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ABSTRACT

The study reported in this paper, combined qualitative (observation, interview and case study techniques) and quantitative (questionnaire and survey instruments) methods (n=3,182 Grade 10 students). The study (1) examined the relationship of current teaching practices to a number of variables that affected students' learning in science laboratory classrooms, (2) examined which factors affected academic success in an external science achievement examination, and (3) examined whether an education productivity model in the science education area was applicable to a developing country context, namely, Papua New Guinea. The study adapted a classroom environment instrument, the Science Laboratory and through its use demonstrated reliability. Analysis of data indicated boys had a more favorable attitude toward science than girls. Science academic achievement was related to quality and quantity of instruction, science laboratory learning environment scales, and gender. Teachers tended to prefer demonstrations to students doing experiments in small groups. Student laboratory work was highly structured. (PR)

EDUCATIONAL PRODUCTIVITY AND SCIENCE EDUCATION WITHIN A DEVELOPING COUNTRY

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Abstract

This study reported in this paper, combined qualitative (observation, interview and case study techniques) and quantitative (questionnaire and survey instruments) methods. The study (a) examined the relationship of current teaching practices to a number of variables that affected students' learning in science laboratory classrooms, (b) examined which factors affected academic success in an external science achievement examination, and (c) examined whether an educational productivity model in the science education area was applicable to a developing country context, namely, Papua New Guinea. The study adapted a classroom environment instrument, the Science Laboratory Environment Inventory, to the developing country context of Papua New Guinea. The resulting instrument demonstrated adequate reliability, validity and discrimination validity and was able to distinguish between different schools. Analysis of the data generated found similar science laboratory learning environments across most high schools with one of the environment scales, Open Endedness, the least favourable scale. Overall, boys had a more favourable attitude towards science than girls. Multi-variant analysis showed that science academic achievement was related to quality and quantity of instruction, science laboratory learning environment scales and gender. As in other studies in similar countries, male students performed better than female students in external science achievement examinations. It was of some significance to find female students achieved more than male students in a practical science process test.

The study identified some specific aspects of current teaching practices involving science learning environments and students' attitudes towards science, in a developing country context. The typical PNG science teacher was found to largely used factual questions and rarely asked thought provoking questions. There was a strong belief amongst both students and science teachers in this context that copious notes were an important ingredient for the success in the final external science academic examination. The science teachers clearly preferred teacher demonstrations to students doing experiments in small groups. When students were allowed to experiment, the science teacher had already decided the problem to be examine, the experiment, the method and the equipment necessary to solve this problem. In most cases, the science teachers first demonstrated the experiment and explained step-by-step how to do the experiment, then the students conducted the experiment. The science teachers were very didactic in their approach to teaching and there appeared very little variation in approaches to teaching and student experimentation. Students stated that confusion often existed during experiments. At the conclusion of the experiment, the teacher discusses the results, writes copious notes on the chalkboard and the students copies these notes into their workbooks. An examination of the culture helped to explain current teaching practices and students' learning practices within a cultural context. Finally, this study showed that an educational productivity model was applicable to a developing country context.

BACKGROUND AND RATIONALE

Knight and Sabot (1990, p307), in a developing country context, state that:

> "Secondary education imparts cognitive skills that increase labor productivity, investment in secondary education yields a high rate of return, and its expansion contributes substantially to economic growth."

Society is increasingly becoming more concerned about standards of education systems. As a result of this concern about educational standards, many international governments are seeking greater accountability about teachers' use of the educational resources provided by the government. As a consequence of this greater accountability, governments have been examining ways to reduce unnecessary spending and make the education process more effective and efficient. As developing countries spend approximately 22 times less on instructional material per pupil than do developed countries (Caillods & Postlethwaite, 1989), and since one component of teaching in secondary schools that has one of the greatest expenditure lines is the science laboratory, the study reported here examined aspects of science laboratory classrooms within a developing country context and determined whether an educational productivity model is applicable to a developing country context, namely, Papua New Guinea. Educational productivity can be conceptualised using an analogous approach to an economic model of productivity (Walberg, 1981). Here, educational productivity measures the output as the learning 'achieved' compared to the inputs of aptitude, instructional treatment and the environment.

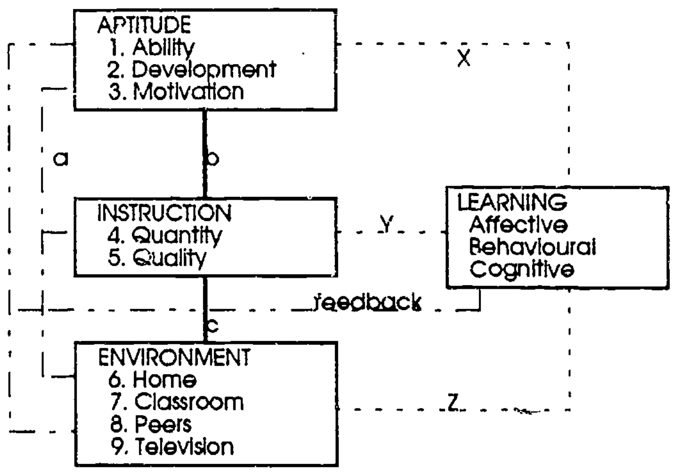

Figure 1. Walberg's (1981) General Educational Productivity Model on the Causal Influences on Student Learning

Walberg (1983, 1984a, 1984b, 1986) suggested that nine major factors require optimisation in order to achieve a model of educational productivity (Figure 1). These nine factors were grouped into three distinct variables:

a) Student aptitude variables
- i) Ability or prior achievement, as measured by standardised tests,
- ii) Development, as indicated by chronological age,
- iii) Motivational, or self-concept, as indicated by personality tests or the student's willingness to apply themselves on learning tasks.

b) Instructional variables
- i) Quantity of instruction that includes the amount of time the students spends in learning,
- ii) Quality of instruction, which includes both the psychological and curricular aspects.

c) Educationally stimulating psychological environment variables
i) Home environment
ii) Classroom or school environment
iii) Peer group environment outside the school
iv) Mass media environment (Fraser et al, 1987).

The economic law of diminishing returns states that there is a maximum output for any given amount of input (Samuelson, 1964). Similarly, Walberg's Educational Productivity Model assumes that interaction of factors occurs by the substitution of factors in ever decreasing returns (Walberg, 1981). Since this interaction of factors could be fairly complex, the model itself does not show interaction terms. While each factor could influence the model, each factor in turn could be influenced by other factors such as the learning of the students. Walberg's Educational Productivity Model recognises that human learning is complex but the model is also economical in terms of factors which coherently and consistently predicts student outcomes. Like the economic productivity model, this educational productivity model does not attempt to identify all those factors that could effect the educational productivity of schools. Those factors that are less alterable by the teacher were excluded from the model. The research reported here attempted to determine within a developing country context, (Papua New Guinea) whether a modified form of Walberg's (1981) Educational Productivity Model is applicable to a developing country context.

Prior research has indicated that there has been a degree of disagreement over the value of the science laboratory classroom as a teaching strategy (Giddings, Hofstein & Lunetta, 1991; Lynch, 1986; Tamir, 1989; Lehman, 1989). Many factors other than physical facilities affect the nature and quality of learning and hence the productivity of the educational system. One of the major factors that appears to affect student learning is the classroom psychosocial environment (Fraser & Fisher, 1982; Fraser, 1989). Additionally, there is substantial evidence which indicates that teachers can make a more substantial difference to student achievement, attitude and motivation in developing countries than what would be expected to find in developed countries (Brophy & Good, 1986; Twoli & Power, 1989). Any variance due to school affects should be reflected in any application of a educational productivity model. Little research has been conducted into the state of science laboratory teaching activities in developing countries. There is virtually no published research into the current teaching practices in Papua New Guinea science laboratory classrooms. These teaching practices could affect the educational productivity.

PURPOSE(S) OF STUDY

This study reported here attempted to fill some of this gap in the research by identifying and describing the nature of current secondary school science laboratory practices within Papua New Guinea secondary schools. Specifically, the research sought to (a) examine in particular the relationship of current teaching practices to a number of variables that could affect students' learning in their science laboratory classrooms, (b) determine which factors affect academic success in an external science achievement examination, and (c) determine whether a educational productivity model is applicable to this context.

METHODOLOGY

The study combined qualitative (observation, interview & case study techniques) and quantitative (questionnaire & survey instruments) methods. The researcher also observed both science teachers and students in science laboratory classes. The sample consisted of 3182 Grade 10 students in 46 secondary schools. Questionnaires administered to students and teachers attempted to examine:
i) students' and science teachers' perceptions of the typical science laboratory teaching practices; and
ii) students' and their science teachers' perceptions of the science laboratory classroom learning environment;
iii) students' attitudes towards science;
iv) relationship of student achievement to learning environment and laboratory classroom teaching variables.

Data about the science laboratory learning environment were collected using a modified form of the SLEI, the Science Learning Environment Inventory (Giddings & Fraser, 1990) which was adapted for use in

Papua New Guinea secondary schools where English was a second language for most students. The modified SLEI had 25 items in 5 scales, namely, Student Cohesiveness, Open-Endedness, Integration, Rule Clarity and Material Environment. Data about students' attitudes towards science were obtained using a modified form of the Test of science-Related Attitudes (Fraser, 1981) and was adapted for use in Papua New Guinea. Data about science teachers' and students' views on the nature of science laboratory activities were obtained by the adaptation of the Science Laboratory Activity Questionnaire (Ost & Swanson, 1968). Data about science achievement was obtained from the 1991 Papua New Guinea School Certificate Science Examination. Data about practical achievement was obtained from administration of an Australian version of the IEA Science Process Test (Giddings, 1991).

SCIENCE LABORATORY LEARNING ENVIRONMENT

A modified version of the SLEI (Giddings & Fraser, 1990) was prepared for Papua New Guinea secondary schools. Field testing the seven scale version of SLEI involved 3182 students from Grade 10 science classes in 46 Papua New Guinea secondary schools. Table 1 clarifies the meaning of each of the five scales in the final version of SLEI by providing a scale description and sample item. The data was subjected to item analysis in order to identify items whose removal would improve each scale's internal reliability. This was achieved by removing a small number of items with low-remainder correlations. This item analysis procedure resulted in the final version of Science Laboratory Environment Inventory (SLEI) for Papua New Guinea secondary schools containing 25 items in 5 scales.

Table 1: Descriptive Information for Each Scale in Personalised Science Laboratory Environment Instrument (SLEI) Scales

Scale Name	Description	Sample Item
Student Cohesiveness	Extent to which students know, help and are supportive of one another.	I work well with others during experiments
Open-Endedness	Extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation.	I can do experiments by myself
Integration	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.	What I learn in class doesn't help me to do the experiments.
Rule Clarity	Extent to which behaviour in the laboratory is guided by formal rules.	I have certain rules to obey in the science laboratory
Material Environment	Extent to which the laboratory equipment and materials are adequate.	Laboratory equipment is in poor working order

Table 2 reports the internal consistency (alpha reliability coefficient) for the SLEI for when the sample is school or individually based. It shows that for the sample of students as individuals, the alpha coefficient ranged from 0.48 to 0.58 and on a school basis, the alpha coefficient ranged from 0.57 to 0.82. It is not surprising to note that the alpha reliability was consistently greater with the school being the unit of analysis rather than with the individual being the unit of analysis. The aggregation that occurs when the school mean is the unit of analysis, results in less variance and a consequential improvement in reliability.

Table 2: Scale Mean , Item Mean, Cronbach Alpha Reliability and Discriminant Validity (Mean Correlation with Other Scales) for SLEI, and Ability to Differentiate between Classrooms

Scale	Unit of Analysis	No of Items	Alpha Reliability	Mean Correlation with Other Scales	Sample Size	Scale Mean	Item Mean	ANOVA Results (Eta^2)
Student Cohesiveness	School Mean	7	.59	.34	43	30.07	4.30	0.30*
	Individual		.49	.27	2,771	29.42	4.20	
Open-Endedness	School Mean	5	.57	.15	43	11.60	2.32	0.14*
	Individual		.48	.09	2,824	11.49	2.30	
Integration	School Mean	5	.73	.27	43	22.32	4.46	0.30*
	Individual		.48	.24	2,843	22.33	4.47	
Rule Clarity	School Mean	4	.77	.37	43	17.95	4.49	0.39*
	Individual		.58	.26	2,823	17.89	4.47	
Material Environment	School Mean	4	.82	.27	43	16.77	4.19	0.28*
	Individual		.57	.21	2,961	16.76	4.19	

*p<0.001

The eta^2 statistic (which is the ratio of 'between' to 'total' sums of squares) represents the proportion of variance explained by class membership.

The reliability data in Table 2 suggests that the refined version of each SLEI scale has acceptable reliability, especially for scales containing a relatively small number of items when either the individual student or the school was used as the unit of analysis. As expected, Cronbach's alpha reliability was higher when the unit of analysis was the school instead of the individual because of the effects of aggregation. The overall reliability of SLEI scales was measured by determining the reliability of the scales when the unit of analysis was the individual ($\alpha = 0.56$) and when the school mean was the unit of analysis ($\alpha = 0.62$). Data about discriminate validity was generated by using the mean correlation of a scale with the other scales on both an individual and school basis. Comparable results were obtained in both cases. Comparing school and individual perceptions, there appears to be no significant differences. The mean correlation shows that each scale is largely independent of each other and so are measuring different entities.

A desirable characteristic of the SLEI is that it is capable of differentiating between perceptions of students in different schools. This characteristic was explored by analysis using one-way ANOVA, with school membership as the main effect and using the individual as the unit of analysis. The results in Table 2 indicated that each scale differentiated significantly ($p<0.001$) between PNG schools. The eta^2 statistic represents the amount of variance in environment scores accounted by school membership and in this study ranged from 0.14 to 0.39.

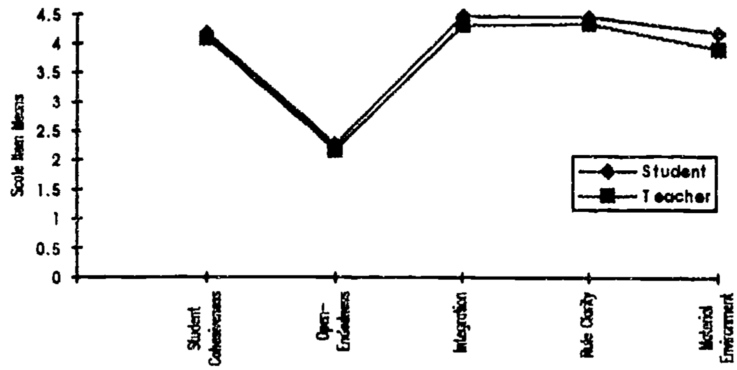

Figure 2: Plot of SLEI Scale Item Means for Students and Science Teachers

Students' scale item means and science teachers' scale item means were plotted in Figure 2. The pattern of this plot was consistent with past research in that open-endedness was the least favourable SLEI scale. (Fraser, 1982a, 1982b, 1982c, 1986b; Fraser, Giddings and McRobbie, 1991). Table 3 showed that integration and rule clarity were clearly the most favourable SLEI scales. As well, Table 3 shows that the SLEI scale means were similar for both students and science teachers. Except for the material environment scale, male and female teachers appeared to perceive the SLEI scales similarly. Figure 2 indicates that students perceived a slightly more favourable laboratory classroom than the one perceived by teachers. Only the material environment showed that the difference in perceptions were significant, students perceiving a more favourable environment.

Table 3: SLEI Scale Item Means of Students and Science Teachers

Scale	Number of Items	Student Mean	Teacher Mean	Male Student Mean	Female Student Mean	Male Teacher Mean	Female Teacher Mean
Student Cohesiveness	7	4.19	4.09	4.21	4.19	4.11	4.04
Open-Endedness	5	2.28	2.18	2.36	2.20	2.19	2.16
Integration	5	4.47	4.32	4.45	4.48	4.35	4.20
Rule Clarity	4	4.46	4.35	4.47	4.48	4.32	4.45
Material Environment	4	4.19	3.91	4.21	4.16	3.84	4.20

Male students scale means and female students scale means were plotted in Figure 3. The pattern was similar with previous research in both developed and developing countries (Fraser, 1982a, 1982b, 1982c, 1986b; Fraser, Giddings & McRobbie, 1991, 1992; Waldrip, 1993) in that Open-endedness was the least favourable SLEI scale.. Female students perceived Integration and Rule Clarity slightly but not significantly more favourable whereas male students perceived student cohesiveness, open-endedness and material environment more favourable. There was no significant difference in male and female students' perceptions of the SLEI.

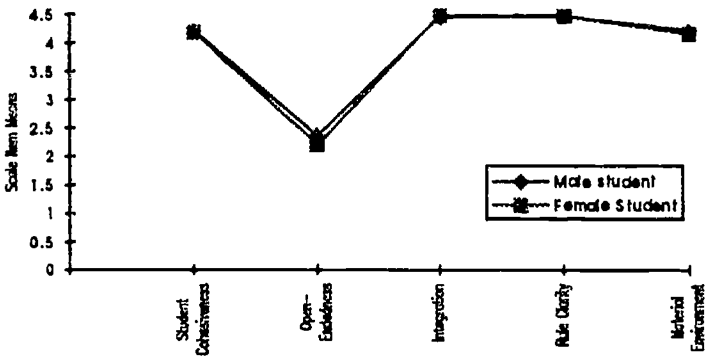

Figure 3: Plot of SLEI Scale Item Means for Male and Female Students

OUTCOMES

This section describes the major outcomes measured by this study, namely science achievement, practical achievement and students' attitudes towards science. Each of these outcomes are treated separately. The data which forms the basis of these results was obtained from the Papua New Guinea School Certificate 1991 science examination, the administration of the Science Process Test, and the student section of the Science Laboratory Activities Questionnaire termed attitudes and student section of the Science Laboratory Activities Questionnaire termed Science Laboratory Learning Environment. The relationships of factors to these outcomes were determined by the use of multivariant analysis.

Table 4: Male and Female Student Means and Standard Deviations and Result of t-tests in School Certificate Science Examinations

Year	Male Students			Female Students					
	n	Mean	sd	n	Mean	sd	t	df	Prob
1986	6102	26.20	6.76	3304	22.63	6.40			
1988	6398	24.47	7.69	3600	20.19	6.99			
1989	6154	24.84	7.08	3701	21.90	6.42			
1990	6472	28.24	8.28	3648	24.93	7.83			
1991	6523	26.30	8.21	4280	23.30	7.85	19.04	10802	.000
Study Sample	1929	27.00	8.11	1182	23.00	8.02	13.41	3109	.000

Students' science achievement level was defined as the score achieved on the external science achievement examination in the Papua New Guinea Department of Education School Certificate 1991 examination. The examination contained 40 multiple-choice items with each usually containing five alternative responses, and 10 short-answer questions. A total of 10,802 students sat this examination. Examination of past School Certificate results indicated (Table 4) that male students consistently outperform female students. For instance, during 1991, male students performed better than female students in both the national (n=10802) and study sample (n=3182). Only 1991 data were available for analysis by t-test. Previous studies have revealed that males outperform females in similar science achievement examinations (Cheung, 1993; Forrest, 1992). Nationally, there was observed a variation between the provinces in the provinces' average mark in the science achievement examination. It also showed female students in all Provinces performed less academically than the male students (Figure 4).

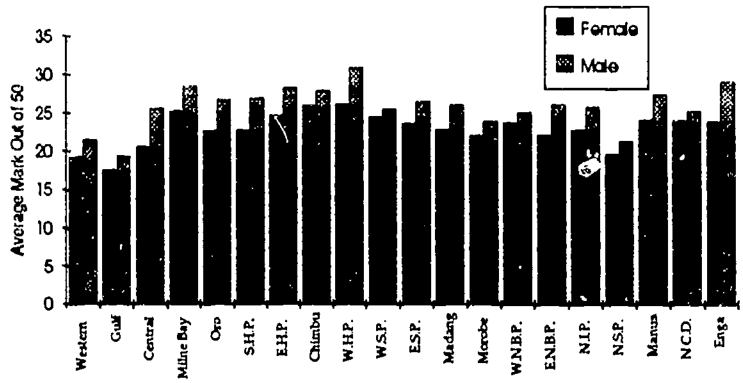

Figure 4. 1991 School Certificate Science Examination by Province by Sex

What caused this variation in the students' science achievement between provinces and the difference between male and female students? Earlier studies examined factors affecting success in secondary schools (Silvey, 1978: Tuppen, 1981) and the gender effects (Palmer, 1978). These studies, while answering some questions, did not produce an overall comprehensive picture of the problems. Past research has often investigated associations between student outcomes and the nature of the classroom learning environment (Fraser, 1986a, 1986c). This study examined students' performance in a science process test. The majority of the students completed a science process test. In this study, female students outperformed male students in the Science Process Test.

There appears to be no published evidence of science laboratory practical skills being examined in PNG. This study attempted to examine the factors affecting practical achievement in science laboratory classrooms using multivariant analysis. The practical achievement was the score representing students' performance on the Science Process test (n = 1836) which was based on the Australian version of an International Science Process test (Giddings, 1991a, 1991b). The scoring method used was similar except that only the total, not the individual section scores were recorded for each student. The Science Process Test was shown to be reliable, analysis of a random sample of 233 scripts resulted in a reliability of 0.60. Students' Attitudes Towards Science was the score representing students' response to a simple 17-item Likert-type questionnaire that had five response alternatives assessing opinions about the science laboratory. The attitude questionnaire had a reliability of 0.62 based on 2754 students' responses.

Table 5 reported the results obtained when the effect of various factors on science achievement, practical achievement and students' attitude towards science were measured. The factors selected were quantity of instruction, quality of instruction, Science Laboratory Environment Inventory (SLEI) scales and gender. The quantity of instruction was assessed through three different variables. Firstly, it was assessed by the number of hours of homework given per week as reported by the teacher. Secondly, it was assessed, as reported by the teacher, by the time each class spent doing experiments in small groups in the science laboratory classroom. Thirdly, it was assessed, as reported by the science teacher, by the frequency the science class used the science laboratory classroom. These three items were combined into a single factor by the summation of responses to these items. The quality of instruction was assessed by the teachers' response to a series of questions about the perceived effect of shortages of science supplies, on demonstrations of experiments, level of laboratory storeroom security, and the availability of water, gas and electricity. The quality of instruction was considered as a single factor which was achieved by combining all of the above items. The PNG version of the science laboratory classroom environment (SLEI) was measured by 25 items asking students how they felt during science class experiments.

Table 5 reported the results obtained when the effect of each factor on student achievement, practical achievement and students' attitudes were investigated in two different ways. First, a simple correlational analysis provided a means for measuring the association between 'outcome performance and each individual factor, ignoring all other factors. Second, because of the interrelations among predictors, multiple regression analysis was used to provide a multivariate test of the joint influence of the set of all factors on an outcome and an estimate of the effect of each individual factor when all factors are held constant.

Table 5: Simple Correlation for Individual and School Unit of Analysis and Standard Beta Weight for Each Productivity Factor.

Productivity Factor	Unit of Analysis	Simple Correlation (r)			Standardised Regression Weight (β)		
		Science Achievement	Practical Achievement	Attitude	Science Achievement	Practical Achievement	Attitude
Quantity of Instruction	Individual	.16**	-.01	-.03	.07*	-.07*	-.01
	Class Mean	.29	-.09	.22			
Quality of Instruction	Individual	.19**	.24**	.05	.15**	.26**	.05
	Class Mean	. .38	.53**	.52*			
Student Cohesiveness	Individual	.13**	.08*	.39**	.09**	.03	.26**
	Class Mean	.26	.29	.58**			
Open-endedness	Individual	.05	-.03	.25**	.03	.00	.19**
	Class Mean	-.13**	-.08	-.06			
Integration	Individual	.14**	.15*	.30**	.12**	.13**	.16**
	Class Mean	.58**	.58*	.57**			
Rule Clarity	Individual	.04	.08*	.27*	-.03	.03	.10**
	Class Mean	.26	-.01	.62**			
Material Environment	Individual	.06*	.04	.19**	-.04	- 04	.04
	Class Mean	.38	.01	.17			
Gender	Individual	-.25**	.11**	-.07*	-.24**	.10**	-.04#
Multiple Regression					.59**	.55*	70**
Sample Size	Individual	1707	987	1590	1707	987	1590
	Class Mean	29	19	29			

# p<.05 * p<.01 **<.001

The multiple regression results in Table 5 are those obtained for science achievement, practical achievement and students' attitudes when the whole set of eight predictors was separately regressed on science achievement, practical achievement and students' attitudes. The information reported for each productivity factor was standardised beta weights, as well as the significance level obtained from a t-test of whether the magnitude of the beta weight is greater than zero. The bottom of Table 5 showed the multiple correlation for the whole set of predictors variables were 0.59 for science achievement, 0.55 for practical achievement and 0.70 for students' attitudes towards science. Table 5 showed a high similarity between the results of the simple correlational analyses and the multiple regression analyses.

SCIENCE ACHIEVEMENT

Students' science achievement level was defined as the score achieved on the external science achievement examination in the Papua New Guinea Department of Education School Certificate 1991 examination. Table 5 reported the results obtained when the effect of various factors on science achievement was measured. The factors selected were quantity of instruction, quality of instruction, Science Laboratory Environment Inventory (SLEI) scales and gender. For science achievement, Table 5 shows that the number of significant correlations ($p<.01$) between achievement and each factor was five at the individual as a unit of analyses level, four of which were significant in the multiple regression analyses in which all other independent variables were held constant. The exception was material environment which was only significant in the correlation analysis and not significant in the multiple regression analysis. The correlation when the school was the unit of analysis will not be discussed here due to the low sample size. The sample size was low because only those schools which provided data on all factors were considered for analyses.

Multiple regression analysis showed that the factors regressed to science achievement were quality and quantity of instruction, the SLEI scale of integration, and gender. This result could suggest that Walberg's Educational Productivity Model which includes the group variables of student aptitude, instruction and psychological environment, could be appropriate to a developing country context, namely Papua New Guinea. It should be noted that because the multiple correlation analysis estimates relationships between outcomes and a particular variable when all other independent variables are held constant, they provide more conservative tests of relationships than simple correlations.

PRACTICAL ACHIEVEMENT

Past research has often investigated associations between student outcomes and the nature of the classroom learning environment (Fraser, 1986a, 1986c). This study examined students' performance in a science process test. The majority of the students were required to complete a science process test. The multiple regression results in Table 5 are those obtained for the full model when the whole set of eight predictors were regressed on the practical achievement. Table 5 also shows a high similarity between the results of the simple correlational analyses and the multiple regression analyses. For practical achievement, Table 6 shows that the number of significant correlations ($p<.01$) between achievement and the factors were six at the individual as a unit of analysis level, four of which were significant in those multiple regression analyses in which all other independent variables were held constant. The exception were the scales of student cohesiveness and the rule clarity which were only significant in the correlation analysis and not significant in the multiple regression analysis. Multiple regression analysis showed that the factors regressed to practical achievement were quality and quantity of instruction, SLEI scale of integration, and gender.

STUDENTS' ATTITUDES TOWARDS SCIENCE

Students' Attitudes Towards Science was the score representing students' response to a simple 17-item Likert-type questionnaire which had five response alternatives assessing opinions about the science laboratory. Overall, students' attitude towards science was similar to that found in many developing South Pacific countries (Waldrip, 1993). It was noted that similar to many previous studies (Gardner, 1975; Schibeci, 1984), females have a less favourable attitude towards science than do males (see Table 6).

Table 6: Results of T-test on Male and Female Students' Attitude Towards Science

Male n	Male mean	Male sd	Female n	Female mean	Female sd	t-value	df	Prob
1718	66.36	7.81	1036	65.42	7.94	3.04	2752	.002

Table 5 reported the results obtained when the effect of various factors on students' attitude towards science. The factors selected were quantity of instruction, quality of instruction, Science Laboratory Environment Inventory (SLEI) scales and gender. For attitudes, Table 5 shows that the number of significant correlations (p<.01) between attitudes and productivity factor was six at the individual as a unit of analyses level, five of which were significant in the multiple regression analyses in which all other independent variables were held constant. The exception was the material environment scale which was only significant in the correlation analysis and not significant in the multiple regression analysis. Multiple regression analysis showed that the factors regressed to students' attitude towards science were gender and the SLEI scales of student cohesiveness, open-endedness, integration, and rule clarity. This result again suggest that Walberg's Educational Productivity Model which includes such group variables, could be appropriate to a developing country context. These results of this study were similar to Giddings, Fraser and McRobbie's (1992) study which found that Student Cohesiveness, Integration and Rule Clarity were significant predictors of attitudes. Giddings, Fraser and McRobbie's (1992) found that Material Environment scale and to a lesser extent Open-endedness scale was also a significant predictor whereas this study noted that Open-endedness was not a significant predictor of attitudes.

OUTCOME INTER-RELATIONSHIPS

Previous research has established a positive correlation between science achievement and students' attitudes towards science (Fraser, 1986a, 1986c). This study found a similar relationship. In this study science achievement consisted of science academic achievement and science practical achievement. Table 7 shows that the correlation between science achievement and attitudes was 0.26 (n=2690) when the student is the unit of analysis and 0.51 (n=44) when the school was the unit of analysis. The table also showed that the correlation between practical achievement and attitudes was 0.13 (n=1557) when the student is the unit of analysis and the correlation was 0.63 (n=29) when the school was the unit of analysis. Finally the table showed that the correlation between science and practical achievement was 0.29 (n=1789) when the student is the unit of analysis and the correlation was 0.81 (n=31) when the school was the unit of analysis. Hence, using the schools' average performance in science academic examination, a good correlation was found to exist between science academic achievement, practical achievement and students' attitudes towards science.

Table 7: Correlation of Science Achievement, Practical Achievement and Students' Attitudes Towards Science

	Unit of Analysis	Science Achievement	Practical Achievement
Students' Attitudes	Individual	.2599	.1300
Towards Science	School	.5052	.6298
Practical Mark	Individual	.2948	
	School	.8106	

Using the individual as the unit of analysis, there was a positive but poor correlation between these three outcomes. Using the school as a unit of analysis for the existence of correlation suggests that there are important school factors present that affect outcomes. This is consistent with studies in other developing countries which found that school factors and teacher quality characteristics do give rise to more variance in achievement than do the influence of family background or socioeconomic status (Heynemen, 1976; Heyneman & Loxley, 1982; Twoli & Power, 1989)

DISCUSSION

As has been previously stated, this study sought to identify and analyse the nature of current school science laboratory practices in Papua New Guinea secondary schools and to determine the appropriateness of an educational productivity model to this developing country context. Implied in an examination of factors associated with educational productivity is the possibility that the nature of educational change in Papua New Guinea could be better understood as a result of this study. As Zaharlick (1992, p122) states:

> "To bring about educational change, it is important to have knowledge and understanding of the total context of schooling.... Approaches to improving instruction, curriculum, evaluation, or any other aspects of the educational process that do not take into consideration the surrounding context are at a decided disadvantage in achieving long term success."

It is therefore important when considering educational productivity to examine in detail the surrounding context. To simply analyse the results of this study and any relationships that could have been identified, could ignore important social and cultural factors such as local customs and mores that could have a significant effect on the teaching practices and learning. It could be possible, as Laosa (1979) argues, that individuals become frustrated and produce increased misunderstandings, and hence learning is affected when they do not understand another's culture.

Gannicott (1987) has argued that Papua New Guinea receives a low return for educational investment if one applies a rate of returns analysis. He claims that the returns from this educational investment to the country as a whole is low by standards of other developing countries. However, Gannicott fails to see beyond the perceived cash benefits/costs. In his argument, Gannicott provides poor documentary evidence for his claim that Papua New Guinea educational standards are low. Culturally in Papua New Guinea society, a return on investment or a loan, can be viewed as amply returned in a non-cash form and could even be considered equal or better than a cash benefit (Hogbin, 1973; Whiteman, 1986). McGavin (1991a, 1991b) also argues that Gannicott has not understood Papua New Guinea culture and society and therefore has made some unjustified assumptions about the use of data in order to reach the conclusion that the educational productivity is low.

As Zaharlick (1992) implies, educational productivity could only be optimised when the context is accounted for. In this study, culture was an important part of the context. Consequently, the sensitivity of Walberg's Educational Productivity Model could be further enhanced if cultural variables are shown to be necessary for an adequate explanation of the results of this study. The effect of these cultural variables on the results of this study are briefly discussed. The factors comprising the cultural effect variable included gender, race, traditions and tribal beliefs.

Gender

It was not surprising to find such a low proportion of female teachers (20%) compared to the female student population (39%) in Papua New Guinea secondary schools. Also women are expected to handle all family matters and acquiesce to the male (Brown, 1986). Within Papua New Guinea society, there is a clear delineation between the roles of males and females (Hogbin, 1973; Whiteman, 1986). From a sociological or cultural perspective, men perceive themselves as the money managers and so are more likely to seek employment. Women are seen as being in charge of the house and garden and not capable of making these types of decisions by many areas of Papua New Guinea society. Men will often refuse to help in areas regarded as women's work (Herdt, 1987). Taking women away from the garden is regarded as an economic loss in many countries (Kelly, 1987; Turner, 1990) and is viewed as such within Papua New Guinea. Educating a girl could be viewed as a questionable pursuit as it is possible that the money spent on educating her will not be recovered. This is because the girl, once married, will n ,. continue to work due to child-rearing constraints or is viewed as less likely to obtain a job (Whiteman, 1986).

Quality Of Instruction
Examination of the results of this study revealed that the profile of a Papua New Guinea secondary science teacher is that of a male who is in his late twenties or early thirties. This science teacher is three year trained (usually post-Grade 10) and has a Diploma of Science Teaching usually awarded from one particular institution. During the 1984 to 1991 time period, the percentage of science teachers with the most basic allowable teaching qualification had decreased from 78.9% to 61.5%. At the same time, the percentage of science teachers with advanced or upgraded qualifications had increased from 21.1% to 38.5%. This significant increase in teachers with more advanced qualifications are important for a comparatively young education system. It is also apparent that the science teachers are largely remaining for an extended period within the school system as the average age and experience of the teachers have increased during the years 1984 to 1991. This increase in both teachers' qualifications and teaching experience should, hopefully, result in a higher level of teaching and student learning. It could be inferred that the education system is retaining it's educated and experienced teachers. As there is an increasing proportion of locally trained science teachers, the local culture is more likely to become an important factor in their teaching practices and student learning practices.

Teaching Practices
The study suggested Papua New Guinea science teachers are very stereotyped in their teaching practices. This assertion is illustrated by the fact that teachers show very little variation in the design and implementation of experiments, preferring to minimalise students' input in the form of questions or ideas and that giving directions was the second most common observed teacher activity. Avalos (1991) in studying community (primary) school teachers, reached a similar conclusion. Sociologically and culturally, an elder must remain in charge of a situation (Hogbin, 1973) and so it is not surprising then, to find that similarly the teacher feels that they must be in control of the class. In Papua New Guinea society, the elders are the source of knowledge and often the younger members are perceived to be full of foolish ideas. Directions emanate from the elders and so in teaching, the teacher likewise directs the class. Confirming this view, Apelis (1980, p4) in his paper looking at the contribution anthropology has made to education, states that Papua New Guinea teachers "like to impose a teacher-centred classroom in order to keep control of the system." Yet, during school visits a number of teachers privately requested impromptu lesson demonstrations. These teachers expressed voluminous appreciation for these demonstrations as they were able to observe a class in action. It could be argued that teachers are reflecting cultural norms and mores by providing a comparatively high level of directions to the class so as to maintain class control. At the same time, these teachers appeared to appreciate observing new methods that they could then start to imitate.

Experimentation Procedure
The fact that teachers like to explain how to do experiments in a pedantic step-by-step fashion is partially explained by teachers wanting to maintain control but also because during teacher training, it is often stressed that teachers must carefully explain how to do experiments to the students. Teachers often used demonstrations because the strategy had been stressed in their training as important, and demonstrations are becoming more common as science supplies are often difficult to obtain and consequently there is often insufficient quantities of materials and equipment for student use. It could be argued that teachers felt unsure about their knowledge about the experiment and therefore feel in better control if they perform the experiment. So combining all of these factors with the notion that the elders demonstrate new learning in Papua New Guinea society, and that imitation, similar to Africa (Brown, 1975), is the most usual form of tribal learning (Herdt, 1987), it is not surprising that teachers frequently demonstrate experiments to their class. Consequently, students expect to have things demonstrated to them rather than have the opportunity to try out for themselves.

It could appear that the student sometimes design the experiment, once the teacher has presented the problem. But this was more likely to be a result from the confusion that was present in the classroom. In such a situation, the teacher most probably had given the experiment and explained the instructions. The students had most probably either not really listened to the instructions or did not really understand them, and so were not sure of the instructions and therefore had to work out what was happening. Students, not willing to appear that they didn't understand the experiment, would try and work their way through the experiment. Culturally, especially for a young person, it is disadvantageous to retreat from an established position (Whiteman, 1986). Hence, in class, students try to give the "correct" answer and prefer not to contribute if they are unsure.

Questioning

Lesson observations indicated that factual questions were usually asked. This observation concurs with that of Avalos (1991). Avalos examined the teaching practices of community (primary) school teacher trainees within Papua New Guinea and had found that teachers generally liked to ask factual questions. But what happens if the questions being asked is not the response that the teacher feels comfortable with? Data about teachers listening to students' ideas seem to suggest that unsolicited responses or responses that could produce non-expected ideas were not welcomed. This should not be surprising. Culturally, age has more respect. Adult's opinions are respected while a child's opinion is often viewed as of somewhat little value. Within adult groups, older members are more respected, especially if one can quote the appropriate historical events during discussions. However, display of selected and perceived vital leadership skills could enhance a younger adult's respect. Conversely, serenity in an older person causes loss of respect. Since the older person's ideas must be listened to, students could perceive that the teacher is not really interested in their ideas. Culturally, it seems acceptable for a younger person to ask an elder for their opinion and so it is not surprising to find that mainly factual questions are asked. An elder is an older or more experienced member of the society and is usually a male member. Any other type of questions could be seen as challenging society and hence their acceptance within the tribal hierarchy. Brown (1975) concurs with the explanation given here when he comments that African children must not be seen as challenging the beliefs and behaviour of their elders.

In tribal learning, the child is often drilled with factual questions to ensure that learning has occurred (Hogbin, 1973). It could be argued that it was not surprising to find that male teachers are less likely to listen to students' ideas. This appears to be partly due to the perceptions that males occupy a superior place in Papua New Guinea society and as such, they are less likely to accept a younger person's ideas. Hvitfeldt's (1986) study amongst the Hmong minority of Laos noted that in the classroom context, the students preferred a structure that was imposed rather than an individually constructed structure. This explanation could help explain why Papua New Guinea students have the perception that older members of society (teachers) don't listen to their ideas. These students could prefer to be directed by an authority.

Authority

There was also a significant difference between teachers liking to be asked questions (88.1%) and listening to ideas (68.9%). This could be explained by an examination of cultural norms. Typically in Papua New Guinea society, an elder tells the listeners the required knowledge and could be asked, in the process, some clarification questions, but the listener will not be expected to create new ideas or challenge the explanation. Since the elder knows more, the listener will not challenge the idea but if the listener does challenge the idea, the listener could be ignored and even ostracised from his/her society (Whiteman, 1986).

The necessity of recourse to a cultural explanation for some of the results of this study is reinforced when perceptions regarding students' willingness to give or seek help is examined. Students' perceived reserve to seek or give help can be interpreted as unwillingness on the part of the student. However being subservient to a leader is part of the culture of a Papua New Guinea society (Herdt, 1987). Also culturally, it seems unwise to appear or found to be wrong (Whiteman, 1986). So students could well be hesitant to take the risk of giving or receiving help within the science laboratory classroom. It could be argued that if a student needs help, then they are admitting to the class their need of help and could thereby lose some prestige. It seems more acceptable for an older member of the society (for example, the teacher) to accept blame for an event than it is for a younger member (for example, a student). It has been argued that if one is found to be at fault, the younger member at a critical stage of life, would have to endure the shame for a longer period than would the older person (Herdt, 1987; Whiteman, 1986). If they give help, they could make an error and this could also cause some loss of prestige. An older, more experienced person seems more likely to take this risk and would have to bear any loss of prestige for a shorter time than a younger person would need to. So, it could be argued that it is not surprising to find teachers (being older) perceiving students (being younger) as being more likely to be unwilling to take the risk of giving or seeking help. A major concern in Papua New Guinea society seems to avoid doing something wrong but rather being shown or found out to be wrong (Whiteman, 1986). However to take a risk and succeed reinforces and develops one's prestige or importance in the society. This could very quickly results in a class polarising into a large group who hesitate to give any class input and into a small group who give the majority of any input. This small group will consist mainly of the student leaders belonging to that class.

From a sociological and cultural perspective, and being the authoritative figure in the classroom, the teacher must show that (s)he are in control, hence (s)he decide who is in each group. It appears that the teacher perceives themselves as being more responsible and superior in wisdom and knowledge than the students, and as they were told in teacher training college, they plan all experimental activities. At no stage does the teacher appear to relinquish control to the student. In fact, all students do the same experiment at the same time and rarely are they involved in planning the problem to be investigated or how to investigate the experiment. Similarly it could then be argued that it is not surprising that science teachers like to demonstrate experiments as this gives them the feeling that they are in control.

Quantity of Instruction

Teachers felt that less than a quarter of their time was spent doing experiments in small groups. If resources are so scarce, then it would not be surprising to find such a low level of students themselves performing experiments. If the level of resources is low and there is difficulty in obtaining science supplies, then it is not surprising to find that the equipment would be in poor working order, So if this was true, then it is not surprising to find that teachers feel restricted about performing demonstrations or experiments. Another factor restricting the teacher is the perception that the science laboratory is crowded and teachers find it somewhat difficult to move around many Papua New Guinea science laboratory classrooms. It appears that these science teachers would feel less likely to perform demonstrations or to conduct class experiments and so their students would spend less time doing experiments in class. This low rate of experimentation would then seem to indicate to the students that experiments were unimportant as time is important in Papua New Guinea societies. The degree of importance seems to be nearly always reflected in the quantity of time spent on the task.

Science Laboratory Learning Environment

The learning environment is an important aspect of the science laboratory classroom. Students and teachers had similar perceptions. Comparison to Fraser, Giddings and McRobbie's (1991) study showed a similar shape to the plot of SLEI scales, suggesting that features of the learning environment is similar in the countries studied. However, the finding that no significant differences existed between science teachers and students and between male and female students is different to that of Fraser et al's findings. But this could be due to similar perceptions between male and female students of authoritarism. Students are taught from birth to especially respect male elders (John Paul Chao, 1986), and so it could be argued that since the majority of Papua New Guinea science teachers are male, it should not be surprising to find that students have similar perceptions of the learning environment. Similarly, it seems not surprising that there are similar perceptions between science teachers and students. From childhood, all tribal members are taught societal expectations and not to challenge what they have been taught. Again this similar perception between students and their science teachers could be explained by appealing to their similar perceptions of authoritarism.

So far in this discussion, many of the results have been explained using cultural explanations. Even though a measure of cultural influence was not developed as part of this study, it is obvious from the explanations given, that culture is an important variable that can influence outcomes and could need to be included in any model of educational productivity so as to optimise the sensitivity of the model. The results showed that a number of factors were found to be significant predictors of students' academic achievement, practical achievement, and attitudes towards science when respectively controlled for each other in this study. Arguably this suggests that science and practical achievement, and students' attitudes are influenced by a number of common factors, all of which are important, with no one factor over-riding the others. It was be argued that this study suggests that Gannicott's (1987) paper that stated that educational productivity of Papua New Guinea was low, is therefore flawed as his paper did not consider a sufficient spread of factors that would affect the sensitivity of educational productivity measurement.

In view of these findings of this study, Walberg's Educational Productivity Model needs to be modified to include a fourth group, namely cultural variables, which includes gender, customs and race. This fourth group of variables will further optimise an increase of educational productivity concerning learning. Cultural variables imply factors that affect the inherit qualities of the students such as gender, race, customs and traditional mores. This modified version of Walberg's Educational Productivity Model will be referred to as the Revised Educational Productivity Model (see Figure 5). This study identified two unalterable factors, gender and culture, as significant independent predictors of outcomes. Still, three school alterable factors were significant independent predictors of outcomes. These alterable factors were quantity of instruction (measured by frequency of use of the laboratory), quality of instruction (measured by the level of resources) and the science laboratory learning environment. This suggests that there are a number of factors that the science teachers can work on if they wish to improve science academic and practical achievement, and students' attitudes towards science.

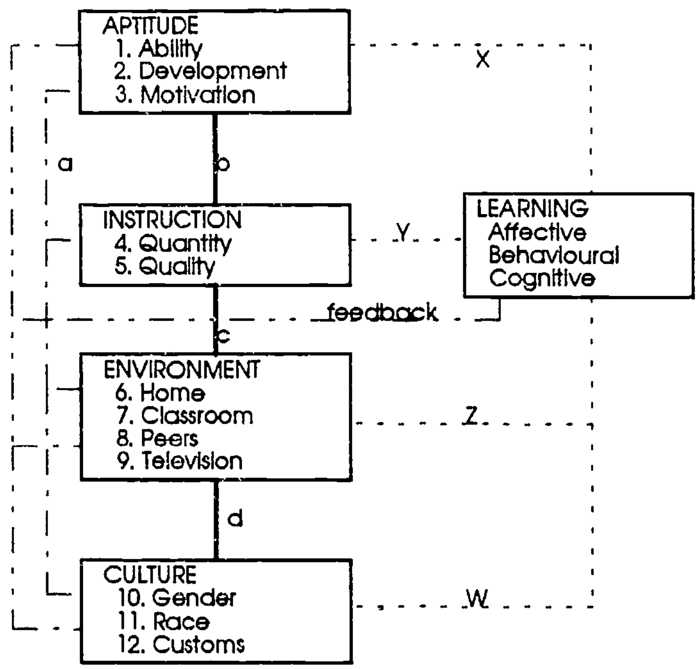

Figure 5. A Revised Educational Productivity Model for Science Education Within Papua New Guinea

The results of this study also showed that a number of factors were significant predictors of student outcomes when mutually controlled for each other in this study. This suggests that a number of factors rather than one dominant factor, could affect outcomes. In particular, quantity of instruction, quality of instruction, learning environment, gender and culture are significant predictors of outcomes when controlled for other factors. It should also be kept in mind that the Revised Educational Productivity Model assumes that interaction of factors occurs by substitution of factors in ever decreasing returns

(Walberg, 1981). That is, the level of educational productivity is limited by the weakest factor. Finally, the results of multiple correlation analysis generally support the appropriateness of the Revised Educational Productivity Model when culture is considered as a variable. That is, the most sensitive educational productivity model for a developing country includes the cultural variable (Figure 5). This study also divided the science achievement outcome into two achievement components, namely, a science academic achievement outcome and a science practical achievement outcome. It noted whether these factors of aptitude, instruction, environment and culture, influence practical work.

SUMMARY

Overall, the study found that the typical Papua New Guinea science laboratory classroom is not well maintained or well equipped even though the country has received a major boost in the level of science funding in the last few years. Many Papua New Guinea science teachers are teaching about things they have never experienced. This is evidenced by the fact that teachers did not view excursions or field trips as a science-related activity. The science teachers must teach in science laboratory classrooms which often lack basic science equipment and they often lack the necessary confidence to perform the experiments. Their training and background indicates that they have had only minimal exposure to other than very traditional recipe-type approach to laboratory classroom experiments. Hence this study was important in that it identified some specific aspects of their current teaching practices involving science laboratory learning environment, and students' attitudes towards science.

There were similar perceptions of the science learning environments across most Papua New Guinea secondary schools. An interesting feature of the learning environments was that the scale on open-endedness was the least favourable scale. Responses regarding current teaching practices supported the finding that open-endedness was not a strong factor in Papua New Guinea science laboratory classrooms. Overall, boys had a more positive attitude towards science than girls. It was observed that gender and the SLEI scales of student cohesivesness, open-endedness, integration, and rule clarity positively correlated with students' attitudes towards science. Multivariate analysis showed that a educational productivity model using science education was applicable in a developing country context. Multivariate analysis showed that the science achievement was related to quality and quantity of instruction, SLEI scales and gender. As in similar studies in other countries, male students performed significantly better than female students in external science achievement examination, while in this research, female students performed better in a science process test.

The data also indicate that when possible, teachers prefer to demonstrate experiments to students rather than let students do the experiment. When experiments are performed, examination of teaching practices showed that teachers used a very traditional recipe-type approach to laboratory class experiments. That is, the teacher chose the experiment, the method, and the equipment to be used. The teacher then explained step-by-step how to do the experiment and the student followed the directions.

Culturally, there are different expectations for males and females in Papua New Guinea society. This is reflected in the results of the science achievement and practical achievement tests. Teachers' use of questions and control of the classroom, and students' input can only be adequately explained by appealing to cultural practices. The similarity of perceptions of the science laboratory learning environment is attributed to teachers' and students' similar perceptions of authority and the importance of seniority within Papua New Guinea culture.

Even though a measure of cultural influence was not part of this study, it is obvious from the explanations given, that culture is an important variable that influences outcomes. Of necessity, culture needs to be included in any model of educational productivity so as to optimise the sensitivity of the model. Past research has perceived the need to modify Walberg's Educational Productivity Model to include race and gender. This resulted in the Fraser's (1987) modification to the Educational Productivity Model. The results of this study using multiple regression analysis confirmed the appropriateness of the Revised Educational Productivity Model to a developing country context, namely Papua New Guinea, provided culture was includes as a variable to optimise the sensitivity of the educational productivity model.

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