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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 to examine: (1) the relationship of current teaching practices to a number of variables that affected students' learning in science laboratory classrooms, (2) which factors affected academic success in an external science achievement examination, (3) whether an educational productivity model was applicable to a developing country context, namely Papua New Guinea (PNG). The sample consisted of 3,182 grade 10 students in 46 PNG secondary schools. Overall, boys had a more favorable attitude towards science than girls. Multivariate analysis showed that PNG science academic achievement was related to quality and quantity of instruction, science laboratory learning environment scales and gender. Male students performed better than female students in external science achievement examinations; however, female students scored higher on a practical process test. The study also revealed that PNG science teachers were very didactic in their approach to teaching. An examination of the cultural context provided some help in trying to explain these teaching practices and students' learning patterns. Finally, this study showed that a modified educational productivity model was applicable to the Papua New Guinea context. (ZWH)

EDUCATIONAL PRODUCTIVITY, PEDAGOGY AND CULTURE

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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 to examine: (a) the relationship of current teaching practices to a number of variables that affected students' learning in science laboratory classrooms, (b) which factors affected academic success in an external science achievement examination, (c) whether an educational productivity model was applicable to a developing country context, namely, Papua New Guinea (PNG). The study adapted a classroom environment instrument, the Science Laboratory Environment Inventory, to the PNG context. 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-variate analysis showed that PNG science academic achievement was related to quality and quantity of instruction, science laboratory learning environment scales and gender. As in similar studies in other countries, male students performed better than female students in external science achievement examinations. It was of some significance to find that female students performed better than male students on a practical science process test. The study identified specific aspects of current teaching practices involving science learning environments and students' attitudes towards science, in a developing country context. The study revealed the situation that PNG science teachers were very didactic in their approach to their teaching. An examination of the cultural context provided some help in trying to explain these teaching practices and students' learning patterns. Finally, this study showed that a modified educational productivity model was applicable to the Papua New Guinea context.

BACKGROUND AND RATIONALE

Interviewer: *Are there somethings that you are allowed to do in the village that makes it harder for you to learn at school?*
Student: *Oh yes, like copying other's work. In the village everything is [learnt by] copying....*
Interviewer: *In the village is it acceptable for you to copy?*
Student: *Yes, that is the way we learn. In school we must do our own work.*

(Waldrip & Taylor, 1994).

At times the teaching and learning strategies adopted in the classroom can be perceived as being in conflict with natural (traditional) learning strategies of the learner. Teachers can use practices that may inadvertently conflict with student's home environment, mores and values. Classrooms are becoming increasingly multicultural. Even in developing countries whose schools are often perceived to be relatively homogeneous, there is an increasing amount of cultural mixing within classrooms due to population mobility.

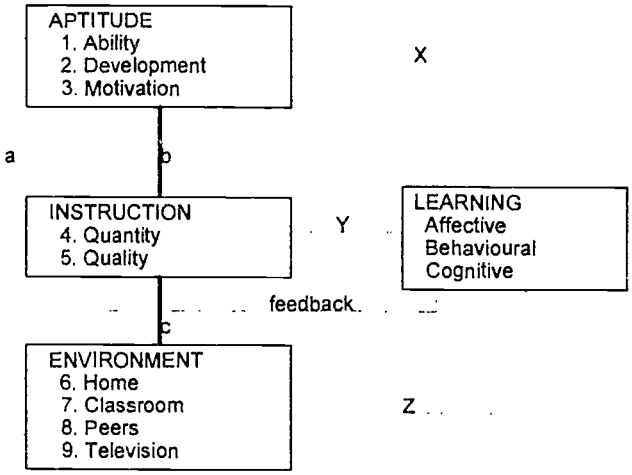
Although it can be misleading to compare students from different countries, the results from the Second International Science Study (SISS) suggests that differences between countries in terms of economic output and students' achievement in science are so appreciable as to attract attention (Rosier & Keeves, 1991). Concern over these SISS results has sometimes resulted in efforts to explain the differences found between countries in terms of cultural differences. Asian countries have often been perceived as having students who are more diligent and hard working (Brown & Comola, 1991). However, many teachers have failed to realise that many of their students, especially if they have similar appearances, may come from communities with widely differing cultural practices.

In many classrooms teachers attempt to enforce the accepted school view of scientific concepts while often failing to recognise the existence of their students' own preconceived views (Osborne & Freyberg, 1986; White & Gunstone, 1992). In those cases where major disparities exist between students' views and the school view, it is possible that the students' learning becomes fragmented and lacking in cohesiveness. These disparities are also often the result of inappropriate selection of teaching and learning strategies. There is evidence that teachers and curriculum developers sometimes fail to recognise that both students and teachers are part of a local culture and that, while undergoing significant changes, persist in cherishing certain traditions and actions (Kay, 1975). That is to say, there is a lack of taking into account the important cultural milieu into which the teaching and learning are to be placed.

Okebukola (1986) argued that the cultural background of the learner may have a greater effect on education than does the subject content. We argue, that unless students can relate the application of what is taught to their own cultural background, then the teaching strategies are likely to be less than effective in enhancing their learning. For sometime now, it has been argued that one of the main

sources of students' learning difficulties is the lack of optimisation between teaching strategies utilised by the teacher and the natural (traditional) learning styles of the learner (Kempa, in press).

Walberg's (1981) model of "educational productivity" suggests that nine factors require optimisation in order to increase affective, behavioural and cognitive learning (Figure 1). These causal influence of student learning include a set of aptitude variables (Ability, Development & Motivation), a set of instructional variables (Quantity & Quality) and a set of environmental variables (Home, Classroom, Peers & Media). We argue that a fourth set of variables could usefully be included. As Zaharlick (1992) implies, educational productivity could only be optimised when the context is accounted for. In this study, the rich and diverse culture of PNG was an important part of the context.



Note: Aptitude, Instruction, and the psychological environment are major direct causes of learning (shown as X, Y, and Z). They also influence one another (shown as a, b, and c) and are in turn influenced by feedback on the amount of learning that takes place (Walberg, 1984, p21).

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

The study reported here focused on what could be viewed as a microcosm of this cultural diversity, namely Papua New Guinea. The Papua New Guinea education system is currently being reformed, resulting in many syllabi revisions. The new education system consists of four school types: elementary schools for pre-school to Grade 2, a primary school for Grades 3 to 8, high schools for Grades 9 and 10 with some of these schools teaching Grades 11 and 12, and some schools only teaching Grades 11 and 12. The elementary schools currently teach using the local vernacular as the main language of transmission but switch to English in Grade 2 (Samana, 1992). This reformation of the education system has increased the utilisation of selected traditional stories which are utilised to develop bridges between the students' cultural heritage and their learning at school. A recent report (Avei, 1993) has been somewhat critical about the outcomes of the Papua New Guinea (PNG) education system. The report claimed that despite increases in both the number of schools and the number of teachers, the PNG education system still used an irrelevant curriculum that produce students who are not effective producers within the community

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).

PURPOSE(S) OF STUDY

Little research has been conducted into the state of science teaching and specifically science laboratory teaching activities, in developing countries. 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 determine (a) the relationship of current teaching practices to a number of variables that affected students' learning in science laboratory classrooms, (b) which factors affected academic success in an external science achievement examination; and (c) whether a modified educational productivity model was applicable to a developing country context, namely, Papua New Guinea (PNG).

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 63 science laboratory classes. Observations and interviews with both students and teachers combined with anecdotal evidence, formed the basis of the data used to establish the cultural context. The sample consisted of 3182 Grade 10 students in 46 PNG secondary schools. Questionnaires administered to students and teachers attempted to examine:

i) students' and science teachers' perceptions of the typical science laboratory teaching practices;

ii) students' and science teachers' perceptions of the science laboratory learning environment;

iii) students' attitudes towards science; and

iv) the relationship of student achievement to learning environment and laboratory classroom teaching variables.

FINDINGS

It is important when considering educational productivity to examine in detail the surrounding context. To simply analyse the results of this study and any relationships that were identified, could have ignored some important social and cultural factors that have a significant effect on the teaching and learning. The effects of some of these cultural variables (gender, race, traditions and tribal beliefs) on the results of this study are briefly outlined.

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. Within Papua New Guinea society, there is a clear delineation between the roles of males and females (Hogbin, 1973; Whiteman, 1986). For example, it was clear that females are generally expected to handle all family matters and to acquiesce to the male in most matters (Brown, 1986). Males will often refuse to help in areas regarded as women's work (Herdt, 1987).

As one student put it:

> *The boys get a job in town, the girls just wait at home and cook for us. That's a good idea.... To me it's good to leave [girls] back in the village*

Consequently, it was not surprising to find male students being less willing to help the female students and that students are more likely to challenge female teachers.

Quality Of Instruction

Examination of the results of this study revealed that the profile of a typical 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. There was a significant increase in teachers with more advanced qualifications during the period 1984 to 1991 period which is 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 markedly during the years 1984 to 1991. As there is an increasing proportion of locally trained science teachers, local culture is more likely to become an important factor in their teaching practices and consequently in the student learning practices.

Teaching Practices

The study reveals that Papua New Guinea science teachers are very stereotyped in their teaching practices. This is illustrated by the fact that most teachers in the sample showed very little variation in the design and implementation of experiment sessions, preferring to minimalise students' input in the form of questions or ideas in the general classroom context and that giving directions was the second most common observed teacher activity. Avalos (1991) in studying community (primary) school teachers, reached a similar conclusion. In such societies, sociologically and culturally, an elder always remains in charge of a situation (Hogbin, 1973) and so it is not surprising then, to find that similarly, the teacher feels it necessary to be in control of the class. In Papua New Guinea society, directions emanate from the elders. So in teaching, the teacher likewise directs the class. Confirming this view, Apelis (1980) 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."

Laboratory Teaching

The fact that teachers explain experimental methodology 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 should carefully explain how to do experiments to the students, less somehow the experiment is unsuccessful. Teachers, however, often used "demonstrations" because the strategy had been stressed in their training as important, and science supplies are often difficult to obtain.

Authority

There was also a considerable difference between students' and teachers' perceptions as to whether teachers listen to students' input. Teachers (68.9%) are more likely than do students (49.0%) to believe that they listen to students. Students' perceived reticence to seek or give help in class can be interpreted as an unwillingness on the part of the student to risk tribal status or prestige. Subservience to a leader is very much part of the culture of a Papua New Guinea society (Herdt, 1987; Whiteman, 1986). Students, therefore, could well be hesitant to take the risk of giving or receiving help within the science laboratory classroom because if a student needs help, then they are admitting to the class their need of help and could thereby lose some status or prestige.

A major concern in Papua New Guinea society is not so much that a person does something wrong but rather that being shown or found out to be wrong is reprehensible (Whiteman, 1986). However to take a risk and succeed reinforces and develops one's prestige or importance in the society. This could very quickly result in a class polarising itself into one large group who would hesitate to give any class input and into another smaller group who would 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, being the authoritative figure in the classroom, the teacher must show that (s)he is in control, hence (s)he decide grouping. 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.

Quantity of Instruction

Teachers spend minimal time allowing the class to do small group experiments. With such scarce resources, it isn't surprising to find such a low level of student-performing experiments. However, this low rate of experimentation seems to indicate to the students that experiments are 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

A modified version of the SLEI (Giddings & Fraser, 1990) was prepared for this PNG project. Field testing the seven scale version of SLEI involved 3182 students from Grade 10 science classes in 46 Papua New Guinea secondary schools. The data was subjected to item analysis in order to identify items whose removal would improve each scale's internal reliability. 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 (Waldrip & Giddings, 1993).

The reliability data suggested that the refined version of each SLEI scale has acceptable reliability, especially for scales containing a relatively small number of items. 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 indicated that each scale differentiated significantly ($p<0.01$) between PNG schools.

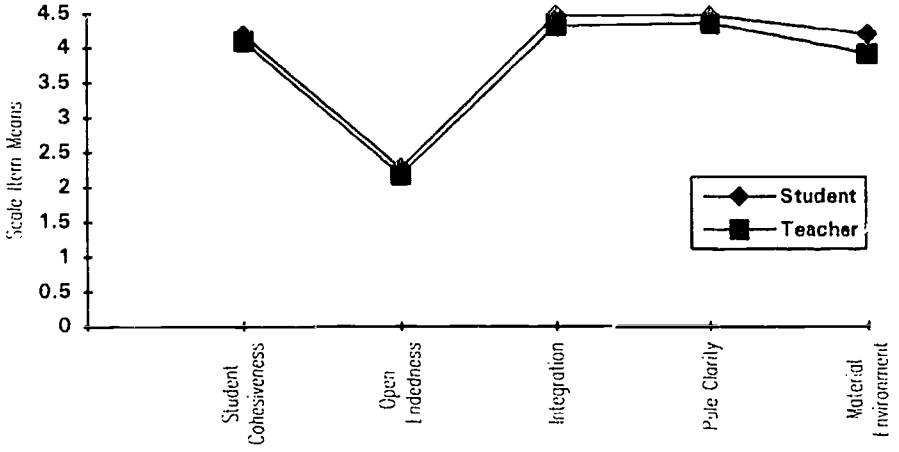


Figure 2: Plot of SLEI Scale Item Means for Students and Science Teachers

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, Giddings and McRobbie, 1992). Figure 2 showed that integration and rule clarity were clearly the most favourable SLEI scales. As well, Figure 2 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 1 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 was significant, students perceiving a more favourable environment.

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, Giddings & McRobbie, 1992; Giddings & Waldrip, 1993) in that Open-endedness was the least favourable SLEI scale.. Female students perceived Integration and Rule Clarity slightly, but not significantly more favourably, whereas male students perceived student cohesiveness, open-endedness and material environment in a more favourable light. There was no significant difference between male and female students' perceptions of their laboratory environment. This study replicated previous studies in that it showed that male students performed better than female students in both science achievement

examinations and attitudes towards science. It was of some significance to find that female students performed better than male students on a practical process test.

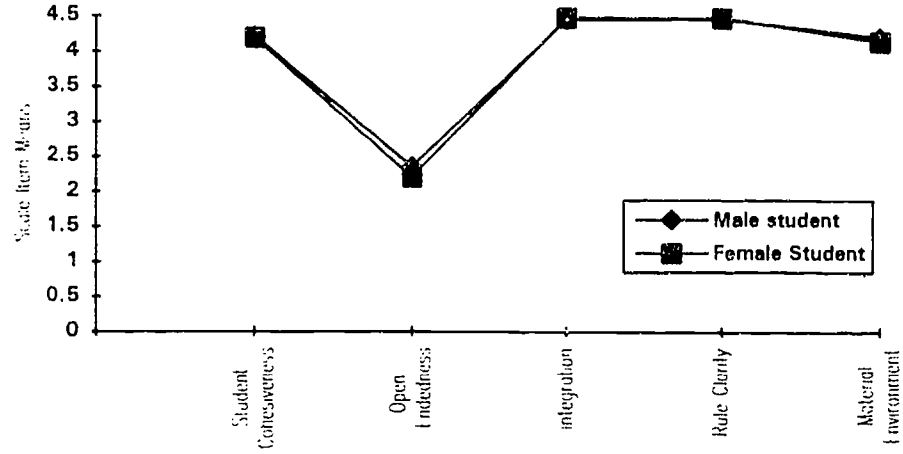


Figure 3: Plot of SLEI Scale Means for Male and Female Students

The finding that no significant differences existed between science teachers and students and between male and female students differs from that of Fraser, Walberg, Welch and Hattie's (1987) findings. This could be due to similar perceptions of authoritarianism in this society between male and female students. 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 to be wary of challenging what they have been taught. Again this similar perception between students and their science teachers could be explained by appealing to their perceptions of authoritarianism.

So far in this discussion, many of the results have attempted to be explained using cultural arguments. Even though a specific measure of cultural influence was not developed as part of this study, it is obvious from the data collected, that culture is an extremely important variable that can influence outcomes and that this variable needs to be included in any model of educational productivity. Other results of the study indicated 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. These factors are: quality of instruction, quality of instruction, gender, and the SLEI scales of Student Cohesiveness, Material Environment, Integration, Rule Clarity and Open-Endedness. 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.

Revised Productivity Model

In view of the findings of this study, we suggest that Walberg's educational productivity model (Figure 1) needs to be modified to include a fourth group of cultural variables, which include gender, custom and race. This fourth group of variables can further optimise educational productivity (Figure 3). This study identifies gender and culture, as predictors of outcomes. Three other school factors were also significant independent predictors of outcomes. These factors were quantity of instruction, quality of instruction, and the science laboratory learning environment.

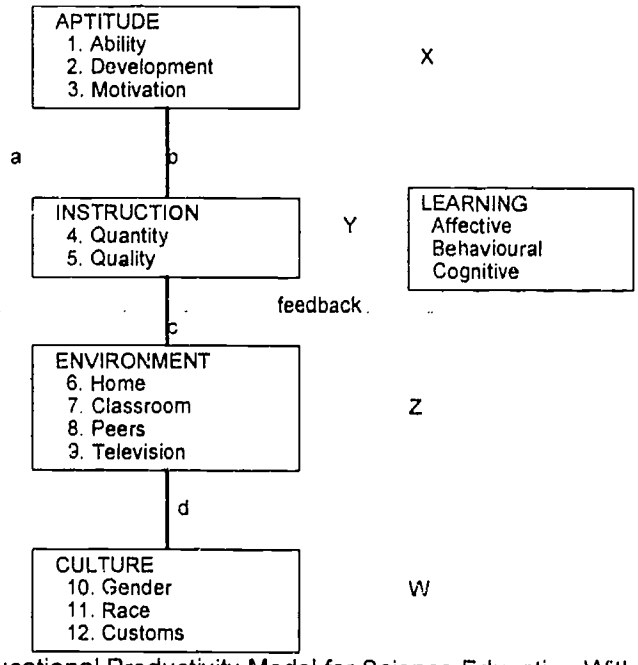


Figure 4. A Revised Educational Productivity Model for Science Education Within Papua New Guinea

The results of this study also indicates 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, 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 a revised educational 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 a revised educational model when culture is considered as a variable (Table 1). That is, the most sensitive educational productivity model for a developing country includes the cultural variable (Figure 4). This study also divided the science achievement outcome into two achievement components, namely, a science academic achievement outcome and a science practical achievement outcome.

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. The science teachers teach in science laboratory classrooms which often lack basic science equipment often lacking 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 teaching laboratory classroom experiments

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 which measures the extent that varied, thought provoking approaches are used during experiments, 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 an educational productivity model was applicable to a developing country context and that the PNG 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 on a science process test.

The data also indicate that when possible, PNG teachers prefer to demonstrate experiments to students rather than let students carry out 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. Patterns of teachers' use of questions and, control of the classroom and input, can be adequately explained by appealing to cultural practices. The similarity of students' and teachers' 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 data examined. that culture is an important variable that influences outcomes. Of necessity, contextual and cultural variables need to be included in any model of educational productivity. Past research has perceived the need to modify Walberg's educational model to include race and gender as shown in Fraser et. al's (1987) modification to the educational model. As Zaharlick (1992) implies, educational productivity can only be optimised when

the context is accounted for. In this study, the rich and diverse culture of PNG was an important part of the context. This study suggests that further optimisation of the educational productivity model is enhanced by the inclusion of a cultural variable, particularly in a developing country context.

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