Concept mapping and pupils' learning in primary science in Singapore

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Abstract

This paper reports on a quasi-experimental study which examined the effectiveness of concept mapping as a revision tool in enhancing pupils' examination performances in primary science. The research objective seeks to determine whether there are significant differences in achievement between the concept mapping and traditional method of revision groups after treatment in both primary gifted and mainstream classes. This research hopes to establish the relationship between pupils' understanding of science concepts along with performance and use of concept mapping as a revision tool in primary science. Findings of this study will be useful towards the implementation of concept mapping as an instructional and revision tool in the primary science classroom.

Objective

The purpose of this study is to examine, in a systematic manner, the effectiveness of concept mapping as a revision tool in enhancing pupils' learning and understanding of primary science concepts.

Interest in knowledge representation and knowledge elicitation has increased greatly over the past decade and new literatures are emerging on this topic. However, a literature search on concept mapping in Singapore classrooms revealed that thus far no systematic studies have been done, especially in the area of primary science education. Research on concept mapping has only been systematically examined and documented in the teaching of lower secondary history (Loh, 1987) and secondary science (Mohamed Nasir, 1992) in the local context. There were three conference/seminar papers involving the use of concept mapping in science in Singapore (Chang, 1989; Lloyd, 1992; Wan, Lee, Goh & Chia, 1992)

This study extends the research on concept mapping done in Singapore to primary science classrooms in terms of its effectiveness and potential in enhancing learning and understanding science concepts as compared to the traditional method of revision using outlining method among both the gifted and main stream pupils.

Significance

Findings from this study will go some way in addressing the lack of knowledge arising from systematic studies on the use of concept mapping in primary science classrooms in Singapore.

It will also complement existing knowledge concerning the use of concept mapping in science classrooms overseas, as well as locally in the use of concept mapping in secondary and non-science classrooms.

Research questions

The following research questions are proposed to further investigate this learning heuristic.

RQ1. Does concept mapping as a revision tool help primary school pupils (both gifted and main stream) achieve better performance in terms of marks in science tests and assessments?

RQ2. Does concept mapping as a revision tool enhance concept retention in pupils?

Background and introduction

The current method of teaching science in primary schools is often didactic and does not engage pupils' prior knowledge actively (Toh, Ho, Chew & Riley, 2003). It is not surprising that pupils learn science concepts by rote (Songer & Linn, 1991). Instead of understanding the science concepts, pupils tend to view science as pieces of information and do not see the big picture of a unit of learning. As a result, new concepts are not assimilated into the long-term memory of the pupils (Novak, 1993) and there is often a lack of understanding of concepts and principles.

As most of these new concepts learnt soon become irretrievable from long-term memory and even if recalled, the learner utilize the knowledge in new contexts, as in novel problem solving. This inability to transfer knowledge is considered as situated learning.

The trend of science questions in recent Primary School Leaving Examination (PSLE) requires more application than recollection of knowledge. (Sample PSLE past year questions). Questions no longer test on direct regurgitation of facts. Questions now require pupils to apply and synthesise concepts to offer solutions to problems. Pupils cannot cope with these demands to answer such PSLE science questions confidently. These observations suggest that local primary pupils may not fully understand the science concepts they are supposed to have learnt, much less to be able to link and apply the learnt concepts.

The Singapore primary science syllabus, though thematically and spirally taught to the pupils over four years, is often characterized by lack of coherence. For example, according to the syllabus, the pupils are taught the topic of materials in primary three followed by that on matter in primary four, without the association that materials learnt in primary three can be subsumed under matter. There is anecdotal evidence that many primary four pupils learn aspects of matter as isolated elements of knowledge instead of well structured and integrated domain-specific knowledge structures, as in relating matter to materials. Such pupils do not appear to possess a well-founded basic framework in which newly acquired concepts can be integrated. This lack of integration is suspected to be at the root of pupils' difficulties concerning concept formation and application of acquired knowledge.

Even with the encouraged inclusion of concept mapping as a teaching method in primary science, as documented in the guide to teaching and learning of primary science (CPDD, MOE, 2004) due to its widespread usage in overseas and foreign studies, most instructions in primary science currently still tend to focus on mastery of scientific words and terms, with the usual sequence of instruction "being assign, recite, test and discuss test." Science instruction remains decidedly didactic. The fact that most science textbooks do not reveal to teachers how to deeply explore content concepts has resulted in no or weak inclusion of concept mapping in science classroom teaching. Even if concept mapping has been used in some primary science classrooms, there has yet to be any systematic research done to gauge its effectiveness in enhancing learning and performance.

In the context of organized systems of education, the impact of time on children's learning is extremely important because the progressive structuring of knowledge and understanding is gradual. For teaching and learning to be successful, we expect learners to acquire not only new knowledge in sufficient depth, but also to retain this knowledge for a long period of time after instruction. There are two reasons for this. First, this concept durability is needed to equip future citizens with the skills and knowledge accumulated over their school lives for use in real-life settings. Second, further learning is to be based on existing prior conceptions of the learner (Bjork, 1996).

The learner and learning: philosophical and theoretical principles

Meaning of meaningful learning

Studies (e.g. Gabel, 1987) have shown that pupils may produce correct answers to various kinds of problems, but their understanding of the underlying science concepts is lacking. On the surface pupils are able to perform the required operations but their shallow understanding results in under performance in the subject.

The key factors contributing to the low level of conceptual understanding and large number of misconceptions among pupils is that current science teaching methods employed do not seek to diagnose or engage pupils' prior knowledge. Didactic instruction encourages passive learning on the part of pupils. This results in pupils coming to science classes with misconceptions, preconceptions or alternative conceptions already formed as a result of their interactions with the world. These alternative conceptions influence how they interpret and construct new conceptions in science lessons. Pupils not exposed to the tools to synthesize information from multiple sources are handicapped at integrative reconciliation of concepts.

The current situation is well summarised by Novak (1993) as "The unfortunate truth is that much school instruction inhibits pupil learning."

Constructivist learning

Meaningful learning occurs when individuals "choose to relate new knowledge to relevant concepts and propositions they already know" (Novak & Gowin, 1984). This is based on the constructivist perspective on learning, where learning is an active process in which the learner is constantly creating and revising his or her internal representation of knowledge when new concepts are linked to familiar concepts existing in the learner's cognitive structure and can be applied to all subject matter. (Duffy, 1992).

Meaningful learning of super ordinate concepts also gives new meaning to relevant subordinate concepts and propositions, which facilitates integrative reconciliation of concepts.

Concept mapping

Novak and Gowin pioneered concept mapping based on the meaningful learning theory by David Ausubel (1963,1968). Concept maps are two–dimensional hierarchical diagrams which illustrate the relationships between and among individual concepts. The basic Novakian concept map illustrate a hierarchy of concepts where more specific and less inclusive concepts are linked together by valid and meaningful propositions and therefore are subsumed under the broader, more inclusive concepts. They rely on three fundamental qualities; hierarchical structure, progressive differentiation and integrative reconciliation (Novak & Gowin,1984).

Links between concepts are shown by the hierarchical structure in which the lower concepts are subsumed beneath those of the higher levels, and the super ordinate concepts are more general than subsumed concepts. Two or more concepts linked together by words create a proposition. The propositions, along with arrows indicating the direction of the relationship help to develop the connections between linked concepts more precisely.

Concept maps are intended to tap into a learner's cognitive structure and to externalize for both the learner and teacher what the learner already knows (Novak & Gowin, 1984). Based on constructivist theory, concept mapping mirrors the constructivist definition of curriculum as the set of learning experiences which enable the learners to develop their understanding (Driver & Oldham, 1986). Researchers (e.g., Heizne-Fry & Novak, 1990) have touted concept mapping as a strategy for promoting meaningful learning. After going through concept mapping, learners are able to link what they have leant to the main concepts.

Concept maps as learning tools in science education

Concept mapping has been applied at all levels of learning and instruction in many contexts. The use of concept maps is becoming more widespread in areas of science education abroad.

In science education, concept mapping has been widely recommended and used in a variety of ways. It has been used to help pupils build and organize their knowledge base in a given discipline or on a given topic. Concept mapping has also been used as a study tool for synthesizing information from multiple sources.

Concept mapping engages the learner in the construction of knowledge by linking sub concepts to more general, inclusive, and abstract concepts, thus bringing about meaningful learning. This tool, when employed by pupils, help them "learn how to learn" (Novak & Gowin 1984) which in turn facilitates pupils to be more aware about the structure of knowledge and the process of knowledge production or meta-knowledge (Novak & Gowin, 1984).

Concept mapping has not only been found useful in promoting pupils' understanding of science concepts, it also facilitate pupils' abilities to solve problems and to answer questions that require application and synthesis of concepts .Concept maps has been used to observe change in pupils' understanding of concepts over time .It can be used to assess what the learner knows as concept maps can be tapped to measure pupils' understanding and to reveal unique thought processes.

Numerous studies have shown that pupils bring relevant knowledge frameworks or varying degree of quantity and quality to learning tasks (Novak, 1987). Concept mapping has not only helped pupils elaborate the conceptual understanding theory they already possess but especially to recognize and modify those knowledge structures that contains misconceptions, alternative conceptions or framework

(Feldsine, 1983; Novak & Gowin, 1984). Thus the acquisition of powerful super ordinate concepts should be a primary goal of effective science teaching. The ability of the mapper to identify and relate the salient concepts to these super ordinate concepts requires and understanding the constitution of the science concepts involved. Thus concept mapping when adopted as an instructional and revision tool promotes higher order thinking and positively impacts on science teaching and learning.

Concept mapping has some effect on achievement and a large positive effect on pupils' attitudes. It has been used to promote positive self-concepts, positive attitudes toward science (Novak & Gowin, 1984) and increased responsibility for learning (Gurley, 1982).As a learning strategy, concept mapping is most effective if it is conducted on an ongoing basis over the course of instruction. This allows pupils to modify their maps as learning occurs and conceptual understanding grows.

From the perspectives of both the theory of learning and the theory of knowledge, the challenge is for science educators to design an instruction strategy that encourage high levels of meaningful learning, including the development of well-organized conceptual frameworks and well-integrated super ordinate concepts. Concept mapping is a locally under tapped means of eliciting pupils' concept structure in a content domain in the area of primary science.

In the area of science curriculum, concept mapping has been used in its development (Starr & Krajcik,1990) and the evaluation of instructional activities for promoting conceptual understanding. Concept mapping is potentially useful to pupils in the local primary science as the local primary science curriculum thematically and spirally groups topics taught across the four years of primary science education. The connections that concept maps facilitate, not only allow local primary pupils to draw associations among the main concepts being presented, but also generate greater retention, application, and understanding of concepts. Concept mapping can therefore be an invaluable instruction and revision tool for primary science pupils for the PSLE tests as they test the science concepts learnt in all four years of Primary science education.

Concept maps as learning tools for young learners

The usefulness of concept mapping as a learning strategy for young children from kindergarten through primary five has been demonstrated (e.g. Stice & Alvarez, 1987; Stow, 1997).

Stow (1997), for example, shows how concept mapping can help children focus on their own learning and hence provide a simple framework for young children (aged 8 to 10) to review and celebrate their achievements in science. Stice and Alvarez (1987) suggest that concept mapping is not only a useful revision tool for young learners but also a means to show pupils that knowledge is more than facts.

Primary grade pupils are capable of developing very thoughtful concept maps which they can explain intelligently to others. (Symington & Novak, 1982).Pupils in class using concept mapping when compared with a group using conventional expository instruction received significantly higher mean scores on an achievement test dealing with nutrition in green plants and respiration in cells (Jegede, Alaiyemola & Okebukola (1990). Novak, Gowin & Johansen (1983) found that 7th and 8th grade science pupils who used concept mapping demonstrated superior problem-solving performance after six months of use.

Research method

Overview

The research design of this study is evaluative which facilitate gathering of empirical data and thereby making possible some valid statements about the effects of concept mapping on pupils' understanding and learning of science.

Two classes from both gifted and mainstream pupils were selected and assigned to two groups. All pupils first attempted the pre test to the topic. Pupils in the experimental group were continuously exposed to concept mapping as a learning and revision tool in concurrence to the topics taught.

Secondly, pupils constructed a concept map in groups of four for the concurrence topic based on the concept lists provided by the teacher. Pupils from the control group outlined the summary in point form for the same topic taught.

Thirdly, pupils from both groups took the post test of the topic and their results were analyzed in a quantitative analysis. The above procedure was repeated for each of the topics covered in the first term for both the gifted and main stream pupils. Pupils' results in the first continual assessment and mid year exam were also compared in an attempt to check on the validity of concept mapping in enhancing the retention of concepts over three months.

Participants

This study took place in an all boy's school cum Gifted Education center receiving the top 1% of boys from the primary three gifted streaming test. All pupils were from Primary four. One class of randomly selected gifted and main stream pupils (N=16, N=40 respectively) were constantly introduced to concept mapping as a topic learning and revision tool for topics covered in the first semester to help them to create a concept map at the end of each of the topics taught. The control class of the gifted and main stream pupils (N=15, N=37 respectively) outlined a summary of the same topics taught using point form. Gifted pupils covered the topics of matter and light in Term 1, the topics of heat and plant parts in Term 2. Main stream pupils covered the topic of matter in Term 1 and the topic of water in Term 2.

Instrumentation

Test formats

To ensure the test validity and comparability of the pre and the post tests for each topic, a table of specifications was drawn up to facilitate the crafting of test questions to involve the same concept and process skills for the topic tested for both the pre and post tests. Based on the past years' tests, multiple choice questions amounting to 5 marks and open ended questions amounting to 10 marks were selected and modified to remain in line with the learning objectives of each topic for the pre tests.

Selected questions were crafted to test pupils' application and linking of concepts. A parallel set of questions was selected for the post tests. A panel of experts comprising of National Institute of Education professors validated the test items, suggested model answers and the marking scheme before finalization of both pre and post tests. Pupils had 30 minutes for the pre and post tests respectively to finish both the multiple-choice questions and open-ended questions for each topic.

Scoring of pre and post tests

The first author evaluated and scored both sets of tests for each of the topics; the scoring adhered closely to the marking scheme. Marks were awarded for each correct option for multiple choice questions and the concept applied for the open ended questions. Wrong choices made for multiple choice questions were not penalized but correction for guess work was factored in. Partial marks according to the marking scheme were awarded for partial concept application in the open ended section of the tests. To ensure the reliability of the scoring scheme, a sample of scripts were scored by the second author.

Concept mapping technique

Procedures during concept mapping training phase

Concept mapping skills began in the third week of Term One and stretched over a term. The teacher explicitly spent one hour guiding the pupils in the experimental group through a concept mapping workshop. In the course of the workshop, the teacher introduced concept maps to the pupils by explicitly informing the pupils of the components and construction of concept maps and the purpose they serve. During the workshop, pupils had hands-on practice to develop concept maps on common topics in groups of four with reference to the concept list for the topics.

Pupils' grasp of concept mapping skills was also facilitated by the use of concept map as part of the instruction and topic revision. When teaching the topic, the teacher explicitly highlighted to the pupils the linkages of the various concepts.

Pupils in both the gifted and main stream experimental classes then worked in groups of four to develop the concept maps during the last 30 minutes lesson for each of the topics covered. Pupils made reference to the concept lists provided for each of the topics. The concept maps created by pupils should extend the list of concepts beyond the reference concept list with hierarchical structure, differentiation and integration among concepts.

Pre exploratory study

A pre exploratory study was carried out with existing primary five pupils who have gone through the primary four syllabus. Five selected pupils from each stream went through the pre test, concept map construction and post tests to ensure the validity of the questions, marking schemes of the tests.

Data analysis of exploratory study

Quantitative analysis of results

The data collected and analyzed included scores for multiple choices and open ended questions in the pre and post tests on the topic of matter and light for gifted and matter for the main stream. Pupils' pre tests scores were checked to ensure the pupils in the experimental and control groups for both gifted and main stream were statistically equivalent. This means that the groups shared similar cognitive structure before treatment and hence the effect of the pupil's prior knowledge on subsequent learning could be taken as equivalent.

Pair sample t-tests were carried out to present statistical significance for the pre and post tests results scored by all pupils. The null hypothesis states there is no significant difference between the means of the results achieved in pre and post tests between the experimental and control group. The alternate hypothesis states that there is a significant difference between the means of the results achieved in pre and post tests between the experimental and control groups. A confidence level of 95% was selected. The comparison of the t value elicited answers to whether concept mapping enhance primary school pupils' (both gifted and mainstream) performance in terms of marks in science.

Discussion

Quantitative analysis

Since the pupils in the control and experimental classes of the gifted and main stream groups were streamed into their current classes based on their primary three results, the control and experimental classes in each group were taken as statistically equivalent and the effect of pupils' prior knowledge on subsequent learning was assumed to be the same. With reference to the tables on Statistical analysis of pre and post test results under appendix , all post tests carried out showed significant differences between the experimental and control group's scores. The post tests showed a trend towards better results in the experimental group for both streams. The increments in means between pre and post tests of the experimental group although small were nevertheless significant. The increment in mean results of the continual assessment over post tests provided an indication and a measure of how well retention of concepts has taken place.

Conclusion

The conclusion drawn from this study is that the use of concept mapping as a revision tool does enhance concept learning in primary science. Pupils in the experimental group who embraced concept mapping as an instructional and revision tool achieved significantly better results as evidenced by the improvement in mean scores of the post test than those in the control group that uses outlining. More significantly, concept mappers achieved significantly better scores in the continual assessment. Thus concept mapping is a potential method to make explicit links and relations between concepts and as a technique to study the coherence between different concepts in pupil's knowledge structures (Novak & Gowin, 1984), visualization of concepts and their interrelationships by concretizing and by explaining the meaning of concepts.

The greater gain score between mid year exam and first continual assessment of the experimental groups in both streams when compared to the control group has given first signs of a positive impact of concept mapping on the durability of pupil science learning. Although concept mapping does not necessarily lead to greater amounts of concept gain, it seems it can have a positive impact on the strength or depth of pupil's constructed conceptions. The similarity of the outcomes over both gifted and main stream pupils of this study, and the significant difference in performance of the experimental and control groups, indicate that this impact is durable over a long period of time.

Concluding remarks

Current primary science curriculum thematically and spirally grouped topics to be taught across the four years from primary three to six. Concept mapping should be tapped fully as a curriculum planning tool to provide a shorthand form for organizing and sequencing ideas. The connections that concept maps facilitate, not only allow primary pupils to draw associations among the main concepts being presented to improve comprehension of science content and process skills, but also generate greater retention, higher order thinking, application, and understanding of concepts.

Concept mapping as a revision tool has the potential to promote meaningful learning and provide the teacher with insights into the mental models of pupils. Through concept maps, teachers are able to access learners' knowledge and reveal unique thought processes and also surface misconceptions harboured by the learner. The patterns developed in pupils' concept maps can be interpreted as being indicative of progressive levels of understanding. This will enable teaching to be more precisely focused on the pupils' needs and so make more effective use of class time.

Concept mapping can be a valuable revision tool for primary science pupils as the Primary School Leaving Examination tests science concepts learnt in all four years of primary science education. Concept maps are particularly useful in helping pupils to have an overview of the science concepts they have learnt over the four years of formal primary science instruction.

Concept maps could also be used to highlight science concepts with varying degrees of magnification to the level of a specific science lesson, with each map showing key concepts and concept relationships necessary to understand the larger or more explicit domain of science.

Concept mapping shows promise in improving the quality of science education and is a potentially valuable learning and revision tool as well as a teaching device in the science educators' toolbox.

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Appendix

Appendix I: Statistical analysis of pre and post test results gifted stream pupils

Table 1a: t test for differences in mean gain score between experimental and control groups in gifted stream MCQ on Matter

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	16	1.1438	1.12759	.28190
	control	15	.0000	.87069	.22481

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	1.744	.197	3.145	29	.004	1.14375	.36362	.40007	1.88743
	Equal variances not assumed			3.172	28.009	.004	1.14375	.36056	.40518	1.88232

The difference in mean gain score is significant ($t = 3.17$, $p \leq 0.05$).

Table 1b: t test for differences in mean gain score between experimental and control groups in gifted stream OEQ on Matter

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	16	1.3750	.88506	.22127
	control	15	.1333	1.06010	.27372

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	.160	.692	3.549	29	.001	1.24167	.34987	.52610	1.95724
	Equal variances not assumed			3.528	27.368	.002	1.24167	.35196	.51995	1.96338

The difference in mean gain score is significant ($t = 3.53$, $p \leq 0.05$).

Table 1c: t test for differences in mean gain score between experimental and control groups in gifted stream MCQ on Light

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	16	1.1656	1.36439	.34110
	control	15	-.2667	1.52836	.39462

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	.176	.678	2.756	29	.010	1.43229	.51964	.36950	2.49508
	Equal variances not assumed			2.746	28.097	.010	1.43229	.52161	.36399	2.50059

The difference in mean gain score is significant ($t = 2.75$, $p \leq 0.05$).

Table 1d: t test for differences in mean gain score between experimental and control groups in gifted stream OEQ on light

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	16	1.2500	.85635	.21409
	control	15	-.0667	.79881	.20625

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	.715	.405	4.419	29	.000	1.31667	.29797	.70726	1.92607
	Equal variances not assumed			4.429	29.000	.000	1.31667	.29728	.70867	1.92466

The difference in mean gain score is significant ($t = 4.43$, $p \leq 0.05$).

Table 1e: t test for differences in mean gain score between experimental and control groups in gifted stream MCQ on Heat

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	16	1.3331	1.28767	.32192
	control	15	.2680	1.14831	.29649

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	.001	.980	2.424	29	.022	1.06513	.43932	.16662	1.96363
	Equal variances not assumed			2.434	28.934	.021	1.06513	.43765	.16994	1.96031

The difference in mean gain score is significant ($t = 2.43$, $p \leq 0.05$).

Table 1f: t test for differences in mean gain score between experimental and control groups in gifted stream OEQ on Heat

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	16	1.3750	.88506	.22127
	control	15	.1333	1.06010	.27372

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	.160	.692	3.549	29	.001	1.24167	.34987	.52610	1.95724
	Equal variances not assumed			3.528	27.368	.002	1.24167	.35196	.51995	1.96338

The difference in mean gain score is significant ($t = 3.53$, $p \leq 0.05$).

Table 1g: t test for differences in mean gain score between experimental and control groups in gifted stream MCQ on plant parts

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	16	1.2469	.90450	.22612
	control	15	.2667	1.14947	.29679

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	1.246	.274	2.648	29	.013	.98021	.37020	.22306	1.73735
	Equal variances not assumed			2.627	26.604	.014	.98021	.37312	.21410	1.74632

The difference in mean gain score is significant ($t = 2.63$, $p \leq 0.05$).

Table 1h: t test for differences in mean gain score between experimental and control groups in gifted stream OEQ on plant parts

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	16	1.5000	.81650	.20412
	control	15	.5333	1.06010	.27372

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	.549	.465	2.855	29	.008	.96667	.33855	.27425	1.65908
	Equal variances not assumed			2.831	26.308	.009	.96667	.34145	.26521	1.66813

The difference in mean gain score is significant ($t = 2.83$, $p \leq 0.05$).

Table 1i: t test for differences in mean gain score between experimental and control groups in gifted stream MCQ on test 2 and test 1

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	16	1.5013	1.36545	.34136
	control	15	.5353	.98385	.25403

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	.773	.386	2.246	29	.032	.96592	.43003	.08641	1.84542
	Equal variances not assumed			2.270	27.257	.031	.96592	.42551	.09322	1.83861

The difference in mean gain score is significant ($t = 2.27$, $p \leq 0.05$).

Table 1j: t test for differences in mean gain score between experimental and control groups in gifted stream OEQ on test 2 and test 1

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	16	1.6875	1.54785	.38696
	control	15	.5333	.85496	.22075

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	5.421	.027	2.545	29	.017	1.15417	.45348	.22669	2.08164
	Equal variances not assumed			2.591	23.666	.016	1.15417	.44550	.23401	2.07432

The difference in mean gain score is significant ($t = 2.59$, $p \leq 0.05$).

Statistical analysis of pre and post test results of main stream pupils

Table 1k: t test for differences in mean gain score between experimental and control groups in main stream MCQ on Matter

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	40	.9738	1.23660	.19552
	control	37	.0000	1.17390	.19299

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	1.525	.221	3.537	75	.001	.97375	.27529	.42535	1.52215
	Equal variances not assumed			3.544	74.945	.001	.97375	.27472	.42646	1.52104

The difference in mean gain score is significant ($t = 3.54$, $p \leq 0.05$).

Table 1l: t test for differences in mean gain score between experimental and control groups in main stream OEQ on Matter

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	40	.5750	1.59948	.25290
	control	37	-.2703	1.89515	.31156

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	1.682	.199	2.120	75	.037	.84527	.39863	.05116	1.63938
	Equal variances not assumed			2.106	70.726	.039	.84527	.40128	.04508	1.64546

The difference in mean gain score is significant ($t = 2.11$, $p \leq 0.05$).

Table 1m: t test for differences in mean gain score between experimental and control groups in main stream MCQ on water

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	40	1.1073	1.07466	.16992
	control	37	.1084	1.19020	.19567

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	.003	.959	3.870	75	.000	.99887	.25811	.48469	1.51305
	Equal variances not assumed			3.854	72.638	.000	.99887	.25915	.48235	1.51540

The difference in mean gain score is significant ($t = 3.85$, $p \leq 0.05$).

Table 1n: t test for differences in mean gain score between experimental and control groups in main stream OEQ on water

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	40	.5750	1.25856	.19900
	control	37	.0000	1.10554	.18175

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	1.538	.219	2.123	75	.037	.57500	.27088	.03538	1.11462
	Equal variances not assumed			2.134	74.810	.036	.57500	.26950	.03810	1.11190

The difference in mean gain score is significant ($t = 2.13$, $p \leq 0.05$).

Table 1o: t test for differences in mean gain score between experimental and control groups in main stream MCQ mid year examination compared to first semester test

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	40	.6743	1.08398	.17139
	control	37	-.1435	1.03092	.16948

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	.622	.433	3.386	75	.001	.81776	.24152	.33664	1.29889
	Equal variances not assumed			3.393	74.938	.001	.81776	.24104	.33759	1.29794

The difference in mean gain score is significant ($t = 3.39$, $p \leq 0.05$).

Table 1p: t test for differences in gain score between experimental and control groups in main stream OEQ mid year examination compared to first semester test

Group Statistics

	exp_ctr	N	Mean	Std. Deviation	Std. Error Mean
gainscor	experimental	40	2.0250	1.36790	.21628
	control	37	.7838	.91697	.15075

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
gainscor	Equal variances assumed	5.091	.027	4.638	75	.000	1.24122	.26762	.70809	1.77434
	Equal variances not assumed			4.708	68.566	.000	1.24122	.26364	.71522	1.76722

The difference in mean gain score is significant ($t = 4.71$, $p \leq 0.05$).

Appendix II: Table of specifications for pre and post tests for the various topics for gifted and main stream

Table of specifications on matter and light

Questions	Basic Process Skills							
	Observing	Comparing	Classifying	Measuring and Using apparatus	Communicating	Analysing	Generating	Evaluating
Matter								
MCQ								
1 recollection								
2						/		
3						/		
4			/					
5							/	

OEQ								
1					/	/	/	
2				/				
3			/					
Light								
MCQ								
1						/		
2						/		
3						/		
4								/
5							/	
OEQ								
1				/				
2						/	/	
3							/	
4						/		

Table of specifications on heat and plant parts

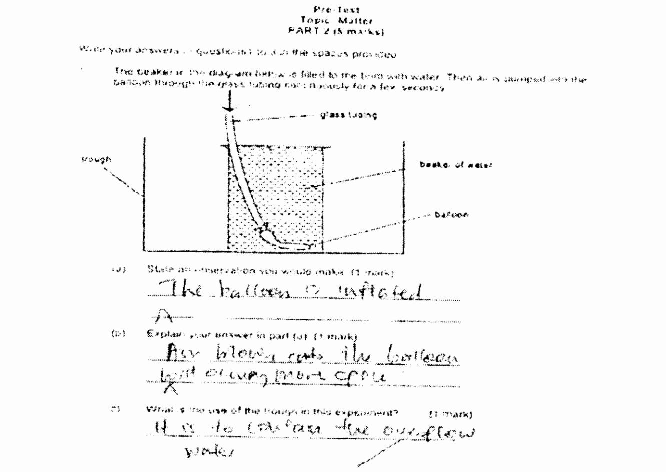
Questions	**Basic Process Skills**							
	Observing	Comparing	Classifying	Measuring and Using	Communicating	Analysing	Generating	Evaluating
Water								
MCQ								
1	/							
2						/		

3							/	
4								/
5					/			
OEQ								
1						/	/	
2					/			
3							/	

Table of specifications on water

Questions	**Basic Process Skills**							
	Observing	Comparing	Classifying	Measuring and Using apparatus	Communicating	Analysing	Generating	Evaluating
Water								
MCQ								
1	/							
2						/		
3							/	
4								/
5					/			
OEQ								
1						/	/	
2					/			
3							/	

Appendix III: Sample pupils answers from the pre tests for the various topics in both streams



Pre-Test
Topic: Matter
PART 2 (5 marks)

Write your answers to questions 1 to 3 in the spaces provided

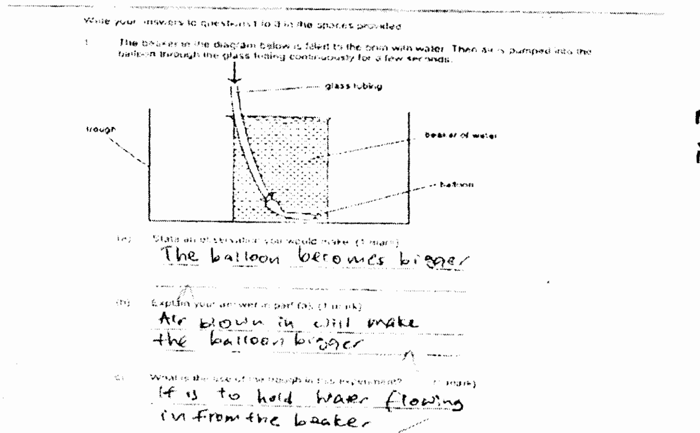
The beaker in the diagram below is filled to the brim with water. Then air is pumped into the balloon through the glass tubing continuously for a few seconds.

(a) State an observation you would make. (1 mark)
The balloon is inflated

(b) Explain your answer in part (a). (1 mark)
Air blown into the balloon will occupy more space

(c) What is the use of the trough in this experiment? (1 mark)
It is to contain the overflow water

most improved



Write your answers to questions 1 to 3 in the spaces provided

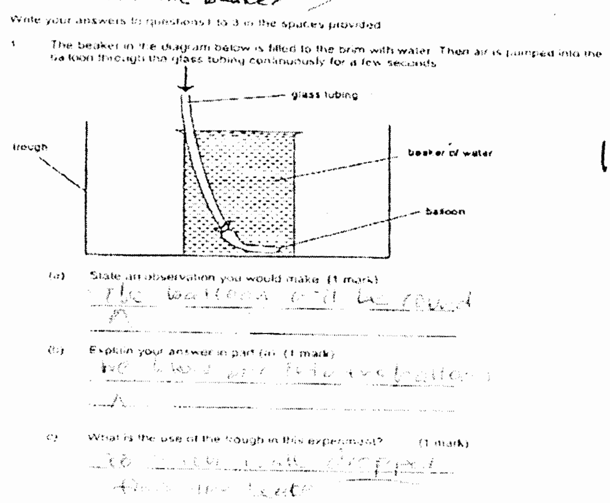
1 The beaker in the diagram below is filled to the brim with water. Then air is pumped into the balloon through the glass tubing continuously for a few seconds.

(a) State an observation you would make. (1 mark)
The balloon becomes bigger

(b) Explain your answer in part (a). (1 mark)
Air blown in will make the balloon bigger

(c) What is the use of the trough in this experiment? (1 mark)
It is to hold water flowing in from the beaker

Moderately improved



Write your answers to questions 1 to 3 in the spaces provided

1 The beaker in the diagram below is filled to the brim with water. Then air is pumped into the balloon through the glass tubing continuously for a few seconds.

(a) State an observation you would make. (1 mark)
The balloon will be round

(b) Explain your answer in part (a). (1 mark)
[illegible]

(c) What is the use of the trough in this experiment? (1 mark)
[illegible]

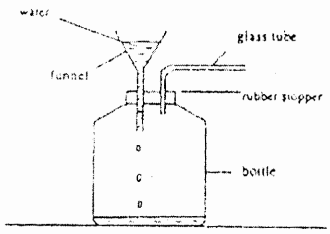
least improved

Appendix IV: Sample pupils answers from the post tests for the various topics in the order of most improved, moderately improved and no improvement in both streams

Post-Test
Topic: Matter
PART 2 (8 marks)

Write your answers to questions 1 to 3 in the spaces provided

1. David set up the experiment as shown below. He poured 50 ml of water into the funnel and recorded the time taken for all the water to flow into the bottle. Water



He repeated the experiment, changing the diameter of the glass tubes each time. He recorded the results as shown in the table below.

Diameter of the glass tube (cm)	Time taken for 50 ml of water to flow into the bottle (seconds)
0.4	12
0.5	10
0.7	6
0.9	2

(a) What is the aim of David's experiment? (1 mark)

The aim is to find out the relationship between the diameter of tube and time take for water to flow in to beaker

(b) What is the relationship between the diameter of the glass tube and the time taken for all the water to flow into the bottle? (1 mark)

The greater the diameter of the glass tube the shorter the time taken for the water to flow

c) What is the use of the glass tube in this experiment? (1 mark)

Act as independent Variable

Most improved

(a) What is the aim of David's experiment? (1 mark)

Time for water to flow in and diameter of glass tube

(b) What is the relationship between the diameter of the glass tube and the time taken for all the water to flow into the bottle? (1 mark)

The bigger the glass tube the faster the water will flow into the bottle

c) What is the use of the glass tube in this experiment? (1 mark)

To allow air inside the bottle to

Moderately improved

(a) What is the aim of David's experiment? (1 mark)

To see whether water can flow in

(b) What is the relationship between the diameter of the glass tube and the time taken for all the water to flow into the bottle? (1 mark)

to allow water to flow in

c) What is the use of the glass tube in this experiment? (1 mark)

to allow air to flow in

least improved