RESEARCH PROJECT

ASSESSING THE EFFECTIVENESS OF USING THE COLOURED BEADS MODEL IN THE TEACHING AND LEARNING OF MONOHYBRID INHERITANCE TO ‘O’ LEVEL STUDENTS AT ALHEIT HIGH SCHOOL.

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Declaration

I Manyenga Proud declares that this research project herein is my own work and has not copied or lifted from any source without acknowledgement of the source.

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Signature ……………………………………………………………………………………………

Supervisor…………………………………………………………………………………………

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Dedications

To my precious kids Marvis and Nyasha who had to miss the love of a caring father during the demanding period of study.
Abstract

This study was structured to assess the effectiveness of using the coloured beads model in teaching and learning of monohybrid inheritance to ordinary level biology students at Alheit high school. A two group post-test only design was used, where the treatment group was allowed to model monohybrid inheritance with coloured beads at the end of the topic while the control group was not. The practical work on using the coloured beads model, a test and two questionnaires were the main instruments used. The model was found to greatly improve learning as 11 out of 24 pupils exposed to it passed the test given with at least 70% compared to only 3 out of 24 who got at least 70% for the group not exposed to modeling monohybrid inheritance with coloured beads. Based on the findings of this study it was recommended for teachers to use the beads model in teaching and learning of monohybrid inheritance. A need for teachers to allow discussions during the modeling is encouraged.
Acknowledgements

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CHAPTER 1

1.1 Introduction

This chapter begins by giving a brief background to this study explaining why the researcher set on to find out the effectiveness of using coloured beads to model monohybrid inheritance. It gives the main problem under study and outlines further questions the researcher needs to answer so as to get a solution to the main problem of whether or not the coloured beads model improves learning to ‘O’ level biology students. The importance of this research are explained as well as its delimitations and limitations. The chapter ends by defining some major terms as they were used in this study.

1.2 Background to the study

Research on effectiveness of particular commonly used media in science has gained little attention over the years. This is so despite the fact that students commonly show a lot of misconceptions emanating from practical work done under the supervision of teachers. Of particular reference is when the media is used in a simulation because here the teacher will need to ensure his students link the simulation to the concepts he wants them to master and if not properly done, higher chances of creating misconceptions occur.

Several textbooks at ordinary level recommend the use of coloured objects of the same size as media in teaching and learning monohybrid inheritance (Darwin, 2008; Clegg and Mackean, 2007; Jones and Jones, 2001). This shows the great extend of this method as a tool in teaching and learning of monohybrid inheritance. The Zimbabwe School Examinations Council (ZIMSEC) ‘O’ level biology syllabus (2013-2017) also give the use of coloured beads as a suggested activity for use by teachers in teaching and learning of monohybrid inheritance.

Practical activities are thought to effectively enhance learning (Lassiter, 2010, Science Community Representing Education, 2008 and Dillon, 2008). Some students at Alheit high school have however over the years found comprehending the use of the beads model confusing, often failing to link the beads to monohybrid inheritance. Some have been seen to simply memorise the media without comprehending its significance as shown by inability to correctly answer higher order questions which would seem obvious if linked with mastery of the model. The intended broad application of learnt concepts to real life situations is thus lost hence defying the whole purpose of learning. While several recommendations for the use of coloured beads in learning monohybrid inheritance exist, these are without substance as no literature has been found on the effectiveness of this method particularly in Gutu district.

Despite the praise given by some people to practical work some researchers have shown doubts on its benefits to students. Hodson (1991) for example, described the way practical work is done in schools as being ill-conceived, confused and unproductive. Similar doubts as
to the effectiveness of practical work were echoed by Abrahams and Millar (2008). It is therefore not clear as to whether a practical activity like using coloured beads to model monohybrid inheritance is of any benefit to students. This study will try to give evidence based recommendations on the use of coloured beads in the teaching and learning of monohybrid inheritance to ‘O’ level students particularly at Alheit High School.

1.3 Statement of the problem

While coloured beads are commonly used in the teaching and learning of monohybrid crosses to ‘O’ level students it is not clear whether they really improve learning to students as some even seem to fail to interpret their involvement.

Aim’ Of The Study

The aim of the study was to find out the significance of modeling monohybrid inheritance with coloured beads to O’ Level biology students

1.4 Research questions

- is there any difference in performance of students who have been taught monohybrid inheritance using coloured beads and those who have been taught through the traditional lecture method combined with class discussions?

- how does distribution of test scores differ among students taught using the beads model and those taught without using the model?

- can use of coloured beads help change students’ perceptions of the concept of monohybrid inheritance?

- what are the views of students on modelling monohybrid inheritance with coloured beads during a lesson?

1.5 Importance or significance of the study

The concept of monohybrid inheritance is taught to most biology students. It is an important topic towards understanding of inheritance and evolution with applications in other concepts such as maintenance of biodiversity, breeding, genetic engineering and biotechnology which today have gained significant attention as far as research and applications to save human problems are concerned. As such beginners in biology need to master this important concept. In Zimbabwe, monohybrid inheritance is taught to ‘O’ level students. Several textbooks and the ZIMSEC ‘O’ level biology syllabus recommend the use of coloured beads to model monohybrid inheritance as an activity useful to the teaching and learning of monohybrid inheritance. This is therefore widely used by teachers following this syllabus. The results of this research will therefore provide evidence-based recommendations to teachers for inclusion of coloured beads on activities necessary for teaching and learning of monohybrid inheritance. It will therefore enlighten teachers and
enhance improved learning on the part of students. This will be through implementation of
the use of the coloured beads model in teaching and learning of monohybrid inheritance or
seeking alternative methods of achieving objectives. If on the other hand findings fail to
support the use of the coloured beads then recommendations done may be done in a way
to change the method of integrating coloured beads into teaching and learning of
inheritance or suggesting other activities which can be used in the teaching and learning of
monohybrid inheritance in place of the beads model. It will also open up further research
questions which when answered finally leads to improved learning.

1.6 Delimitations of the study

The study will focus on ‘O’ level biology students at Alheit High School in Gutu district of
Masvingo Province. It will be based on aspects of monohybrid inheritance specified in the
ZIMSEC ‘O’ Level biology syllabus which require pupils to be able to:

(i) describe complete dominance.

(ii) predict possible outcomes of monohybrid crosses.

(iii) explain co-dominance.

(iv) draw genetic diagrams to show how a characteristic is inherited.

1.7 Limitations of the study

The study focused on the teaching and learning of monohybrid inheritance to beginners
who were of average age 16 yrs and had gone through the Zimbabwe Junior Certificate(ZJC)
science education. The results of the study may therefore not be applicable to a wider
population due to the fact that students in Gutu district until a year before this study with
the introduction of the Zimscience kit had not been doing much practical work. Student
attitudes towards practical work could therefore have been exaggerated by the use of the
coloured beads. The other major problem which affected this study was that it was
impossible and unethical to isolate all of the participants completely. The two groups of
children used in the study attended the same school. It is reasonable therefore to assume
that they mixed outside of lessons and shared ideas, potentially contaminating the results.
On the other hand, if the children were drawn from different schools to prevent this, the
chance of selection bias would arise, because randomization would not be possible.

1.8 Definition of terms

Allele: one of the alternative forms of a gene. In cells of organisms other than gametes,
alleles of a gene are always in pairs. An allele is said to be dominant when it can express
itself in the presence of a alternative allele and recessive when it cannot.

Modelling: carrying out a practical activity to illustrate how a process occurs by
manipulating physical objects representing main features of the process.
**Coloured beads model:** a practical activity involving manipulation of coloured beads representing alleles to follow inheritance of characteristics. It involves simulation of inheritance techniques where coloured beads show the behaviour and effect of alleles as they are passed from parents to offspring.

**Control group:** group of students taught monohybrid inheritance through supervised class discussions, question and answer, presentations and chalkboard illustrations as well as taking and explaining notes.

**Treatment group/ experimental group:** group of students who after being taught monohybrid inheritance through supervised class discussions, question and answer, presentations and chalkboard illustrations as well as taking and explaining notes were finally exposed to the coloured beads model.
CHAPTER 2

Review of related literature

2.1 Introduction

This chapter is focused on literature whose main purpose is to help the researcher to define the position to be occupied by the research within the body of knowledge which has accumulated to date on similar issues. In this chapter similar researches by other scholars will be cited. The literature is expected to give the researcher a starting point in search of new knowledge on which a case could be built through the use of logical and systematic analysis and synthesis of diverse views. The researcher will also look at how studies of monohybrid inheritance emerged. Some recommended student activities in the learning of monohybrid inheritance will be given and reasons for preference to use the beads model to other methods are explained. The researcher will then examine how the beads model is integrated into the teaching and learning of monohybrid inheritance. Keeping in mind that recommendations for improving teaching methods can be done through comparison with other methods so as to discard one in favour of the other, the chapter will end by examining ways used in comparing teaching methods.

2.2 Practical work in science teaching and learning.

Modern day teaching is inclined towards putting the child at the centre stage of learning, allowing them to construct their own knowledge rather than being passive recipients of information (Rwambiwa, 2001). This often is linked to the emphasis on practical work. Practical work is defined as that in which students manipulate and observe real objects and materials (Abrahams and Millar, 2008). In England 13 to 14 year olds spent much of their lesson time doing practical science activities (Woodley, 2009). In Zimbabwe the emphasis on practical work in science is evidenced by the effort made recently to distribute Science kits to schools. The role of teachers therefore has shifted from being possessors of knowledge to being facilitators in learning, scaffolding the child into realising their own potential.

Alesandrini (1981) suggests that learning is improved when pictures or physical objects supplement verbal materials, when learners draw their own pictures during studying and when they are asked to generate mental pictures while reading or studying. Studies by Meyer (1997) also provide evidence that teaching through visual and symbolic modes results in more efficient learning of difficult science concepts because the human mind is supported by both auditory and visual concepts. This concurs with Cobb (1997) who shares similar sentiments on cognitive efficiency on media when he stated that some media and symbol systems lead to greater learning results for some students. He noticed that the effect of media can vary with students.
Advantages of practical work

The advantages of practical work were summarised by Wellington (1998) who suggested that they stem from cognitive arguments, affective arguments and skills arguments.

From the cognitive argument it is said that practical work can engage students, help them to understand the process of scientific investigation and develop their understanding of concepts (Woodley, 2009). The Science Community Representing Education (SCORE) (2009) echoed similar sentiments when it reported that when practical work is done well it can stimulate and engage students’ learning at different levels, challenging them mentally and physically in ways that other scientific experiences cannot.

Models in particular have been seen to provide accurate and useful representation of knowledge that is needed when solving problems in some particular way (Gage and Berliner, 1992). A model makes a process of understanding a domain of knowledge easier because it is a usual expression of the topic. Gage and Berliner went further to reveal that students who study models may recall as much as 57% more on questions concerning conceptual information than students who receive instruction without the advantage of seeing and discussing models.

Under the affective argument practical work is said to be motivating and exciting, generating interest and enthusiasm (Wellington, 1998). There is evidence that practical work increases students’ sense of ownership of their work and can increase their motivation (SCORE, 2008). Rehman and Haider (2013) stressed the importance of motivation in learning and stated that with motivation students can do any task and achieve the goal.

The skills argument stresses that practical work promotes transferable skills such as observation, prediction and inference which are important in life and to future scientists.

limitations of practical work

Abrahams and Millar (2008) have strongly questioned the positive effects associated with practical work as done at schools. They recognised that for practical work to help in developing students’ scientific knowledge, the students must make links between two domains of knowledge: the domain of objects and the domain of ideas. They stated that making these links may however be challenging and require assistance from teachers who often overestimate the cognitive capabilities of their students.

It is also found that the way a presentation is done may affect learning as it may create misconceptions (Meyer, 1997). Recognising this, Hodson (1991) described the way practical work is done in schools as being ill-conceived, confused and unproductive.
2.3 The coloured beads model.

Stockler (1994) pointed out that a talk about models may refer to distinct objects such as scale models, visual representations, numerical solutions of equations, simulations, idealised or tentative hypothesis and many more. In this study a model is taken synonymously with a simulation. The coloured beads model is taken to refer to a simulation of inheritance techniques with coloured beads showing the behaviour and effect of alleles as they are passed from parents to offspring. It is thus a practical activity involving manipulation of coloured beads representing alleles to follow inheritance of characteristics.

2.4 The beginning of studies in monohybrid inheritance

Monohybrid inheritance was first studied by Gregor Mendel in 1856 through his experiments on pea plants leading to the development of the gene concept in which it was found that, a character in an individual is represented by two alleles of a gene which can either be both dominant, recessive or one dominant and the other recessive (Clegg and Mackean, 2007).

2.5 Monohybrid inheritance as taught at ‘O’ Level

The teaching of monohybrid inheritance usually involves pupils being able to define terms gene, allele, dominant allele, recessive allele, homozygous individual, heterozygous individual, genotype phenotype and being able to correctly use the terms as well as predicting genotypic and phenotypic ratios arising from the monohybrid crosses by using genetic diagrams(ZIMSEC ‘O’ Level biology syllabus,2013-2017). Assessment of the attainment of objectives is also based on these concepts as evidenced in the following ZIMSEC biology past exam papers(November 2003 Paper 1 number36, November 2011 Paper 1 number37, November 2013 Paper 1 number36, November 2002 Paper 2 number10, June 2012 Paper 2 number 10 and November 2012 Paper 2 number9).

2.6 Teaching and learning activities on monohybrid inheritance

Monohybrid crosses can be difficult to present in a novel way in an introductory biology course (Lassiter, 2010). Morden methods of teaching and learning are based on child centred approaches where learners are actively involved (Rwambwiwa, 2001). In the teaching of monohybrid inheritance several practical activities can be planned by teachers. These may include repeating Gregor Mendel’s pea experiments (Clegg and Mackean, 2007), the breeding of maize to trace inheritance of characteristics like kernel colour or shape (South Carolina State University, n. d.), carrying out breeding experiments with an organism that has a short life cycle like Drosophila melanogaster (Siti, 2010), examining phenotypes of corn produced from parents of known genotypes then discussing how they might have been produced and modelling monohybrid inheritance with use of coloured beads (Jones and Jones, 2001; Clegg and Mackean, 2007; Darwin, 2008; etc). The first two methods are time consuming as the plants have to be grown to flowering stage or maturity to notice
phenotypes. The third method involving use of *Drosophila melanogaster* can be done within two weeks (Siti, 2010) but may pose a challenge to teachers in form of the facilities to keep the *Drosophila melanogaster* for the experiments. The fourth method can be done within an hour as a planned laboratory activity involving some counting (Siti, 2010). It may however need to be cemented by another practical which involve an animal. This is mainly because pupils may end up having the wrong impression that the concept of monohybrid crosses is limited to plants upon going through an activity involving corn (Lassiter, 2010). Lassiter (2010) went further to show higher enjoyment on a model that involves use of an animal to illustrate monohybrid crosses than using a plant by students who aim carriers in human and veterinary medicine. Enjoyment in itself has the psychological effect of increasing concentration, curiosity and thus comprehension and retention of concepts. This procedure which lassiter (2010) demonstrated with the use of zebrafish (*Danio rerio*) is again difficult to use in most Zimbabwean schools due to lack of adequate resources. It is the fifth method, use of the coloured beads model, which most teachers may end up finding easy to integrate in their lessons as evidenced by recommendations in some national biology syllabuses (Cambridge ‘O’ Level biology syllabus (5090) for examinations in June and November 2015; and ZIMSEC’O’ level biology syllabus (5008) for 2013-2017). This is because the materials for use in this activity are readily available and also considering the fact that it is a neutral activity which does not create a bias as to whether monohybrid crosses are limited to plants or animals.

### 2.6 Modelling monohybrid inheritance with use of coloured beads

Use of coloured beads in modelling monohybrid crosses involves pupils following well designed procedures where beads represent alleles (Appendix i). The colour of the seed denotes dominance or recessiveness of alleles. Containers of seeds with same colour represent organisms with homozygous genotypes while those with equal numbers of two different colours denotes organisms with heterozygous genotypes. During the use of coloured beads in modelling monohybrid inheritance, crosses are demonstrated by randomly picking a bead from one container then picking another from another container without looking and recording the colours of the two seeds representing the genotype of the zygote. This is repeated until the number of offspring needed for the experiment is produced (Twesigye, and Fraser, 2006). Pupils are made to complete tables from which discussions and conclusions on monohybrid crosses can be done. While this method improves student psychomotor skills through handling materials, allows active student participation which improves retention as well as putting students at the centre stage of learning hence likely to lead to lifelong learning (Rwambiwa, 2001), some students at Alheit high school have over the past four years shown difficulties in interpreting the experimental procedures. This often produced some misconceptions likely to result in confusion and decreased performance on standardised tests on monohybrid crosses.
2.7 Research gap

The researcher has noted that while the beads model is a well documented method of enhancing learning and teaching of monohybrid crosses and seems to be most convenient for use by teachers when resources and time are limiting, its effectiveness on teaching and learning of ‘O’ level students has never been put to test. It is therefore upon this background that the researcher finds interest in the model.

2.8 How to compare teaching methods

The improvement of teaching methods has always been done through comparison with other methods. In comparing the effectiveness of two teaching methods Merril (1995) used a quasi-experimental design involving pretesting and posttesting control and experimental groups. Data analysis was done through a statistical procedure, the analysis of covariance. A statistical test, the t-test was also applied in comparing “Planned lecture” Versus “Cooperative learning” in teaching hypertension in undergraduate medical students (Sobhani, Ahmadi, Jalili, Nadiahhatmi, Olang, Eslami and Gatmiri, 2012). In comparing the effectiveness and efficiency of two teaching methods Ozmen and Unal (2008) used criterion referenced tests. There were only four participants in the study so no statistical tests were used in data analysis but simply comparison of scores obtained. Shuttleworth (2009) suggests the t-test for independent samples as a way of analysing data following a two-group posttest-only randomised experimental design.

2.9 Summary

This chapter has considered some arguments for and against practical work in science. Focus has then been made towards the topic Monohybrid inheritance done at ‘O’ Level biology as based on ZIMSEC learning objectives and the various activities which are recommended for effective learning. An evaluation of the different recommended practical activities has been considered with particular reference to Zimbabwean schools. Having singled out the use of coloured beads as the most feasible activity to employ in illustrating monohybrid crosses a particular examination of this method has been done as a guideline to chapter 3 on methodology. Realising that no particular work has been found on the effectiveness of the coloured beads model in illustrating monohybrid crosses at Alheit high school, a turning point towards interest in this research area has been pointed out. Finally an examination on methods available for comparing teaching methods was done to guide the researcher on methodology and data analysis later.
CHAPTER 3
Methodology

3.1 Introduction

This chapter focuses on how data from which conclusions of the study were derived was obtained. It begins by looking at the research design used and justification for its use. The population on which the study is based is defined then the sampling technique explained highlighting its appropriateness. Operational details in terms of how and who administered the research instrument during data collection are given. Ways of reducing subjectivity during this stage are highlighted. A data analysis plan is suggested before finally giving a brief discussion of the ethical considerations taken care of during this research.

3.2 Research design

The research seeks to assess the effectiveness of using ‘the coloured beads model’ in the teaching and learning of monohybrid inheritance to ‘O’ level biology students at Alheit high school. In order to determine this effectiveness, a mixture of qualitative and quantitative approaches were used though the research was largely quantitative. Qualitative research is that in which findings are not arrived at by statistical procedures while quantitative research presents statistical results in the form of numbers (Chiromo, 2009). Combining quantitative and qualitative data was done as a way of triangulation to improve validity and reliability of research findings, allowing verification of results from quantitative data using qualitative data. Triangulation is the combination of methodologies in the study of the same phenomenon (Denzin, 1978). The two approaches to research were also combined to facilitate explanation of research results where qualitative data would be used to understand unanticipated results from quantitative data. This was particularly important in this research since no similar research on effectiveness of use of coloured beads in teaching and learning had been done before at the school and in Gutu district.

On the quantitative part of the research, a two-group experimental posttest-only randomised design was used. An experimental design is where the researcher controls the factors to which the subjects are subjected during the period of inquiry (Chiromo, 2009). Its major features are the manipulation of independent variables, random selection and assignment of subjects to groups as well as employment of a control group. In this study where test scores after a teaching method involving the beads model were compared with those in which the model was not involved in teaching and learning, the independent variable was whether or not the beads model was used in teaching and learning of monohybrid inheritance while the dependent variable was the mean test score obtained by students.

This design is said to be a ‘two-group’ since an experimental group (exposed to use of coloured beads to model monohybrid inheritance) and a control group (not exposed to use
of coloured beads) were used. It is a ‘posttest only’ since the performance of the two groups were compared only after subjection to treatment.

The qualitative aspect of this research was on where the researcher obtained information about students’ learning in both the control and treatment group through open ended questions on questionnaires.

3.3 Research instruments

The practical work with coloured beads (Appendix i) was one of the research instruments used. A test administered at the end of the topic on Monohybrid inheritance (Appendix ii) was taken as the main research instrument producing quantitative data. Two questionnaires, one for the control group (appendix iii) and the other for the treatment group (Appendix iv) were also used as research instruments to allow for collection more quantitative data and some qualitative data.

(i) Practical work with coloured beads

The practical procedure was drawn by the researcher by consulting some ‘O’ Level textbooks (Darwin, 1998 and Jones and Jones, 2001). The tasks for students were written down (Appendix i) and validated by asking colleagues to read through it and raise any unclear stages as well as pilot-testing it with students from another school.

(ii) The Test

The test was used as the main research instrument to obtain quantitative data. It was given at the end after subjects were exposed to different treatments. Its advantage was that it made it possible to obtain data in the form of figures which could allow for interpretation by statistical means. Analysis of data by statistical means is unique to experimental designs. To enhance validity of this instrument, test questions were extracted from ZIMSEC ‘O’ Level biology past examination papers. This is because ZIMSEC is a reputable national examinations board which assesses achievement of syllabus objectives hence the effectiveness of the coloured beads model in the teaching and learning of monohybrid inheritance. The main disadvantage of this research instrument was that internal validity with the use of a test would be threatened by the fact that some students would have already revised the past examination papers containing the questions hence would simply reproduce what they would have covered and this wrongly imply they learned better. This was reduced by slightly changing questioning then validating the meanings by asking colleagues. Its other disadvantage was that validating the instrument by pilot-testing within the population under study was not possible as it would threaten internal validity through diffusion whereby information about the test would spread to other students from the students used for pilot testing to the rest of the population. This would be disastrous if by any chance the spreading would be differential between the treatment and the control group. Taking this into consideration the pilot testing was done using another population
where a sample of students were taken from a different school which had covered the topic. While pilot testing with a different population may generally seem inappropriate, this could not be so in this particular case since the different school chosen follows the same ‘O’ level biology syllabus and writes the same biology examination at the end of the ‘O’ level course hence the two populations were very similar.

(iii). The questionnaires

A questionnaire is a form of inquiry which contains a systematically compiled and organised series of questions that are sent to the population samples (Chiromo, 2009). The questionnaires used in this research contained both open ended and closed questions (Appendices iii and iv). Closed questions were used to assess the effectiveness of use of coloured beads in teaching and learning of monohybrid inheritance in terms of: how it could affect the general view of the topic by students as compared to other topics done; its effect on enjoyment of lessons; how students rate its effectiveness in reinforcing genetic concepts; how it affects students’ ability to define new terms in the topic as well as its effectiveness in enhancing ability to correctly draw genetic diagrams. This therefore yielded quantitative data. Focus was given on these aspects as they cover the objectives stated in the ZIMSEC syllabus objectives under monohybrid inheritance. The open ended questions allowed subjects to freely make comments hence yielded qualitative data which was important in explaining some unusual findings from quantitative data. The open ended and closed questions used were somehow designed in a way that could allow for checking validity and reliability. This was so because a link was expected in the responses given to closed questions and responses to open ended questions. It thus indirectly tested how truthful the subjects were in their responses. In addition the open ended questions on what students liked most or least in the topic and free comments on the use of coloured beads in teaching and learning of monohybrid inheritance would possibly allow for new information needed for further research.

Questionnaires were used in this research mainly because all subjects, who were ‘O’ Level pupils, were known to be able to read and write hence there could not be problems in giving responses. The questionnaires could also give subjects enough time to respond hence reduce chances of no responses which would otherwise compromise validity of the study considering that the population under study was small. In this situation few responses to questions would thus lead to unrepresentative results. In the study, the main disadvantage of the questionnaire was that students could give false information if they would link the questions to competence of their teacher. This was however reduced by clearly explaining the purpose of completing the questionnaire as a research whose findings would benefit both the teacher and students.
Validity and reliability of the questionnaires were enhanced by asking colleagues at the researcher’s workplace to explain what the questions designed were asking. Where variation to what the researcher set to ask was implied, the questioning was changed until the meanings conformed. Pilot testing was also done with the questionnaires on small samples from a similar population composed of ‘O’ level biology students from other schools. Questionnaire for the control group (Appendix iii) was pilot tested with students from a school which had not included the use of coloured beads in their lessons on monohybrid inheritance while that for the treatment group (Appendix iv) was pilot tested with students who had been exposed to modelling monohybrid inheritance with coloured beads. This was important to check the subjects’ perception of meanings of questions, terms and instructions.

3.4 Population

The study was based on Form 4 biology students at Chingombe 2 Alheit High School. There were 50 students doing biology at the school in Form 4. The class had 27 boys and 23 girls. These students were therefore taken to make up the population of study.

3.5 Sample and sampling procedure

A random sample of 48 students, the first 22 girls and 26 boys was obtained from the population by using the hat system. This is whereby the subjects making up the population are coded and the codes written on identical cards which are then mixed up in a hat before they are then randomly picked from the hat until the required number is obtained. A randomised block design was used to assign the treatment to subjects. The male students and female students represented the blocks. These blocks were used because academic performance in biology at the school had been found to be different between the male and female students with males found to perform better as based on test scores obtained on earlier chapters covered. Within the blocks subjects were randomly assigned into the control and treatment groups by using the hat system. This sampling technique was chosen for its fairness in making comparisons as each participant had an equal chance of being selected into either group. Simple random sampling was avoided as it would by chance include members of the same sex in one group and thus threatening internal validity. Of the 50 students in the population one boy and one girl were not included in the study to maintain equal numbers of boy or girl students in the control and treatment groups. However these students were allowed to take part in all lesson activities and were only excluded on data analysis.

3.6 Data collection procedure

Using the hat system students at the selected school were randomly put into two groups, the control group and the experimental group. The groups were formed some three weeks before the students took part in the experiments. This allowed a chance for some selected
lessons to be conducted with students in their respective groups. These lessons were designed to be conducted in the same way except for the difference in students involved. This served to reduce suspicion of anything when finally the treatment was administered to the experimental group. This therefore improved internal validity which was likely to be threatened by diffusion whereby treatment would spread from the treated to the untreated

(i) Applying the treatment

Students in the treatment group were allowed to go through the practical work (Appendix i) within two 35 minute periods. The lesson was introduced by describing the objectives of the practical and discussing what the containers of beads represented. During the practical the teacher was expected to move around assisting students, helping them linking the activities with theory. The teacher would also have to call for whole class discussion when he saw it fit. On the following day, the first 35 minutes of the biology lesson after the practical were used for discussions to consolidate the practical activities. Misconceptions as seen from students’ answers to questions asked were corrected.

As students in the treatment group were receiving the treatment those in the control group continued with presentations, discussions and some question and answers on the topic.

(ii) Administering the test

All participating students were told of the test some two days before it was written. The test was written by the students on the same day and at the same time. Lesson activities prior to writing the test were the same for the control and treatment groups except where the treatment group was exposed to modelling monohybrid inheritance using coloured beads. Lessons were conducted by the teacher of the students after a discussion of the teaching methods with the researcher. The student’s usual teacher was found suitable to administer the test to avoid students suspecting they were being observed. If this could happen then validity could be threatened by the ‘Hawthorne effect’. This effect is whereby an increase or change in performance by subjects occurs simply because subjects learn they are being observed (Chiromo, 2009). While this may not seem to bring a significant change in performance for a test designed to assess understanding of concepts, it must be emphasised that this could possibly lead to resentful demoralisation where individuals may become less productive suspecting that another group obtained special treatment. The ‘John Henry effect’ where the untreated group suspect others received a special treatment then work hard to see to it that the expected superiority of the treatment group is not demonstrated could also begin to show. This could be expressed through cheating by students in the test.

The test was also marked by the usual teacher of the students using a marking scheme prepared and discussed by the teacher and researcher. To improve reliability and reduce
subjectivity, the researcher also obtained samples of marked scripts, remarked them and then used them to moderate other students’ marks before data was analysed.

(iii) Administering questionnaires

Two questionnaires (Appendices iii and iv) were used in data collection. The researcher administered the questionnaires to subjects with assistance of the students’ teacher. The questionnaires were completed on the same day by the treatment and control group before the lesson to compensate the control group on using coloured beads to illustrate monohybrid crosses was done. To ensure students freely take part in completion of the questionnaires the purpose of the research was clearly explained. The control and treatment groups were given different questionnaires (Appendix iii for control group and Appendix iv for treatment group).

3.7 Data presentation and analysis procedures

The test score for each student was obtained. To allow for comparison, the test results were presented in the form of a stem and leaf diagram. This served to show the two data sets side by side making comparison easier. It also gave an idea of the distribution of the results as would be obtained from a bar graph or histogram and had an added advantage of retaining raw data which was used to calculate mean scores and pass rates. Comparison of the mean scores was then done by use of the t-test for independent samples.

Quantitative data from questionnaires was presented in the form of bar graphs for easy comparison of information under different categories considered. Qualitative data was organised into themes relating to learning of aspects of monohybrid inheritance. Some excerpts were included to gain understanding of the effect of use of coloured beads to represent alleles in teaching and learning of monohybrid inheritance to ‘O’ level biology students from the respondent’s perspective.

3.8 Ethical considerations

Research ethics are defined as the principles of right and wrong that guide researchers when conducting their research (Chiromo, 2009). During this research several ethics were considered and are described in the different stages of the research. Among them were seeking consent from the school administration to carry out the research with students. Subjection of students to different treatments during the research would also raise ethical questions hence it was ensured that the control group was also exposed to modelling monohybrid inheritance after the test was written. Some extra lessons on biology were also later arranged to cover up for time lost when some lessons had to be done separately for the same class during the period of research. Confidentiality of respondents to questionnaires was assured and maintained as no names or sex was included in the questionnaires.
3.9 Summary

This chapter has shown how research data was obtained by looking at the research design employed, research instruments, population studied, sample and sampling techniques used. An evaluation was done at each stage to consider the limitations and advantages with reference to this particular study. A data presentation and analysis procedure used in the next chapter was suggested. The chapter ends by summarising the ethical considerations taken care of under this stage of research.
CHAPTER 4

DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Introduction

In this chapter, research findings were presented, analysed and discussed through the effective use of a stem and leaf diagram, a table, a statistical test, bar graphs and careful use of quotes.

4.2 Effect of using coloured beads on performance

The distribution of test scores for the treatment and control group was found to be different as shown in Fig 4.1.

Control group | Treatment group
---|---
3 0 2 0 7 | 3 3 0 7 7
7 7 7 3 3 3 0 0 0 4 7 | 7 7 3 3 3 0 0 5 3 7
7 3 6 0 0 3 3 7 | 3 3 7 0 3 3 3 7 7 7
3 8 3 3 7 7 | 3

Key

| Control group | treatment group: control group- 40% | treatment group- 47% |
---|---|---|
04 7 | 4 | 7

Fig 4.1. Distribution of test scores for the control and treatment groups.

The use of coloured beads to represent alleles in modelling monohybrid inheritance was found to have a significant increase in performance of students giving a pass rate of 71% for the treatment group compared to 54% for the control group. Analysis of the results using the t-test for independent means also suggested a significant difference in the performance of pupils exposed to modelling inheritance through the use of coloured beads and those not
exposed to the model ($t_{calc} = 2.34 > t_{crit} = 2.01$). This improvement in performance is in line with studies by Gage and Berliner (1992) who found that students who study models may recall as much as 57% more on questions concerning conceptual information than students who simply receive instruction without the advantage of seeing and discussing models.

By examining the stem and leaf diagram (Fig 4.1) it is seen that 11 pupils out of the 24 on the treatment group excelled with at least 70% compared to only 3 pupils on the control group. This shows that the practical with coloured beads greatly improved students’ thinking skills as suggested by Chaplin (2007). This could be particularly so as students had a chance to discuss and share ideas since they were working in pairs.

A study by Meyer (1997) also provided evidence that teaching through visual and symbolic modes results in more efficient learning of difficult science concepts. This is because the conscious human mind is supported by both auditory and visual buffers. Through the beads model therefore, pupils were able to visualise the action taken by alleles in monohybrid inheritance hence could follow the inheritance process. This then explains why they got higher scores in the test.

### 4.3 Why more students got scores at the lower extreme on the treatment than on the control group.

From Fig 4.1 5 students had 40% and below on the treatment compared to only 3 on the control group. This result contradicts the general view arising from overall pass rates and mean scores that the use of coloured beads improves learning. However it is in line with an observation by Woodley (2009) who noticed that offering a good practical task that achieves its aims of effectively communicating a clearly defined set of ideas may be difficult to achieve. This concurs with Hodson’s view (1991) who got to the extend of describing the way practical work is done at schools as being ill-conceived, confused and unproductive. In practical work, the cognitive challenge for students is often underestimated with the result that teachers appear unaware that some tasks are much more demanding than students can handle on their own. Looking at the comments by students on how they felt about the practical on coloured beads, an important comment arose in support of the above as “Teacher must give more explanations. The link between genes, alleles, gametes and the coloured beads was confusing.” The comment emphasises how some students may become lost during the practical activity with coloured beads. Although the teacher was supposed to assist students during the practical this comment shows that some students felt teacher intervention was not sufficient. There is evidence that teachers may only monitor completion of set procedures without ensuring that students get the underlying principles of set practical activities. As such, some students may successfully obtain expected results and the teacher thinks they have mastered the concepts yet they may have not at all. Teachers must therefore be ready to scaffold pupils in each practical activity so that they make correct cognitive links between a given practical and theory (Abrahams and Millar, 2008).
While the procedure for the practical allowed for discussions with the teacher these were probably not helpful considering that they were completed on the following day. That less students were seen on the lower extreme at the control group could also be explained to be a result of more revision done when the control group was doing practical work with coloured beads.

### 4.4 Students’ rating of the topic of Monohybrid inheritance

As shown in Fig 4.2 below, 62.5% of the students rated the concept of monohybrid inheritance as being easy to understand on the treatment compared to only 25% on the control group.

![Graph showing student ratings on the concept of monohybrid inheritance.](image)

**Fig 4.2.** Student ratings on the concept of monohybrid inheritance in relation to other biology topics covered.

The difference in number of students finding the concept easy on treatment and control groups can be explained in terms of the increased sense of ownership by students of their learning which arise from doing practical activities (Johnstone and Al Shualili, 2001). This sense of ownership increase students’ motivation and once motivation is increased students’ learning is improved (Rehman and Haider, 2005). As students went through the activities in modelling monohybrid inheritance with coloured beads, motivation could also be enhanced through a sense of competition which occurred among paired students. It could also arise from the sense of responsibility which developed as they worked to successfully complete the tasks given. The activity also gave a chance for the teacher to move around and have some close teacher-student interactions. The teacher thus
motivated more students through some praises as he moved around and had a chance to attend to particular students’ problems. All this helped motivate students (Rehman and Haider, 2005) and therefore improved confidence among them, explaining why more students on the treatment group finally found the topic easy. With an increased self efficacy there is higher academic achievement (Bandura, 1997). From this discussion it is therefore important to notice that the higher performance in the test by the treatment group than by the control group (Fig 4.1) could also be explained from the improved confidence in mastery of aspects shown in Fig 4.2.

4.5 Students’ enjoyment of learning monohybrid inheritance

As shown in Fig 4.3 below 50% of the students who were exposed to modelling with coloured beads were also seen to have shown higher enjoyment in learning monohybrid inheritance compared to only 29% in the control group. On the other hand 54.2% showed no enjoyment in the control group compared to 16.7% for the treatment group.

![Fig 4.3. Students’ enjoyment of the topic ‘Monohybrid inheritance.’](image)

The results show that the use of coloured beads improves enjoyment of the topic. Studies have shown that an absence of enjoyment is one of the foundational reasons for young people failing to achieve their potential (Goetz, Nathan, Hall, Anne, Frenzel, & Pekrun, 2006). Rwambiwa (2009) pointed out that learning becomes easier when student interest is captured. This
therefore implies that it became easy for students to understand the topic on monohybrid inheritance as using the beads made them enjoy it.

4.6 Students’ assessment of effectiveness of using coloured beads in learning monohybrid inheritance

Students were asked to assess the effectiveness of the use of coloured beads on their mastery of three aspects which are reinforcement of genetic concepts, definition of terms and the drawing of genetic diagrams using three categories of responses which are ineffective, moderately effective and effective. The distribution of responses was as shown on Fig 4.4.

![Bar chart showing students’ assessment of the effectiveness of the coloured beads model on aspects of their learning.](image)

Fig 4.4. students’ assessment of the effectiveness of the coloured beads model on aspects of their learning.

As on Fig 4.4 above for each aspect assessed the proportion of students who thought the coloured beads model was ineffective did not exceed 25%. As an active learning exercise, the use of coloured beads in simulating monohybrid inheritance help build critical thinking skills (Dillon, 2008) which are desired in Bloom’s taxonomy of critical thinking and can help students perform better in exams (Chaplin, 2007). Discussion of questions during the practical activity (Appendix i) together with other questions generated and discussed by students would help students understand concepts better.
4.7 What students liked best and least in the topic of Monohybrid inheritance

Four themes emerged from students’ responses on what they liked best or least and these were categorised as; mastery of concepts, interaction, nothing and writing. It was clear that many students on the control group were limited to put their likes on mastery of concepts with many indicating that they did not like the topic as it was difficult. One student put off by the need to be able to define new terms made the comment, “who would like to define several new terms in one topic?” In contrast a student exposed to modelling monohybrid inheritance commented “it came so natural to me to distinguish the terms allele and gene as well as genotype and phenotype during discussions following the practical with beads.” From the two comments one can conclude that students can more easily learn new terms when they use them in lesson activities rather than trying to come up with the definitions simply written by teachers as notes. This is in line with the constructivist perspective that learners construct knowledge by solving genuine meaningful problems (Lunetta, Hofstein and Clough, 2007). Since the test used for assessment of learnt concepts (Appendix ii) had some terms to be defined and distinguished it then explains why students exposed to modelling with coloured beads performed better as shown on Table 4.1 and Fig 4.1.

4.8 Students’ feelings on the use of coloured beads.

Students liked the practical with coloured beads as many felt it was interesting and improved understanding of concepts. Taking just two comments in support of this, one student had to say

“at least we had a chance to discuss our challenges with the teacher during the practical” and the other had to say “it made me think and see the topic in a different way. It opened up my mind. I can now distinguish some terms and follow steps for drawing a genetic diagram.”

From the first comment it is clear that the teacher did not normally attend to all students’ needs. This was particularly so considering the large biology class. However when the coloured beads model has to be used in a lesson it becomes more likely that most students are attended to as the teacher will have to monitor students working through the practical activity. This is unlike in the traditional lecture method where the teacher may be found concentrating on bright student as they are the ones who will quickly respond to questions occasionally asked as the lesson progresses.

From the second comment the practical really seem to have a significant effect on mastery of concepts. This concurs with the study by Meyer (1997) which provided evidence that teaching through visual and symbolic modes results in more efficient learning of difficult science concepts mainly because the conscious human mind is supported by both auditory and visual buffers. Through the beads model therefore, pupils were able to visualise the action taken by alleles in monohybrid inheritance hence could follow the inheritance
process. Through manipulating the beads students were able to learn through the enactive mode (Bruner, 1966). They were also able to see through the viewpoint of the teacher and this is important in learning (Millar, 2004). While Millar (2004) pointed out that discussion without practical work may equally enable students to gain scientific concepts, he stressed that this can be so where prior student experience will provide a base on which to start the discussion. In this view the coloured beads model was useful as no previous experience with alleles could have occurred to students. This in turn explains why students exposed to modelling with coloured beads performed better

4.9 Summary

Presentation of data in the form of a stem and leaf diagram, a table, bar graphs and some written descriptions has allowed the researcher to establish that the use of coloured beads in modelling monohybrid inheritance improves learning. This increase has been explained in terms of other researchers’ findings on similar work. Realising the absence of particular work on use of coloured beads to model monohybrid inheritance by other researchers, the researcher has also attempted to explain the findings of this particular research by considering how students rate the model as used in their learning. Their views showed that the model gives them confidence in mastery of concepts hence the increased performance. A decreased performance on some students associated with the use of this model has been explained in terms of the need to by teachers to closely monitor their students and clarify concepts when necessary during the lesson as suggested by the students themselves. Work by other researchers has been cited to support raised arguments.
CHAPTER 5

Summary, conclusions and recommendations

5.1 Introduction

This chapter outlines how the research to assess the effectiveness of using coloured beads to represent alleles in the teaching and learning of monohybrid inheritance to ‘O’ level students was done. Major research findings and their interpretation is given. The chapter ends by giving recommendations to teaching monohybrid inheritance as well as recommendations for further studies arising from this study.

5.2 Summary

The main thrust of this study was to assess the effectiveness of the beads model in the teaching and learning of monohybrid inheritance to ‘O’ level students by examining test scores for the two groups of pupils taught. One group was taught using the model and the other was not exposed to the model. Conditions other than the use of the model were controlled between the two groups. Subjects were randomly placed into the two groups. The same number of students was used in each group and there was same distribution of male and female students.

Data gathering was done through the use of questionnaires and a test administered to the subjects.

The results obtained were presented using descriptive statistics and some excerpts. The treatment group showed a higher percentage of pupils who excelled than the control group. Control group on the other hand had a higher percentage of pupils in the 40%-49% mark range and a relatively lower percentage below 40% test score than the treatment group.

These findings showed that the beads model greatly improves learning.

5.3 Conclusions

The research findings have shown that the bead model has a positive effect on the overall performance of pupils. It greatly improves learning. It has been shown to improve performance of averagely performing students to levels of excelling. The effectiveness of the beads model in improving teaching and learning has however not been found to stretch across all pupils as an increase in the number of very low achievers has also been found bringing in the aspect of confusion which may be introduced during its implementation.

5.4 Recommendations

Basing on the research findings the teaching of monohybrid inheritance really have to involve well organised modelling of monohybrid cross with coloured beads as it has been
found to greatly improve learning process. For effectiveness the following suggestions are made.

- modelling with beads should be done at the end of the topic so that pupils link the action of beads to behaviour of alleles during inheritance.

-teachers should set clear objectives for the practical and ensure these are achieved.

-Teachers must not only monitor the completion of stages of the model but scaffold pupils in linking the action of the beads to the action of alleles and their significance in inheritance. This can be done by asking questions.

-students should be allowed to discuss the practical and ask questions.

- responses to written questions on the practical procedure given for student discussion should be checked and used

5.5 Further research

A clear need arise to design an effective way of integrating the coloured beads model into teaching and learning so as to cater for all students.
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APPENDICES

Appendix i

Practical: Modelling monohybrid inheritance.

Materials

3 containers, 100 red beads, 100 yellow beads, plastic 500 cm³ beakers

Procedure

You will need to work in pairs for this investigation.

(a) Place 100 red beads in one container to represent the gametes of the tall parents. Place 100 yellow beads in the second container to represent the gametes of the dwarf parents.

(b) Withdraw a bead from each container. Each bead withdrawn represents a gamete containing a single gene of a pair. Place the beads together. This represents the process of fertilization, by which the paired nature of genes in the offspring is re-established. The pair of beads represents the genotype of an individual of the F₁ generation.

(c) If you continued to withdraw pairs of beads as above, what would be the genotype of all the F₁ individuals?

(d) To simulate the gametes of F₁ generation, place 100 beads (50 red and 50 yellow) in each container. One container represents the female gametes produced by the F₁-generation; the other represents the male gametes produced by F₁ generation.

(e) Shake the containers vigorously for 30s.

(f) To produce the F₂ generation, withdraw a bead from each container (with your eyes closed) and place them together. Your partner should note the combination of genes obtained. This represents the genotype of an F₂ individual.

(g) Discard the pair of beads into the spare container.

(h) Repeat steps (f) and (g) until all the beads have been paired and their combination noted.

(i) Calculate the ratio of phenotypes of the F₂ individuals.

(j) Record the ratios obtained by other groups in your set and calculate a set average ratio.

Discussion of results

1. Why were the beads shaken in step (e) and withdrawn with closed eyes?

2. Present your results in the most appropriate way.

3. How does your ratio and the set average ratio compare with Mendel’s prediction? Explain any differences.

4. Explain how this practical acts as a model for inheritance and breeding in peas.
Appendix ii

TEST: INHERITANCE (40 minutes)

1. Define the following terms:
   (i) Dominance
   (ii) Homozygous
   (iii) Genotype. [3]

2. (a) Distinguish between
   (i) Allele and gene
   (ii) Phenotype and genotype [4]
   (b) Describe how Down’s syndrome is inherited in humans. [4]
   (c) A woman of blood group O has a child who is also blood group O. The woman claims a
       man of blood group AB is the father of the child. Show by means of a full genetic diagram if
       this man is the father of the child. [7]

3. Fig. 1 shows the inheritance of wing colour in beetles. Allele A for black colour is
   dominant to allele a for white colour.

   ![Fig. 1 offspring of beetles showing inheritance of wing colour]

   (a) Define the term dominant allele. [2]
   (b) Explain by means of a genetic diagram how offspring in Fig. 1 was produced. [6]
   (c) State all possible parental genotypes which could produce the following offspring
       phenotypes.
       (i) White beetles only. [2]
       (ii) Black beetles only. [2]
Appendix iii

Questionnaire for pupils (control group)

I am a student at Bindura University of Science Education. This questionnaire seeks information for writing up a research project whose purpose is to improve the teaching and learning of monohybrid inheritance at Ordinary Level Biology. All information you provide will be treated with confidentiality and shall be used purely for academic purposes.

Hint: show your responses by circling the appropriate letter or filling in blank spaces provided

Questions

1. How do you rate the topic of Monohybrid inheritance among other topics in biology?
   A. Easy      B. Difficult      C. undecided

2. How do you rate your enjoyment of lessons on monohybrid inheritance?
   A. Low enjoyment      B. No enjoyment      C. High enjoyment

3. What did you like best in the topic ‘Monohybrid inheritance’?

   …………………………………………………………………………………………………………………………………………………………………

4. What did you like least in the topic ‘Monohybrid inheritance’?

   …………………………………………………………………………………………………………………………………………………………………
Appendix iv

Questionnaire for pupils (treatment group)

I am a student at Bindura University of Science Education. This questionnaire seeks information for writing up a research project whose purpose is to improve the teaching and learning of monohybrid inheritance at Ordinary Level Biology. All information you provide will be treated with confidentiality and shall be used purely for academic purposes.

Hint: show your responses by circling the appropriate letter or filling in blank spaces provided

Questions

Section A (The topic ‘Monohybrid inheritance’)

1. How do you rate the topic of Monohybrid inheritance among other topics in biology?
   A. Easy                              B. Difficult                                  C. Undecided

2. How do you rate your enjoyment of learning monohybrid inheritance?
   A. Low enjoyment           B. No enjoyment                 C. High enjoyment

3. What did you like best in the topic ‘Monohybrid inheritance’?

   ……………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………

4. What did you like least in the topic ‘Monohybrid inheritance’?

   ……………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………

Section B (The use of coloured beads)

Assess the effectiveness of the lesson on use of coloured beads on your understanding of the following concepts.

1. Reinforcing genetic concepts
   A. Ineffective   B. Moderately effective   C. Effective

2. Definition of terms
   A. Ineffective   B. Moderately effective   C. Effective

   A. Ineffective   B. Moderately effective   C. Effective

4. Briefly comment on how you feel about the use of coloured beads in illustrating monohybrid inheritance.

   ……………………………………………………………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………………………………………………………
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