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EVALUATION OF DIAGNOSTIC AND REMEDIAL ASPECTS OF A MICROCOMPUTER PROGRAM ON SPEED.

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A Research Project submitted to the Faculty of Education, University of the Witwatersrand, in part fulfilment of the requirements for the Degree of Master of Education.

Johannesburg, 1984

DECLARATION

I hereby declare

(i) that this research project is my own work,

(ii) that this research project has not been submitted to any other university.

A.I. Zietsman

ABSTRACT

This study is an evaluation of the remedial and diagnostic components of a microcomputer program on speed.

The program is based on a conceptual change model developed within the field of cognitive science research. The influence of research in cognitive science on the current research in science education is discussed as well as recent research in the field of kinematics in the context of science education.

The literature relevant to the study is reviewed, and the design of the study and the evaluation procedures are described.

The results of the investigation are presented and analysed and finally, conclusions from these findings are presented.

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CHAPTER 1.

1.1 INTPODUCTION

The dubious position in which science education in this country finds itself is confirmed by the extensive coverage of the issue in the popular press and the obvious concern of policy-makers in education (HSRC report : Provision of Education in the RSA, 1981). Although the crucial shortage of science teachers and the poor pass rates of matriculants in Physical Science tend to focus attention on schools, the high failure rate of students in first year physics and chemistry indicates that the problem is definitely present at the tertiary level (Behr, 1982; van Wyk and Crawford, 1983). The growing number of reported studies dealing with science education in international journals of education, physics and others, also suggest a worldwide concern.

Physics is commonly considered difficult by students, and searches for sources of difficulties encountered by students have identified factors such as the abstractness of the material, the degree of logical precision required in problem solving , sophistication in the type of reasoning required and mathematical skills required (Clement, 1982; Champagne, Klopfer and Gunstone, 1982; Larkin, McDermott, D.Simon and A.Simon, 1980). A substantial and growing body of research, conducted mainly in the past two decades (reviewed by Driver and Erickson, 1983), has [illegible]clusively that students possess their own, stable under[illegible]f basic concepts in physics based upon their experiences. These "conceptual frameworks" very

often differ significantly from the formal viewpoint of physicists, thus interfering with instruction in classrooms and contributing significantly to students' learning difficulties in physics. It is therefore acknowledged by researchers in the field of science education that teachers of science (in this discussion physics) should allow for the existence of such misconceptions in their instructions. Confronting students with their alternative conceptions and allowing them the necessary experiences and time to resolve them may lead to a fuller understanding of the basic concepts, thus increasing the effectiveness of science education.

Acknowledging that there are many different and complex factors causing learning difficulties in science, this study examines the effectiveness of one attempt to better science instruction. The microcomputer program evaluated in this research report is concerned with an alternative conception of speed, first documented by Trowbridge and McDermott (1980). The program, designed in accord with a conceptual change model proposed by Posner, Strike, Hewson and Gertzog (1982), confronts the students with their alternative conception and provides remedial sequences aimed at influencing them to changing these undesirable conceptions and hence increasing the effectiveness of instruction.

1.2 STATEMENT OF THE PROBLEM SITUATION AND RESEARCH QUESTIONS

The microcomputer program evaluated in this investigation was designed to diagnose and remediate an alternative conception on speed. Enough evidence exists to claim that the program's diagnostic section is

effective, but although it is confirmed that the remedial sequences produce significant conceptual changes in students holding the alternative conception, it is not clear that the change might occur indirectly as a result of the use of the diagnostic part of the program (Hewson, 1983). This concern leads to the first two research questions:

(1) Are the conceptual changes of students mainly due to the use of the diagnostic part of the program?

(2) Are the conceptual changes of the students mainly due to the use of the remedial sequences of the program?

Research on the effectiveness of simulations as instructional aids (see Kulik, Bangert and Williams, 1983; Benedict and Butts, 1981) suggests that there is little or no difference in the learning outcomes from simulations as opposed to traditional instructional methods. However, since doubts were expressed concerning the effectiveness of simulations in diagnosing the same alternative conceptions as for example by using real objects in the diagnostic process (Larkin, in private communication with Hewson), it was decided to evaluate this aspect as well.

The third research question deals with this aspect:

(3) Is the same alternative conception diagnosed by both the simulation and the experiment, in other words - do the students perceive the real life motion to be the same as the simulations?

1.3 IMPORTANCE OF THE STUDY

Evaluating efectiveness of the remedial sequences of the program is considered important since the program could be offered to other physics instructors as a learning aid to enhance the conceptual understanding of basic physics. Establishing the extent to which the intended outcomes are realised would thus be valuable.

The study also examines the degree to which the simulations of kinematical motion correspond with the real life situation they were designed to simulate. Although Megarry (1978) argues that research on the internal validity of simulations and computer games should be laid to rest since inconclusive results from scores of studies indicate that it would be wiser to concentrate on improving and refining the instruction strategy in question (Hubbard, 1972); this investigation will be important in that the effectiveness of simulations as an alternative to real experimentation in diagnosing and remediating alternative conceptions will be established.

In addition to this, the study validates the conceptual change model on which the program was designed. This model is important for instructional aspects other than computer aided instruction, thus implying that the findings from the study would be important to other facets of science instruction.

1.4 STATEMENT OF ASSUMPTIONS

(1) Only students holding the alternative conception of speed will be

involved in the evaluation of the remedial sequences of the program. Since it has been established that the same alternative conceptions are held by students at all levels - from primary school to graduate level (Hewson, 1981; Osborne and Gilbert,1979), and even by science teachers (Helm, 1980); it is assumed that the sample need not be selected randomly. The diagnostic part of the program will be selecting the participants for the evaluation of the remedial sequence.

(2) In accord with the assumption above, the age, prior instruction in physics or grade level of the participants is not considered important.

1.5 LIMITATIONS AND DELIMITATIONS OF THE STUDY

(1) Factors such as maturation of participants and conceptual changes due to factors other than the use of the microcomputer program are not considered, thus limiting the generalizability of the findings.

(2) Although all people - adults and children, professional students and lay men - may hold the alternative conception of speed, the study is limited to learners in institutions where formal teaching is provided.

(3) Few schools in the Johannesburg area use microcomputers for instruction, with the result that random selection of participants was not possible. It was therefore decided to use available samples (Students and scholars) from which the diagnostic tests identified the participants in the investigation into the effectiveness of the two

sections of the program.

(4) Previous use of the microcomputerprogram at the University of the Witwatersrand have indicated that relatively few students hold the alternative conception of speed. This was confirmed in this study, since only twenty-six of the seventy-four participants tested, held the conception. The statistical tests was therefore performed with small numbers, perhaps resulting in less significant results.

1.7 METHODOLOGY

In this section a brief description of the research design, instruments and sampling is included.

(a) Research design

(i) Pretest-posttest experimental design

A pretest-posttest comparison of an experimental and a control group was used for the collection of data. The diagnostic test on the simulation as well as the diagnostic test designed by Trowbridge and McDermott (1980) were used as pretests.

Subjects identified as holding the alternative conception on speed in the diagnostic testing were randomly assigned to an experimental group and a control group. Participants in the experimental group were asked to complete the remedial sequences of the program, but the control group not. The remedial sequences are therefore seen as a

"treatment".

After a time delay of two weeks, the diagnostic test on the computer was administered to all participants again.

The design can be represented as:

experimental	(A)	SO	X	O
control	(B)	SO		O

where S is the selection process

O the diagnostic test (pretest)

X the remedial sequences (treatment)

O the diagnostic test (post-test).

(ii) Interviews

The responses of participants were recorded during the administration of the experimental diagnostic test to investigate the first research question and short interviews similar to those conducted by Trowbridge and McDermott (1980), were conducted in this phase of the testing.

(b) Sampling

Students from a first year ancillary course in physics at the University of the Witwatersrand as well as Standard 8 (Form III) pupils from and English medium secondary school in Johannesburg

participated in the investigation.

(c) Instruments

Diagnostic tests in the form of a simulation and a real experiment were used as pretests, whilst the remedial sequences of the microcomputer program were regarded as the treatment in the design. The diagnostic test of the computer program was also used as the post-test.

CHAPTER 2.

REVIEW OF LITERATURE

2.1 ALTERNATIVE CONCEPTIONS

Since the classical studies of Jean Piaget, researchers in science education have been interested in the conceptions of science held by young children. Research in cognitive science conducted mostly in the past two decades have brought a new understanding of the prior knowledge and conceptions of students and scholars of the natural sciences. It is from research in this field that "...a new consensus on the nature of learning has begun to emerge.." (Resnick,1983 : 477) which has a direct bearing on how physics can be taught (and learned) most effectively. The theory of learning underlying this consensus, the schema theory, suggests that a person activates a schema (or schemata) which becomes a structure for interpreting familiar situations and for reasoning about new information in a learning situation. If the available schemata do not match up to the incoming information, the bits of new information are isolated, easily forgotten or become inaccesible to memory (Resnick, 1983; Rumelhart and Ortony, 1977).

In this context, research in science education has provided significant evidence that students of all ages use implicit theories derived from previous experiences on which to base reasoning about new concepts in their attempt to make sense of their experiences. A wealth of investigations probing students' understandings of natural

and technological concepts have been recorded in many diverse topics in physics, chemistry, mathematics and the life sciences (summarised in Driver and Erickson, 1983). All these alternative conceptions, for example "... force is a quantity in a moving object in the direction of motion..."(Osborne and Gilbert, 1980), are quite different from those of scientists and they support the proposition of Ausubel (1968) that students aquire extensive knowledge about the natural world from their contact with the social and physical milieu. Nussbaum and Novick (1981 : 1) describe this knowledge as including some

> "...naive metaphysical assumptions about the physical world which are incompatible with the metaphysical foundation of current scientific conceptions.."

The following important findings were recorded as general characteristics of students' alternative conceptions :

(1) students' ideas are not isolated bits but part of conceptual structures providing sensible and coherert understandings of the world from their point of view (Champagne, Klopfer and Anderson, 1980);

(2) Ausubel's (1968) observations that children's ideas are amazingly tenacious and resistant to change are supported; for example Champagne, Klopfer and Gunstone (1982 : 3) found that this prior "world" knowledge is not only"...logically antagonistic to the content to be learned (but) often persists after physics instruction...":

(3) students in classrooms often unknowingly misinterpret what they are taught so that the new information should not be in conflict with their earlier ideas (Osborne, 1981).

The evidence that students' prior knowledge is an important aspect of their learning of science is overwhelming, resulting in the consensus that science teachers will have to confront this aspect of learning in their instruction.

2.2 INTERVENTION TO BRING ABOUT CONCEPTUAL CHANGE.

The instructional strategy evaluated in this study deals with an alternative conception on speed first identified by Trowbridge and McDermott (1980). They documented the difficulties that first year students have in understanding the concept of velocity in one dimension. Their study indicates that students in introductory physics courses confuse the concepts speed and position and that even after instruction, approximately one-fifth of the students still confused these concepts in their study. They also found that some students could provide a correct definition of velocity, but

> "... they did not understand the concept well enough to be able to determine a procedure they could use in a real physical situation for deciding if and when two objects have the same speed. Instead they fell back on the perceptually obvious phenomenon of passing..." (Trowbridge and McDermott, 1980 : 1027).

In other words, when two objects were next to one another (in the same position) the students claimed that they were moving at the same

speed. The researchers used apparatus which allowed them to demonstrate the same motion repeatedly in order to diagnose the students' alternative conception.

Their strategy for confronting the students with their alternative conception could easily be implemented in a teaching program but for the awkwardness of the apparatus. Recognizing this possibility, Hewson (1983) designed a microcomputer program to diagnose the same alternative conception using the same strategies.

In addition to the diagnostic aspect, the program also provide remedial sequences aimed at directing the students to change to an acceptable conception, thus ensuring that the students understand the concept well enough to develop a procedure for deciding if and when two objects have the same speed. The program was designed in accord with a conceptual change model, proposed by Hewson (1981) and Posner et al. (1982). The model proposes that a student will only change from an existing conception to another if the new conception is seen to be intelligible, plausible and fruitful by the student.

To facilitate conceptual change the model suggests

(1) diagnosis of the alternative conception;

(2) remediation - that is confronting the student with the alternative conception in such a way as to create dissatisfaction with the conception and proving to the student that the new conception is more useful than the old.

2.3 MICROCOMPUTERS IN LIAGNOSIS AND REMEDIATION OF ALTERNATIVE CONCEPTIONS.

The advantages and merits of microcomputers in education have been debated extensively, and numerous studies have been conducted to investigate the claimed superiority of computer-based teaching over traditional teaching methods. Kulik, Bangert and Williams (1983) conclude in an analysis of major studies on the effects of computer-based teaching, that results and relationships claimed by the researchers were far from statistically significant. Early, comprehensive studies by Cherryholmes (1966), Visonhaler and Bass (1972) and Jamison, Suppes and Wells (1974), as well as later investigations (Benedict and Butts, 1981) have reported few negative effects and many positive effects. Increase of student motivation and interest are positive effects found most frequently by researchers (see Delpierre, 1983; Benedict and Butts, 1981). In a recent investigation by Jones, Kane, Sherwood and Avner (1983) at the University of Illinois (Urbana-Champaign), the performance of students in a physics course of which a major component of the instruction is computer-based were compared with the performance of students receiving only traditional instruction. Statistically significant results show that students in the computer-based course scored better overall.

The application of computers in the area of simulations have been described as "..perhaps the most exiting and potentially the most rewarding.." of all the possible applications of computers in education (Dowsey in Megarry, 1977:58). Bork (1978) points out that simulations on computers can provide a wide range of experiences not

found in the everyday world or in the laboratory, to students of physics. There are many circumstances which prevent students from directly experiencing physical phenomena, for example - complex and scarce equipment (high energy physics), very long or very short time scales and the difficulties involved in taking readings.

Several simulations of physics experiments and physical phenomena exist and are used extensively, but as Bork (1978) suggests, many problems are involved in designing simulations which appeal to students and which serve them well. In this context, substantial progress has been made in evaluating the pedagogical value of simulations - that is, the educational value of simulations in teaching specific material to students. However, Norris and Snyder (1982:73) report that few studies have been done to examine the external validity of simulations - that is the "..transferability of academic insights into useful and effective real-world orientations.." A second concept of external validity - the degree to which the simulations correspond with the real-life situations they are designed to simulate, is regarded as crucial by Twelker (1968 : 35):

> "Supposedly, what is taught in instruction must fit real life. If there exists a 'credibilty gap' between instruction and the operational world, then the learner is at a disadvantage when it comes to either performing in the real world, or understanding what the real world is like."

The simulations to be evaluated in this study are used in two contexts, that is to diagnose and remediate an alternative conception of speed. The value of diagnostic testing on microcomputers is

acknowledged (Okey and McGarity, 1982); providing benefits such as the availability of the computers to students, increasing academic engagement of students and reducing the work load of teachers. The "kace" programs provide an additional benefit in assisting students to overcome a learning difficulty (the alternative conception) and could therefore be regarded as a significant addition to current applications of microcomputers in education.

CHAPTER 3

PROCEDURE

3.1 SUBJECTS

Thirty-four Standard 8 (Form III) scholars from a secondary high school in Johannesburg as well as forty students from an ancillary course in first year physics at the University of the Witwatersrand served as subjects in this study. The scholars have never had formal instruction in kinematics, in other words the concepts speed, velocity, acceleration and others has never been formally defined in a classroom situation. The students have received intensive instruction in kinematics, both at school-level and at university. The selection is considered appropriate, since research in science education has shown conclusively that neither age nor prior instruction excludes the existence of alternative conceptions. However, the tests were administered to the students at a time when they were not engaged in formal discussions of the concepts velocity and speed with their lecturers. Informal discussions with fellow students could not be controlled, thus limiting the generalizability of results, as indicated in chapter 1.

Previous use of the diagnosis program indicated that a relatively small proportion of students and scholars hold this alternative conception (Hewson, 1983). This was confirmed by the investigation, since only fourteen scholars and twelve students were identified as using the "passing" criterion. One scholar was lost due to illness,

therefore only twenty-five subjects participated in the final investigation into the respective effectiveness of the diagnostic and remedial parts of the program.

3.2 COLLECTION OF DATA

(a) Diagnostic tests

The diagnostic tests on the microcomputer program were administered to all subjects. Ideally the diagnostic test designed by Trowbridge and McDermott (1980) should also have been administered to all participants, but restraints on time has limited this procedure to the investigation with the first-year students. Short, unstructured interviews were conducted whilst the students were tested on the real experiment. Information collected in the interviews provided additional data towards answering the first research question.

(b) Remedial intervention.

Subjects identified as holding the alternative conception on speed by the initial tests were randomly assigned to a control and an experimental group. The experimental group participants were required to work through the remedial sequences, but not to repeat any of the diagnostic tests following this.

After a time-delay of a week, all subjects were required to repeat the diagnostic tests of the computer program. Subjects from the experimental group still holding the alternative conception were allowed to repeat the remedial sections, but information concerning

any further conceptual changes in these subjects was not used. Subjects from the control group with their alternative understanding of the concept unchanged now continued to the remedial sequences and the subsequent diagnostic tests - thus providing more information on the effectiveness of the intervention.

As many students as practicable were interviewed after the last test to gain more insight as to why conceptual change has occurred (or not).

3.3 EXPERIMENTAL INSTRUMENTS

(a) Diagnostic tests (real experiment designed by Trowbridge and McDermott, 1980)

Linear motion was demonstrated by steel balls rolling along plastic U-channels in an experimental set-up similar to that used by Trowbridge and McDermott. Two speed comparison tasks were used by these researchers and were replicated as carefully as possible.

(i) Speed comparison task 1.

Ball A and ball B travel from left to right, but ball B has an initial velocity greater than that of A. B passes ball A, but since it is travelling up an incline, it slows down, allowing A to pass it before it comes to rest, as illustrated in figure 1. A distance-time graph of the task is presented in figure 2. The graph was not used in the interviews. During the observation students were asked to indicate where the two balls have the same speed and to explain their choice.

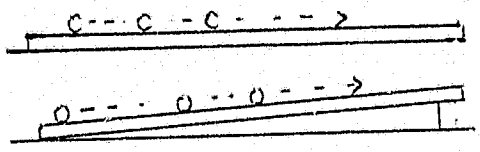


figure 1

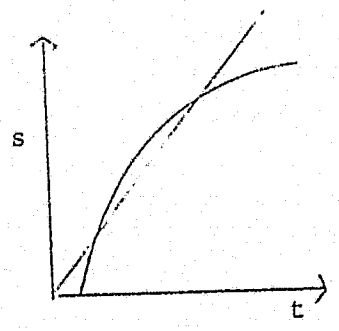


figure 2

(ii) Speed comparison task 2.

Trowbridge and McDermott used a second task in which the balls did not pass one another, arguing that the perception of passing might be significantly more striking and obvious than the phenomenon of keeping the same distance apart, thus causing students to identify passing points unintentionally.

In the second task ball B starts with a high initial velocity travels up an incline, slowing down and finally comes to rest. The second ball, C, starts from rest from a point ahead of B and accelerates down a gradual incline (illustrated in figure 3). B never overtakes C, as shown in the graph (not used in interviews) in figure 4. The same questions were asked - that is, the students had to identify positions where the balls had equal speeds and were required to provide the criteria used to make the identification.

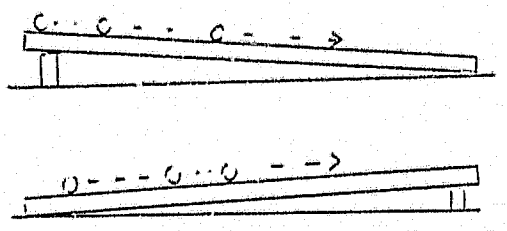


figure 3

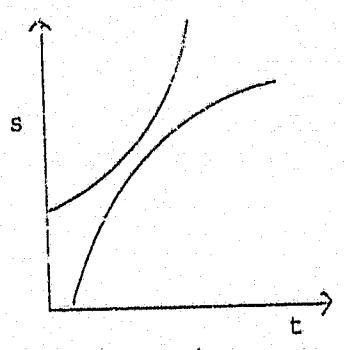
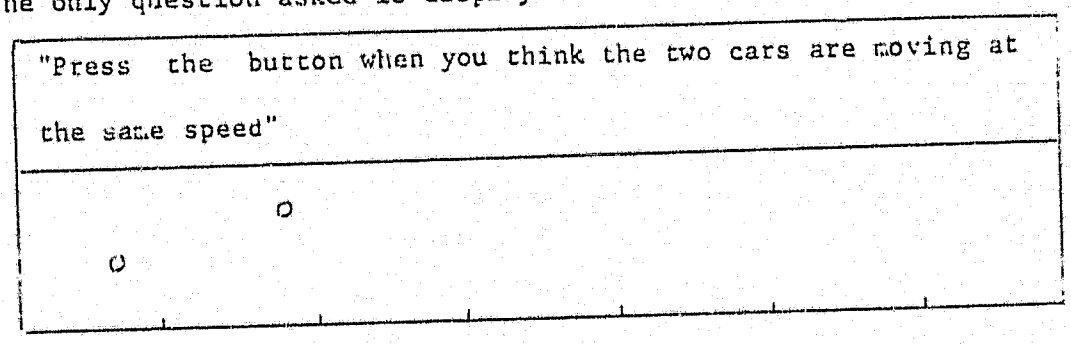


figure 4

(b) Diagnostic tests (simulations on microcomputer designed by Hewson, 1983)

Six different "races" between two "cars" are used as diagnostic tests. Two races are simulations of the speed comparison tasks of Trowbridge and McDermott, and the other were designed to distinguish between the correct and the position criteria. There are no incidents where both cars are moving side by side at the same speed, and the acceleration or deceleration which affect the perceptual appearance of the races without changing the essential components of the tasks, are varied continually. Distance-time and speed-time graphs of the six races are presented in Appendix A.

The only question asked is displayed at all times:



The races are divided into seven equal time intervals, during which it is possible to classify a response as either correct or "passing". During some of the time intervals, usually at the start or end of a race, responses that are in neither of the above categories are classified as random responses. Races were designed with several intervals where a response was consistent with one criterion but inconsistent with the other.

The responses are stored as C (the correct response); P (the "passing" response) and X for random responses.

A participant with a score C > 4; P < 2 and X < 2 is considered competent, congratulated and the program is terminated.

An example of recorded responses is presented in Appendix B.

Participants with scores other than the above are required to complete the remedial sequences, and could then repeat the diagnostic phase if they wished to.

Detailed descriptions of the races are available in Hewson (1983 and 1984).

(c) Remedial sequences (simulation on microcomputer designed by Hewson, 1983)

This phase consists of two races, one aimed at creating dissatisfaction with the "passing" criterion, lowering its value from a plausible conception to being only intelligible. The other race presents the correct criterion as an effective alternative to the "passing" criterion, thus an intelligible and plausible conception as opposed to the old conception (Hewson, 1983).

The first race has the one car stationary in the centre of the screen. The other car travels from left to right across the screen at a constant speed, passing car 1 in the process.

The cars are travelling at the same speed across the screen in the second race, with the one a constant distance behind the other.

The responses are stored as C (the correct response); P (the "passing" response) and X for random responses.

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The cars are travelling at the same speed across the screen in the second race, with the one a constant distance behind the other.

The distance-time and speed-time graphs of the races are presented in Appendix C.

During the races the following question is displayed at the top of the screen:

"Are both cars moving at the same speed - when they are at the same place?"

At the end of both the races two questions stressing the difference between speed and position are asked:

"At any stage of their race:

- were they at the same place, at the same time?
- were they moving at the same speed?"

Participants who provide wrong responses are alerted to the fact and corrected.

More detailed descriptions of this phase of the program are available in Hewson (1983 and 1984).

3.4 VALIDITY AND RELIABILITY OF THE EXPERIMENTAL INSTRUMENTS

The experimental tasks were tested for validity and reliability by Trowbridge and McDermott (1980), whereas the validity of the simulations will be invetigated in this study. Previous tests with the computer program has conclusively proved its reliability (Hewson, 1983).

CHAPTER 4

PRESENTATION AND ANALYSIS OF DATA

4.1 EVALUATION OF THE EFFECTIVENESS OF THE SIMULATIONS

The data collected from the first-year physics students' performances on the reconstructed speed comparison tasks, as well as the recorded responses on the microcomputer program for the six diagnostic races, were analysed quantitatively to determine whether the simulations identified the same alternative conceptions as the original experiment.

The data obtained from the twenty-five students who completed the experimental tasks and the diagnostic races is reported in Table 1.

TABLE I

correct response in both cases	13
"passing" response in both cases	10
mixed response	2

Correct responses - discussion

The thirteen students with correct responses consistently used the same criterion to determine the positions of equal speed in both the diagnostic procedures. The following responses were recorded during interviews :

The balls (cars) are moving at the same speed when....

"..the distance between them remains the same..." - 6 students;

"..they stay 'equidistant'..." - 2 students;

"..the distance between then does not increase or decrease...." - 2 students;

"..the displacement between them stays equal..." - 1 student;

"..they don't move further apart..." - 1 student.

One student identified the equal-speed instances correctly but gave vague explanations when interviewed whilst doing the speed comparison tasks; for example "...I just look at them.....they look as if they have the same speed...". He gave the same nonsensical reasons when interviewed after completion of the diagnostic races, but claimed that it was easier to "...estimate when their speeds are equal..." on the simulation. Two other students remarked spontaneously that the simulation was "clearer", "easier to judge" than the real experiment, and one remarked that the simulation was more "fun" but "...went on to long..".

There is clearly no difference in the way these students observed the diagnostic tests in real experiment or as simulations of motions.

(b) Passing responses - discussion

The incorrect "passing" criterion was used consistently by ten students in deciding on the instance of equal speed in both the diagnostic procedures. Responses recorded include :

The balls (cars) have the same speed

"...where they pass (cross) each other..."

"...where they are in the same position..."

Students holding the alternative conception of speed identified equal-speed positions using the same criterion in both the diagnostic test procedures. Similar to the students with a correct conception, there is no difference in their observation of real motion and simulated motion.

(c) Mixed responses - discussion

A "mix" of the correct criterion and the passing criterion was recorded in two interviews.

Student A used the "passing" criterion consistently in the real experiment, but corrected himself in the third diagnostic race on the computer - now using the "equal distance apart" criterion. Going back to the experiment he subsequently identified equal-speed instances correctly, still using the "equal distance apart" criterion.

Student B completed the diagnostic races on the computer, consistently identifying equal-speed instances using the "passing" criterion. When interviewed during the real experiment she consistently gave correct responses, with reasoning not quite satisfactory initially - for example: The balls are moving at the same speed when "....they sort of stay together..". When asked to clarify this reasoning, she decided that the balls "stay together" because the "separation" between them did not change.

Both the students completed the remedial sequences after these interviews and gave only correct responses in the second diagnostic test on the microcomputer.

Although both students used different criteria on the two tasks, they appeared to perceive velocity in the same way in both cases. Their alternative conceptions were changed by the diagnostic races, and after conceptual change they both viewed the apparatus as being no different from the simulation (although less clear); thus confirming the observations described in (a) and (b).

4.2 EVALUATION : REMEDIAL AND DIAGNOSTIC SECTIONS

All twelve participants in the experimental groups (six scholars and six students) changed their alternative conception after intervention. However, in the control group only one of seven scholars and one of six students changed their alternative conception. The responses of the experimental and control groups are examined separately to

contrast the effectiveness of the remediation against that of the diagnostic part of the program.

(a) Analysis of the experimental group data

The correct (C) scores and the combined random and "passing" (P + X) scores of both experimental samples before and after the remedial section of the program was administered, were compared using a chi-square test and the 0,05 level of significance was chosen as the critical value.

The data is reported in Table II

TABLE II

	C	P+X	total
pretest	19	30	49
posttest	31	14	45

(students)

	C	P+X	total
pretest	28	47	75
posttest	32	27	59

(scholars)

A null-hypothesis for this part of the investigation would state that participants' conception of speech were unaffected by the remedial sequences of the programme; observed changes would only be due to chance.

The chi-square values obtained ($X^2 = 16,7$; df = 1; $p < 0,001$ for the students sample and $X^2 = 9,16$; df = 1; $p < 0,01$ for the scholar sample) are statistically significant and the null-hypothesis can be rejected.

It can be accepted that intervention in the form of the remedial sequences had an effect : increasing the correct scores and decreasing the random and "passing" scores.

(b) Analysis of the control group data

The correct (C) scores and the combined random and "passing" (P + X) scores of the control group (scholars) were obtained to compare the pre- and posttest performances of the students.

A chi-square test was performed and the 0,05 level of significance was chosen as the critical value.

The data is presented in Table III.

TABLE III

	C	P+X	total	
pretest	21	28	49	(scholars)
posttest	21	21	42	

	C	P+X	total	
pretest	15	32	47	(students)
posttest	21	28	49	

A null-hypothesis stating that there is no difference in the status of the scholars' alternative conception after administration of the diagnostic test is accepted, since the chi-square value obtained (χ^2 = 0,46; df = 1; p > 0,20) indicate that no significant change in the scores of the scholars occured.

The chi-square value obtained for the student sample (χ^2 = 2,59; df = 1; p > 0,1) indicate that the null-hypothesis must be accepted, thus no significant change in the scores of the students.

(c) Discussion

When considered separately, it is clear that the diagnostic tests are not an effective intervention, whereas the remedial sequences are. However, the high P+X and C scores in the control group make a direct comparison difficult, particularly for the sample of the scholars.

These high P+X and C scores of the scholars distort the picture, as they tended to use a "passing" criterion as well as the correct criterion and were perfectly satisfied to use them alternately, an indication that they did not understand the concept velocity. The students in the control group seem to have decided on one criterion since their C scores are low compared to the P+X scores.

A simple order of magnitude calculation based on the number of students who changed their conception of velocity confirms the statistical significance of the results above (private communication, M. Gering). Assuming that the sample is uniform (null-hypothesis), we

find that

p(change) = 6/13

p(unchanged) = 7/13.

The probability of six out of six scholars in the experimental group changing, with only one of seven in the control group changing their alternative conception, is given under the assumption of the null-hypothesis by :

$$p = 7 \cdot \left(\frac{6}{13}\right)^6 \cdot \left(\frac{7}{13}\right)^7$$

$$= 0{,}013$$

which is significant at the 0,01 level, and similarly for the students. If the samples are considered as one (in view of chapter 1, 1.4), the results become more significant statistically.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 THE EFFICACY OF THE SIMULATIONS

It was predicted that the microcomputer program would produce the same diagnosis as Trowbridge and McDermott's (1980) speed comparison tasks. The rationale behind this prediction was that there exists no "credibility gap" (Twelker, 1968) between the simulations and the operational world.

Newson (1983 : 18) proposes that

> "...while no controlled experiment has been performed, it seems unlikely that the two tests are tapping two significantly different conceptions."

The results of this study indicate that this is indeed true. The fact that two subjects used an incorrect criterion on the microcomputer but the correct criterion on the speed comparison tasks does not weaken but strengthen this statement. Both the students changed their conceptions while doing the diagnostic races and these changes were then sustained to the real experiment.

5.2 THE EFFECTIVENESS OF THE PROGRAM

The results obtained strongly indicate that the remedial section of the program does produce significant conceptual changes in the

students and scholars holding the alternative conception. It is also shown that there is a low possibility of conceptual change occuring indirectly as a result of the use of the diagnostic part of the programme only.

Hewson (1983) found a statistically significant change over a seven month period, but suggests that the change could have been instigated by one (or more) of the following factors:

(1) formal instruction;

(2) maturation;

(3) indirectly through the use of the diagnostic section.

In this investigation the first two factors could not contribute significantly towards conceptual change : none of the participants received formal instruction during the course of the investigation, and maturation is ruled out since the maximum time lapse between the pre- and posttests was two weeks.

Trowbridge and McDermott (1980) found that approximately 40% of students initially using the wrong criterion changed after "successive trials" in individual interviews. Results obtained in this study show that successive administration of the diagnostic races did not produce significant change - in other words change did not occur indirectly as a result of the use of the diagnostic races.

There are students such as A and B described in 4.2 who changed after the first two races in the diagnostic tests. The program must therefore be extended to record the responses of participants in each

individual race if the effect of the first two diagnostic races has to be evaluated.

Conclusion:

It can therefore be concluded that the microcomputer under study is an effective form of an active intervention for student use to overcome confusion between the related, but different concepts of speed and position.

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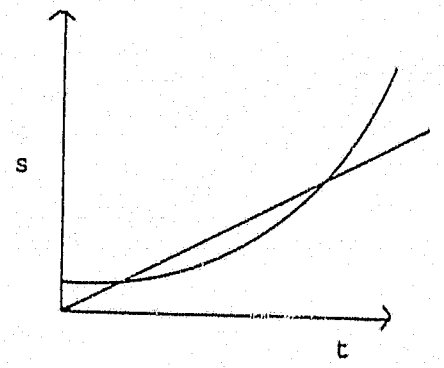
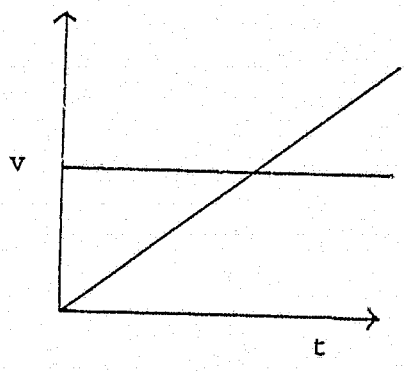
APPENDIX A

DISTANCE - TIME AND SPEED - TIME GRAPHS OF THE DIAGNOSTIC RACES.

RACE 1





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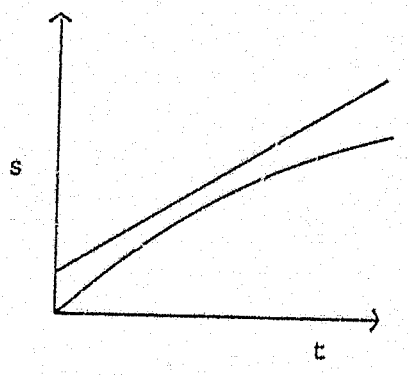

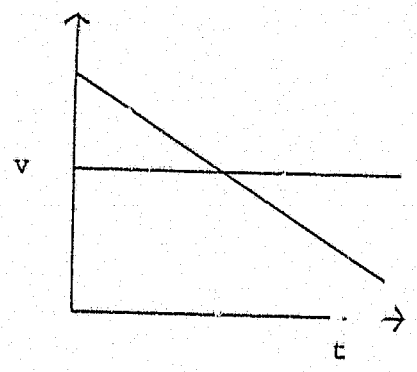

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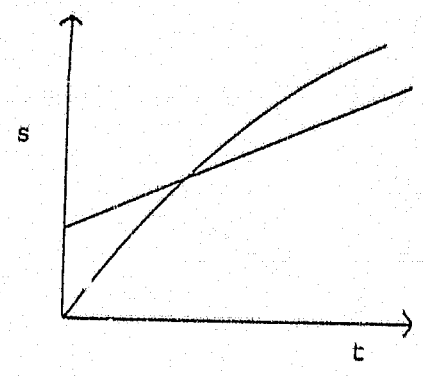

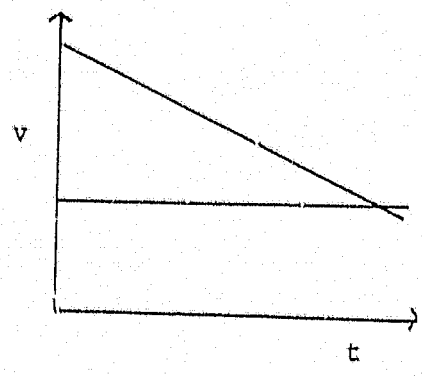

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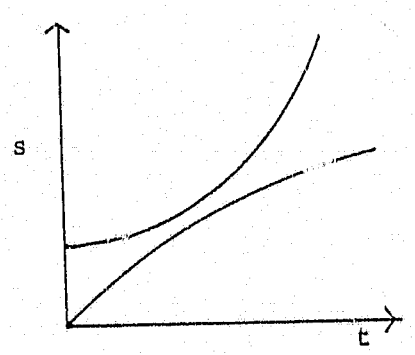

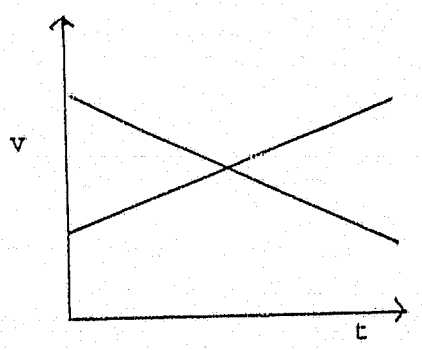

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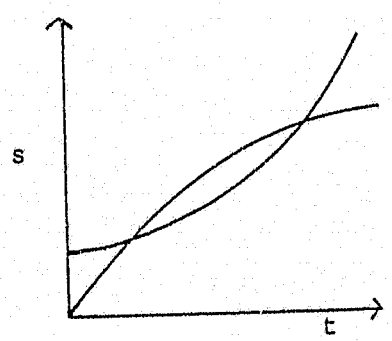

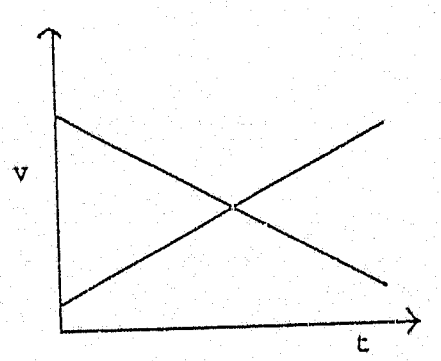

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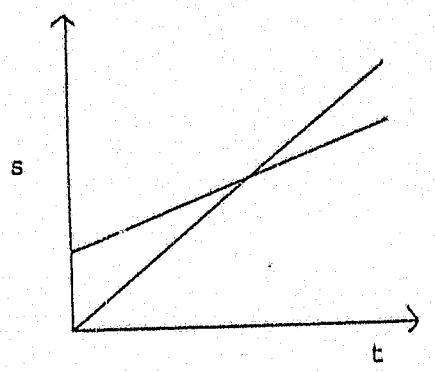

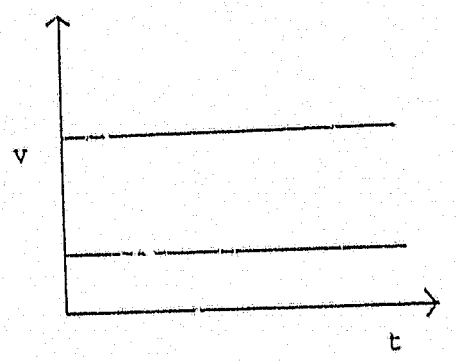

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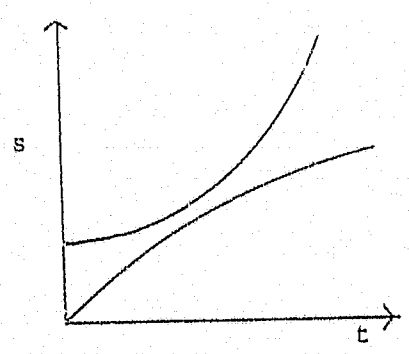

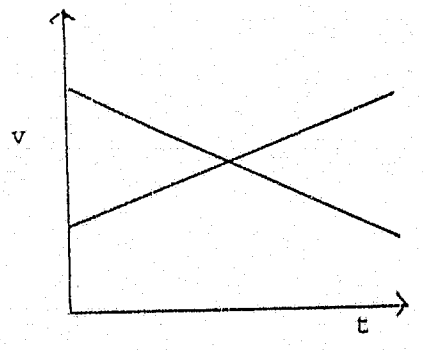

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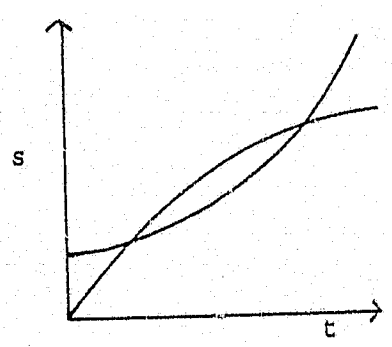

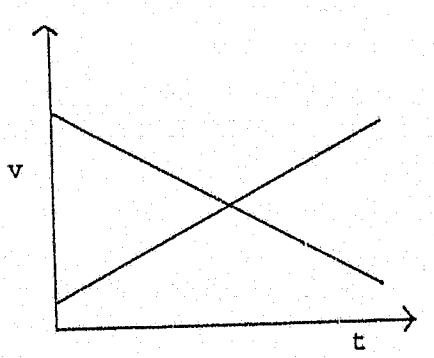

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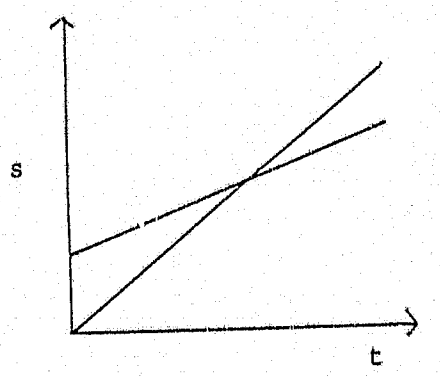

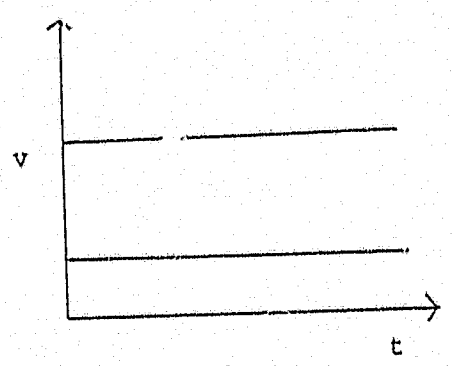

APPENDIX B

RESPONSES OF THE DIAGNOSTIC RACES.

STUDENT RESPONSES TO RACE 1

```
THIS PROGRAM READS STUDENT RESPONSES
TO THE 'RACE PROBLEM'. THESE HAVE BEEN
RECORDED IN THE FILE NAMED 'RESPONSE'.

THIS PROGRAM REQUIRES A PRINTER.

ONCE THE DATA IS PRINTED, THERE IS
THE OPTION OF EMPTYING THE STORAGE FILE.


PRESS 'RETURN' TO CONTINUEDO YOU WANT TO SEE HOW THE OUTPUT
IS INTERPRETED? (Y/N)INTERPRETATION OF OUTPUT

OUTPUT IS IN THE FORM:
NAME  N  C  P  X  CC  CP  SS  SP
 N - ATTEMPT NO.
 C - NO. OF CORRECT RESPONSES (EX 6)
 P - NO. OF PASSING RESPONSES
 X - NO. OF UNCATEGORIZED RESPONSES
CC - COMMENT ON CORRECT RESPONSES
CP - COMMENT ON PASSING RESPONSES
     IF 0 QUESTION NOT ASKED OF 'NAME'
        1 'NAME' AGREES WITH STATEMENT
        2 'NAME' DISAGREES WITH STMNT.
SS - RESPONSES TO SAME SPEED QUESTIONS
SP - RESPONSES TO SAME PLACE QUESTIONS
     IF 400: 'NAME' DID NOT SEE RACES
     NO. IN FORM XYZ
     X - 2,3 REFERS TO SPEED, PLACE
     Y,Z - NO. OF CORRECT RESPONSES TO:
       Y - SECOND REMEDIAL RACE
       Z - FIRST REMEDIAL RACE

PRESS 'RETURN' TO CONTINUETHE DATE TODAY IS ?Y

DO YOU WANT TO READ RESPONSES? (Y/N)OPEN RESPONSE
DO YOU WANT OUTPUT TO PRINTER? (Y/N)
```

STUDENT RESPONSES TO THE RACE PROBLEM

```
ASHICHI JEREMIAH      1 5 1 2 0 0 400 400
MALAPO GEORGE         1 5 1 3 0 0 400 400
SIMON                 1 3 5 1 1 1 211 311
BECKER LOUISE         1 4 4 2 1 1 211 311
MASEMOLA SAMSON       1 0 0 0 0 0 400 400
KWAN VALERIE          1 5 1 5 0 0 400 400
ROUX MICHELE          1 5 0 2 0 0 400 400
BROWN RUSSELL         1 5 0 1 0 0 400 400
LEHRER THERESIA       1 5 0 3 0 0 400 400
FENELLA INGRAM        1 5 0 3 0 0 400 400
CALDRECPOTI BRENDA    1 0 6 0 0 2 201 311
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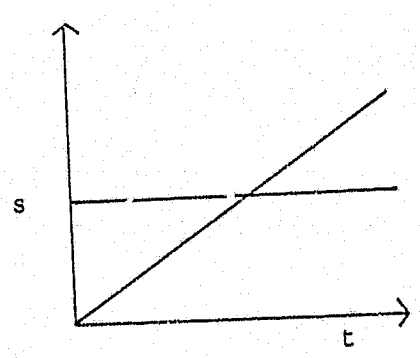
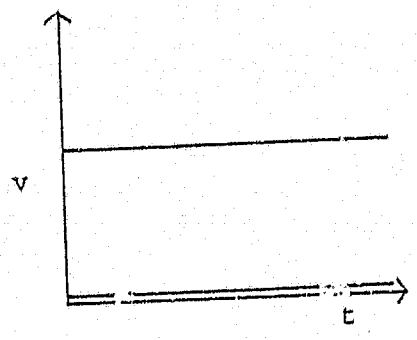
APPENDIX C

DISTANCE - TIME AND SPEED - TIME GRAPHS OF THE REMEDIAL RACES.

RACE 1





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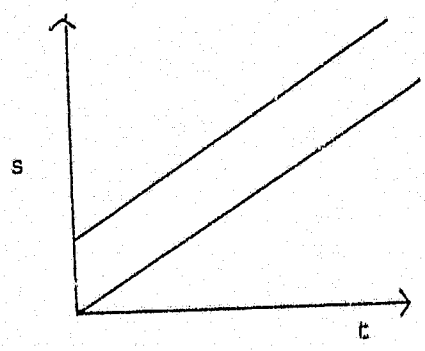

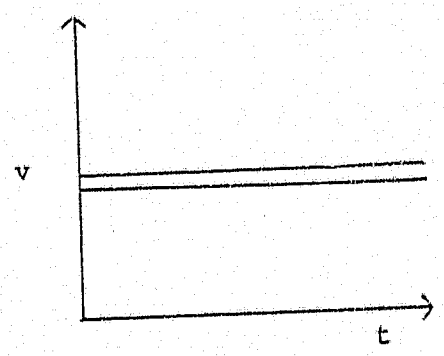

APPENDIX D

CONCEPTUAL CHANGE

Attempts have been made by various investigators to describe what happens when a learner with an alternative conception is faced with a new conception at variance to their own. Hewson (1981) suggests the following:

(i) Rejection of the new conception.

(ii) Rote memorisation, that is the new conception is not reconciled with the existing knowledge.

(iii) Conceptual change, in other words the new conception replaces the old.

(iv) Conceptual capture - the new conception is reconciled with existing conceptions.

"Reconciling the conceptions implies that there are significant inferential links between them, that there are no contradictions between them, that they are parts of the same integrated set of ideas and that there is consistency between them."

Hewson (1981 : 390)

The model of conceptual change considers the case of a learner whose existing conceptions are challenged by a new conception. Before the conceptual change can occur (where the new conception replaces the existing) it is proposed that the following four conditions be

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(iii) Conceptual change, in other words the new conception replaces the old.

(iv) Conceptual capture - the new conception is reconciled with existing conceptions.

> "Reconciling the conceptions implies that there are significant inferential links between them, that there are no contradictions between them, that they are parts of the same integrated set of ideas and that there is consistency between them."
> Hewson (1981 : 390)

The model of conceptual change considers the case of a learner whose existing conceptions are challenged by a new conception. Before the conceptual change can occur (where the new conception replaces the existing) it is proposed that the following four conditions be

satisfied:

(i) There must be some dissatisfaction with the existing conception.

(ii) The new conception must be intelligible that is the learner must be able to make sense of the new conception.

(iii) The new conception must be initially plausible suggesting that the world in which the new conception is true, is in harmony with the world of the learner.

(iv) The new conception must be fruitful that is it must be beneficial and productive to the learner.



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