Students' perceptions of factors that contribute to their performance in science project work

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Abstract: The perceptions of secondary three students on factors that contribute to their performance in science project work were examined. The study employed a combination of quantitative and qualitative approaches in a two-phase research design. Quantitative methods were dominant in this study while qualitative methods were used to supplement information obtained from the former to make the study more comprehensive and to gain a fuller understanding.

In the quantitative phase, a questionnaire was administered to students engaged in The perceptions of secondary three students on factors that contribute to their performance in science project work were examined. The study employed a combination of quantitative and qualitative approaches in a two-phase research design. Quantitative methods were dominant in this study while qualitative methods were used to supplement information obtained from the former to make the study more comprehensive and to gain a fuller understanding.
science project work. Data obtained were analysed using regression analysis to determine the relationships between the variables and the extent to which the factors were perceived by students to contribute to their performance in science projects. Results revealed that students perceived their abilities and the characteristics of their mentors as factors that contributed most to their performance, while the availability of resources was not perceived to be so. It was also found that students' examination results correlated positively with their performance in science projects. Regression analysis indicated that this factor contributed to their performance in science project more than the other three factors.
In the qualitative phase, focus group interview was employed to obtain data to supplement those obtained from the quantitative phase. From the interview sessions, additional factors that the students perceived to contribute to their performance in science project were identified.

The findings of this study indicated that students should be given the necessary training to enhance their performance in science project work. It is also important to train teachers adequately to provide students with effective mentorship. Such findings would be useful for educators who are planning to start a science research program in their schools. They can also be taken into consideration by educators who are in the process of refining their schools' research programs.
Keywords: science, project, performance, factors, perception

Introduction
Background of study

Project work was implemented in all Singapore schools in 2000 (Ministry of Education [MOE], 2004). In the primary schools, it was carried out at Primary 3,4 and/or Primary 5, while in the secondary school it was undertaken at Secondary 1,2 and/or Secondary 3. Beyond secondary schools, project work was implemented in junior colleges in Year 1 pre-university classes. From 2003, pre-university students have to sit for the Project Work examination and the results achieved are considered for admission to local universities from 2005 and beyond (MOE, 2004). The MOE thus saw Project Work as an avenue that allows students to explore the "inter-relationships and inter-connectedness of subject-specific knowledge".

In an independent school, which will be referred to as School X in the present study (School X is the school at which the present researcher teaches), project work was implemented before the MOE decided to implement it in all schools. Being an independent school, School X had a certain amount of autonomy to vary its curriculum from the one stipulated by the MOE (Yip, Eng & Yap, 1997). Hence, School X was able to make project work part of its curriculum even before the MOE decided that schools should do so. In the early 1980s project work in School X was an enrichment activity to enhance the learning of pupils and nurture independent learners. Today, in School X, project work has grown from a small scale, optional activity to become a compulsory part of the school's curriculum that provides opportunities for students to develop skills in the cognitive and affective domains. Students are awarded marks for project work that contribute to their final examination results.

Significance and purpose of study

In alignment with School X's mission to nurture leaders in research, the Science and Maths Research Program (SMRP) was implemented in 2005. This program is one of the special programs offered to Secondary 3 students who qualify academically (Hwa Chong Institution, 2005). It aims to develop students' passion in science and mathematics research through project work. In this program, students are provided with the necessary resources, in terms of mentorship (by teacher or external experts), research funds, and library and laboratory facilities to enable them to undertake an in-depth study of a topic of their choice. The program also provides the necessary training in research skills which the students need to execute their projects. The students work in groups of three or four and during the course of the project, are assessed at several rounds of judging by teachers to check their progress. Upon completion of the project, the groups participate in the school's annual Projects Competition where they receive an award and grade for their work.

Having implemented the program for one year, it is timely to investigate what students perceive as factors that contribute to their performance in project work. As time was limited, this study only focussed on students' performance in science project work. The findings of this study will provide information to the school for consideration when reviewing the program so that improvements can be made. In addition, since all schools in Singapore carry out science project work at various levels (which may not be as extensive as in School X), they may also benefit from the findings of the present research.

For the education community at large, this present study would serve to provide insight into perceived factors that contribute to the success or failure of science project work and add to the scarce information available.

Literature review

Many factors contribute to students' academic achievement. In the present study, these factors are placed in three categories: students' abilities, mentor's characteristics and availability of resources. Students' academic achievement specifically refers to their performance in science project work.

Students' abilities

Problem-based learning (PBL) instructional approach requires students to work in groups to find solutions to real-life problems (Ngeow & Kong, 2001). Thomas (2000), in his research on PBL summarised that projects are a complex exercise that originate from demanding "questions or problems" and require students to design, solve problems, make decisions, investigate and work independently over a long duration. He also said that at the end of the exercise, students are usually required to come up with a product or presentation.

According to Ngeow and Kong (2001), in order to meet the challenges in PBL, being able to think critically, being able to work in groups and optimizing the use of time and resources are essential. Science project work can be seen as an extensive PBL activity in which students need to find ways to verify a scientific phenomenon or solve a scientific problem. Hence, the abilities required of students for PBL are similar to those needed for science project work. For the purpose of this present study, students' abilities that may be perceived to contribute to students' performance in science project work were selected with reference to Ngeow and Kong's study. They include abilities like critical thinking, creative thinking, the ability to manage time and the ability to work cooperatively with others.

According to Torrance (1990) creative thinking and learning encompass the abilities to evaluate, which include being able to detect problems and inconsistencies. Creative thinking also involves "the creation or generation of ideas, processes, experiences or objects" (Saskatchewan Education Website, http://www.sasked.gov.sk.ca/docs/policy/cels/el4.html). In addition, Chaffee (2003) defined creative thinking as "the act or habit of using our thinking process to develop ideas that are unique, useful, and worthy of further elaboration".

Torrance (1990) felt that teachers can help students to develop creative thinking by giving students the opportunities to learn independently, do self-initiated projects and experimentations. In School X of the present study, such opportunities are provided by allowing students to engage in project work. When students are engaged in science project work they are often required to identify a problem and find solutions to it. When students carry out experiments in their science projects, they may encounter inconsistencies, thus being able to detect them is essential.

Sonmez and Lee (2003) observed that Problem-based Learning (PBL) gave students the chance to learn independently and develop critical thinking skills. Scriven and Paul (1992 cited in Serfeith, 1997) defined critical thinking as

> *the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action.*

In their definition of critical thinking, Scriven and Paul (1992) listed the activities students engage in when they do science projects.

Most of the literature reviewed to date documents various learning activities, such as PBL and discovery learning, as a means to the ends of achieving student outcomes like being able to think critically and creatively (Cruickshank & Olander, 2002; Fougere, 1998; Gonzales & Nelson, 2005). In this study, the researcher will do the reverse of treating the abilities of students to think critically and creatively as the means that enable students to perform in science project work. Hence, the researcher will investigate students' perceptions of whether such abilities are perceived as contributing factors of their achievement in science project work.

Mentor's characteristics

The quality of the teacher affects his or her instructional practices to promote student learning. Good teachers are able to create a positive learning climate and employ appropriate teaching methods that can bring about student learning. Research shows that teacher quality variables are influential in affecting student achievement (Kaplan & Owings, 2001). Content knowledge is one of the teacher qualities that contribute to student achievement (Darling-Hammond, 2000 cited in Kaplan & Owings, 2001). Furthermore, it has also been found that teachers who have college education in subject areas that correspond to their teaching subjects have students who perform better in science and mathematics achievement tests compared to students who do not have similarly qualified teachers (Blair, 2000; Goldhaber & Brewer, 1999; Haycock, 1998; Wenglinsky, 2000 all cited in Kaplan & Owings, 2001). It would therefore be interesting to determine if the content knowledge and technical training of teachers would similarly affect their abilities to mentor students in science project work. In this study, an attempt will be made to see if students and teachers perceive this to be so.

Ngeow and Kong (2001) pointed out that teachers play an important role in helping students in PBL in which students need to work in groups. According to them, the teacher can encourage good teamwork by helping students understand what teamwork means and the merits of it. In this study, ability of the teacher to get the students to work as a team was thus included as one of the perceived mentor's characteristics contributing to students' performance in science project work.

In addition, for the group to do well, the teacher also needs to monitor group progress and provide sufficient feedback to the students so as to steer the group forward (Ngeow & Kong, 2001). As mentioned, earlier, science project work can be seen as an extensive PBL activity, thus the teacher guiding student in science project work will need to play similar roles as the teacher implementing PBL.

Balas (1998) observed that teachers play a very important role in the success of students' science fair project as they "engage students in the process of seeking and gaining knowledge" through their interactions with them. This is of particular relevance to the present study as the types of project students present at science fairs are similar in nature to those that students do in the participating school.

Reilly (1992) listed the following as the roles of a mentor to a student undertaking a project:

- identify the students' needs for intellectual and technical training and provide guidance as appropriate
- monitor the students' progress regularly
- identify and recommend opportunities for students to develop the project
- identify and procure resources necessary for the development of the project

Hence, in this study, the researcher will include the abilities of the teacher to carry out the above roles as mentor's characteristics.

Availability of resources

Holt and Smith (2002) reported that the effect of school facilities on student achievement have been shown by several researchers that availability of good school facilities does increase student achievement. According to Holt and Smith (2002), Berkkum (1995) observed that school facilities and student achievement are positively related in North Dakota High Schools. Another study showed that students learn better in modern schools where up-to-date technology is available (NEA, 2000 cited in Holt and Smith, 2002).

At a press release, the Ministry of Education of Singapore (MOE, 2003) reported that Singapore students emerged first in Mathematics and Science in a study where Grades 4 and 8 students from 49 countries participated. The study was carried out by the International Association for Evaluation of Educational Achievement based in Boston, USA, on students from 49 countries of Grade 4 (Primary 4) and Grade 8 (Secondary 2). A sample comprising 6700 Primary 4 and 6000 Secondary 2 students from Singapore took part in the survey of the study. The Secondary 2 students came from all the streams in secondary education including Special, Express, Normal (Academic) and Normal (Technical). Students of school X in the present study, belong to the Special Stream. The study found that one of the reasons why Singapore students perform very well in science is the availability of school resources which included laboratory equipment and materials, computer hardware and software, instructional materials, library materials and budget for supplies. In fact, the study reported that Singapore has the highest Index of Availability of School Resources amongst all the participating schools.

In the present study, the researcher investigated if students perceived the availability of resources like laboratory facilities and materials, research funds and library resources to be factors contributing to students' performance in science projects.

Methods and approaches

1. Conceptual framework

Quantitative approaches are known for generating consistent, objective and systematic comparisons while qualitative approaches are able to increase the scope and depth of a study (Punch, 2005). Hence in this present study, a combination of the two approaches was adopted as the research strategy. The approaches were employed separately in a two-phase design (Creswell, 1994). Quantitative methods were dominant in this study while qualitative methods were used to supplement information obtained from the former to make the study more comprehensive.

In this study there are four groups of independent variables and one dependent variable as shown in Figure 1 below:

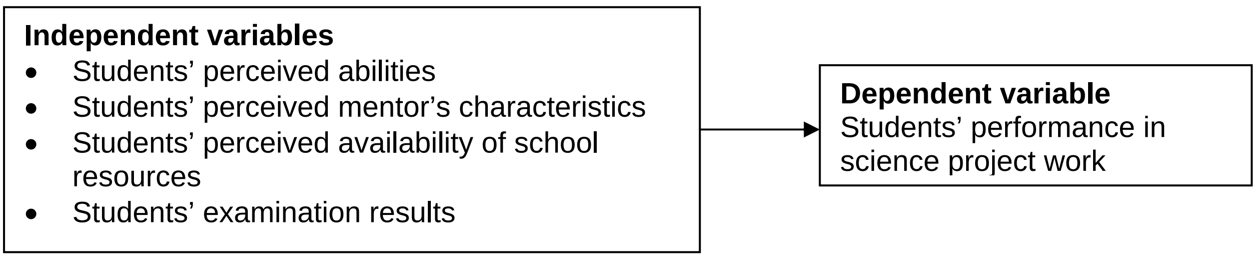


Figure 1. Independent and dependent variables in the study

In the first phase of this study, a questionnaire was used to obtain data that enabled the identification of the factors that contribute to students' performance in science project work, as perceived by the students. As the type of award students obtained at School X's 2005 Projects Competition judging was used as the indicator for their performance in science project work, the questionnaire was administered to current Secondary 4 students involved in science project work in that year. Following this, the relationship between each of these perceived factors and students' performance in science project work was investigated.

The student respondents were asked to write down their 2005 examination results in terms of a Mean Subject Grade and the award they obtained for their science project in the same year so that the relationship between the students' performance in examinations and science project work can be examined.

In order to collate students' views and experience not captured by the survey, focus group interview was employed in the second phase of the study so that a fuller understanding is gained.

2. Quantitative Approach

Quantitative data were obtained in the form of survey results comprising students' responses to the items in the questionnaire and their examination and project competition results from 2005.

2.1 Instrumentation

A survey allows the relationships between variables to be studied (Punch, 2005). Since the purpose of this study is to examine the relationship between students' performance in science projects and various perceived factors that are student-related or school-related, a survey questionnaire was designed to collect the data.

2.1.1 Survey questionnaire

A questionnaire (which is reproduced in Appendix 1) was designed to determine what students perceive as factors that affect their performance in science project work. A set of instructions and the purpose of the survey were included prior to the survey section to allow the students to see the relevance of the survey so that they would be encouraged to respond candidly.

Items were created based on the literature reviewed on factors that affect students' performance in project work. The survey instrument had a total of 40 items grouped into three sections as follows:

Table 1. *Items in the survey questionnaire*

Section	Type of item	Total number of items
Part A: Students' abilities	Positive items	13
	Negative items (reverse-scored)	7
Part B: Mentor's characteristics	Positive items	7
	Negative items (reverse-scored)	3
Part C: Availability of resources	Positive items	7
	Negative items (reverse-scored)	3
	Total no. of items	40

Each item in the instrument was responded to using a four-point Likert scale, which comprised options that expressed varying degrees of agreement or disagreement to the statement. Care was taken not to allow a neutral response by not having an odd number of options. The use of a Likert scale allows each individual to be placed on a continuum of agreement or disagreement toward a factor based on his total score of the items (Sax, 1997).

2.1.2 Instrument subscales

Part (A) To what extent do students perceive that their abilities contribute to their performance in science project work?

Items in this part sought to find out whether students perceived that their abilities to do well in examinations, to think creatively, to think critically, to manage their time and to work as a team contribute to their performance in science project work.

According to the Creativity Checklist of the Department of Education and Training of the Government of Western Australia (2006), creativity of students can be assessed by their abilities in terms of Fluency, Flexibility, Originality and Elaboration. In this part of the survey, seven items that pertained to the ability to think creatively were designed according to the abilities associated with the four areas of creativity.

This part of the survey also contained seven items that concerned the ability to think critically. These were designed based on the attributes of a critical thinker as documented by The Critical Thinking Community (2004) and Ferrett (1997 cited in the Alamo Community College District Website (2000)http://www.accd.edu/sac/history/keller/ACCDitg/SSCT.htm).

Of the remaining items in this part of the survey, four concerned the students’ abilities to manage their time and to work as a team. Two (items 11 and 16) were reversed scored items to check on whether students think it is their abilities or their team mates’ abilities that contribute to the success of their project thus contributing to the awards they obtained for their project work.

In this part of the questionnaire, there was a total of 20 items, of which seven were reverse-scored so as to check for inconsistency in response. Consistency in the responses was further increased by randomly distributing the items so that items concerning the various abilities of students were not clustered together and no more than three positive or negative items appear consecutively.

The types of items in this part of the instrument are summarised as follows:

Table 2. *Items in Part (A) of survey questionnaire*

Student ability	Type of item	Item number in survey	Total number of items
Creative thinking	Positive	1,5,9,13,17	5
	Negative (reverse-scored)	3,6	2
Critical thinking	Positive	2,7,10,15,18,20	6
	Negative (reverse-scored)	14	1
Time management	Positive	12	1
	Negative (reverse-scored)	8	1
Teamwork	Positive	4	1
	Negative (reverse-scored)	19	1
Student ability versus team mates' abilities	Negative (reverse-scored)	11,16	2
		Total no. of items	20

Part (B) To what extent do students perceive that mentor's characteristics contribute to their performance in science project work?

There are 10 items in this part of the questionnaire, three (items 3, 6 and 9) of which are reverse-scored. Items in this section were designed based on the attributes of an effective mentor as listed by Reilly (1992).

Part (C) To what extent do students perceive that the availability of resources contribute to their performance in science project work?

This part of the questionnaire contains 10 items of which three (3, 5 and 8) are reverse-scored items. These items seek to determine if students perceive the availability of school resources like laboratory facilities and equipment, research materials, research funds and library resources contribute to their performance in science project work. This part was included in the questionnaire as studies by Holt and Smith (2002), Berkkum (1995) and the Ministry of Education of Singapore (2003) have shown that availability of school resources affected the academic achievement of students.

2.2 Collection of quantitative data

2.2.1 Sample

The questionnaire was administered to science project groups, comprising current Secondary 4 students (15+ year old boys) that participated in the school's 2005 Projects Competition. The students in these groups are enrolled in the school's Science and Maths Research Program (SMRP). Steps were taken to ensure that the questionnaire was administered to approximately equal numbers of students from the different categories of awards so that the perceptions of students who have performed well and those that have not performed well in project work can be collated for analysis. The total sample size was 67 boys.

As can be seen from Table 3, there was a relatively equal spread across participants according to the types of awards obtained.

Table 3. *Composition of student sample in quantitative survey*

Award obtained at Projects Competition	Number of students
Higher distinction	12
Distinction	13
Honourable Mention	15
Merit	12
Participation	15
Total	67

The number of students surveyed was determined according to the 2005 Projects Competition results. It was not possible to have exactly equal number of participants in each award category in the survey due to the unequal distribution of awards amongst the participants in the actual competition last year. Hence, decisions were made according to the number of award winners in each category keeping the number of students surveyed from each category relatively similar.

2.2.2 Students' examination results

Examination and project work results were obtained by asking students to fill in these information on the questionnaire so that correlations between the actual achievements of the students and the survey results can be made later. Information sought included:

- award obtained for science project work in 2005
- subject area (biology, chemistry or physics) that their project (done in 2005) belonged to
- 2005 examination results: mean subject grade and grade for subject area to which the project belonged

The 2005 End of Year Examination results of the students surveyed were obtained from the final mean subject score which is computed by taking the average of the grades of all subjects. This is because the students often have to draw on the knowledge and skills from other subject areas apart from science, especially English and Mathematics, to complete their science project as completing the project entails writing a report and analysing numerical data. The critical and creative thinking training students get from other subject areas will also come in handy for project work.

2.3 Analysis of quantitative data

2.3.1 Psychometric Analysis of survey instrument

Before analyzing the relations of the variables, the reliability of the survey instrument was examined. In the case of reliability, the internal consistency of the items in each part of the survey instrument was examined to see if the items were "consistent with each other or working in the same direction" (Punch, 2005). Cronbach's alpha was computed for each part of the instrument to provide an indication of their reliabilities.

2.3.2 Analysis of quantitative data

2.3.2.1 General statistical measurements

Although the survey was implemented in one instance, it was actually made up of three parts. One part sought to investigate students' perceptions of their abilities that contribute to their performance in science project work. The second part sought to study whether students' perceived their mentor's characteristics contributed to their performance in science project work. The third part examined whether students perceived the availability of resources as a factor that contributed to their performance in science project work.

A summary of the data for each part of the survey was done using the concepts of central tendencies. The modes and variance of each section of the survey were computed from the person total scores (X) of each part of the survey.

2.3.2.2 Relationships between variables

a) Correlation analysis

Pearson product-moment correlation coefficient (*r*) was used to determine how, and the extent to which, the independent variables (students' abilities, mentors' effectiveness and availability of resources) were related to the dependent variable (students' performance in science project work). The "*r*" values for the actual examination results, students' perception of their abilities, mentors' effectiveness and availability of resources with respect to the awards students obtained for their science project work were computed.

The value of "*r*" ranges from -1.00 to +1.00. An "*r*" value close to ± 1 would imply a strong relationship between the perceived factor (students' abilities, mentor's characteristics or availability of resources) or examination results and the students' performance in science project work. On the other hand "*r*" values close to zero will mean that the perceived factor or the examination results and students' performance in project work are not related (Punch, 2005).

Using the person total scores (X) from the survey (students' abilities, mentor's characteristics and availability of resources), students' examination scores and science project scores (awards obtained were converted to scores: 5 for Higher distinction (A+), 4 for Distinction (A), 3 for Honourable Mention Award (B+), 2 for Merit (B) and 1 for Participation (C/D)), scattergrams were plotted to illustrate the relationships between the various variables.

b) Multiple linear regression analysis

According to Punch (2005), multiple linear regression analysis allows researchers to study how more than one independent variable affects a dependent variable. In this study, multiple linear regression analysis was used to compute the squared multiple correlation coefficients between the independent variables and the dependent variable, R^2, which will give the researcher a direct estimate of how much each independent variable (students' abilities, mentor's characteristics, resource availability and examination results) contributes to the variation of the dependent variable (science project performance). Regression weight analysis was also used to determine the standardised partial regression coefficients for the three perceived factors and students' examination results to find the extent to which each affects the students' performance in science project relative to one another.

3. Qualitative Approach: Focus group interviews

3.1 Sample

Deliberate sampling was conducted to decide who should be interviewed. In order to obtain meaningful and accurate response, the participants in the focus groups were those who shared certain similar characteristics. This was due to the reason that people tend to reveal more to those whom they see as belonging to their kind (Litosseliti, 2003). Thus only students involved in science project work were interviewed, as they were the ones who have the shared experience of engaging in science research. They were expected to respond freely and accurately based on what they had gone through.

Students were selected according to the awards they obtained at the school's Project Competition 2005. Four students belonging to the High Performers Group (students who obtained the Higher Distinction, Distinction or Honourable Mention awards i.e. grades A+ to B) and three students (the fourth student did not turn up for the interview) belonging to the Low Performers Group (awarded Merit or Participation i.e. grades C to D) were interviewed. Both groups were interviewed separately.

3.2 Collection of qualitative data

Focus group interviews allow certain aspects of a research topic which may have gone unnoticed in other methods to surface (Punch, 2005). In addition, such interviews also put the participants in a more natural environment than individual interviews as the participants influence and are influenced by others as they experience in the real world. When focus group interviews are done in small groups, participants will have more opportunity to voice their views in a less threatening environment thus enabling the researcher to obtain candid responses to a topic (Litosseliti, 2003). The data obtained from the interviews served to supplement the quantitative data obtained in the earlier phase of data collection.

In this study, qualitative data came from information obtained from focus group interviews with students in groups of 3-4. A semi-structured interview schedule (reproduced in Appendix 2) was employed through the use of some pre-planned, open-ended questions to start the session but as the session progresses, participants were encouraged to speak as they see fit. In this way, the interviewer had some "freedom to probe various areas and raise specific queries during the course of the interview" (Frankfort-Nachmias & Nachmias, 1996, p. 235). To allow semi-standardization, the same questions were asked in the same sequence and manner but yet allowing the participants some freedom of expression as the occasion arises.

The researcher personally invited the students to be interviewed a few days before the session. The purpose of the interview was explained to the students. On the day of the interview, the researcher personally reminded the students. Despite this, one student from the low performers group did not turn up.

During the interview, a list of factors affecting students' performance in science project work as listed in the survey questionnaire was provided to the students to be interviewed for reference. Students were then asked to state factors to add to the list provided.

3.3 Analysis of qualitative data

During the interview, notes were taken by the researcher. At the end of the interview sessions, the responses were collated and summarised. Additional factors that were perceived to contribute to student performance in science project were identified to add to the list generated from the quantitative data.

Results

1. Quantitative Data

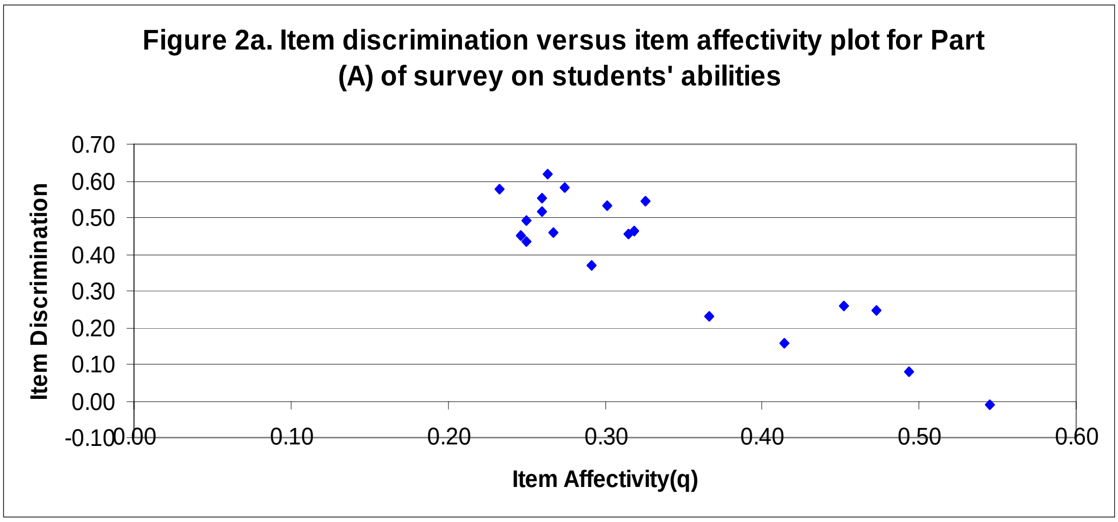
1.1 Psychometric analysis of the survey instrument

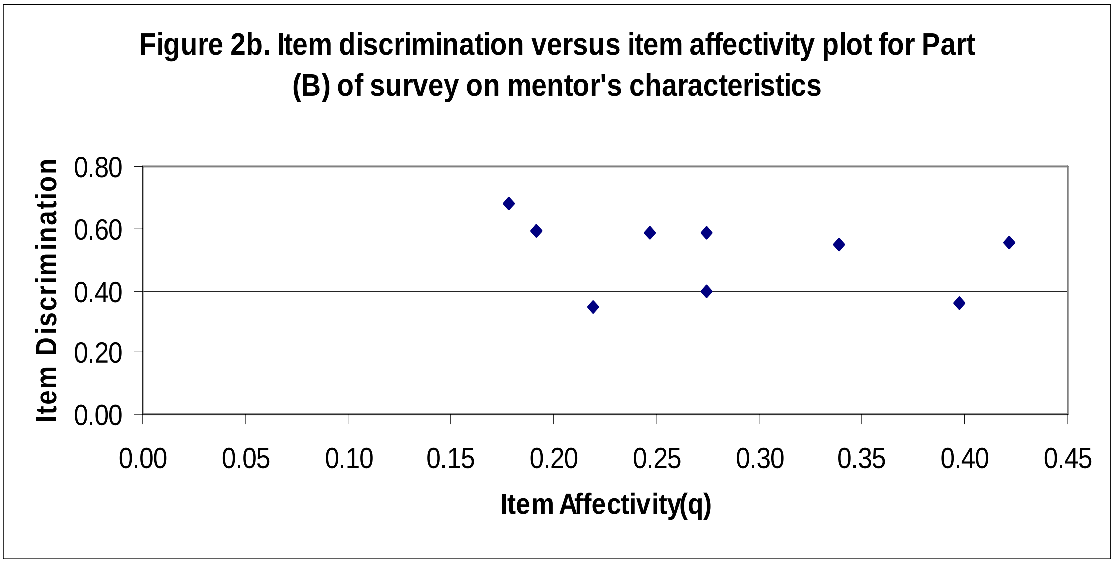
Cronbach's alpha was calculated for the three sections of the instrument and values were as seen in Table 4.

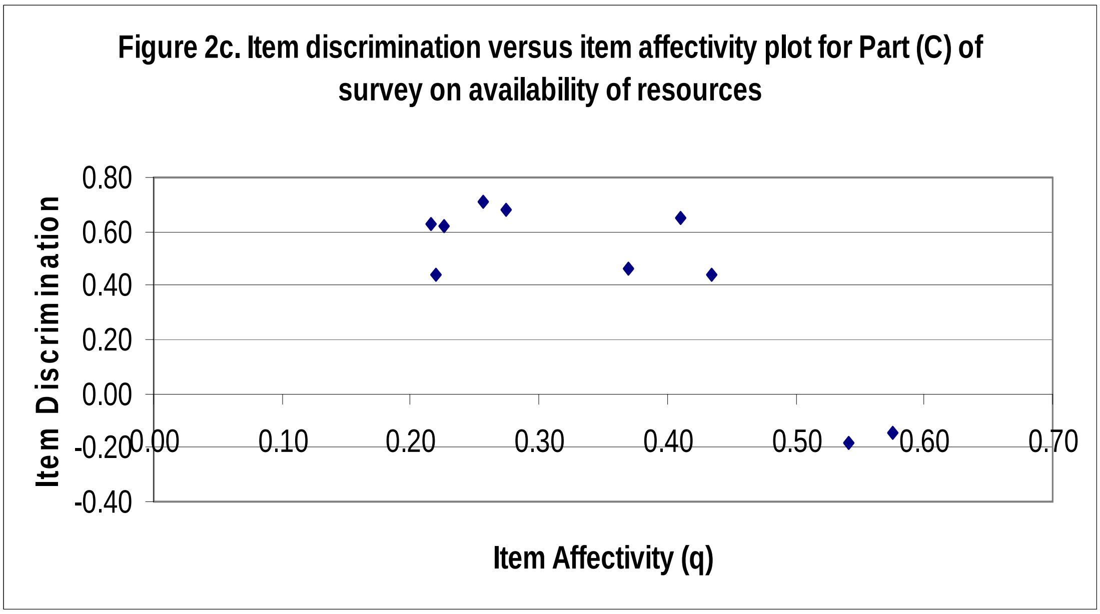
Table 4. *Reliability of various parts of the survey instrument*

Section of survey	Part (A): Students' abilities	Part (B): Mentor's characteristics	Part (C): Resource availability
Reliability (Cronbach's alpha)	0.7	0.6	0.5

As can be seen, the reliabilities of the section on students' abilities (Part (A)) and mentor's characteristics met the acceptable level of 0.6 while the section on resource availability was relatively low. Part (A) had the highest reliability among the three sections and Part (C) the least. This could be due to the fact that students could better identify themselves with items that concerned themselves in Part (A) and to a lesser extent with those that concerned mentors and availability of resources in Parts (B) and (C) respectively. In addition, administering the instrument without pilot testing could also have contributed to the low reliabilities obtained since items were presented to the students without improvement. The low reliability of Part (C) compared to the other sections of the survey could also be explained by examining the item discrimination of the sections. Figures 2a to 2c show the plots of item discrimination versus item affectivity of the three sections of the survey.







The above plots indicate that most of the items in the survey fell within the acceptable affectivity of 0.2 – 0.6 except for two items in Part (B). Although these items had low affectivities, their item discrimination coefficients were rather high (0.68 and 0.59), hence, they were suitable to remain on the instrument.

It was also observed from the above plots that the item discrimination coefficients for most items fall within the acceptable range of 0.2 – 0.8 except for three items (out of 20 items i.e., 15%) in Part (A) and two items (out of 10 items i.e., 20%) in Part (C). One of these items in Part (A) and two items in Part (C) had negative discrimination coefficients and hence did not correlate positively with the overall measure. These items were unsuitable to remain on the instrument. The relatively high proportion of items with negative correlation to the overall measure in Part (C) might have contributed to the low reliability of this section of the survey.

As Part (C) was observed to have the above problems, survey findings pertaining to resource availability presented in this study should be read with caution.

1.2 Central tendencies of quantitative data

The frequency distribution of the students' total scores for each section of the survey is shown in Figures 3a to 3c. The figures show that all Person Total Scores (X) were normally distributed.

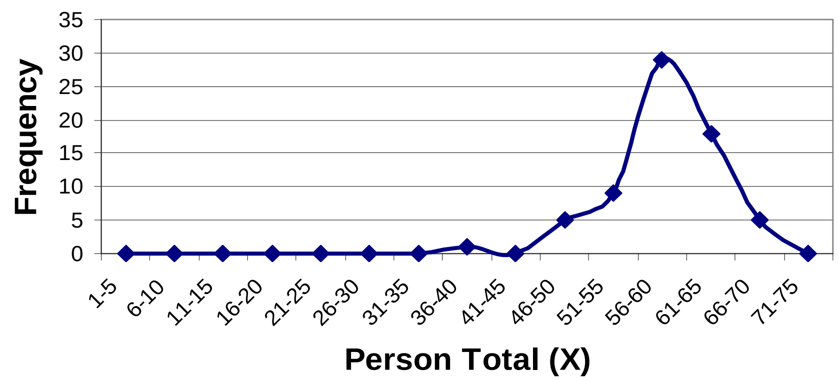


Figure 3a. Frequency distribution curve of person total score (X) of Part (A) of survey on student abilities

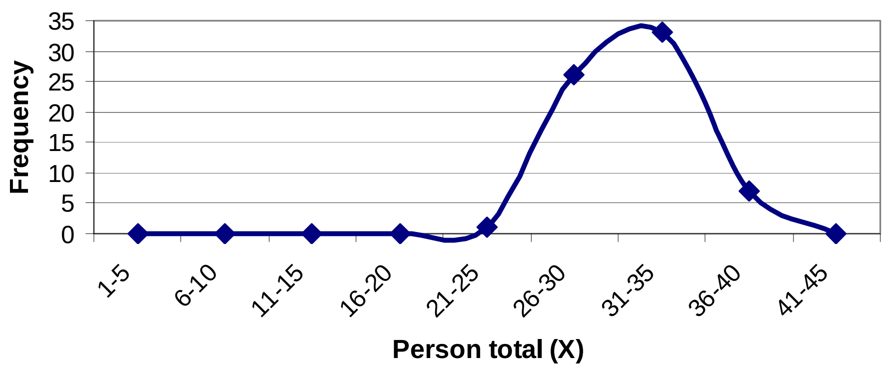


Figure 3b. Frequency distribution curve of person total score (X) of Part (B) of survey on Mentor characteristics

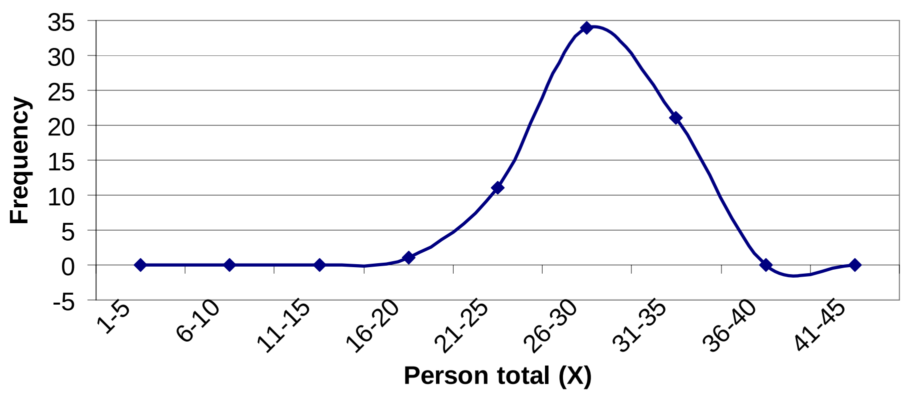


Figure 3c. Frequency distribution curve of person total score (X) of Part (C) of survey on Resource availability

The modes of the person total score (X) were computed and these are shown in Table 5.

Table 5. *Mode, variance and cut-off scores of the various parts of the survey*

Item	Part (A)	Part (B)	Part (C)
Mode	61-56	31-35	26-30
Variance	28.91	10.44	11.09
Cut – off score	60	30	30
% of scores (Person total, X) above cut - off	53.4	73	37

It can be seen in Table 5 that for all the sections of the survey, the modes are at or above the cut-off scores for the respective sections. It can also be observed that for Parts (A) and (B) of the survey, more than half of the students (53.4% for Part (A), 73% for Part (B)) responded favourably to the items. However, for Part (C), less than half of the students (37%) responded favourably to the items. These indicate that most of the students perceived that students' abilities and mentor's characteristics contributed to their performance in science projects. On the other hand, the availability of school resources was not perceived by most of them to be a factor that affected their performance in science projects. This concurred with the findings at the focus group interview. Both the high and low performers in science projects were of the opinion that out of the three factors listed in the survey, the abilities of the students and mentor's characteristics contributed to their performance with the former having a greater contribution. However, all the students interviewed thought that availability of resources only affected them to a smaller extent or not at all.

The following are some responses of the interviewees regarding their perceptions of how the three factors contributed to their performance in science projects:
With regards to students' abilities:
"It is of no use having the best mentor in the world for a student who simply does not have the abilities or attitude for project work."
With regards to students' abilities versus mentor's characteristics:
"Although mentor's characteristics is not the factor that affects my performance most, it is still important as students need to be pushed to do well."
With regards to availability of school resources compared students' abilities and mentor's characteristics:
"I don't think the availability of school resources is as important as the other two factors as a resourceful student will find means to obtain the resources that are required. Success, in my opinion, is very much in the hands of the student."

1.3 Correlation analysis

Correlation analysis was done by computing the Pearson Product –Moment Correlation Coefficient (r). Values obtained for the various factors studied are tabulated in Table 6.

Table 6. *Correlation between factors that contribute to students' performance in science project and science project grade*

	Student ability	Mentor's characteristics	Resource availability	Examination Score
Project Grade	0.281*	0.264*	0.386**	-0.317**

*p< 0.05 level (2-tailed) **p< 0.01 level (2-tailed)

The correlation coefficients (r) in Table 6 indicate that the correlation between resource availability and student performance in science project is the greatest among the factors. However, this result is disregarded because of the low reliability of the survey instrument concerning this factor. Thus excluding resource availability, the correlation coefficients indicated that the students perceived that their abilities contributed most to their performance in science project in comparison to their mentors' characteristics. It was also observed in this study that the students' examination scores had a much stronger correlation to their performance in science project compared to the other perceived factors.

1.4 Multiple Linear Regression Analysis

In order to investigate the extent to which the three factors in this study contribute to the students' performance in project work multiple linear regression was calculated and associated scattergrams plotted. The scattergrams are seen in Figures 4a to 4c.

Figure 4a. Relation between science project score and students' abilities

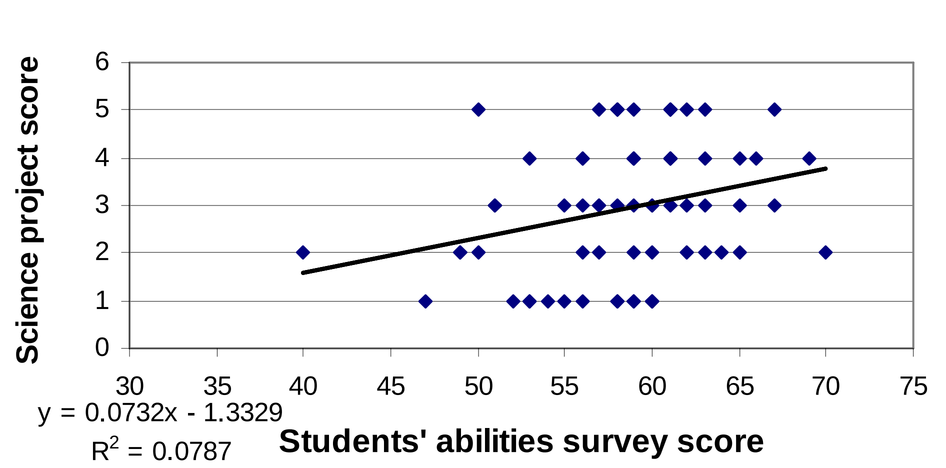
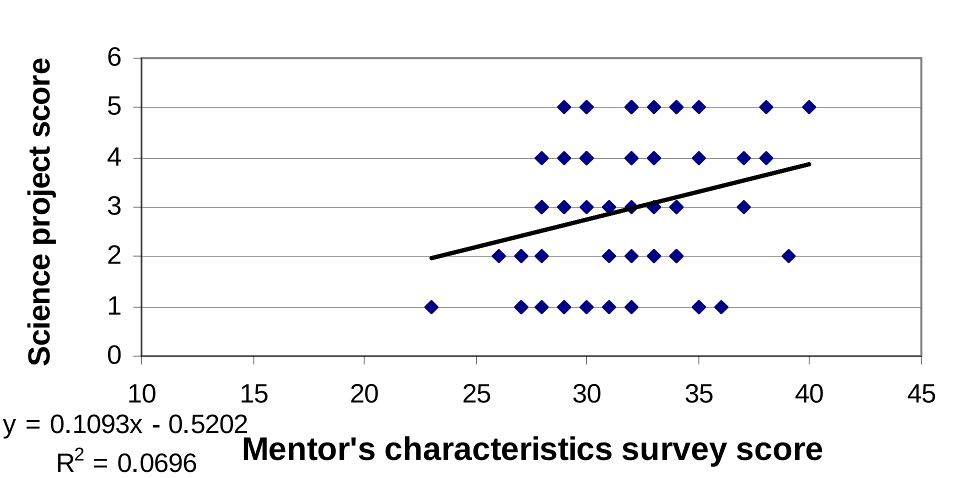
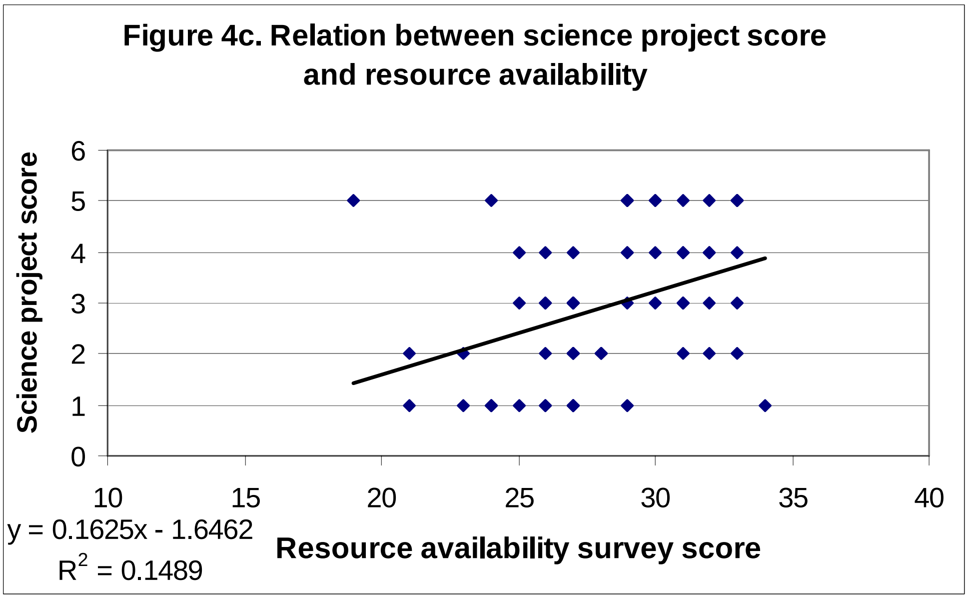


Figure 4b. Relation between science project score and mentor's characteristics





From Figures 4a to 4c, it can be observed that all the regression lines have positive slopes. This indicated that the three factors studied in the survey, namely students' abilities, mentor's characteristics and availability of school resources were all perceived by students to contribute to their performance in science projects. A comparison of the squared multiple correlation coefficient (R^2 values) revealed that students perceived that their abilities (R^2=0.08) contributed to their performance slightly more than that of their mentor's characteristics (R^2=0.07). However, it was interesting to note that although the person total score (X) seemed to show that most of the students did not feel that the availability of school resources contributed to their performance in science projects, the R^2 value (0.15) for this factor was the highest among the three studied in the survey. At the focus group interview session, all the students indicated that only students' abilities and mentor's characteristics contributed to their performance in science project. Although the opinions of the seven students interviewed was not representative of the 67 who participated in the survey, the results from the multiple linear regression analysis of Part (C) of the survey and its R^2 value should be taken with caution as this section of the survey has a low reliability as mentioned earlier.

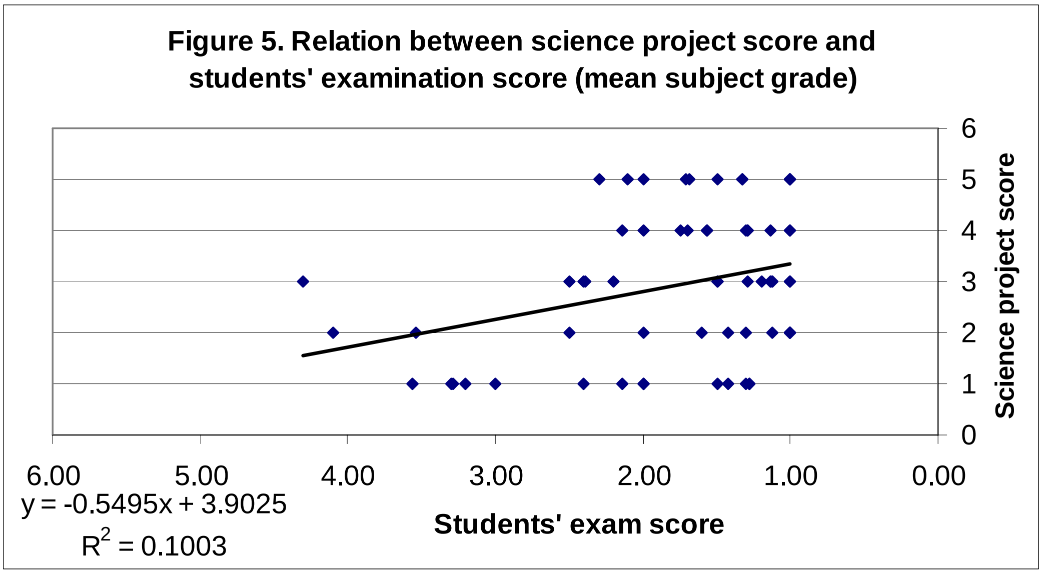
From the multiple linear regression analysis, the following regression equation was obtained:

Science project score = - 4.540 + 0.175SA* + 0.098MC* + 0.297RA*

*Legend:

SA = score for Part (A) of survey on Students' Ability
MC = score for Part (B) of survey on Mentor's Characteristics
RA = score for Part (C) of survey on Resource Availability

The above equation indicates the values of the standardised coefficients (β) of each of the three factors studied in the survey with availability of school resources carrying the greatest weight (0.297) followed by students' abilities (0.175) and mentor's characteristics (0.098). However, as the reliability of the survey on resource availability was below the required 0.6, the high weightage of the factor of resource availability should not be considered valid. Hence, comparison of β values of the factors, students' abilities and mentor's characteristics, would imply that the former was perceived to contribute more to the students' performance in science project.



In this study, the relationship between the students' actual ability to do well in examinations and their performance in science projects was also examined. A scattergram (Figure 5) was plotted to illustrate the relationship. The students' examination score, in terms of Mean Subject Grade, was used as an indicator of their actual ability to do well in examinations. It can be seen that the students' examination score correlated positively with their performance in science projects. This means that those who did well in examinations also did well in science projects. As the examination scores were based on the Mean Subject Grade (MSG) on a scale of 1-6 with 1 being the best and 6 being worst, its relation to project scores would appear negative as the latter was based on a scale of 1-5 but with 1 being the worst (C/D grade) and 5 being the best (A+ grade). Hence, the axis of the examination scores was reversed in the scattergram to illustrate the actual positive relation between the two variables.

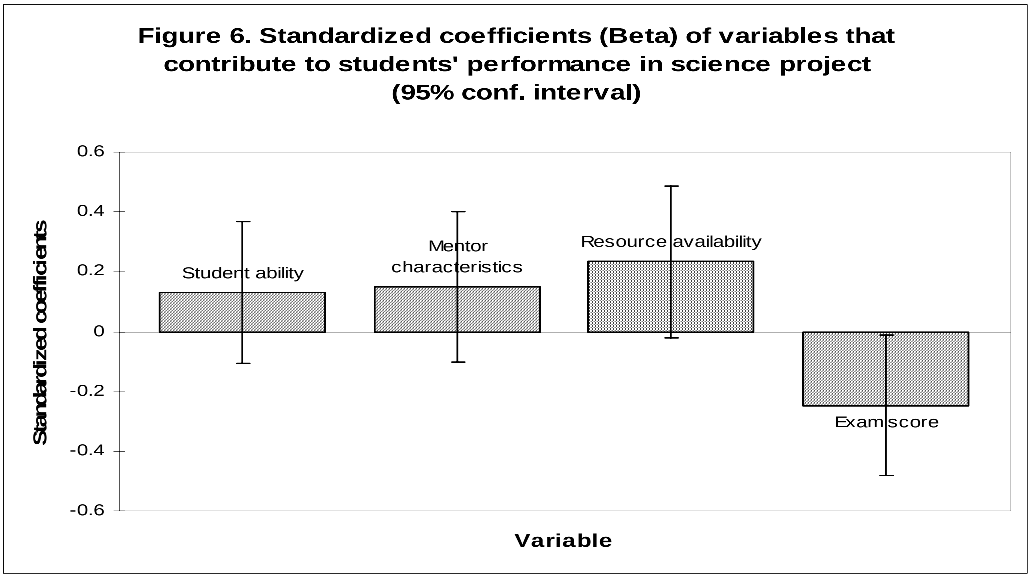
In comparing the R^2 value of the examination scores (R^2=0.10) to those of the other three factors studied in the survey, it was observed that the examination scores contributed to the students' performance in science project more than the rest of the factors examined using the survey. This was further confirmed by the β value of 0.247 of this factor when it was compared with the other three factors examined as illustrated by the following regression equation:

Science project score = - 3.014 + 0.129SA* + 0.150MC* + 0.234RA* - 0.247ES*

* Legend

SA = score for Part (A) of survey on Students' Ability
MC = score for Part (B) of survey on Mentor's Characteristics
RA = score for Part (C) of survey on Resource Availability
ES = students' examination score

The standardised coefficients (β) are illustrated graphically in Figure 6. Note that the β value of the students' examination score was negative due to the scale on which this score was based as discussed above. Hence in using the β value as an indication of the relative weights of the factors (variables) contributing to students' performance in project work, only the absolute of the factors would be considered. A higher absolute β value of a factor would imply that the factor has a greater weight in contributing to the students' performance in science projects.



During the focus group interview, students from the group comprising high performers in science project said that the ability to do well in examinations did not always imply a corresponding ability in science projects. According to them, the reason was that the abilities needed to do well in science projects were different from those needed for examinations. However, interviewees belonging to the low performers group held the opposite opinion. They thought that skills like being able to think critically were required in both examinations and science projects. Hence, being able to do well in examinations would also imply an equal ability in science projects. This, they felt was especially so when their project was related to topics taught in the lessons. They explained that having some background knowledge related to that of their project gave them a good head start. An example cited was the topic of "cloning". This topic was included in the current syllabus that all Biology teachers use in teaching. Hence, students working on a project that required the cloning of genes would be at an advantage as they already understood the basic principles underlying this area of research.

2. Qualitative data

Qualitative data were collected through focus group interviews with a group of four students who did well in their science project (high performers) and a group of three students who did not do well in their science project (low performers). In this section, information stemming from the interviews that were not reported in the preceding sections is presented.

Besides asking the students to rank the three main categories of factors (they encountered in the survey questionnaire) that they perceived to contribute to their performance in science project, the students were also asked to list additional factors belonging to the three categories. Tables 7a and 7b summarise the additional factors that surfaced for the categories of students' abilities and mentor's characteristics. The students did not point out any additional factors pertaining to availability of school resources. The remarks of the students about each factor were also included.

Table 7a. *Additional factors related to category of Students' abilities*

No.	*Respondent	Factor
1.	H	Factor: Ability to “think big” Remarks: I think that a student has to know very well about the opportunities for external project competitions that they can sign up to showcase their projects. With this, they can stretch their potential to the fullest and also gain recognition for their efforts.
2.	H	Factor: Ability to coordinate with mentor well Remarks: The mentor plays a very important role in giving advice and suggestions on how the project can be improved. If the student is able to work well with the mentor and updates him/her frequently about the project, I believe the project will be successful.
3.	H/L	Factor: IT skills Remarks: (H): These skills are needed to enable students to search for non-print (internet) resources, to create effective presentations, to write up reports (web-based reports in the case of school X). (L): There is a need to impress judges with impressive presentations to get better scores.
4.	H	Factor: Oral skills Remarks: These skills enable students to present/communicate findings of project to judges to obtain good awards.
5.	H	Factor: Interpersonal skills/ conflict management Remarks: These skills enable members to work together despite differences in opinions.
6.	L	Factor: Being meticulous/ pay attention to details Remarks: Students need to be careful in checking experimental procedures to minimise errors.
7.	L	Factor: Stay calm in times of crises Remarks: Students should not panic when met with problems but should stay calm and troubleshoot to solve the problems.
8.	L	Factor: Having the same priority Remarks: If members of the group have the same priority with regards to the project, members would be able to get together to get work done and not let other commitments slow down work.

* H= high performers; L= low performers

Table 7b. *Additional factors related to category of Mentor's Characteristics*

No.	*Respondent	Factor
1.	H	Factor: Being caring/ understanding/flexible with deadlines Remarks: Mentors should try to understand limitations (e.g. having a busy schedule of co-curricular activities or other school commitments) of students that led to them being unable to keep to deadlines and not penalise them if they have valid reasons.

* H= high performers; L= low performers

Students were also asked to list factors that did not belong to the three categories that they thought contribute to their performance in science project. Their responses are tabulated in Table 8. The remarks of the students for each factor are presented in the table as well.

Table 8. *Additional factors not related to the 3 categories mentioned in the survey*

No.	*Respondent	Factor
1.	H	Factor: Composition of team Remarks: The project team should comprise members with different talents e.g. good content knowledge, good IT skills etc. so that synergy of members will enable project to be developed maximally.
2.	H	Factor: Number of project groups working in the laboratory Remarks: More students meant lower availability of equipment, which may slow down progress of project.
3.	H	Factor: Students' choice of research topic Remarks: Students should choose a topic that has higher chance of getting good data so that a good report may be written for assessment.
4.	L	Factor: Students' commitments in co-curricular activities Remarks: If in leadership position, students will have lesser time for projects.
5.	L	Factor: Students' past experience in project work Remarks: Upper secondary students are at a greater advantage because they have done projects in previous years of study, and hence know how to avoid pitfalls and can manage time better.
6.	L	Factor: Having a clear goal Remarks: "Knowing what I want makes me work towards my goal."
7.	H/L	Factor: Weightage of project grades in students' Assessment Remarks: If project grades forms a substantial part of the examination grades, students will be more inclined to put in more effort to do up a good project.

* H= high performers; L= low performers

In addition to the above, students were asked to give their responses to the question of whether factors related to the socio-economic status of students would affect their success in project work. Both the high and low performers claimed that they did not observe this to be the case. However all felt that having parents who are experts in their area of project would give them some advantage over others. Such parents, they felt, would be able to advise them appropriately in the area of their research. Alternatively, they might be able to provide them with the links to external experts who might then give them the support they require. Supports from the experts may be in terms of professional advice or the provision of laboratory facilities not available in the school.

The students also cited financial support from parents as a helpful factor as the money they obtained from their parents can be used to buy materials they require. However, if their projects require large expensive scientific equipment, they would still put their request to the school through their mentors.

The students felt that the most important parent-related factor was the understanding from their parents that they need to spend long hours after school to work in the laboratory and hence return home late. They felt that it was important that their parents trust them and consent to them working the laboratories during after school hours so that they would have sufficient time to work on their projects.

Conclusion and discussion

Findings of study

In this study, quantitative data from survey results indicated that students generally agreed that all three factors, namely, students' abilities, mentor's characteristics and availability of resources contributed to their performance in science project. Multiple linear regression analysis showed that the availability of resources is perceived by students to contribute most to their performance in science project work, followed by their abilities and mentor's characteristics. However, as the reliability (Cronbach's alpha = 0.5) of the survey instrument that examined availability of school resources is below the minimum of 0.6, its contribution to students' science project work should be considered invalid. Hence, it can only be concluded that the first two factors were perceived by the students to contribute to their science project performance with students' abilities being the greater contributor than mentor's characteristics. This agreed with the findings from the focus group interviews where both the high and low performers in science projects stated that it is their abilities that would ultimately determine how they did in their science projects.

In the survey instrument, items pertaining to critical and creative thinking were included to see if students perceived these abilities as factors contributing to their performance in project work. The findings regarding these students' abilities being a factor that contributes to their performance in science project agreed with those of researchers like Ngeow and Kong (2001) who reported that students' abilities in critical thinking are essential for PBL, whose nature of activities could be as complex as project work. In addition, the findings of this present study on students' abilities were also consistent with findings on creative thinking being an important element in problem solving (Casey & Howson, 1993).

It was also found that students' examination scores correlated positively with their science project scores. This implies that the students' ability to do well in examinations is another factor that contributes to their science project performance although it may not be perceived by the students (high performers in project work) who were interviewed to be so.

Focus group interview was carried out to determine additional factors that contribute to students' performance in science projects. The factors are as listed in Table 9 according to the category they belong to. The source of opinion is indicated in the respondent column.

Table 9. *Additional factors that students perceive to contribute to their performance in*

science project

Category	No.	*Respondent	Factor
Students' abilities		H	Ability to "think big
		H	Ability to coordinate with mentor well
		H/L	Having good IT skills
		H	Having good oral skills
		H	Having good interpersonal skills/ conflict management
		L	Being meticulous/ pay attention to details
		L	Ability to stay calm in times of crises
		L	Having the same priority among team members
Mentor's characteristics		H	Being caring/ understanding/flexible with
Others		H	Composition of team
		H	Number of project groups working in the laboratory
		H	Students' choice of research topic
		L	Students' commitments in co-curricular activities
		L	Students' past experience in project work
		L	Students having a clear goal
		H/L	Weightage of project grades in students' assessment

*** H= high performers; L= low performers**

With regards to mentor's characteristics, the findings of this present study showed it is a factor perceived by students to have a certain bearing on their performance in science project work. This finding agreed well with reports that the teacher played a pivotal role in the success of PBL (Casey & Howson, 1993; Ngeow & Kong, 2001) and science fair projects (Balas, 1998).

Although the reliability of the survey regarding resource availability was low, it is still worth noting that 37% of the respondents agreed that it was a factor that contributed to their performance in science project. In fact, observations that school resources affect students' achievement in Mathematics and Science had been reported by the Ministry of Education of Singapore (MOE, 2003) while Holt and Smith (2002) and Berkkum (1995) wrote that school facilities affected student achievement in general. In this study, the small proportion of students that perceived that school resources contributed to their performance in science project may be the same group who were engaged in projects that involved more sophisticated experiments which required the use of various school facilities like the laboratory, library or computer. It is not surprising that some of the students do their projects outside the laboratories as these students may be those who were engaged in projects that do not require special equipment (e.g. innovation projects) or they might be using the facilities or resources provided by their external mentors at institutions of higher learning or research.

Implications of study

In view of the students' perception that their abilities and mentor's characteristics are the two main factors that contribute to their performance in science projects, the implications would be that in order to ensure students do well science projects, it would be advantageous to provide students with the necessary training to build up on their abilities to think critically and creatively. In addition, teaching students how to manage their time and interpersonal skills would also be essential. Student training can be done early in the year before project work begins in the form of research modules. Teachers can conduct these sessions or experts from institutions of higher learning or research can be engaged.

As with the students, training modules can also be conducted for teachers who are new to mentoring projects. These sessions can be carried out by teachers who are experienced in mentoring or engaging the service of relevant experts or sending teachers for available in-service courses.

With regards to school resources, the school should still continue to provide the necessary facilities for science projects as there is an increasing number of students who are keen to carry out more sophisticated science research that will require specialised laboratory equipment. In addition, the provision of research facilities on the school campus would help to reduce the time students have to travel to external institutions to use their facilities thus giving the students more working time.

Limitations

It should be acknowledged that the items of the survey instrument might not be comprehensive enough to identify all the factors that are perceived by students that contribute to their performance in science project work. In addition, because the instrument was self-designed and not pilot-tested, its reliability is relatively low. Hence, the findings of this study should be read with caution, especially the section concerning resource availability.

The validity of an instrument refers to what the test measures and how well it does so (Anastasi, 1988). In this study the validity of the instrument was not examined, as there was no similar construct to compare with.

There might be a certain amount of bias in the data obtained from the focus group interviews as the interviewer (the researcher of this study) is the mentor of some of the students. This may cause the students to give politically correct answers to questions asked. Hence, the students were assured that they would not be penalized for giving candid responses.

Effects of certain situational factors like the mental or physical condition of the respondents may also affect the type of response obtained. Hence, the time at which the interview was carried out was planned such that it did not fall on the day before a test so that the students would not be too stressed or tired to think through the questions asked and would be in a better state to provide truthful feedback.

Data obtained from the interview could not be taken as representative of the all the students enrolled in the SMRP due to the small sample size of seven as compared to about 200 enrolled students.

As time and manpower for the study were limited, only a small number of students were interviewed (seven students) and surveyed (67 students). In addition, some students might not be available to be interviewed or participate in the survey and some survey responses had to be excluded because of their inconsistencies.

In this study, sampling was only restricted to 15+ year old male students as School X is a boys' school. With the small sample space, it was not possible to make any sound generalizations for all students involved in science project.

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Appendices

APPENDIX (1). Questionnaire to study students' perceptions of factors that contribute to their performance in science project work.

Dear Student,

I am conducting this survey to study your perception of factors that contribute to your performance in science project work at Projects Competition 2005. I would appreciate it if you could examine the factors listed in the survey and indicate the extent to which you agree that they contribute to your performance in project work last year.

Your candid response will certainly help me improve the SMRP.

Thank you for your time and effort.

Yours sincerely,
Mrs Har Hui Peng

Please provide the following information about yourself:

1. Indicate your achievement at Projects Competitions 2005 by ticking the award you obtained in the following table:

Achievement	Please tick one
Higher distinction (A+)	
Distinction (A)	
Honourable Mention (B)	
Merit (C)	
Participation (D)	

2. Circle the subject that your project belonged to in 2005: Biology / Chemistry / Physics
3. Complete the table regarding your 2005 Final Examination Results:

Item	Result
Overall MSG (Mean Subject Grade)	
Grade obtained for subject indicated in item (2) above.	

Instructions

Factors that may contribute to your performance in science project are grouped into 3 main types in the survey: your abilities, your mentor's effectiveness, and the availability of resources. These factors are placed in Parts A, B and C respectively.

Read each statement of Parts A, B and C carefully. *Circle* the number that best represents your response to the statement.

Part (A) To what extent do you think that your abilities to do the following contribute to your performance in science project work?

Reverse scored items*	Item no.	Item	Strongly Disagree	Disagree	Agree	Strongly agree
	1.	Generate original ideas.	1	2	3	4
	2.	Interpret collected information/data to come with a logical conclusion.	1	2	3	4
√	3.	Do things by conventional methods.	1	2	3	4
	4.	Work as a team.	1	2	3	4
	5.	Apply knowledge from one subject to another.	1	2	3	4
√	6.	Stick to one way of doing things once I decided it is the correct way.	1	2	3	4
	7.	Do well in examinations.	1	2	3	4
√	8.	Work last minute without having to plan ahead.	1	2	3	4
	9.	Turn a simple idea into one that is of greater depth and complexity.	1	2	3	4
	10.	Formulate clear questions.	1	2	3	4
√	11.	Join a team comprising people who are very capable.	1	2	3	4
	12.	Manage time effectively.	1	2	3	4
	13.	Resourceful in finding/generating alternatives to a problem when a particular way of doing things does not work.	1	2	3	4
√	14.	Collect any information/data that comes my way.	1	2	3	4
	15.	Communicate effectively with others to solve complex problems.	1	2	3	4
	16.	Leverage on my friends' talents most of the time.	1	2	3	4
	17.	Come up with different ways of completing a task.	1	2	3	4
	18.	Collect relevant information/data.	1	2	3	4
	19.	Work in isolation from my friends/teammates.	1	2	3	4
	20.	Identify patterns or relationships in data collected.	1	2	3	4

*This column was removed in the actual questionnaire.

Part (B) To what extent do you think that having a mentor with the following characteristics contributes to your performance in science project work?

Reverse scored items*	Item no.	Item	Strongly Disagree	Disagree	Agree	Strongly agree
	1.	Gives me relevant guidance to carry out project.	1	2	3	4
	2.	Has the technical expertise to teach me the skills that my project requires.	1	2	3	4
√	3.	Leaves me to work on my own most of the time.	1	2	3	4
	4.	Sources and obtains materials/equipment necessary for the development of my project.	1	2	3	4
	5.	Has knowledge in my area of research.	1	2	3	4
√	6.	Never checks on me unless I initiate a meeting.	1	2	3	4
	7.	Able to get my group to work as a team.	1	2	3	4
	8.	Monitors my progress regularly.	1	2	3	4
√	9.	Leaves me to source for all the materials I need for my project.	1	2	3	4
	10.	Helps me come with alternatives when I'm stuck with a problem.	1	2	3	4

*This column was removed in the actual questionnaire.

Part (C) To what extent do you think that the following items regarding resources contribute to your performance in science project work?

Reverse scored items*	Item no.	Item	Strongly Disagree	Disagree	Agree	Strongly agree
	1.	Having access to well equipped laboratory facilities in the school.	1	2	3	4
	2.	Availability of research funds provided by the school.	1	2	3	4
✓	3.	Having access to laboratory facilities outside school (e.g. at research institutions or universities) through my <u>own contact</u>.	1	2	3	4
	4.	Availability of research materials (perishables e.g. chemicals, specimens) in school.	1	2	3	4
✓	5.	Having sufficient funds of my own to meet the needs of my project.	1	2	3	4
	6.	The school's library resources provide me with useful information to do a good project.	1	2	3	4
	7.	The school's computer facilities enable me to do up a good project.	1	2	3	4
✓	8.	Having sufficient non-laboratory based resources (e.g. computer, references) of my own to meet the needs of my project work.	1	2	3	4
	9.	Availability of research equipment (e.g. instruments like balances, laminar hoods, spectrometer, laser systems etc.) in school.	1	2	3	4
	10.	Most of the resources for my project were provided by the school.	1	2	3	4

*This column was removed in the actual questionnaire.

APPENDIX (2). Focus Group Interview Questions

1. Besides the list of students' abilities provided, what other students' abilities do you think contribute to the success of science project work?

List of students' abilities (provided to participants):
Students' ability:

(a) to do well in examinations
(b) to think creatively
(c) to think critically
(d) to manage their time
(e) to work as a team

2. Besides the list of mentor's characteristics/abilities provided, what other mentor's characteristics/abilities do you think contribute to the success of science project work?

   List of mentor's characteristics/abilities (provided to participants):

   (a) have relevant technical and content knowledge for the project
   (b) able to identify the students' needs for intellectual and technical training and provide guidance as appropriate
   (c) monitors the students' progress regularly
   (d) able to identify and recommend opportunities for students to develop the project to a greater height, e.g. get group to participate in national competitions (students are given bonus points for their science project for such participations)
   (e) able to identify and procure resources necessary for the development of the project
   (f) able to get the students of the group to work as a team

3. Which of the three factors (students' abilities, mentor's characteristics and availability of resources) is the most important in affecting a student's performance in project work? Why?

4. Do you think the socio-economic differences of students would affect their success in project work? Why?

5. Are there other factors besides students' abilities, mentor's characteristics and availability of resources that affect students' success in project work?