Teacher and Student Perceptions of Critical and Creative Thinking within a Science Programme for High Ability Females in Singapore: Implications for Classroom Practice and Staff Development

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ABSTRACT:

It can be rationalised that the education of high ability students is of immense importance to society, based on the principle that many of tomorrow's pioneers within the field of science will originate from this group of individuals. Consequently, these students must be equipped with critical and creative thinking skills to fulfil their intellectually demanding roles within the field of science. One way that this might be achieved is to incorporate critical and creative thinking skills into a science programme for high ability learners. This paper reports on a quantitative study that was performed to investigate teacher and student perceptions of critical and creative thinking within a science programme for high ability females at a secondary school in Singapore. Several strong correlations were identified between teachers' classroom practice and students' critical / creative thinking within the classroom. It was also discovered that students were more likely to use critical thinking skills within a science classroom compared to any other subject, but that they were more likely to use creative thinking skills while preparing for competitions such as Future Problem Solving and Odyssey of the Mind. These findings have implications for staff development within the school and the use of classroom strategies to teach critical and creative thinking.

● **Introduction**

Giftedness and creativity are very tightly interwoven. Runco (1993) believes that, "Creativity is a very important facet of giftedness" (p. 16) while Renzulli (2005, pp. 265-266) goes so far as to include creativity in his Three-Ring definition of giftedness in confluence with above-average ability and task commitment.

Creativity has been defined in the literature in a variety of different ways, some focusing on the creative person, some the creative process while others focus on the creative product (Amabile, 1996, pp. 20-22). Gardner (1993, p. 35) has chosen to define creativity through the person, "The creative individual is a person who regularly solves problems, fashions products, or defines new questions in a domain in a way that is initially considered novel but that ultimately becomes accepted in a particular cultural setting."

Critical thinking has been defined by Paul and Elder (2003, p. 1) as "...that mode of thinking – about any subject, content or problem – in which the thinker improves the quality of his or her thinking by skilfully taking charge of the structures inherent in thinking and imposing intellectual standards upon them." Paul and Elder (2004, pp. 3-8) continue by arguing that critical thinking and creative thinking are inseparable, "When engaging in high quality thought, the mind must simultaneously produce and assess, both generate and judge the products it fabricates. In short, sound thinking requires both imagination and intellectual standards." This suggestion has implications for education. Assuming that it is possible to teach critical thinking within the classroom, is it possible to teach it in isolation, separate from creative thinking? Can creative thinking be taught in isolation from critical thinking?

Nickerson (1987, pp. 30-32) offers several compelling reasons why thinking skills (although not made explicit, from his criteria for good thinking, it can be inferred that Nickerson is addressing both critical and creative thinking) should be taught in school. One reason is to enhance the possibility of an individual leading a successful life, which is complimented by Sternberg and Grigorenko's theory of successful intelligence in which they note:

> If individuals accept that the modern labour world makes analytical, creative, and practical abilities not only a matter of preference but also a matter of necessity, then it is only logical to conclude that the mastery of analytical, creative, and practical skills must be an important outcome of education. (Sternberg & Grigorenko, 2007, pp. 25-26)

A second reason is that good thinking is essential for good citizenship, providing an individual with the cognitive tools to make intelligent decisions about public concerns. A third reason is to improve an individual's psychological well-being, as it is assumed that an individual with good thinking skills will live an interesting and rewarding life as compared to an individual who is equipped with poor thinking skills. Finally, and most importantly, thinking skills should be taught to develop minds that are capable of solving the global problems faced by humanity (Tan-Willman & Gutteridge, 1981, p. 148) although in a Utopian society, such thinking skills would probably never have allowed problems of such magnitude to exist in the first place. Examples of such global problems have recently been identified by experts ("14 Challenges for the Next 50 Years," 2008) and include; making solar energy affordable, providing access to clean water and engineering better medicines.

Such open-ended real world problems can be carefully crafted into Creative Problem Solving exercises (Treffinger, Isaksen & Stead-Dorval, 2006) for students to develop their thinking skills. The teacher may measure the students' level of thinking by assessing the fluency, flexibility, originality and elaboration of their solutions using a well constructed rubric. But, do activities such as Creative Problem Solving really contribute to the development of students' thinking skills?

Although good reasons have been proposed as to why critical and creative thinking skills should be taught in schools, one essential question for experts working in the field of education is whether or not critical thinking and creative thinking (Burke-Adams, 2007, p. 60; Robinson, 2001, p. 114) can be taught in the classroom, or is an individual's ability to think critically and / or creatively predominantly determined by their genetic make-up? While there is still debate as to whether or not creative thinking skills are domain general or domain specific (Kaufman & Baer, 2004; Plucker & Beghetto, 2004) the literature on the effects of teaching creative thinking skills appears to be slightly less controversial. Runco (2004, p.29) believes that everybody has the potential to be creative, and that training can enhance an individual's creative productivity. Lubart and Guignard (2004, p. 51) agree that training in divergent thinking can improve an individual's creative performance while Hunsaker's (2005, p. 292) review of the research that has been performed to evaluate the effectiveness of creativity training programmes concludes that teaching creative thinking skills can benefit students' performance. Finally, Gagné's (2005)

Differentiated Model of Giftedness and Talent clearly includes creativity as a natural ability which can be developed, under the influence of intrapersonal catalysts and environmental catalysts, into a systematically developed skill. Paul and Elder clearly believe that critical thinking skills can be developed within an individual, and have produced a range of booklets containing information and directions that an individual may use to improve the quality of their thinking, for example, Paul's Wheel of Reason (Paul & Elder, 2003, p. 2).

Rationale for the Study:

The literature reviewed for the introduction to this paper reports that critical and creative thinking can be and should be taught to all students, especially high ability learners. As a consequence, this research was performed in an attempt to determine teachers' and students' perceptions of critical and creative thinking within a science programme for high ability females in Singapore, with the objective of making recommendations to enhance classroom practice and staff development. The research questions that guided this study were:

① Teachers' Perceptions: How often do science teachers use classroom practices that might encourage their students to engage in critical / creative thinking? What supports and what opposes the use of these classroom practices?

② Teachers Perceptions: How confident are science teachers in using classroom practices that might encourage their students to engage in critical / creative thinking?

③ Teachers Perceptions: To what extent does teachers' confidence in using a specific classroom practice that might encourage their students to engage in critical / creative thinking correlate with how often teachers' actually use these pedagogies within the classroom?

④ Student's Perceptions: How often do students use critical / creative thinking skills during their science lessons?

⑤ Teachers' and Students' Perceptions: To what extent does the frequency with which teachers use classroom practices that might encourage their students to engage in critical / creative thinking correlate with students' perceptions of how often they use critical / creative thinking skills during their science lessons?

⑥ Students' Perceptions: In which areas of the school's curriculum do students use critical / creative thinking skills the most?

The research design was primarily quantitative in nature, with some qualitative feedback collected through participants' written responses to optional questions. Surveys were used to collect information from the science teachers to determine the frequency with which they use specific classroom practices that might encourage their students to engage in critical / creative thinking. The survey also determined teachers' confidence in using certain classroom strategies that might encourage their students to engage in critical / creative thinking. In addition, surveys were also used to collect data from the secondary school students with regard to how often they use critical and creative thinking skills during their science lessons. The students were also asked to rank various components of the school's holistic education programme to determine the areas in which they use critical / creative thinking skills most frequently.

Sampling and Data Collection:

The secondary school for high ability girls in Singapore was selected as a convenient sample for this research. Approximately 1800 girls attend the school, arranged equally into four levels according to their age; Secondary One (12 to 13 years) Secondary Two (13 to 14 years) Secondary Three (14 to 15 years) and Secondary Four (15 to 16 years). The students no longer sit for O' Level examinations at 16 years of age. Instead, by virtue of a recently introduced Integrated Programme, the students progress directly to a local Junior College where they eventually sit for their A' Level examinations.

The school has been designated as a Centre for the Education of the Gifted and Talented by the Ministry of Education for Singapore and admits many of Singapore's top female primary school students based upon one or more of the following criteria:

- A Primary School Leaving Examination result within the region of 270 out of 300.
- Recognised potential within the field of art, music, sport or more formal academic subject such as science.
- A member of the Gifted Education Programme. Students are identified for the Gifted Education Programme, using a battery of tests, at Primary Three.

Most of the school's student population are Chinese (*ca.* 85%) followed by Indian (*ca.* 10%) with a minority of the students being Malay (*ca.* 4%) and Eurasian (*ca.* 1%).

The school has 33 science teachers (12 biology, 12 chemistry and 9 physics) ranging in teaching experience with high ability students from 1 to 32 years (mean = 6.1 years, median = 4 years, mode = 1 year).

Thirty one out of the 33 science teachers were available to participate in this study, of whom 29 (93.5% of those surveyed, 87.9% of the total) returned the survey form within the required time period. The survey questions were modified from a needs assessment survey published jointly by the National Association for Gifted Children, the Council for Exceptional Children and The Association for the Gifted (Kitano, Montgomery, VanTassel-Baska & Johnsen, 2008, pp. 109-111).

A convenient, stratified sample of Secondary Three (n = 28) and Secondary Four (n = 29) students were used in the study, giving a total sample size of 57 students. Secondary One and Secondary Two students were purposefully excluded from the study for several reasons:

● The lower secondary science curriculum is modular. As a consequence, at the time of the study, none of the lower secondary students would have completed their study of all three sciences; biology, chemistry and physics.

● At the time of the study, none of the lower secondary students would have engaged in any Research Studies projects. These are self-directed projects, similar to the Type III enrichment described in Renzulli's Schoolwide Enrichment Model (Renzulli & Reis, 1994). Failure to participate in a Research Studies project would exclude one of the options on the students' survey form, leading to a potentially biased response from the lower secondary students.

● At the time of the study, very few of the lower secondary students would have had the opportunity to participate in competitions such as Future Problem Solving, Odyssey of the Mind or the Creative Heuristic Application Of Science. Failure to participate in a competition would exclude one of the options on the students' survey form, leading to a potentially biased response from the lower secondary students.

The data was analysed in alignment with the research questions, Pearson's coefficients (Ary, Jacobs, Razavieh & Sorensen, 2006, pp. 148-155) being calculated to evaluate correlations between data sets.

● **Results and Analysis**

Table 1: Teachers' Response to Survey: Perceptions of Classroom Practice

Question: How often do you carry out each of the following activities in your classroom / laboratory?	Never	Occasionally	Usually	Almost Always
Respect students' unique and unusual solutions to problems:	0 (0%)	4 (13.8%)	10 (34.5%)	15 (51.7%)
Use open-ended questions with more than one answer:	0 (0%)	14 (48.3%)	11 (37.9%)	4 (13.8%)
Purposefully give the students poorly defined problems to solve:	9 (31.0%)	18 (62.1%)	2 (6.9%)	0 (0%)
Use Bloom's Taxonomy (*e.g.* analysis, synthesis, evaluation):	1 (3.4%)	10 (34.5%)	14 (48.3%)	4 (13.8%)
Use Paul's Wheel of Reason to direct thinking:	9 (31.0%)	7 (24.1%)	12 (41.4%)	1 (3.4%)
Model *critical* thinking for the students:	2 (6.9%)	10 (34.5%)	13 (44.8%)	4 (13.8%)
Model *creative* thinking / *creative* behaviour for the students:	5 (17.2%)	13 (44.8%)	10 (34.5%)	1 (3.4%)
Provide the students with opportunities for *creative* productivity:	3 (10.3%)	13 (44.8%)	12 (41.4%)	1 (3.4%)
Encourage the students to take responsible risks:	0 (0%)	10 (34.5%)	17 (58.6%)	2 (6.9%)
Create a "permissive" or "accepting" classroom environment:	1 (3.4%)	4 (13.8%)	13 (44.8%)	11 (37.9%)
Reward students for *creative* productivity:	2 (6.9%)	13 (44.8%)	12 (41.4%)	2 (6.9%)
Use *creative* thinking heuristics such as SCAMPER:	17 (58.6%)	11 (37.9%)	1 (3.4%)	0 (0%)
Provide the students with opportunities for inquiry and research:	0 (0%)	10 (34.5%)	14 (48.3%)	5 (17.2%)
Engage students in powerful discussions, .*e.g.* Socratic Seminars:	13 (44.8%)	15 (51.7%)	1 (3.4 %)	0 (0%)
Use Paul's Intellectual Traits, *e.g.* Intellectual Courage:	12 (41.4%)	12 (41.4%)	5 (17.2%)	0 (0%)
Use problem based learning activities:	1 (3.4%)	16 (55.2%)	11 (37.9%)	1 (3.4%)

Table 1 shows teachers' perceptions of how frequently they use certain classroom practices that might encourage their students to engage in critical / creative thinking. It is clear that some classroom practices are used very frequently, such as "Respecting students' unique and unusual solutions to problems" and "Creating a permissive or accepting classroom environment." This should be applauded because similar classroom practices have been shown to encourage creative thinking amongst students. Chambers (cited in Renzulli, 1992, p. 179) found that teachers who were receptive to students' unconventional answers and taught in an informal way were likely to encourage a high degree of creative productivity amongst their students. Amabile's literature review of environmental influences on creativity (Amabile, 1996, pp. 203-210) shows that informal, as opposed to formal classrooms, foster creativity amongst students.

However, it is clear that other classroom practices are seldom used, such as "Using creative thinking heuristics such as SCAMPER" and "Engage students in powerful discussions, e.g. Socratic Seminars." When surveyed to identify factors that opposed the implementation of these classroom practices, 86.2% of teachers said that there was insufficient time within the curriculum, 48.3% cited the diverse range of student needs within their classroom, 44.8% said that there were insufficient materials and 31.0% believed that there was insufficient training. Teachers with only one year's experience at the school were most likely to cite the final reason, and it is in contrast with 82.8% of teachers who said that attending conferences and training outside of school supported their implementation of these classroom practices. Other reasons given by teachers in written response to this question included, insufficient time for planning lessons, the personal comfort level of the teacher / students, and misalignment between the curriculum and assessment.

To further investigate why teachers might use some classroom practices more often than others, teachers were asked to rate how confident they were at using certain pedagogies. The results are summarised in **Table 2** and correlations between confidence and frequency of use are presented in **Table 3**.

Table 2: Teachers' Response to Survey: Confidence in Classroom Practice

Question: How confident are you in implementing each of the following activities in your classroom / laboratory?	Don't Implement	Not Confident	Somewhat Confident	Very Confident
Use Paul's Wheel of Reason to direct thinking:	3 (10.3%)	9 (31.0%)	11 (37.9%)	6 (20.7%)
Model *critical* thinking for the students:	0 (0%)	4 (13.8%)	19 (65.5%)	6 (20.7%)
Engage students in powerful discussions, *.e.g.* Socratic Seminars:	6 (20.7%)	11 (37.9%)	8 (27.6%)	4 (13.8%)
Use Paul's Intellectual Traits, *e.g.* Intellectual Courage:	9 (31.0%)	8 (27.6%)	9 (31.0%)	3 (10.3%)
Model *creative* thinking / *creative* behaviour for the students:	1 (3.4%)	10 (34.5%)	15 (51.7%)	3 (10.3%)
Use *creative* thinking heuristics such as SCAMPER:	2 (6.9%)	13 (44.8%)	12 (41.4%)	2 (6.9%)
Use problem based learning activities:	0 (0%)	3 (10.3%)	15 (51.7%)	11 (37.9%)
Create a "permissive" or "accepting" classroom environment:	0 (0%)	3 (10.3%)	15 (51.7%)	11 (37.9%)

Table 3: Correlation Between Teachers' Confidence in Using Classroom Practice and Teachers' Frequency of Using Classroom Practice:

Correlation between Teachers' Confidence in using Classroom Practice and Teachers' Frequency of using Classroom Practice:	Pearson's *r*
Teachers' confidence in using Paul's Wheel of Reason to direct thinking – *correlated with* – How often teachers use of Paul's Wheel of Reason to direct thinking.	0.36 [c] (weak correlation)
Teachers' confidence in modelling critical thinking for their students – *correlated with* – How often teachers model critical thinking for their students.	0.80 [a] (very strong correlation)
Teachers' confidence in engaging students in powerful discussions, e.g. Socratic Seminars – *correlated with* – How often teachers engage students in powerful discussions.	0.58 [b] (moderate correlation)
Teachers' confidence in using Paul's Intellectual Traits, e.g. Intellectual Courage – *correlated with* – How often teachers use Paul's Intellectual Traits.	0.77 [b] (strong correlation)
Teachers' confidence in modelling creative thinking for their students – *correlated with* – How often teachers model creative thinking for their students.	0.76 [a] (strong correlation)
Teachers' confidence in using creative thinking heuristics such as SCAMPER – *correlated with* – How often teachers use creative thinking heuristics.	–0.14 [c] (negligible correlation)
Teachers' confidence in using problem based learning activities – *correlated with* – How often teachers use problem based learning activities.	0.09 [c] (negligible correlation)
Teachers' confidence in creating a "permissive" or "accepting" classroom environment – *correlated with* – How often teachers create a "permissive" or "accepting" classroom environment.	1.00 [a] (very strong correlation)

a = High confidence in the classroom practice and high frequency of use. **b** = Low confidence in the classroom practice and low frequency of use.
c = High confidence in the classroom practice and low frequency of use.

Correlations between the teachers' confidence in using a classroom practice and the teachers' frequency of implementing the classroom practice can be seen to fall into three main categories:

① Strong Correlation: The teachers are confident in using the classroom practice and implement it with high frequency, e.g. modelling critical thinking (r = 0.80). This particular example is important because teacher behaviours, such as modelling of critical and creative thinking (Ugur, cited in Burke-Adams, 2007, p. 60) have been shown to have a positive influence students' thinking.

② Strong Correlation: The teachers are not confident in using the classroom practice and implement it with low frequency, e.g. Paul's Intellectual Traits (r = 0.77). It is advised that classroom practices which fall into this category should be the subject of staff training and development, including workshops and mentoring by Senior Teachers. However, it is incorrect to assume that classroom practices which teachers are confident in using will be used with high frequency.

③ Negligible / Weak Correlation: The teachers are confident in using the classroom practice but implement it with low frequency, e.g. Pauls' Wheel of Reason (r = 0.36). Existence of this category infers that there are other variables, in addition to confidence, that affect a teacher's decision with regard to the type of classroom practice to use. Such variables include availability of materials and curriculum time. Additional materials may be purchased (which requires money) or developed within the school (which requires time). In addition, topics may be omitted from the science curriculum, thus allowing teachers and students time to explore the remaining topics in more depth, e.g. by using Socratic Seminars. While this would not have been feasible within the original O' Level programme, it is possible with the school's new Integrated Programme. However, teachers are somewhat reluctant to do this as they perceive that the students still require a strong foundation of knowledge to prepare them for the A' Level syllabus at Junior College.

Table 4 presents students' perceptions of how often they use critical and creative thinking skills during their science lessons.

Table 4: Students Perceptions of How Often They Use Critical Thinking and Creative Thinking During Their Science Lessons

Thinking Skill:	Never	Occasionally	Usually	Always
Critical Thinking	0 (0%)	17 (29.8%)	33 (57.9%)	7 (12.3%)
Creative Thinking	0 (0%)	40 (70.2%)	17 (29.8%)	0 (0%)

Table 5 shows how teachers' perceptions of how often they use a certain classroom practices correlate with the students' perceptions of how often they use critical / creative thinking during their science lessons.

Table 5: Correlation Between Frequency of Teachers' Classroom Practice and Frequency of Students' Critical / Creative Thinking:

Correlation Between Frequency of Teachers' Classroom Practice and Frequency of Student's Critical / Creative Thinking:	Pearson's *r*
How often teachers respect students' unique and unusual solutions to problems – *correlated with* – How often students use creative thinking in their science lessons.	–0.22 [e] (weak negative correlation)
How often teachers use open-ended questions with more than one answer – *correlated with* – How often students use creative thinking in their science lessons.	0.92 [d] (very strong correlation)
How often teachers purposefully give the students poorly defined problems to solve – *correlated with* – How often students use creative thinking in their science lessons.	0.74 [d] (strong correlation)
How often teachers use Bloom's Taxonomy (e.g. analysis, synthesis, evaluation) – *correlated with* – How often students use critical thinking in their science lessons.	0.98 [d] (very strong correlation)
How often teachers use of Paul's Wheel of Reason to direct thinking – *correlated with* – How often students use critical thinking in their science lessons.	0.55 [d] (moderate correlation)
How often teachers model critical thinking for their students – *correlated with* – How often students use critical thinking in their science lessons.	0.97 [d] (very strong correlation)
How often teachers model creative thinking for their students – *correlated with* – How often students use creative thinking in their science lessons.	0.92 [d] (very strong correlation)
How often teachers provide their students with opportunities for creative productivity – *correlated with* – How often students use creative thinking in their science lessons.	0.89 [d] (very strong correlation)
How often teachers encourage their students to take responsible risks – *correlated with* – How often students use creative thinking in their science lessons.	0.62 [d] (strong correlation)
How often teachers create a "permissive" or "accepting" classroom environment – *correlated with* – How often students use creative thinking in their science lessons.	–0.10 [e] (negligible correlation)
How often teachers reward their students for creative productivity – *correlated with* – How often students use creative thinking in their science lessons.	0.90 [d] (very strong correlation)
How often teachers use creative thinking heuristics such as SCAMPER – *correlated with* – How often students use creative thinking in their science lessons.	0.09 [f] (negligible correlation)
How often teachers provide their students with opportunities for inquiry and research – *correlated with* – How often students use critical thinking in their science lessons.	0.97 [d] (very strong correlation)
How often teachers engage their students in powerful discussions, e.g. Socratic Seminars – *correlated with* – How often students use critical thinking in their science lessons.	–0.37 [f] (weak negative correlation)
How often teachers use Paul's Intellectual Traits, e.g. Intellectual Courage – *correlated with* – How often students use critical thinking in their science lessons.	–0.18 [f] (negligible correlation)
How often teachers use problem based learning – *correlated with* – How often students use creative thinking in their science lessons.	0.97 [d] (very strong correlation)

d = Teachers' perceptions of how often they use the classroom practice correlate strongly with students perceptions of how often they use critical / creative thinking during their science lessons.
e = Teachers perceive that they use the classroom practice with high frequency, but there is negligible or weak correlation with students' perceptions of how often they use critical / creative thinking during their science lessons.
f = Teachers perceive that they use the classroom practice with low frequency, but there is negligible or weak correlation with students' perceptions of how often they use critical / creative thinking during their science lessons.

Correlation between teachers' perceptions of how often they use a certain classroom practice and students' perceptions of how often they use critical / creative thinking during their science lessons can be seen to fall into three main categories:

① Strong Correlation: Teachers' perceptions of how often they use the classroom practice correlate strongly with students' perceptions of how often they use critical / creative thinking during their science lessons. Most of the items in **Table 5** fall into this category, e.g. there is a very strong correlation (r = 0.98) between teachers' perceptions of how often they use Bloom's Taxonomy and students' perceptions of how often they use critical thinking in their science lessons. It is very important to recognise that these results only show correlation and do not prove causality, i.e. it cannot be inferred from these results that the student's use of critical thinking is a direct result of the teachers use of Blooms' Taxonomy in the classroom, there are many other complex variables involved.

② Negligible / Weak Correlation: Teachers perceive that they use the classroom practice with high frequency, but there is negligible or weak correlation with students' perceptions of how often they use critical / creative thinking during their science lessons. There are two similar examples in this category, both of which focus on the teachers' readiness to create a permissive classroom environment in which students' unique solutions to problems are respected. It is unlikely that these classroom practices are limiting the students' creative thinking. On the contrary, they are probably encouraging the students' creative thinking, but only to the point where other variables become limiting. Lubart and Guignard (2004, p.49) state the importance of teachers as role models who value student's ideas while Runco (2007, p. 155) states the importance of a psychologically safe environment in which students can be creative.

③ Negligible / Weak Correlation: Teachers perceive that they use the classroom practice with low frequency, but there is negligible or weak correlation with students' perceptions of how often they use critical / creative thinking during their science lessons. The three classroom practices that fall into this category, i.e. the use of Socratic Seminars, Paul's Intellectual traits and creative thinking heuristics, are pedagogies that can be identified as areas for improvement. They are seldom used by teachers (none of the teachers surveyed used them "almost always") and yet are powerful strategies with which to develop students' thinking. It is believed that these pedagogies, if improved through teacher training and mentorship by Senior Teachers, have the potential to increase and improve critical and creative thinking amongst students in their science lessons.

Table 6: Secondary Three and Secondary Four Students' Perceptions of the Curriculum Areas in Which They Perform the Most Critical / Creative Thinking

Ranking of Subjects by Students – Critical Thinking			
Secondary Three		Secondary Four	
Subject:	Rank	Subject:	Rank
Science Lessons	2.5	Science Lessons	2.3
Competitions	2.9	Competitions	4.4
Math Lessons	3.1	Math Lessons	3.0
Research Studies	3.1	Research Studies	3.5
Humanities Lsn.	3.9	Humanities Lsn.	3.6
English Lessons	5.7	English Lessons	5.4
CCA	5.8	CCA	6.4
Mother Tongue	6.5	Mother Tongue	6.9
Physical Ed.	7.6	Physical Ed.	7.8
Correlation between Sec. 3 and Sec. 4 response, *r* = 0.95			

Ranking of Subjects by Students – Creative Thinking			
Secondary Three		Secondary Four	
Subject:	Rank	Subject:	Rank
Competitions	1.3	Competitions	3.3
Research Studies	2.8	Research Studies	3.7
Science Lessons	4.0	Science Lessons	4.1
Humanities Lsn.	4.4	Humanities Lsn.	4.2
CCA	4.7	CCA	5.1
English Lessons	5.1	English Lessons	4.4
Math Lessons	5.8	Math Lessons	4.9
Physical Ed.	6.0	Physical Ed.	7.0
Mother Tongue	6.1	Mother Tongue	6.0
Correlation between Sec. 3 and Sec. 4 response, *r* = 0.83			

Table 6 shows the Secondary Three and Secondary Four Students' perceptions of the curriculum areas in which they perform the most critical / creative thinking. Science is rated most highly for critical thinking, although only 12.3% of the students indicated that they "almost always" used critical thinking during their science lessons. Mother Tongue ranks very low on the list for both critical and creative thinking, and this is probably due to the fact that the students still have to sit for the O' Level Mother Tongue examination. As a consequence, the school's Mother Tongue teachers do not have the same flexibility as the other subject teachers in terms of curriculum design and lesson planning. Physical education is also ranked very low in spite of the fact that sports and games require the design and development of tactics and strategies.

Students perceive that they use creative thinking most often during competitions such as Odyssey of the Mind and Future Problem Solving. This is not surprising since both competitions rely very heavily on creative problem solving strategies (Cramond, 2005, pp. 27-35). Research Studies, which would be classified as Type III enrichment under Renzulli's Schoolwide Enrichment Model (Renzulli & Reis, 1994) also ranks very high for creative thinking, and may involve the students designing and performing their own experiments. While Research Studies is a service that all students are involved in, competitions are services that only some or few students tend to be involved in. This is in agreement with the Levels of Service approach to education (Treffinger, Young, Nassab & Wittig, 2004). A possible alternative is to integrate training for competitions, such as Odyssey of the Mind, into the Secondary One curriculum, thus making it available to all students. This will at least allow all students to have exposure to creative problem solving strategies, such as SCAMPER (Treffinger, Isaksen & Stead-Dorval, 2006, p. 56) even though not all students will necessarily participate in the final competition. Such a strategy could also be implemented to teach critical thinking. It is envisaged that all Secondary One students could receive instruction on Paul's Wheel of Reason, Intellectual Standards and Intellectual Traits, culminating in a Socratic Seminar. Individual subjects could then build on this foundation and continue to teach critical thinking that is appropriate to the discipline, a so-called "mixed model" approach that combines a general approach to teaching critical thinking with either an infusion or immersion approach (Ennis, 1989, p. 4).

● **Conclusions and Recommendations**

In summary, the science teachers that responded to the survey use a wide variety of classroom practices, to different extents, in an attempt to engage their students in both critical and creative thinking. Reasons why the science teachers do not use certain classroom practices very frequently include lack of confidence, lack of time in the curriculum, lack of training and lack of materials. While there are strong correlations between teachers' perceptions of how often they use certain classroom practice and students' perceptions of how often they use critical / creative thinking during their science lessons, this does not prove causality.

The students perceive that they use critical thinking most frequently in their science lessons, although the fraction that report that this happens "almost always" is a rather diminutive 12.3%. Students are more likely to use critical thinking skills during their science lessons than they are to use creative thinking skills. The students perceive that they use creative thinking skills most frequently during competitions, such as Future Problem Solving.

Recommendations may be made in two areas, teacher training and teaching resources to support classroom practice. Initially, teacher training may appear to offer an immediate solution to some of the issues raised by this research. However, while teacher training programmes to teach thinking skills do exist (Juntune, 1979; Schlichter, 1986) Scot, Callahan and Urquhart (2009, pp. 49-50) found that teachers who participate in professional development programmes to learn pedagogies for teaching high ability learners are unlikely to use their knowledge in the classroom due to a lack of time because they need to prepare their students for high stakes exams. Burke-Adams (2007, p. 59) concurs, saying that high stakes exams cause educators to teach factual information to their students at the expense of critical and creative thinking skills. While this may not apply to such a large extent in a secondary school running an Integrated Programme, science teachers are still mindful that they need to prepare their students for A' Level examinations in which creative thinking is rarely rewarded. In addition, VanTassel-Baska et al. (2008) have found that effective teacher training in a specific area, such as differentiation, takes at least two years of regular attendance at workshops, classroom observations, and mentorship by Senior Teachers. Thus, teacher training, while recommended, will not lead to immediate improvements in teachers' classroom practice.

Obtaining and developing resources so that the science teachers have a ready-made database of materials to support their classroom practice would address some of the concerns of the teachers who participated in this research. Examples might include:

● Gallagher, Stepien and Rosenthal (1992) advocate the use of poorly defined problems for students to solve. Not only do poorly defined problems challenge students to think critically and creatively, but they also allow for differentiation through the way that the students respond to the open ended questions (Hertzog, 1998).

● Tan-Willman and Gutteridge (1981) and Cooper (1998) advocate the development of moral reasoning amongst the gifted and talented. Students' critical thinking and moral reasoning can be challenged and developed by giving them ethical dilemmas from the field of science, for example, *The Ethical Chemist* by Kovac, (2004).

● Reis (2005, pp. 240-241) suggests that high ability females should develop their critical and creative thinking skills by studying and evaluating the biographies of creative women.

● Davis (1989, p. 83) suggests that students develop their creative thinking by trying to find solutions to authentic problems through engagement in small group projects similar to Renzulli's Type III enrichment (Renzulli & Reis, 1994).

● Thought provoking experiments which challenge the students to question their prior knowledge and integrate it with new information to construct new meaning (Jolliff, 2007).
● Inquiry-based experiments which require students to propose a hypothesis-based upon their prior knowledge and then design, perform and evaluate an experiment to investigate their theory (Lechtanski, 2000).

● **Limitations of the Study and Suggestions for Future Research**

There are several limitations to this study. Firstly, although the number of teachers involved in the study was (given the single school setting) as large as possible, the number of students should have been greater. In addition to this, random, rather than convenient sampling should have been used to select students for participation in the study. Secondly, this study only demonstrates correlation between certain variables; it does not attempt to prove causality. As a consequence, extreme caution should be taken when attempting to generalise the findings to other populations. A third limitation is teachers' and students' understanding of the terms used on the survey forms. There are immediate problems with defining creativity (Runco, 1993, p. 16) and teachers may not have been familiar with all of the terms used on the survey, e.g. "Socratic Seminar" and "Intellectual Traits." A fourth issue is that the quantity, and not the quality of classroom practices and students' thinking was captured by the survey forms. Future research should use a greater variety of data collection techniques, such as lesson observations using the Classroom Observation Scale, Revised (Kitano et al., 2008, pp. 96-101) and interviews. Finally, the number of relatively new teachers participating in the study may influence the results. Although all new teachers would have received initial training on pedagogy for teaching critical and creative thinking, they may not have had the time to digest the information and apply it effectively within their classrooms.

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