a particular distractor had wooed the attentions of the brighter children. Rather, in the author's view, it says something about individual differences between children, and the dangers of applying general tendencies in particular situations and to specific individuals. This point will be developed more fully in Chapter Five.

"HIDE AND HUNT": ATTITUDE TEST.

Two subject choice preference schedules (see Appendix One) were used to assess possible changes of attitude of the pupils towards natural history as a direct result of playing the game. The author felt that it was not enough to demonstrate that the children had enjoyed the game, or preferred taking part in simulation-games to learning by more "traditional" methods. This enjoyment has been adequately established by other authors (see, for example, Livingston[58], Cohen [16], Brenenstuhl [11]) though whether it is entirely a product of the nature of the game process or a relatively short-lived novelty effect is harder to demonstrate. Rather than attempt to quantify the pupils' obvious enjoyment of learning by "playing", the author felt it would be more significant to demonstrate an increased interest in the whole area of natural history. The first question required the pupils to select four subjects, out of twelve, for study as a class topic during ensuing weeks. The results are given in fig. (ix).

Fig. (ix) Attitude question one: a comparison of pre- and post-test scores expressed as the percentage of children selecting the appropriate option to indicate an interest in natural history.

Category.	Sample	Pre-test	Post-test	Gain
Control Group	32/30	36.7	35.0	-1.7
Experimental Group	93/90	41.4	43.6	2.2
Boys	48/48	33.3	28.6	-4.7
Girls	45/42	50.0	60.7	10.7
Bright Children	23/28	45.7	45.5	-0.2
Average Children	50/37	38.0	45.3	7.3
Dull Children	20/25	45.0	39.0	-6.0
Bright Boys	7/11	32.1	22.7	-9.4
Average Boys	29/22	31.9	31.8	-0.1
Dull Boys	12/15	37.5	28.3	-9.2
Bright Girls	16/17	51.6	60.3	8.7
Average Girls	21/15	46.5	65.0	18.6
Dull Girls	8/10	56.3	55.0	-1.3

Plainly, the results are too inconsistent for any conclusions to be drawn. It is nevertheless interesting to note that the strong positive changes are all girls' scores and to recap that it was the girls, and particularly the average girls, who achieved the stronger gains in the cognitive tests.

The second question in the attitude section of the tests was a straightforward Likert Scale in which pupils were asked to rate various subjects as being very interesting, quite interesting, O.K, rather uninteresting, or very boring. The results are shown in fig. (x).

Fig. (x) Attitude question two: a comparison of pre- and post-test scores, expressed as the percentage of children selecting the appropriate option to indicate an interest in natural history.

Category.	Sample	Pre-test	Post-test	Gain
Control Group	32/30	59.4	60.0	0.6
Experimental Group	93/90	64.0	68.3	4.3
Boys	48/48	53.1	57.3	4.2
Girls	45/42	75.6	81.0	5.4
Bright Children	23/28	73.9	73.2	-0.7
Average Children	50/37	57.0	62 2	5.2
Dull Children	20/25	70.0	72.0	-2.0
Bright Boys	7/11	53.6	59.1	5.5
Average Boys	29/22	46.6	52.3	5.7
Dull Boys	12/15	68.8	63.3	-5.5
Bright Girls	16/17	82.8	82.4	-0.4
Average Girls	21/15	71.4	76.7	5.3
Dull Girls	8/10	71.9	85.0	13.1

Whilst the general trend of scores is slightly more positive than that of question one, there is, once again, some inconsistency of the results. The scores of the girls are considerably higher than those of the boys (a mean post-test score of 81% for the girls compared with 57.3% for the boys), so although the gain in the girls' scores which might be attributed to the game is only 5.4%, it is operating on a very high threshold.

"HIDE AND HUNT": MOTIVATION.

The level of pupil on-task involvement was assessed by means of an interaction schedule. Two pupils selected at random, were closely watched by an independent and non-participating observer, who assessed their behaviour at ten second intervals. The results comprise fig. (xi).

Fig. (xi). Interaction Schedule: Pupil 'A'.

ACTIVITY.

mins. \ secs.	5	15	25	35	45	55
0	I	I	I	I	I	I
1	I	I	I	I	I	I
2	I	I	I	I	I	I
3	I	I	I	I	I	I
4	D	I	I	I	I	I
5	I	I	I	I	I	I
6	I	I	I	I	I	I
7	I	I	I	I	I	I
8	I	I	I	I	I	I
9	I	I	I	I	I	I
10	I	I	I	I	I	I
11	I	I	I	I	I	I
12	I	I	I	I	I	I
13	I	D	I	I	I	I
14	I	I	I	I	I	I
15	I	I	I	I	I	I
16	I	I	I	I	I	I
17	I	I	I	I	I	I
18	I	I	I	I	I	I
19	I	I	I	I	I	I
20	I	I	I	I	I	I
21	I	I	D	I	D	I
22	I	I	I	I	I	I
23	I	I	I	I	I	I
24	I	I	I	I	I	I
25	I	I	I	I	I	I
26	I	I	I	I	I	D
27	I	I	I	I	I	I
28	I	I	I	D	I	I
29	I	I	I	I	I	I
30	I	I	I	I		

I (Involved with task)
= 178

D (Distracted by event outside task)
= 6

DISCUSSION.

mins. \ secs.	5	15	25	35	45	55
0	I	I	I	I	I	I
1	D	I	I	I	I	I
2	I	I	D	I	I	I
3	I	I	I	I	I	I
4	I	I	I	I	I	I
5	D	D	I	I	I	I
6	I	I	I	I	I	I
7	I	I	I	D	I	I
8	I	I	I	I	I	I
9	I	I	I	I	I	I
10	I	I	I	I	I	I
11	I	I	I	I	I	D
12	I	I	I	I	I	I
13	I	I	I	I	I	I
14	I	I	I	I	D	I
15	I	I	I	I	I	I
16	I	I	I	I	I	I
17	I	I	I	I	I	I
18	I	I	I	I	I	I
19	I	I	I	I	I	I
20	I	I	I	I	I	I
21	D	I	D	I	I	I
22	D	I	I	I	I	D
23	I	I	I	I	I	I
24	I	I	I	D	I	I
25	I	I	I	I	I	I
26	I	I	I	D	D	I
27	I	I	I	I	I	I
28	I	I	I	I	I	

I (Involved with task)
= 153

D (Distracted by event outside task)
= 14

Fig. (xi). Interaction Schedule: Pupil 'B'.

ACTIVITY.

mins.	10	20	30	40	50	60 secs.
0	I	I	I	I	I	I
1	I	I	I	I	I	I
2	I	I	I	I	I	I
3	I	I	D	I	I	I
4	I	I	I	D	I	I
5	I	D	I	I	I	I
6	I	I	I	I	I	I
7	I	I	I	I	I	I
8	I	I	I	I	I	I
9	I	I	I	I	I	I
10	I	I	I	I	I	I
11	I	I	I	I	I	I
12	I	I	I	I	I	I
13	I	I	I	I	I	I
14	D	I	I	I	I	I
15	I	I	I	D	D	I
16	I	I	I	I	I	I
17	I	I	I	I	I	I
18	I	I	I	I	I	D
19	I	I	I	I	I	I
20	I	I	I	I	D	I
21	I	I	I	I	I	D
22	D	I	I	I	I	I
23	I	I	I	I	I	I
24	I	I	I	I	I	I
25	I	I	I	I	I	I
26	I	D	I	I	I	I
27	I	I	I	I	I	I
28	I	I	I	I	I	D
29	D	I	I	I	I	I
30	I	I	I	D		

I (Involved with task)

= 170

D (Distracted by event outside task)

= 14

DISCUSSION.

mins.	10	20	30	40	50	60 secs.
0	I	D	D	I	I	I
1	I	I	I	I	I	I
2	I	I	I	I	D	I
3	I	I	I	D	I	I
4	I	I	I	I	I	I
5	D	I	I	I	I	I
6	I	I	I	I	I	I
7	I	I	I	I	I	I
8	I	I	I	I	I	I
9	I	I	I	I	I	I
10	I	I	I	I	D	I
11	I	I	D	I	I	D
12	I	I	I	I	I	I
13	I	I	I	I	I	I
14	I	D	I	I	I	I
15	I	I	I	I	I	I
16	I	I	I	I	I	I
17	I	I	I	I	I	I
18	I	I	I	I	D	I
19	I	I	I	I	I	I
20	I	I	I	I	D	I
21	I	I	I	I	I	I
22	I	I	D	I	I	I
23	I	I	D	I	I	I
24	I	I	I	I	D	D
25	I	I	I	I	D	I
26	I	D	I	I	I	I
27	I	I	I	I	I	

I (Involved with task)

= 151

D (Distracted by event outside task)

= 14

The results show pupil 'A' to have been involved with the task 97.6% of the activity time and 91.6% of the discussion time, and pupil 'B' to have been involved 92.4% of the activity time, and 90.4% of the discussion time. By any standard, these are high levels of involvement, and though a larger sample of pupils would have proved more persuasive evidence, nevertheless a clear indication of concentration and effort on the part of the pupils is obvious here.

As indicated elsewhere, no direct attempt was made to compare the effectiveness of "Hide and Hunt" with any other teaching methods. Some would argue that the interaction analysis data presented above would be more valuable had a comparison been made between the involvement of the two children in the game situation, and the application which they showed in a different type of lesson. Such a comparison would be fraught with confounding variables such as teacher effectiveness and was therefore not attempted in this research.

"HIDE AND HUNT": TEACHER OPINIONS.

The two teachers who normally teach science to the classes which took part in the experiment each completed an eleven-item questionnaire during the week following the playing of the game. They had, of course, observed the game sessions. A copy of the questionnaire appears in Appendix One. It consists essentially of three parts. The first four questions require an evaluation of the effectiveness of the game as a teaching/learning technique. The questions take a semantic differential form: the teachers were required to mark an eleven centimetre line which separated two contrasting descriptions which might form the answer to the question posed. Thus, question one asked:

> To what extent does the game motivate the children to become involved?

greatly ———————————————————— not at all

In each of the four questions the more supportive response was at the left hand end of the line. A score was compiled for each teacher based on the device of giving ten points for a mark anywhere in the first centimetre, nine points for a mark in the next centimetre and so on, viz:

POINTS SCORED	10	9	8	7	6	5	4	3	2	1	0

The scores for "Hide and Hunt" derived by this system were 33 and 37, both out of 40. This gives a mean score equivalent to 87.5%.

The following four questions explore the most appropriate use of the game within the school context. Responses indicate that the two teachers felt that the game was being pitched at an appropriate age level, and that average and below average children would benefit most from it. Both teachers were uncertain that the game would have a beneficial effect on other science teaching, and stated that the technique would need to be part of a complete teaching programme.

The remaining three questions focus on the teachers' views of simulation-games in general and on strengths and weaknesses of this particular game. The following advantages of the use of the game were suggested:

1. It provided a variation in teaching technique.
2. It was enjoyable.
3. It extended science beyond the classroom.
4. It involved everyone, even the weakest children.
5. It applied science to other curricular areas.
6. The role play actively reinforced the concepts.

The following disadvantages were pointed out:

1. Extensive preparation time is required.
2. Less able pupils might be unable to transfer the ideas from the game to reality.

3. Noise levels might be disturbing to classes in adjacent areas.
4. Used too often, simulation-games can prove to be a problem. Children might see games as better than conventional teaching, which is sometimes necessary.
5. The availability of an appropriate space at the right time.
6. The game would have been more effective if fitted into the schedule of current work.

No suggestions were given by either teacher for improving the game.

"THE DINOSAUR GAME": COGNITIVE TEST.

This test consisted of four items, of which the first two were designed to test a knowledge of the basic principles of adaptation and inherited characteristics, and the following two were aimed to test the pupils' ability to apply these principles in two different evolutionary contexts. All questions were in multiple-choice form. Questions one and two required only one response each, but question three required three. Question four was in six parts.

Once again the tests were completed anonymously, and The Wilcoxon Matched-Pairs Signed-Ranks Test was used to compare scores at pre- and post-game stages. The test papers were coded with B or G, and 1, 2 or 3 as described at the beginning of the chapter.

The results of the Wilcoxon Matched-Pairs Signed-Ranks Test are given in Fig. (xii).

Fig (xii). Comparison of pre- and post-test scores for year three children using Wilcoxon Matched-Pairs Signed-Ranks Test.

CATEGORY	Sample	T=	T-	z-Score	Significance Level (p=)
Control Group	29/32	46	20	1.156	0.123
All Children	87/82	6	60	2.401	0.008
All Boys	42/38	9.5	56.5	2.090	0.018
All Girls	45/44	5	61	2.491	0.006
Bright Chn.	30/33	14	52	1.689	0.046
Average Chn.	37/31	5	61	2.490	0.006
Dull Children	20/18	13	53	1.778	0.038
Bright Boys	12/12	25	30	0.255	0.401
Average Boys	21/18	5	61	2.490	0.006
Dull Boys	9/8	18	48	1.334	0.092
Bright Girls	18/21	8	58	2.225	0.013
Average Girls	16/13	9	57	2.135	0.016
Dull Girls	11/10	11	55	1.957	0.025

The experimental group show a gain at post-test which is significant at the 0.01% level. The control group show a slight loss at post-test, compared with their pre-test score. Gains by the girls are greater than those of the boys. All gains apart from the "bright boys" who fared much worse, are significant at the 0.05% level or better. The bright boys had shown a particularly high pre-test score, and although they did not exhibit much improvement, their post-test score was in fact the highest of the various sub-groups. This type of comparison is best revealed by reference to Fig. (xiii). It appears that average, and to a lesser extent duller children, benefitted from the game more than brighter children. Although the three groups scored as predicted in the post-test (ie. bright children

60.0%, average children 47.2% and dull children 41.4%) the distances separating them had decreased in the post-test (bright children 65.8%, average children 63.3%, dull children 54%).

Fig. (xiii). A comparison of pre- and post-test scores, expressed as the percentage of children obtaining the correct answer, for the various sub-groups of children under investigation.

CATEGORY	Sample	Pre-Test	Post-Test	Gain
Control Group	29/32	48.6	56.3	-2.3
Experimental Gp	87/82	50.2	62.3	12.1
All Boys	42/38	54.3	65.1	10.8
All Girls	45/44	46.5	59.9	13.4
Bright Children	30/33	60.0	65.8	5.8
Average Chn.	37/31	47.2	63.3	16.1
Dull Children	20/18	41.4	54.0	12.6
Bright Boys	12/12	68.2	68.9	0.7
Average Boys	21/18	51.1	67.2	16.1
Dull Boys	9/8	43.4	54.5	11.1
Bright Girls	18/21	54.5	64.1	9.6
Average Girls	16/13	42.1	58.0	15.9
Dull Girls	11/10	39.7	53.6	13.9

A more detailed question-by-question analysis is given in Appendix Two. This analysis reveals certain inconsistencies in terms of the gain score. For instance, although there was an overall mean gain of 12.1% by the experimental group considered as a whole, a lower mean post-test score was obtained for question one than the pre-test score. The children who played the game failed to grasp the concept concerned. However, closer examination reveals two interesting points. First, the pre-test score of 65.5% is considerably higher than most other questions (the mean pre-test score is

50.2%). Secondly, at post-test the pattern of choice of distractors was rather different to that at the pre-test stage. Question one states:

1. The survival of a species of animal for millions of years is most likely to happen if:-

(a) It is a clever animal.
(b) It lays more eggs than other animals.
(c) It adapts to changes in its environment.
(d) It moves more quickly than the animals that feed on it.
(e) It eats many different foods.

Each of the alternatives represents a plausible contributory factor in terms of the survival of a species of animal. Each of the distractors, (a), (b), (d) and (e) is referred to on the cards accompanying the game (see page 32). It is only in the sense that answer (c) provides the most likely cause that the distractors are less correct.

Choice of answers is shown in Fig (xiv).

Fig. (xiv). Number of pupils who chose one of five alternative answers to question one.

	A	B	C	D	E	TOTAL
PRE - TEST	5	14	57	7	4	87
POST-TEST	3	21	50	2	6	82

Distractor (B) represents an idea expressed on the card as "You now lay more eggs", which is rewarded with the bonus, "MOVE ON TWO SQUARES". In the post-test seven more children chose this alternative. To the extent that fecundity is a most plausible contributor to survival, the game had not misled the pupils. The limitation of their learning was that they had not risen to the level of understanding where they could recognise alternative (c) as being a more generalised statement which would apply to a greater number of instances than the other alternatives. The surprising aspect of the whole thing was that so many chose the "right" answer in the pre-test!

The other occurrence of a depressed post-test score revealed in the statistical Appendix Two is question 3 (c). Once again this question was posed in a multiple-choice form, and 3(c) represents one of the three most likely explanations in an interpretative exercise about animal survival. The mean pre-test score for question three is 68.2%, and the mean post-test score 75.6%. Within the context of this improvement there were greater gains in the direction of the other "correct" answers, at the expense of 3(c). This trait was more in evidence for boys than for girls.

Further comparisons between the experimental and control groups were made by use of the Mann-Whitney U Test. No significant difference was evident between the pre-test scores of experimental and control groups (U=58.5; z=0.132) but comparisons at the post-test stage are significant at the 5% level (U=26;z=28;p=0.011).

The question of sensitisation of the experimental group by the pre-test experience, discussed in detail in relation to "Hide and Hunt" (pages 49 to 54), was also examined with the third year data. A summary is given in fig. (xv).

Once again there is considerable inconsistency of the results. This tendency is also revealed in separate sex analyses, which are not presented here. An analysis of the pre-test scores of the two experimental classes provides us with a similar type of variability, which further supports our earlier conclusion that cluster-sampled groups cannot adequately be compared in this way.

Fig. (xv). A comparison of mean post-test scores, expressed as the percentage of children obtaining the correct answer, for the experimental group and control group two (no pre-test).

QUESTION	Experimental Group	Control Group Two	Hypothesised Gain Due To Pre-Test
1	64.8	53.6	+11.2
2	50.0	50.0	0
3a	83.3	92.9	- 9.6
3b	88.9	75.0	+13.9
3c	59.3	50.0	+ 9.3
4a	64.8	64.3	+ 0.5
4b	50.0	92.9	-42.9
4c	70.4	82.1	-11.7
4d	22.2	46.4	-24.2
4e	61.1	57.1	+ 4.0
4f	68.5	67.9	+ 0.6
Overall mean	62.1	73.2	-11.1

"THE DINOSAUR GAME": ATTITUDE TEST.

The test used to illuminate any possible change in attitude towards natural history has already been discussed in relation to "Hide and Hunt" (see page 57) and appears in Appendix One. The results of question one are shown in Fig. (xvi) and question two in Fig. (xvii).

Fig. (xvi). Attitude question one: a comparison of pre- and post-test scores, expressed as the percentage of children selecting the appropriate option to indicate an interest in natural history.

CATEGORY	Sample	Pre-Test	Post-Test	Gain
Control Group	29/32	46.6	47.7	+1.1
Experimental Gp.	87/82	41.4	46.3	+4.9
All Boys	42/38	31.5	33.6	+2.1
All Girls	45/44	50.6	57.4	+6.8
Bright Children	30/33	47.5	46.2	-1.3
Average Children	37/31	39.2	46.0	+6.8
Dull Children	20/18	36.3	47.2	+11.1
Bright Boys	12/12	41.7	29.2	-12.5
Average Boys	21/18	26.2	31.9	+5.7
Dull Boys	9/8	30.6	43.8	+13.2
Bright Girls	18/21	51.4	56.0	+4.6
Average Girls	16/13	56.3	65.4	+9.1
Dull Girls	11/10	40.9	50.0	+9.1

Some interesting comparisons may be made between figures (xvi) and (ix). In both cases the experimental group, with sample sizes 93 and 87, had a pre-test mean of 41.4%. In the case of the group that played "The Dinosaur Game" the post-test mean was rather higher, representing a gain in score of very nearly 5%. This gain was, once more, stronger in the case of the girls, and particularly the middle range and lower ability groups. The greatest positive change of attitude was shown by the dull boys, although their resulting score was still much lower than that of the girls (ie. 43.8% compared with 57.4%).

Fig. (xvii). Attitude question two: a comparison of pre- and post-test scores, expressed as the percentage of children selecting the appropriate option to indicate an interest in natural history.

CATEGORY	Sample	Pre-Test	Post-Test	Gain
Control Group	29/32	62.1	60.2	-1.9
Experimental Gp.	87/82	58.0	50.3	-7.7
All Boys	42/38	49.4	47.4	-2.0
All Girls	45/44	66.1	52.8	-8.3
Bright Children	30/33	55.8	47.0	-8.8
Average Chn.	37/31	58.8	58.9	+0.1
Dull Children	20/18	60.0	41.7	-18.3
Bright Boys	12/12	47.9	33.3	-14.6
Average Boys	21/18	46.4	54.2	+7.8
Dull Boys	9/8	58.3	53.1	-5.2
Bright Girls	18/21	61.1	54.8	-6.3
Average Girls	16/13	75.0	65.4	-9.6
Dull Girls	11/10	61.4	32.5	-28.9

Plainly, from the point of view of the game designer, these results are disappointing. They either indicate that the game induced a negative change of interest, or that question two was not actually reflecting the change of attitude for which it was designed. To examine the likelihood of this second hypothesis we need to examine the internal consistency of the results themselves (see Figure (xviii)).

Fig. (xviii). A comparison of the scores for attitude question two for the boys and girls of the three classes which made up the experimental group.

GROUP	Boys Pre-Test	Boys Post-Test	Girls Pre-Test	Girls Post-Test
Class A	30.4	35.4	58.3	51.8
Class B	67.8	69.2	66.7	48.3
Class C	No Pre-test	36.5	No Pre-test	58.3

These figures point to slight gains by the boys in both classes A and B. The mean loss of 2.0% expressed in fig. (xvii) results from the inflation of the boys pre-test score by a control group mean of 50.0%, and a corresponding deflation brought about by the inclusion of class C in the final mean score.

In a similar way the mean score for the average girls at post-test suffers from the loss of a control group with high interest (78.1%) and corresponding substitution of the no-pre-test control group, in which the score for the average girls reflects less interest (65.0%). The significant drop in score shown by class B girls is largely a reflection of the responses of the least able group, who dropped from 75.0% to 37.5%.

Although these experimental artefacts account for some of the variance in scores, nevertheless it must be concluded that an hour's exposure to "The Dinosaur Game" did not appear to positively influence the children's rating of "How animals compete for food" as a subject of study. In order to make a more precise examination of this issue it would be necessary to arrange the sampling procedures in a more rigorous way, and identify each pupil's papers so that individual changes of attitude could be noted. The attendant problems of bias associated with the lack of anonymity have been alluded to elsewhere (page 44).

"THE DINOSAUR GAME": MOTIVATION.

The non-participant observation procedures used to assess the on-task involvement of the pupils were the same as those used for "Hide and Hunt" and are described on pages 44 and 59. The results appear as Figure (xix).

Fig. (xix). Interaction Schedule Pupil 'A'.

ACTIVITY.

mins.	5	15	25	35	45	55 secs.
0	I	I	I	I	I	I
1	I	D	I	I	I	I
2	I	I	I	I	D	I
3	I	I	I	I	I	I
4	I	I	I	I	I	I
5	I	I	I	I	I	I
6	I	I	I	I	I	I
7	I	I	I	I	I	I
8	I	I	I	I	I	I
9	I	I	I	I	I	I
10	D	I	I	I	I	I
11	I	I	I	I	I	I
12	I	I	I	I	I	I
13	I	I	I	I	I	I
14	I	I	I	I	I	I
15	I	I	I	I	I	I
16	I	I	I	I	I	I
17	I	I	D	I	I	I
18	I	I	I	I	I	I
19	I	I	I	I	I	D
20	D	I	I	I	I	I
21	I	I	I	I	I	I
22	I	I	I	I	I	I
23	I	I	I			

I (Involved with task) = 135

D (Distracted by event outside task) = 6

DISCUSSION.

mins.	5	15	25	35	45	55 secs.
0	I	I	I	I	I	I
1	I	I	I	I	I	I
2	I	I	I	I	I	I
3	I	I	I	D	I	I
4	I	I	I	I	I	I
5	I	I	I	I	I	I
6	I	D	I	I	I	I
7	I	I	I	I	I	I
8	I	I	I	I	I	I
9	I	I	I	I	I	I
10	I	I	I	I	I	D
11	I	I	I	I	I	I
12	I	I	I	I	I	I
13	I	I	I	I	I	I
14	I	I	I	I	I	D
15	D	I	I	I	I	I
16	I	I	I	I	I	I
17	I	I	I	I	I	I
18	D	I	D	I	I	I
19	I	I	I	I	I	I
20	I	I	I	I	I	I
21	I	D	I	I	I	I
22	I	I	I	I	I	I
23	I	I	I	D	D	I
24	I	I	I	I	I	I
25	I	I	I	I	D	I
26	D	I	I	I	I	D
27	I	I	D	I	I	I
28	I	I	D	I	I	I
29	I	I	I	I	I	D
30	I	I	I	I	I	I
31	D	D	I	I	I	I
32	I	D	D	I	I	

I (Involved with task) = 177

D (Distracted by event outside task) = 20

Fig. (xix). Interaction Schedule Pupil 'B'.

ACTIVITY.

mins.	10	20	30	40	50	60 secs.
0	I	I	I	I	I	I
1	I	I	I	I	I	I
2	I	I	I	I	I	D
3	D	I	I	I	I	I
4	I	D	D	I	I	I
5	I	I	I	I	I	I
6	I	I	I	I	I	I
7	I	I	I	I	I	I
8	I	I	I	I	I	I
9	I	I	I	D	I	I
10	I	I	I	D	D	I
11	D	I	I	I	I	I
12	D	I	I	I	I	I
13	I	I	I	I	I	I
14	I	I	I	I	I	I
15	I	I	I	I	I	I
16	I	I	I	I	I	I
17	I	I	I	I	D	I
18	I	I	I	I	I	I
19	I	I	I	I	I	I
20	I	I	I	I	I	D
21	I	I	I	I	I	I
22	I	I	I	I	I	I
23	I	I	I			

I (Involved with task) = 130

D (Distracted by event outside task) = 11

DISCUSSION.

mins.	10	20	30	40	50	60 secs.
0	I	I	D	D	I	I
1	I	I	I	I	I	D
2	I	I	I	I	I	I
3	I	I	D	I	I	I
4	I	D	I	I	I	I
5	I	I	I	I	I	I
6	I	I	I	I	I	D
7	I	I	I	I	I	I
8	I	I	I	I	I	I
9	I	I	I	I	I	I
10	I	I	I	I	I	I
11	I	D	I	I	D	D
12	D	I	I	I	I	I
13	I	I	I	I	I	I
14	I	I	I	I	I	I
15	I	I	I	I	I	I
16	I	I	D	I	I	I
17	I	I	I	I	I	I
18	I	I	I	I	I	I
19	I	I	I	I	I	D
20	I	I	I	D	I	I
21	I	I	I	I	I	I
22	I	I	D	I	I	I
23	I	I	D	I	I	I
24	I	I	I	I	D	D
25	I	I	D	I	D	I
26	I	I	D	I	I	I
27	D	I	I	I	I	I
28	I	D	I	I	I	D
29	I	I	I	I	I	I
30	I	I	D	I	I	I
31	I	D	D	I	I	D
32	I	D	I	I	I	

I (Involved with task) = 169

D (Distracted by event outside task) = 28

The results show pupil A to have been involved with the task 95.7% of the activity time and 89.8% of the discussion time, and pupil B to have been involved for 92.2% of the activity time and 85.8% of the discussion time. Although the results are not quite as high as those of "Hide and Hunt", they nevertheless, in the author's view, represent high levels of involvement, and testify to the motivating power of the game.

"THE DINOSAUR GAME": TEACHER OPINIONS.

Teacher opinions were solicited by means of an identical questionnaire to that used for the evaluation of "Hide and Hunt" (see page 62 for details, and Appendix One for a copy of the questionnaire).

The scores for questions 1 - 4, which were derived in the way described on page 63, were 31 and 34, out of a possible 40. The mean score is equivalent to 81.3%.

The teachers' responses to questions seven and eight suggested that they felt that the game was being pitched at an appropriate age level, and that bright or average children would benefit more than weaker pupils. Both teachers were uncertain that the experience of the game would benefit other science teaching, unless it was employed as an integral part of a complete teaching programme.

General comments on the advantages and disadvantages of simulation-games in school have already been given (page 63). In addition, two "strenghts" and two "Weaknesses" of "The Dinosaur Game" were stated as follows:

1. The game is essentially simple, based on a familiar idea.
2. The idea of survival is "brought across" well.
3. The reading was difficult and might present weaker children with problems.
4. The simulated evolutionary change was too rapid.

CHAPTER FIVE.

DISCUSSION.

This research has been concerned with two separate simulation-games, both entirely different to each other. At this stage it will be valuable for us to compare them, so that discussion of their effectiveness can grow from a more closely argued view of their characteristics.

A number of dimensions have been developed by game designers to define differences between simulation-games. Some, such as those of Taylor and Walford [91] and Abt [1] focus on the philosophy which underpins the games, and are useful for comparing games by authors with very different aims. Others are concerned with game structure and functioning. Reference will be made to three of these, together with three further dimensions which have been constructed with a view to highlighting contrasts between "Hide and Hunt" and "The Dinosaur Game".

Judith Gillespie (in Stadsklev [86]) focuses on the notion of choices within the game context. In "Hide and Hunt" the players are required to make choices continually and thereby develop strategies which make them more effective as players. Apart from the single arbitrary choice between adopting the role of a carnivore or a herbivore, players in "The Dinosaur Game" cannot make choices at all. Their moves are controlled by factors within the structure of the game itself. They play no role as decision makers and cannot develop strategies to improve the effectiveness of their play. They can, of course, construe the value of changes which occur to their dinosaur, and while they can do nothing to bring them about, they may be led to appreciate their significance.

Jerome Bruner [13], writing of ways in which concepts may be represented in the teaching process, distinguishes between enactive, iconic and symbolic representation. In a very direct way, the contrast in style of the two games is a contrast between enactive and iconic modes of representation. "Hide and Hunt" is a highly active role-playing simulation in which the fears and thrills of the hunters and hunted are physically experienced by the children. Pupils sitting round the table playing "The Dinosaur Game" are more remote from reality. Their excitement springs from a desire to win the game; their fears are fears of losing in the game context.

Ron Stadsklev [86] writes of the nature of competition experienced by players of simulation-games. In "Hide and Hunt" the competition is interacting in the sense that the players' actions directly affect those of other players. The competition which underpins "The Dinosaur Game" is autonomous in that the principal competition is between the player and the game structure, and player-player conflicts only relate to the extent to which each is successful in the game's outcome.

There is a strong contrast too in the nature of the playing skill required in the two games. Pupils will be more likely to be successful in "Hide and Hunt" if they develop the skills which the game simulates. Their learning of evasion strategies is a product of an urgent personal need. The playing skills of "The Dinosaur Game" are not the skills of evolution. The children are required to read cards, collect or forfeit counters and move a token around a board. Their familiarization with vocabulary of evolution, with the phrases which encapsulate the concepts of survival, is by rote practice and by responding to the teacher's questions.

The role of the teacher, as one who forges the link between the game and the reality it represents, is thus different in the two games. In "Hide and Hunt" he is the interpreter of the children's own responses. In "The Dinosaur Game" he interprets the game outcomes themselves.

Further contrast between the two games is provided by the rule structure. In "Hide and Hunt" it is flexible: the children respond to a situation of minimal constraints. If their behaviour takes them beyond the bounds of what had been anticipated, then this provides a new definition of the boundaries of reality of the game and requires interpretation. The fleeing prey-child who hastily climbs the hall curtains is acting out a real-life drama. The rule structure of"The Dinosaur Game" is altogether more rigid. There are closely-defined procedures for play, and innovations would either be condemned as cheating, or evaluated according to the established game tone.

From a practising teacher's point of view, any useful evaluation of the games is going to be based on questions like...... What was going on during the hour in which the game was being played? Were the children involved with what they were doing? Did they learn anything? Did their attitudes towards natural history change?

In terms of the performance of the two games, the answers to these questions are fairly consistent. In both cases, significant gains in knowledge were evident in the groups of children who had played the games. The gains were greater in "Hide and Hunt" than in "The Dinosaur Game" (a mean increase in the percentage of children obtaining the correct answer of 16%, compared with 12.1%), and greater for girls than for boys (girls' gains 17.5% and 13.4% compared with boys' gains 14.5% and 10.8%). The high level of involvement of the children was reflected by high scores on the interaction-analysis schedule and by very positive scores on the teachers' ratings ("Hide and Hunt" mean activity score 95%, mean discussion score 91%, teachers' rating-questions 1 and 2 - 100%; "The Dinosaur Game" mean activity score 94%, mean discussion score 87.8%, teachers' rating-questions 1 and 2 - 92.5%). Both of the games were well received by the teachers, especially "Hide and Hunt". No significant changes in attitude appeared to have been induced by playing either game, although a slight overall gain was evident with "Hide and Hunt" and throughout both populations of children tested the girls were more interested in natural history than the boys. (Second year boys scored 28.6% and 57.3% on the attitude test compared with 60.7% and 81% for girls; third year boys scored 33.6% and 47.4%, girls 57.4% and 52.8%).

Although the measured differences in the effectiveness of the two games is not very great, "Hide and Hunt" proved to be rather more successful in achieving its aims. The author believes that the greater success of "Hide and Hunt" is related largely to the more potent quality of experience which it offers relative to that of "The Dinosaur Game". There is much truth in the adage:

"I hear and I forget;
I see and I remember;
I do and I understand."

In "Hide and Hunt", in a very real sense, the pupils "do" predator-prey relationships. "The Dinosaur Game" is, perhaps inevitably, one step further removed towards the abstract.

Four principal constraints impose limitations on the findings of this research. It will be as well for us to examine these in some detail.

First, there are problems associated with the research design. One of the most awkward of these proved to be the changing nature of the experimental population between pre- and post-test stages. Thus, although 48 boys took both pre- and post-tests, and 45 girls took the pre-test compared with 42 at post-test, this population was not stable. The sub-group of average children changed from 50 at pre-test to 37 at post-test. Naturally, children who had been absent for some part of the experimental programme were identified, their papers coded accordingly, and they were placed in the appropriate group for assessment purposes. Thus a pupil who belonged to one of the classes designated as the experimental groups, and who took both tests but missed the game itself, was scored up as one of the control group. Even so, the changing nature of the composition of the various sub-groups proved to be problematical at times (see page 47 for a specific example). The alternative strategy of pupils writing their names on the test-papers, and signing a register for the game sessions, would have reduced these problems, although possibly generated others.

Largely because individual children could not be identified, the principal bonus of the Solomon Design, the control of the effect of the pre-test, proved to be elusive. Considerable within-group variance of scores was evident; a more sensitive measure of the source of that variance could only be based on the monitoring of the progress of individual pupils.

A second source of limitation is related to the test instruments. Any short-coming in terms of the reliability or validity of the test instruments is likely to have a knock-on effect on the meaning of the research findings. Comments relating to the construction of the tests have been made elsewhere (pages 43 and 44). During the construction process many different types of problem arise. Individual items of a particular test are hard to evaluate in isolation. Total scores formed as the sum of marks allotted to individual questions in a test are not true totals unless it can be demonstrated that the intervals between the scores are equal. It is difficult to compare a child who gets questions one and two of a test right with another who correctly answers questions three and four. Again, where a test is based on teachers' opinions, and some sort of numerical grade is allocated, it is difficult to relate that grade to any standard criterion. For instance the score 87.5% was introduced on page 63 as an attempt to quantify two teachers' responses to a number of questions. 87.5% sounds very impressive, but the amount of information it conveys is restricted by the reader's inability to relate it to a universal criterion. Had there been available hundreds of other similar ratings of other games or other lessons then 87.5% could be evaluated within a wider context.

Problems of this type undoubtedly cause difficulties in the interpretation of research findings. However, like the surveyor who improves the accuracy of his measurements by triangulation, the educational researcher who adopts a broad-spectrum approach to his empirical investigations, who attempts to illuminate the problem from a number of different perspectives, anticipates that the juxtaposition of evidence from different sources will lend strength to his argument. Each particular measure may have an inherent weakness, so that more than one reasonable interpretation of the data it generates is feasible. The use of several different measures reduces the likelihood that one of these alternative hypotheses will find consistent support.

Two further limitations of this study as a fair assessment of the effectiveness of the games have been touched on earlier, but nevertheless deserve attention at this stage. The first is that it was only possible to arrange a one-hour exposure to each game; the second, that the games were isolated from the other current learning experiences of the children concerned. Both of these constraints were unavoidable. The staff of the school in which the research was conducted were most co-operative. To have prevailed on them for any longer would have been unreasonable. To have attempted to evaluate the games within the context of an integrated project would have prevented the possibility of partialling out the effects of other teaching methods.

However, it must be stressed that proper use of the games, as teaching/learning instruments rather than as vehicles of a research project, would mean using them alongside other material which they would enrich, and by means of which they would find their proper context. The length of time that particular children would play the games would be subject to the sensitive judgement of their teachers. In almost every case it would need to be more than an hour. Preliminary work with vocabulary would certainly enrich "The Dinosaur Game", especially with weaker pupils. Two forty-minute playing -sessions of "Hide and Hunt" would probably be found to be much more effective than a single hour. Decisions of this sort are best made by individual teachers in particular situations according to the needs of their pupils.

The needs of these pupils, of course, are a matter of individual, as well as local, variation, and it is particular individual children who will benefit most by exposure to "Hide and Hunt", "The Dinosaur Game" or any other experience. In sub-grouping the children according to sex and ability, the author sought to examine whether either of these were key variables in this respect. It appears that as far as these two games are concerned, neither sex nor ability are significant variables. Both groups of girls showed a greater improvement in terms of concepts learned and applied compared with the boys, as well as exhibiting more positive attitudes towards natural history, but within the group that played "The Dinosaur Game", that improvement developed from a lower baseline of raw scores. Despite their improvement, the girls still lagged some five per cent behind the boys in the post-test. In both games the bright children were more successful than the average children, and both of these groups out-shone the dull children. But to a great extent that was to be expected: the children had been grouped by their teachers according to how well they performed in scientific settings.

It is the author's retrospective contention that a search for the characterisitics of the pupil who will respond best to, and gain most from, these two simulation-games, will need to expose correlations with further variables. Some similar work has already been undertaken by other authors. In 1968 Inbar [49] examined the impact of games not only in terms of the players' background characteristics, but also their pre-dispositions, the differences in their experience and behaviour while the game was going on, and the differences in the characteristics of the groups of which they were members. He concluded that:

"interest in the simulation and willingness to participate voluntarily in the session are probably the variables which are the most readily influenced by the person in charge of presenting the game.... One cannot avoid reaching the general conclusion that the person in charge of the session is of tremendous importance."

Undoubtedly this is true, but it also represents a denial of individual differences. A good number of authors have recognised these differences (see Bagley [4], Johnson and Euler [50], Edwards [31], Fletcher [37] and Dukes and Seidner [30] for a preliminary appraisal of this notion) but until very recently little work has been reported which attempts to assess effectiveness of simulation-games in terms of player characteristics.

Eliezer Orbach [64] of The University of Tel-Aviv, suggests that simulation-games are excellent tools of learning for people with a strong need for achievement, but not for those whose fear of failure is greater than their hope of success. She refers to earlier work by L. Adar, of The Jerusalem School of Education, in which success in simulation-games is enjoyed by "curious" people and "sociable" people, but not so much by "conscientious" people - all terms being defined according to test-based criteria.

Linda K Pratt et al [70] have written that the "feeling" type of personality (using a Myers-Briggs Type Indicator, based on Jung's Theory of Types) experienced a higher level of personal participation than did the "thinking" type.

This is merely the tip of an ice-berg. Skillful teachers have long realised that particular teaching methods are appealing to only a limited number of pupils. It is plainly important to know what sort of pupils they are.

The research outlined in this dissertation investigated two simulation-games in terms of their success as measured by various criteria. Six sub-groups of the experimental population were examined to determine the significance of sex and ability as correlates of learning and attitude change induced by the games. These particular personal attributes did not appear to be dramatically significant determinants of pupil success. Further investigation along the same lines but involving different dependent variables should also be undertaken. This type of research would involve testing and describing large numbers of children according to many different personality dimensions. "Curious", "sociable", "conscientious", "feeling" and "thinking" are five of many different characteristics which might be relevant. A very large research project indeed would need to be undertaken for any real hope of significant findings. What may prove to be more valuable would be an ex-post-facto design, in which pupils who have been found to be successful at simulation-games are investigated in a second experimental phase, in order to determine whether they have any common characteristics.

Whilst anticipating that such research would shed more light on the particular simulation-games which were under scrutiny, the present author does not believe that further work will indicate that success in simulation-games depends on a set of stable qualifiable characteristics of the players concerned. Different people will enjoy, and derive most benefit from, different games, and quite probably their involvement will be situation-related, dependent on the skill of the game-presenter and on their own mood at the time, as well as on the nature of the game concerned. These views reinforce the notion that good teaching is about variety. Educators need to consider the uniqueness of their charges, and to accept the responsibility to stimulate them by planning learning experiences which are as exciting as the reality which they describe.

Appendix One. Attitude Test used for both games.

1. Your class is going to study a topic for several weeks. Look at the following 12 subjects and tick the four which you would most like to study.

- [ ] Kings and Queens of England.
- [ ] African Mammals.
- [ ] The Life of Jesus.
- [ ] Transport.
- [ ] Pond Life.
- [ ] Prehistoric Animals.
- [ ] How Machines Work.
- [ ] Jobs People Do.
- [ ] The Romans.
- [ ] Woodland Life.
- [ ] Countries of Europe.
- [ ] Space Travel.

2. How interesting do you think that the following subjects would be to study? (Please tick).

	very interesting	quite interesting	O.K.	rather uninteresting	very boring
Farming in Britain.	☐	☐	☐	☐	☐
Sport.	☐	☐	☐	☐	☐
How animals compete for food.	☐	☐	☐	☐	☐
Life in the Seventeenth Century.	☐	☐	☐	☐	☐

1. Write down four different ways in which animals might avoid being captured by their predators.

2. Since the prey use some of these skills to avoid being captured tick two reasons why they get caught at all.

- ☐ They might be unlucky.
- ☐ There are always more predators.
- ☐ They cannot fly away.
- ☐ The predators are better adapted.
- ☐ They are stronger than the predators.

3. It is not possible to put animals into the two separate groups - predators and prey. Tick the reason why.

- ☐ They would fight.
- ☐ Many animals are both predators and prey.
- ☐ The animals would eat each other.
- ☐ They belong to different families.

4. In any place where animals live, the animals which are best adapted are:-

- ☐ certain to survive.
- ☐ unlikely to survive.
- ☐ most likely to survive.
- ☐ likely to be predators.

(Continued)

5. In any place there is a balance between the numbers of different types of animals. Tick the two things which are most likely to affect this balance.

- [ ] The amount of food.
- [ ] The intelligence of the animals.
- [ ] The rate at which the animals have young.
- [ ] The weaknessof the prey.
- [ ] The speed at which they move.

6. You collect a number of ground beetles, which normally eat small insects, and put them in a large glass jar. You feed them with pieces of meat and fish left over from dinner and put water in the jar regularly. After keeping them for four weeks, when there are 20 of them, you go away on holiday for a month, leaving them without food or water.

Tick thethree most likely things to have happened when you came back.

- [ ] There are now 80 ground beetles some of them had young.
- [ ] There are still 20 ground beetles because this particular type of beetle lays eggs which do not hatch.
- [ ] There are 5 ground beetles left. The others have been eaten by them.
- [ ] The beetles had become diseased and have all died.
- [ ] Some beetles had been eaten. The rest have died from lack of water.
- [ ] Only those beetles which could run quickly had survived.
- [ ] The beetles had changed their diet and survived by eating the soil in the jar.

7. You have collected two full buckets of pond water containing a variety of animals and pieces of pond weed and tipped the whole lot into an aquarium. You then leave the aquarium for a month without touching it. After this time you carry out a survey of small meat eating insects called water boatmen and discover that there are 10 of them in the aquarium. You then begin to add a number of small plants to the water each day. After three weeks you count the number of water boatmen again.

Tick the 3 most likely reasons for the change that you find has taken place.

- ☐ The number of animals which eat plants will be more.
- ☐ The number of water boatment will be less because they don't eat plants.
- ☐ The total number of animals will be less because there is less room.
- ☐ The number of water boatmen will be more because the number of animals which they eat will haveincreased.
- ☐ The water boatmen will be likely to change their feeding habits.
- ☐ The presence of extra food will be likely to alter the balance in the numbers of different animals.

1. The survival of a species of animal for millions of years is most likely to happen if:- (tick one square)

- [ ] It is a clever animal.
- [ ] It lays more eggs than other animals.
- [ ] It adapts to changes in its environment.
- [ ] It moves more quickly than the animals that feed on it.
- [ ] It eats many different foods.

2. Species of animals are able to change to meet new conditions because:- (tick one square)

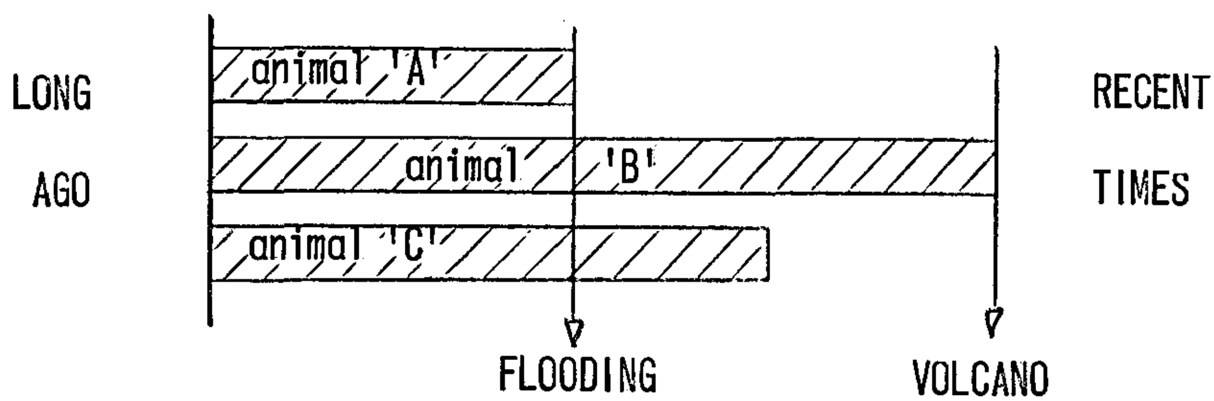
- [ ] Each of them is stronger than those that went before.
- [ ] Some of them can move in different ways.
- [ ] They are trained by their parents to cope with life's problems.
- [ ] Each generation is different from its parents and the best offspring will survive.
- [ ] Some of them are intelligent enough to do this.

3. Ten thousand years ago a large population of insects were found on the leaves of a certain type of plant which they ate. They are now totally extinct.

Tick three statements which are most likely to explain what has happened.

- [ ] The insects cannot survive in water.
- [ ] A new form of disease has killed off the insects.
- [ ] The insects laid too many eggs.
- [ ] The insects decided to live on another plant.
- [ ] Many of the insects' eggs did not hatch.
- [ ] The insects were killed in a storm.
- [ ] A new predator has arrived in the area and wiped out the insects.
- [ ] The insects had become resistant to many diseases.

4. The chart below shows the history of three species of animal all now extinct, which lived on a small island. Animal 'A' died out many years ago at a time of great flooding. Animal 'B' survived this but became extinct when the island was destroyed by a volcano. Animal 'C' died out in between.



	Very likely	Possible	Very unlikely
Animal 'B' died out because it was badly adapted.	☐	☐	☐
Animal 'C' died because of disease.	☐	☐	☐
Animal 'B' was the best adapted animal.	☐	☐	☐
Animal 'A' was very intelligent.	☐	☐	☐
Animal 'C' was the best adapted animal.	☐	☐	☐
Animal 'C' was a fish.	☐	☐	☐

Appendix One: Teacher Opinion Schedule.

1. To what extent does the game motivate the children to become involved?

   (please cross line where appropriate)

greatly ______________________________ not at all

2. To what extent do you feel that the children enjoyed the game?

greatly ______________________________ not at all

3. To what extent are the children able to bridge the gap between the game and the reality it represents?

substantially ______________________________ not at all

4. HIDE AND HUNT: How much does the game teach the children about predator prey relationships?

a great deal ______________________________ nothing

4. THE DINOSAUR GAME: How much does the game teach the children about factors affecting the survival of a species?

a great deal ______________________________ nothing

5. In what way is the experience of playing the game likely to affect other science teaching?

beneficially ______________________________ adversely

6. Please give brief details in explanation of your response to question 5.

7. In what age range would average children be best able to benefit from the game? (please tick).

under 9   9 - 10   10 - 11   11 - 12   12 - 13   over 13

8. In your opinion which group of children will benefit most from the game?

bright children   average children   dull children

9. What do you see as the principle advantages and disadvantages of the use of games in school?

<u>ADVANTAGES.</u>   <u>DISADVANTAGES.</u>

10. What do you see as being the strengths and weaknesses of this particular game?

<u>STRENGTHS.</u>   <u>WEAKNESSES.</u>

11. What changes can you suggest for improving the game?

Appendix Two. Statistics.

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

EXPERIMENTAL GROUP.	Question.	Pre-test % n = 93	Post-test % n = 90
	1	37.1	70.6
	2a	41.9	71.1
	2b	62.4	65.6
	3	49.5	56.7
	4	37.6	58.9
	5a	40.9	68.9
	5b	37.6	77.8
	6a	65.6	83.3
	6b	51.6	48.9
	6c	73.1	85.6
	7a	53.8	63.3
	7b	61.3	66.7
	7c	63.4	66.7

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

CONTROL GROUP.	Question.	Pre-test % n = 32	Post-test % n = 30
	1	33.6	42.5
	2a	56.3	56.6
	2b	68.8	70.0
	3	56.3	56.6
	4	46.9	53.3
	5a	40.6	53.3
	5b	46.9	46.7
	6a	71.9	70.0
	6b	56.3	50.0
	6c	71.9	83.3
	7a	53.1	73.3
	7b	53.1	50.0
	7c	62.5	50.0

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

ALL BOYS.	Question.	Pre-test % n = 48	Post-test % n = 48
	1	37.0	74.0
	2a	35.4	68.8
	2b	60.4	60.4
	3	45.8	58.3
	4	35.4	50.o
	5a	39.6	64.6
	5b	43.8	77.9
	6a	64.6	79.2
	6b	47.9	45.8
	6c	70.8	85.4
	7a	56.3	62.5
	7b	64.6	64.6
	7c	64.6	62.5

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

ALL GIRLS	Question.	Pre-test % n = 45	Post-test % n = 42
	1	37.2	66.7
	2a	48.9	73.8
	2b	64.4	71.4
	3	53.3	54.8
	4	40.0	64.3
	5a	42.2	73.8
	5b	31.1	78.6
	6a	66.7	88.1
	6b	55.5	52.4
	6c	75.6	85.7
	7a	51.1	64.3
	7b	57.8	69.0
	7c	62.2	71.4

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

BRIGHT CHILDREN.	Question.	Pre-test % n = 23	Post-test % n = 28
	1	42.4	75.9
	2a	60.9	85.7
	2b	82.6	75.0
	3	78.3	82.1
	4	47.8	67.9
	5a	39.1	64.3
	5b	34.8	89.3
	6a	78.3	78.6
	6b	69.6	57.1
	6c	73.9	89.3
	7a	47.8	67.9
	7b	65.2	78.6
	7c	82.6	71.4

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tssts.

AVERAGE CHILDREN.	Question.	Pre-test % n = 50	Post-test % n = 37
	1	35.5	70.3
	2a	42.0	62.2
	2b	62.0	81.1
	3	48.0	45.9
	4	36.0	54.1
	5a	38.0	64.9
	5b	36.0	78.4
	6a	62.0	91.9
	6b	44.0	45.9
	6c	76.0	81.1
	7a	54.0	62.2
	7b	60.0	62.2
	7c	54.0	64.9

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

DULL CHILDREN.	Question.	Pre-test % n = 20	Post-test % n = 25
	1	35.0	65.0
	2a	20.0	68.0
	2b	40.0	32.0
	3	20.0	44.0
	4	30.0	48.0
	5a	50.0	80.0
	5b	45.0	64.0
	6a	60.0	76.0
	6b	50.0	44.0
	6c	65.0	88.0
	7a	60.0	60.0
	7b	60.0	60.0
	7c	65.0	64.0

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

BRIGHT BOYS.	Question.	Pre-test % n = 7	Post-test % n = 11
	1	39.3	79.5
	2a	42.9	81.8
	2b	85.8	72.7
	3	71.4	90.9
	4	42.9	72.7
	5a	28.6	45.4
	5b	42.9	100.0
	6a	100.0	54.5
	6b	42.9	36.4
	6c	71.4	81.8
	7a	71.4	72.7
	7b	85.8	81.8
	7c	71.4	72.7

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

AVERAGE BOYS.	Question.	Pre-test % n = 29	Post-test % n = 22
	1	36.2	73.9
	2a	41.4	63.6
	2b	62.1	77.3
	3	48.3	40.9
	4	37.9	45.5
	5a	37.9	63.6
	5b	37.9	72.7
	6a	62.1	90.9
	6b	48.3	50.0
	6c	75.9	86.4
	7a	48.3	63.6
	7b	62.1	63.6
	7c	62.1	59.1

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

DULL BOYS.	Question.	Pre-test % n = 12	Post-test % n = 15
	1	37.5	70.0
	2a	16.7	66.7
	2b	41.7	26.7
	3	25.0	60.0
	4	25.0	40.0
	5a	50.0	80.0
	5b	58.3	66.7
	6a	50.0	80.0
	6b	50.0	46.7
	6c	58.3	86.7
	7a	66.7	53.3
	7b	58.3	53.3
	7c	66.7	60.0

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

BRIGHT GIRLS.	Question.	Pre-test % n = 16	Post-test % n = 17
	1	43.8	73.5
	2a	68.8	88.2
	2b	81.3	76.5
	3	81.3	76.5
	4	50.0	64.7
	5a	43.8	76.5
	5b	31.3	82.4
	6a	68.8	94.1
	6b	81.3	70.6
	6c	75.0	94.1
	7a	37.5	64.7
	7b	56.3	76.5
	7c	87.5	70.6

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

AVERAGE GIRLS.	Question.	Pre-test % n = 21	Post-test % n = 15
	1	34.5	65.0
	2a	42.9	60.0
	2b	61.9	86.7
	3	47.6	53.3
	4	33.3	66.7
	5a	38.1	66.7
	5b	33.3	86.7
	6a	61.9	93.3
	6b	38.1	40.0
	6c	76.2	73.3
	7a	61.9	60.0
	7b	57.1	60.0
	7c	42.9	73.3

YEAR TWO: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

DULL GIRLS	Question.	Pre-test % n = 8	Post-test % n = 10
	1	31.3	57.5
	2a	25.0	70.0
	2b	37.5	40.0
	3	12.5	20.0
	4	37.5	60.0
	5a	50.0	80.0
	5b	25.0	60.0
	6a	75.0	70.0
	6b	50.0	40.0
	6c	75.0	90.0
	7a	50.0	70.0
	7b	62.5	70.0
	7c	62.5	70.0

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

EXPERIMENTAL GROUP.	Question.	Pre-test % n = 87	Post-test % n = 81
	1	65.5	61.0
	2	28.7	35.8
	3a	74.7	86.6
	3b	65.5	84.1
	3c	64.3	56.1
	4a	35.6	64.6
	4b	36.7	64.6
	4c	62.1	74.3
	4d	27.6	30.5
	4e	42.5	59.8
	4f	49.4	68.3

YEAR THREE. Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

CONTROL GROUP.	Question.	Pre-test % n = 29	Post-test % n = 32
	1	75.9	62.5
	2	20.7	37.5
	3a	75.9	75.0
	3b	72.4	59.4
	3c	55.2	56.3
	4a	41.4	50.0
	4b	51.7	50.0
	4c	48.3	46.9
	4d	20.7	18.8
	4e	27.6	21.9
	4f	44.8	31.2

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Tests.

ALL BOYS.	Question.	Pre-test % n = 42	Post-test % n = 38
	1	73.8	68.4
	2	31.0	36.8
	3a	69.0	92.1
	3b	64.3	78.9
	3c	71.4	57.9
	4a	47.6	68.4
	4b	40.5	65.8
	4c	73.8	76.3
	4d	26.2	23.7
	4e	45.2	73.7
	4f	54.8	73.7

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre-and Post-Test.

ALL GIRLS.	Question.	Pre-test % n = 45	Post-test % n = 44
	1	57.8	54.5
	2	26.7	34.1
	3a	80.0	81.8
	3b	66.7	88.6
	3c	57.8	54.5
	4a	24.4	61.4
	4b	33.3	63.6
	4c	51.1	72.7
	4d	28.8	36.4
	4e	40.0	47.7
	4f	44.4	63.6

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Test.

BRIGHT CHILDREN.	Question.	Pre-test % n = 30	Post-test % n = 33
	1	83.3	69.7
	2	30.0	33.3
	3a	80.0	97.0
	3b	86.7	87.9
	3c	73.3	63.6
	4a	60.0	75.8
	4b	50.0	57.6
	4c	60.0	78.8
	4d	26.7	24.2
	4e	50.0	63.6
	4f	60.0	72.7

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Test.

AVERAGE CHILDREN.	Question.	Pre-test % n = 37	Post-test % n = 31
	1	75.7	64.5
	2	24.3	38.7
	3a	78.4	80.6
	3b	56.8	80.6
	3c	70.3	64.5
	4a	27.0	61.3
	4b	29.7	67.7
	4c	62.2	74.2
	4d	8.1	25.8
	4e	37.8	61.3
	4f	48.6	77.4

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Test.

DULL CHILDREN.	Question.	Pre-test % n = 20	Post-test % n = 18
	1	20.0	38.9
	2	35.0	33.3
	3a	60.0	77.8
	3b	50.0	83.3
	3c	40.0	27.8
	4a	15.0	50.0
	4b	30.0	72.2
	4c	65.0	66.7
	4d	65.0	50.0
	4e	40.0	50.0
	4f	35.0	44.4

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Test.

BRIGHT BOYS.	Question.	Pre-test % n = 12	Post-test % n = 12
	1	83.3	66.7
	2	33.3	33.3
	3a	75.0	100.0
	3b	91.7	75.0
	3c	83.3	66.7
	4a	83.3	91.7
	4b	83.3	58.3
	4c	75.0	83.3
	4d	25.0	8.3
	4e	50.0	83.3
	4f	66.7	91.7

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-test.

AVERAGE BOYS.	Question.	Pre-test % n = 21	Post-test % n = 18
	1	85.7	77.8
	2	33.3	44.4
	3a	71.4	83.3
	3b	52.4	83.3
	3c	76.2	66.7
	4a	33.3	61.1
	4b	23.8	61.1
	4c	71.4	77.8
	4d	9.5	33.3
	4e	47.6	72.2
	4f	57.1	77.8

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Test.

DULL BOYS	Question.	Pre-test % n = 9	Post-test % n = 8
	1	33.3	50.0
	2	22.2	25.0
	3a	55.6	100.0
	3b	55.6	75.0
	3c	44.4	25.0
	4a	33.3	50.0
	4b	22.2	87.5
	4c	77.8	62.5
	4d	66.7	25.0
	4e	33.3	62.5
	4f	33.3	37.5

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Test.

BRIGHT GIRLS.	Question.	Pre-test %	Post-test %
		n = 18	n = 21
	1	83.3	71.4
	2	27.7	33.3
	3a	83.3	95.2
	3b	83.3	95.2
	3c	66.7	61.9
	4a	44.4	66.7
	4b	27.7	57.1
	4c	50.0	76.2
	4d	27.7	33.3
	4e	50.0	52.4
	4f	55.6	61.9

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Test.

AVERAGE GIRLS.	Question.	Pre-test % n = 16	Post-test % n = 13
	1	62.5	46.2
	2	12.5	30.8
	3a	87.5	76.9
	3b	62.5	76.9
	3c	62.5	61.5
	4a	18.8	61.5
	4b	37.5	76.9
	4c	50.0	69.2
	4d	6.3	15.4
	4e	25.0	46.2
	4f	37.5	76.9

YEAR THREE: Percentage of Children Obtaining Correct Answer to Cognitive Test Items at Both Pre- and Post-Test.

DULL GIRLS.	Question.	Pre-test % n = 11	Post-test % n = 10
	1	9.1	30.0
	2	45.5	40.0
	3a	63.7	60.0
	3b	45.5	90.0
	3c	36.4	30.0
	4a	Nil	50.0
	4b	36.4	60.0
	4c	54.6	70.0
	4d	63.7	70.0
	4e	45.5	40.0
	4f	36.4	50.0

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