Science Process Skills and Cognitive Preference Styles*

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ABSTRACT

The study examined the differences in cognitive styles between two comparable groups of students at the Grade 9 (Secondary 3) level, namely the LSS (Lower Secondary Science) group who had been exposed to the practical-based, inquiry-oriented type of science and the non-LSS group of students who had studied the more traditional type of science in the "old" science curriculum. Their differences in science achievement are measured by the common IEA *Science Paper-Pencil, Multiple Choice Criterion Test* and also, by the *Science Process* or *Practical Test* (which measured three levels of process skills, such as the observation/manipulation, reasoning and investigation skills). Variance in science achievement thus measured is examined against the 4 cognitive preference styles of the students, (measured by the Combined Cognitive Preference Inventory) namely the "recall", "principles", "applications" and "questioning" modes of thinking. The findings indicated that (a) the attainment of the science process or practical skills was characterised by the type of science curriculum (LSS or non-LSS) and it was significantly associated with the achievement level of students, (b) the cognitive preference pattern covaried according to the students' level of science achievement and the type of curriculum and (c) the weak but significant relationship between performance in the science practical skills and the students' modes of cognitive style have important implications for teachers who are concerned about the intended effects of changes in the science curriculum on the consequent learning behaviour or cognitive outcome of their students.

Introduction

Since the 1960s, many science curricula have been restructured to focus on the learning and use of the scientific methods. In these new curricula, much of the learning of science was directed at the attainment of science process skills through laboratory investigative experimentation.

A recognition of the importance of teaching the laboratory investigative skills, coupled with the development of new innovative science curricula in the West, led to the review and revision of the Singapore General Science syllabus at the lower secondary level. After many years of trial testing, the new Lower Secondary Science (LSS) syllabus, together with instructional materials was eventually introduced by the Ministry of Education to all schools in 1983.

The new science syllabus adopted an interdisciplinary treatment of science topics. It stressed the need to prepare students to ac-

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quire progressively a mastery of the cognitive thinking and investigative skills that were associated with the scientific processes. To match the intentions of the science curriculum, the science syllabus was translated into multimedia instructional materials that were directed at helping students to conduct experiments on their own, design simple experimental procedures, record observations, analyse data and draw inferences. Students had to spend about 50% of their curriculum time conducting laboratory experiments. It was thus intended that students who had studied the new science curriculum would develop not only knowledge and skills in the science processes but also scientific attitudes such as curiosity and a questioning frame of mind.

Reports culled from literature have shown that desirable learning outcomes such as a higher level of cognitive thinking and a higher cognitive preference for critical questioning, were demonstrated by students exposed to the laboratory investigative experience. However, it cannot be taken for granted that the new and innovative changes in the LSS curriculum would necessarily result in a corresponding change in the learning behaviour and attitude of our students.

To find out whether the two years of LSS laboratory-based science learning experience has made a substantial difference in the way students learn science, a study was made to compare the outcome of a sample of students who did the LSS curriculum with that of an academically equivalent sample of students who continued with the General Science course. The study was to find out the difference between the two groups in

i) their performance in the science practical test in which science process skills were tested, and
ii) the measure of their cognitive preference.

An attempt was also made to find out if a relationship existed between students' ability to perform the science practical test and their cognitive preference style.

Procedure

The sample for this study comprised 426 secondary 3 students, all aged 14. Stratified random sampling was used in the selection of subjects. The study made use of three instruments to assess the outcome of science learning. These were the IEA-SISS *Science Achievement Test* (conducted in the Second International Science Study (SISS) under the auspices of International Association for the Evaluation of Educational Achievement), the *Science Practical Test* and the Cognitive Preference Test as measured by the *Science Learning Response Form.*

All the students in the sample took the IEA-SISS Science Achievement Test which comprised 30 multiple choice questions on Biology, Chemistry and Physics. Based on their performance, the LSS and non-LSS students were matched to control for initial differences in academic achievement. The results of the test were also used to group the subjects in the LSS and non-LSS samples into three ability groups, viz. the high (H), the average (Av) and the low (L) ability groups.

The Science Practical Test was taken from the SISS Science Process Exercise which consisted of two alternate forms, Sets A and B. To raise the difficulty level of the test, both Sets A and B were modified slightly by the addition of a few higher order practical items. Students who were randomly assigned to perform either the Set A or B Test were assessed in three practical tasks, each related to one science discipline, namely Biology, Chemistry and Physics. The main practical skills tested were (i) observation/manipulation, (ii) reasoning and (iii) investigation, the definitions of which were adopted from Kempa and Ward (1975). Data collected were in the form of raw scores obtained by students. Group mean scores of Practical Tests A and B were analysed separately because of the differences between the two sets of tests in the level of difficulty, total score and number of test items.

The Science Learning Response Form (SLRF) which was adapted from Tamir's Combined Cognitive Preference Inventory (CCPI) was used to determine the cognitive preference style of both the LSS and non-LSS students. The instrument measures four cognitive preference modes, namely recall, principles, application and questioning modes. The description of the four modes is adopted from

Heath (1964) and operationalised as follows:

(a) *recall (R):* acceptance of scientific information for its own sake, ie. without consideration of its implication, application or limitation.
(b) *principles (P):* acceptance of scientific information because it exemplifies or explains some fundamental scientific principle or relationship.
(c) *questioning (Q):* critical questioning of scientific information as regards its completeness, general validity or limitation.
(d) *application (A):* acceptance of scientific information in view of its usefulness and applicability in a general, social or scientific context.

The instrument, SLRF, was checked for reliability and construct validity with respect to the four cognitive preference modes in a separate trial study prior to its use in the main study. Scores based on students' ranking of statements according to their own preference were summed for each cognitive preference mode. Group mean total scores of each cognitive preference mode were analysed to identify the cognitive preference pattern of both LSS and non-LSS students.

The overall scheme of the research study is shown in Fig. 1.

FIGURE 1 OVERALL SCHEME FOR THE RESEARCH STUDY

Year	Chronological Sequence	Activity: LSS Group	Activity: Non-LSS Group
1982 & 1983	2 years of Science learning experience at Secondary 1 & 2 (Grades 7 & 8) prior to present study.	Pilot schools followed LSS curriculum with the following characteristics: i) The programme was intended to be laboratory-based with students actively involved in practical investigation. ii) LSS teaching was based on a set of specially designed multi-media science instructional materials.	Non-pilot schools continued with the conventional General Science curriculum which has been in use since 1960. Teachers assumed the authoritative role and science was taught directly from the commercially published textbooks.
1984	Secondary 3 Science (Grade 9)	The same cohort of students opt to offer science by electing from a variety of science subjects, namely Science, Combined Science, Pure Sciences etc. Some students in the *Normal* course do not study science at all.	
	IEA Science Study in April	Sample of Secondary 3 students sat for the SISS Science Achievement Test and responded to a battery of other socio-educational questionaires.	
	Current study in July/August	Selected 9 pilot LSS schools which represent the high, average and low achieving schools based on SISS Science Achievement Test. Number of subjects = 210	9 non-LSS schools which were matched with the LSS group according to: i) high, average and low achieving schools ii) course ie. Special, Express and Normal iii) type of science subjects offered at Secondary 3 Number of subjects = 216
		Both groups were administered the i) *Science Practical Test* using SISS Science Process Test for Population 2 (students at Grade 9), and ii) *Cognitive Preference Test* using the *Science Learning Response Form* (a slightly modified Form of Tamir's Combined Cognitive Preference Inventory).	

Results of the Study

The differences in performance between the LSS and non-LSS students in the Practical Tests are compared graphically in Figs. 2 and 3.

FIGURE 2 COMPARISON OF PERFORMANCE ON THE SCIENCE PRACTICAL TEST (SET A) BETWEEN THE LSS AND NON-LSS STUDENTS

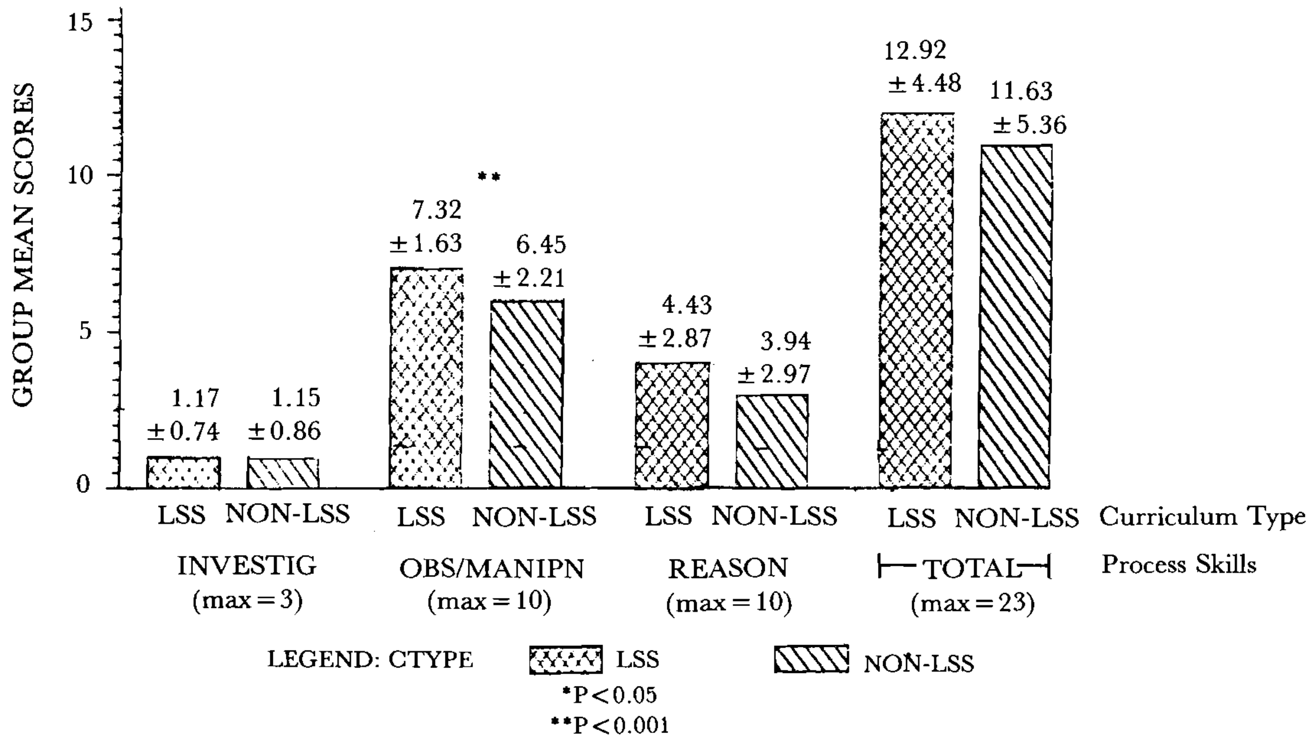
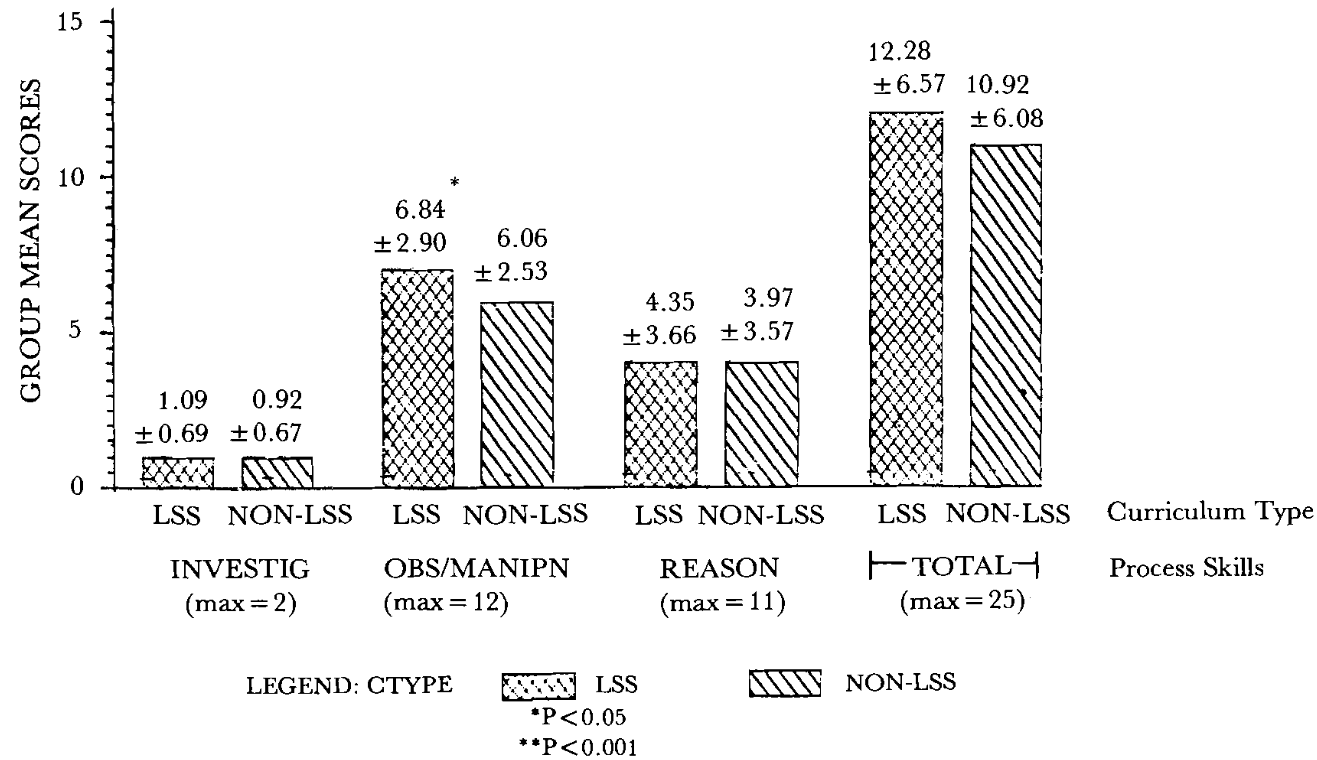


FIGURE 3 COMPARISON OF PERFORMANCE ON THE SCIENCE PRACTICAL TEST (SET B) BETWEEN THE LSS AND NON-LSS STUDENTS



For the three different categories of science process skills, a significant difference existed between the LSS and non-LSS students only in the observational/manipulative skills at the 0.01 and 0.05 levels for Tests A and B respectively. LSS students on the whole performed significantly better in observational/manipulative skills in the science practicals than non-LSS students. At the reasoning and investigation levels, the difference, if any, is not significant.

Table 1 compares the mean cognitive preference scores of students in the LSS and non-LSS courses. Findings were made for the whole test as well as for the sub-tests comprising only biological or physical science content. A high positive (Q-R) score difference was interpreted by Kempa and Dube (1973) as an indication of a student's willingness and desire to acquire scientific knowledge beyond that already possessed.

The results indicate a significant difference in the cognitive preference between the LSS and non-LSS students. The LSS students seem to have a higher preference for recall and a lower preference for questioning than their non-LSS counterparts. The high Q-R scores for the non-LSS group suggest that non-LSS students have a higher preference to acquire knowledge beyond that already possessed. When examined under different subject content, it is noted that this difference in preference between the LSS and non-LSS groups in the Biology sub-test corresponds closely to the results obtained for the whole test. No significant difference between the LSS and non-LSS groups for all the four cognitive modes is found for the Physical Science sub-test. This could be due to the fact that it is not a pure discipline but rather a subject made up of both Chemistry and Physics. The difference in response for the two sub-test (ie. Biology and Physical Science) is not unexpected as Tamir (1975, 1976, 1978) has stressed that the cognitive preference styles could be quite different for different subject matter. While Rogel (1974), in his study on 'Achievement and Cognitive Preference Styles of Chemistry Students' found no significant difference in cognitive preference styles between twelfth-grade students of different chemistry curricula, Tamir (1975) was able to find significant difference in cognitive preference styles for similar grade Biology students

TABLE 1 MEAN COGNITIVE PREFERENCE SCORES OF LSS AND NON-LSS STUDENTS

	Cog Pref Mode	Mean Score (n = 426)	LSS Mean	(n = 214) sd	Non LSS Mean	(n = 212) sd	F df(1,424)
	R	45.21	46.29	8.35	44.11	9.73	6.17**
Whole	P	51.17	51.29	5.48	51.05	5. 38	0.21
	A	52.11	52.14	5.51	52.07	5.86	0.02
Test	Q	51.52	50.30	10.24	52.75	11.06	5.61*
	Q − R	6.31	4.00	17.14	8.63	19.58	6.74**
	R	22.04	22.81	5.07	21.26	5.51	9.05**
Biological	P	26.53	26.59	3.83	26.46	3.58	0.12
	A	26.20	26.29	3.78	26.11	3.60	0.27
Sub test	Q	25.23	24.32	5.75	26.15	6.29	9.87
	Q − R	3.19	1.51	9.64	4.89	10.92	11.45**
	R	23.17	23.49	4.51	22.85	5.28	1.79
Physical	P	24.61	24.70	3.50	24.58	3.65	0.11
Science	A	25.90	25.85	3.45	25.96	3.62	0.12
Sub test	Q	26.29	25.98	5.91	26.59	6.07	1.12
	Q − R	3.12	2.50	9.59	3.75	10.52	1.64

*p < 0.05 **p < 0.01

between BSCS and non-BSCS curricula in Israel.

That LSS students had attained a high level of competence in the observational and manipulative skills was of no surprise. Two years of intensive hands-on laboratory work which covered about 50% of the LSS curriculum could have contributed to the results.

While most studies have found that students taught under new innovative curricula have developed a questioning frame of mind and a liking for curiosity, this study has findings contrary to the expectations of the curriculum developers. The higher preference for recall by the LSS group does not match the objectives of the curriculum which is intended to be inquiry-oriented.

In the attempt to correlate results of science process skills with students' cognitive preference modes, some statistically significant coefficients with respect to specific subject content were obtained. Table 3 gives the correlation coefficients for the whole sample as well as the LSS sub-sample according to the subject content. The correlation coefficient results of the non-LSS sub-sample are not shown as they are non-significant and are of no value for interpretation.

Although the correlation results are low, it does reveal some interesting links between students' cognitive preference and their ability to perform the process skills. For example, performance using reasoning skills in the practical test correlated negatively with the 'recall' mode (r = −0.32) and positively with 'scientific curiosity' on the Q — R scale (r = 0.29). This seems to indicate that LSS students who are good in reasoning skills would tend to show a low cognitive preference for recall and an inclination towards 'scientific curiosity' with respect to the Biology content.

Conclusion

Notwithstanding some limitations of the test instruments and the constraints of the test administration, the findings have provided satisfactory evidence to show that the performance of the LSS students are superior to the non-LSS

TABLE 2 SUMMARY OF RESULTS OF STUDIES MADE ON COGNITIVE PREFERENCE STYLES FOR DIFFERENT CURRICULA

Reference		Discipline	Groups (1)	Compared (2)	Findings Cognitive Styles Recall R	Princ. P	Quest. Q	Applic. A
Heath	1964	Physics	PSSC	Traditional	2	1	1	ns
Marks	1967	Chem	CBA	Traditional	2	1	1	ns
Atwood	1967/68	Chem	Chem Study	Traditional	2	ns	•1	1
Mackay	1972	Physics	PSSC Posttest	Pretest	2	1	1	2
Dube	1971	Chem	Nuffield (High Achievers)	Traditional	ns	2	ns	1
Dube	1971	Chem	Nuffield (Low Achievers)	Traditional	1	ns	ns	2
Rogel	1974	Chem	Chem Study (High Achievers)	Traditional	ns	1	ns	2
Rogel	1974	Chem	Chem Study (Low Achievers)	Traditional	1	1	2	2
Tamir	1975	Biology	BSCS	Non BSCS	2	ns	1	ns

•The numbers represent the group that had a higher score in that particular area;

ns = No significant difference

(Reproduced from Tamir, P, 1975, p 239)

TABLE 3 CORRELATION OF COGNITIVE PREFERENCE MODES WITH PRACTICAL TEST SKILLS ACCORDING TO SUBJECT CONTENT FOR WHOLE SAMPLE & LSS SUB-SAMPLES

	Practical Skills	R		P		A		Q		Q — R	
		Bio	PS	Bio	PS	Bio	PS	Bio	PS	Bio	PS
Whole Sample n = 426	Observatn/ Manipulatn	−0.11*	—	—	—	—	—	—	—	—	—
	Reasoning	−0.21**	—	0.18**	—	—	—	0.10*	—	0.17**	—
	Investigatn	NT	−0.12**	NT	—	NT	0.11*	NT	—	NT	—
LSS n = 214	Observatn/ Manipulatn	−0.23**	−0.14*	—		—				0.19**	
	Reasoning	−0.32**		0.21**	−0.15*	—	0.14*	0.20**		0.29**	
	Investigatn		−0.15*	NT		NT	0.14*	NT		NT	

Only significant correlations are indicated *p < 0.05
NT = not tested **p < 0.01

students in practical skills, particularly in the lower order process skills of observation/manipulation. The LSS students in general have been found to show a stronger cognitive preference for recall and a lower cognitive preference for questioning than their non-LSS counterparts. While there are plausible reasons to explain why the inquiry traits among the LSS students are not evident in the Science Practical Tests, the unexpected findings regarding the cognitive preference styles of students need further examination.

What has often been pointed out as a powerful influence in the implementation of new curriculum is the attitude and ability of the teachers in carrying out their task to meet curriculum objectives. Sally Brown and Donald McIntyre (1982) had warned that in curriculum innovations, teachers cannot be taken for granted in using new ideas and teaching approaches in ways that are prescribed. Perhaps the assumption that LSS teachers, given the multi-media curriculum and instructional materials and follow-up in-service courses would teach the 'inquiry' or investigative approach, has little or no reality in actual classroom practice. The problem could be a dislocation between what is actually done and what is intended to be taught. With the familiarity of the traditional General Science syllabus which has been taught by all teachers long before LSS and the stress of school examinations on testing of knowledge on content, it is probable that teachers who have been accustomed to emphasize the mastery of science content as an end (ie. to meet examination needs) would tend to continue doing so even with the new LSS curriculum. Hence instead of promoting laboratory investigation under LSS, the conduct of the science practical might have in actual practice been frequently set at the level of merely 'doing' science. That is, science practicals might still be geared to the conduct of the "practical" as prescribed in the workbook, and merely verifying what is already expected or known from the textbook. "Doing" science thus fell short of the need to use the observed data, interpret, analyse or synthesise. As a result, it could be that the science practical experience of LSS was at a level that reinforced the recall mode in the learning process.

The correlation results in Table 3 seem to reaffirm the fact that LSS students who showed a high preference for recall are negatively associated with their competence to use the reasoning skills. It could be argued that these students, by preferring the recall mode of processing science information have not taken advantage of the laboratory-centred LSS course, which is supposed to stimulate critical thinking. On the other hand, those who have acquired good reasoning skills as shown by the better performance in the practical tests are high in the scientific curiosity scale.

This study, has thrown some light on certain learning outcome that result from a curriculum which is intended to be inquiry-oriented and laboratory biased. To trace the real causes that lead to such outcome, the actual teaching-learning process that transpires in the classroom needs to be studied. Are the instructional materials used in the way intended? Are the workbooks too prescriptive, giving students little opportunity to experiment and investigate? Do teachers in practice promote the use of higher order inquiry process skills such as reasoning? To what extent has teacher-directed teaching taken place in the laboratory that results in hampering the 'open-ended' inquiry learning of science? Answers to such questions will certainly help curriculum developers to decide what more needs to be done to meet the intended objective of the LSS curriculum.

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