Title	Exploring the inventive mindset of Singapore students
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Source	*ERAS Conference, Singapore, 24-26 November 2004*
Organised by	Educational Research Association of Singapore (ERAS)

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Exploring the Inventive Mindset of Singapore Students

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Abstract
In a bid to explore the inventive mindset of Singapore students, a toy invention competition was organized to attract budding inventors from amongst the student population. Participants were required to build a prototype based on physics principles so that it could reveal certain aspects of their inventive capabilities. Three evaluation instruments were specially designed to provide data for analyses. The key findings of this exploratory study are that a) students are motivated by intrinsic rewards when entering invention competitions, b) the educational environment is becoming more conducive for inventors, c) female students are just as interested in invention competitions as male students, d) students are not interested in becoming full-time inventors but are willing to take it up as a hobby, e) students from the express stream are more predisposed towards inventing than those from the normal stream. In terms of level of creativity of the entries, it appears that there is still some way to go even though some of the entries are of a high standard.

Introduction

The development of human civilization has depended much on inventions and will continue to do so. Therefore, it is important that we encourage our youths to invent. However, the main objective of this study is not to find ways to improve our youth's inventiveness (i.e. the ability to create and produce devices, machines, etc., that meets a personal or societal need or desire), but to find ways to evaluate the level of inventiveness of our youths. We believe that inventiveness has several aspects, and that if we can find ways to evaluate them, they can provide useful data.
It is important to understand the art and science of inventing. Whilst there is a general tendency in wanting to focus on the product (the invention), the person (the inventor), the inventor's environment and also the inventive process that the inventor adopts are also important..

The **inventor** is not a person with a special attribute. He does not necessarily have to be a well-educated person or one who is considered to be highly creative or even have a high I.Q. To qualify as an inventor, he or she needs only to have invented a product to satisfy his/her or society's need. The product need not even be of a good standard.

The **inventive process** is generally understood to be the process that the inventor goes through towards producing the creative or novel product (the invention). Here, one can see a direct similarity with the creative process. Albaum et al (1976) and Weber (1996) recognized invention as a manifestation of creativity. A number of authors (Ford 1995, Torrance 1988, Gilman 1984) also recognized patents as creative outputs. It is therefore not surprising that creativity has always been a necessary criterion in design or product evaluation. The inventive process is a purpose-driven activity. The creative process can be found in the inventive process as "events" indicating novel ways to overcome obstacles. Overcoming each of these obstacles does not necessarily produce an invention but if the overall purpose is achieved, the end product may be considered as an invention.

The **inventive environment** plays a crucial part in the progress of the inventive process. Carlson and Gorman (1992) attempted to map out the inventive approaches of Bell and Edison when they were inventing the telephone. Their research revealed interesting findings about these two great inventors who were trying to solve the same problem (the telephone) independently. Their inventive approach depended very much on the support they received, their background expertise, and their method of doing things. Even timing, it seems, plays a part.

It is on the foregoing aspects of inventing that this study will focus on.

Significance of this Study

At the Ministry of Education Work Plan Seminar 2003, the Minister for Education announced several key initiatives to nurture the spirit of innovation and enterprise (I&E) among our students in order to prepare them for an innovation-driven future (Shanmugaratnam, 2003). He emphasized the need to realign the curriculum, both formal and informal, to help foster innovation and enterprise. Students are to be encouraged to pick up important thinking and communication skills through independent learning and experimentation. He further emphasized the Ministry's commitment to nurture the spirit of I&E at the 2004 Ministry of Education Work Plan Seminar. The spirit of I&E includes the nurturing of intellectual curiosity, the passion and perseverance to learn, and the courage to live in ambiguity. It is clear that the school has an important role to play in preparing our students to face the challenges of the new economy.

The new economy not only provides new opportunities but also comes with its own sets of rules. Nations that are quick to embrace them will move forward but competition between nations is becoming much more aggressive than ever before. It's not necessarily that a country with more natural resources or cheaper labour will prevail in the economic game. Nations where the spirit of innovation and enterprise percolate to all strata of society will wield tremendous influence.

Tan and Subramaniam (2002) have noted that *'Nations which place emphasis on promoting a spirit of creativity, innovation and inventiveness among their people as well as those which recognize that the culture of scientific enterprise is the acme of human endeavour will ride the new wave'.* They stress that in such a competitive economy, creativity and innovation play a critical role. They also believe that there's much more that can be done in the education system to nurture potential scientists and inventors.

In Singapore, the emphasis on education has always been a priority but never has the emphasis on promoting creativity and innovation among our youths been so great as in recent years. The educational landscape has evolved rapidly over the last decade in pursuit of a creative and innovative workforce. One of the emphases is on nurturing scientists and entrepreneurs among our youths.

Studies have shown that the level of creativity and innovation can be enhanced through appropriate experiences (Gorman & Plucker, 1999). In this study, the experience is in the form an opportunity for students to invent toys.

The pursuit of invention affords an avenue to foster creativity and innovation among students. As the process of invention entails either the act of creating a product that fulfils certain needs or improving a product, creativity and innovation are therefore inherent in the intellectual endeavour which accompanies the process of invention. Likewise, as inventions have shaped the fabric and contours of numerous aspects of society, the potential of enterprise is evident in its pursuit. Thus, invention produces an avenue to foster attributes of innovation and enterprise. The choice of inventing toys based on physics principles was selected for two reasons: firstly, toys can be fabricated using simple materials; and secondly, imposing a physics dimension in the efforts encourages students to apply what they have learnt in the science classroom to the endeavour.

The review of the invention literature indicates that no previous attempt has been made to evaluate the level of inventiveness of students. More specifically, this research aims.

- to explore the inventive mindset of students
- to study the effect of invention competitions on student inventors
- to assess the inventive capabilities of student inventors
- to investigate the role of our education system on student inventors

It is hoped that this exploratory study will shed some useful light on the inventive propensities of our students.

Methodology

Sample

The RJC (Raffles Junior College) Toy Inventors' Challenge was a project adopted by the college to promote I & E. The 2003 competition was basically a test run which involved only the three schools from the Raffles family: Raffles Girls' Secondary School (RGS), Raffles Institution (RI) and RJC. In both years the competition was sponsored by DSO National Laboratories.

The participants in this study were 142 students who responded to a survey after they have participated in the RJC Inventors' Challenge 2004. These students were members of teams that successfully produced a prototype for the competition. This was an important aspect of the study as we were interested only in students who have participated in the invention process.

The competition was open to all students from secondary schools, centralized institutes and junior colleges in Singapore. The students came from different age groups (12 – 19 years old) and streams (Normal Academic, Normal Academic, Express, GEP & SAP). No formal guidance was provided, and the teams were encouraged to work on the inventions using their won initiative and enterprise.

Design of Evaluation Instruments

For the purpose of this study, three evaluation instruments were specially designed and used.

a) Survey Form

The first instrument was a survey form for the participants to complete. The objective of the survey was to investigate the participant's motivation to invent, the level of conduciveness of the environment for inventing, and the nature of the students' inventive processes. These constitute the three subscales of the survey form. The rationale for selecting these attributes is now addressed.

Motivation to Invent

Studies have highlighted the need to understand what factors motivate the potential inventor. Motivation strongly determines how far the undertaken project can progress. Of course, extrinsic motivation (fame, wealth etc) can invoke a strong influence but it has also been proven that intrinsic motivation usually leads to greater likelihood of completing the project. The type of inventor (professional versus hobbyist) also determines the amount of work done, the direction taken, whether or not it was completed, the stage to which it was developed, and even the quality of the marketing effort to promote the invention.

Inventor's Environment

The home and school environment play an important role in determining the type of inventor produced. Such information can help us to understand the type of inventive mindset that is promoted..

Inventive Process

The inventive process is not a well-defined area but biographies of successful inventors like Edison, Galileo and da Vinci do help us to understand and appreciate the important stages in the inventive process. In our study, the students were not subjected to a formal course in invention, even though studies have shown (eg Gorman & Plucker, 1999) that formal courses on the inventive process can significantly influence the students' inventiveness.

The statements for the survey form were crafted based on ideas from the survey literature and the authors' experiences in the previous competition (pilot test). The survey form was validated by three university professors from the National Institute of Education (NIE) and a science teacher from Raffles Junior College. Their comments were taken into consideration before finalizing the survey form. A five point Likert-type scale was used for each statement, ranging from Strongly Agree (SA) to Strongly Disagree (SD). The corresponding numerical measures ranged from 5 for SA to 1 for SD. For negatively worded statements, the numerical measures were reversed.

The survey form appears in Figs. 7, 10 and 12 along with the descriptive statistics for the subscales..

b) Product Evaluation Form

The second instrument was a product evaluation form for use by the judges. It also provides a set of rubrics for the judges to allocate points for the entries in the competition.

This instrument consists of 3 subscales: Creativity, Practicality and Prototype quality. 16 statements were crafted, again based on ideas from the survey literature and the authors' experience in the previous competition (pilot test): 5 each for Creativity and Practicality, and 6 for Prototype.

Literature reviews on invention evaluation (Besemer, 1998; Christiaans, 2002) have suggested that a product can be assessed by including other aspects such as technical quality, attractiveness, logic, etc. However, we felt that the three aspects selected were sufficient and well-defined for the judges to focus on in this exploratory study.

The product evaluation form was validated by three university professors from NIE and a science teacher from RJC. Their comments were taken into consideration before finalizing the survey form. A five point Likert-type scale was again used for each statement, ranging from Strongly Agree (SA) to Strongly Disagree (SD). The corresponding numerical measures ranged from 5 for SA to 1 for SD. All Statements were worded positively.

A sample of the Product Evaluation Form is shown in Annex 1.

c) Invention Design Form

The third instrument was an Inventive Design Form (IDF). The objective of the IDF is to assess the participants' ability to engage in technical description. It also helps to document the operation of the toy in a detailed manner.

Each team was required to complete the IDF before submitting their prototype. Participants were required to describe the background to their inventions and to elucidate the mechanism of their inventions.

The Invention Design Form consisted of the following sections:

a) Background of invention
b) Detailed description of the design of the toy
c) Detailed description of the operation of the toy

d) Reference to related inventions, if any
e) If there are any parts of the invention that you want the judges to pay attention to please list
f) them in point form here. For example; this could be the innovative joints or fabrication
g) technique that you're thinking of using.
h) Why do you think that this toy has a potential of being a hit in the toy industry?

A sample of the Invention Design Form is appended in Annex 2.

Procedure

The toy competition was publicized to all secondary schools, centralized institutes and junior colleges via postal mail and electronic mail. Students desirous of participating in the competition, either individually or as a team, need to complete a web-based Registration Form. They were then given two months to work on the design of their invention before submitting their Invention Design Form. All of these forms were then scrutinized by a school-based internal committee, and those fulfilling the desired criteria were given two months to work on their prototypes. These prototypes have then to be submitted to the organizers.

The judging of the entries was carried out on 17 July 2004. It began with a briefing on the judging procedure for the panel of judges. Two entries from the previous year's competition were shown to the judges in order to familiarize them with the Product Evaluation Form.

The panel consisted of eight judges:
Judge A: Physics teacher with no prior experience in judging of inventions.
Judge B: Economics teacher with no prior experience in judging of inventions.
Judge C: Master of Education student with some experience in judging in invention competitions.
Judge D: Senior staff from the Singapore Science Centre, with considerable experience in judging invention competitions.
Judge E: Marketing manager from Stikfas Pte Ltd, a successful toy company based in Singapore and with no prior experience in judging of inventions.
Judge F: Business manager from Stikfas Pte Ltd and with no prior experience in judging of inventions.
Judge G: General manager from Stikfas Pte Ltd and with no prior experience in judging of inventions.
Judge H: NIE lecturer with considerable experience in judging several types of competitions.

As time was a major constraint, and in order to avoid judging fatigue, the entries were evaluated in two phases:
1) Grouped Preliminary Evaluation
2) Critical Evaluation

In the first phase, the 53 entries were divided into two groups. The entries were pre-ranked by the organizers using the Product Evaluation Form (PEF). All entries with odd ranking numbers were put into one group and the even ones into the second group. The rationale is to avoid having too many good entries into one group as the judges will be also divided into two groups during the first phase. The judges were instructed to conduct a quick superficial evaluation and select the best 14 entries from each group for the second phase. A total of 28 entries were thus selected for the second phase. In the second phase, judges were required to evaluate the selected 28 entries using the PEF The scores from the PEF were also used to rank the entries for the toy competition.

Results & Discussion

The three instruments employed in this study have produced a wealth of data for analyses. For convenience, we consider each separately.

a) Survey Form

Initial findings showed some interesting results (Fig.1) An extremely large proportion of the participants came from the express stream. The number of participants from the GEP (Gifted Education Programme) was small. There were also no female participants among the GEP student.

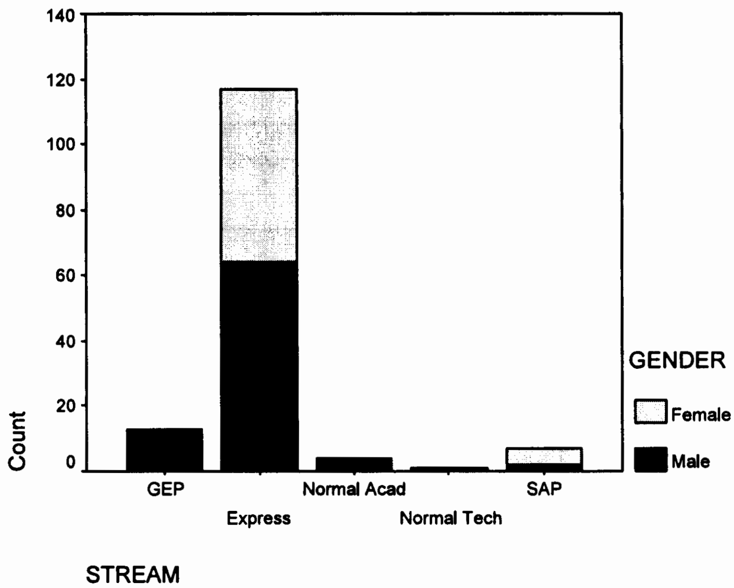

Figure 1. Constitution of participants by stream

Fig 2 shows that a large majority of the participants were secondary school students, mainly in the age group from 13 to 17 year olds.

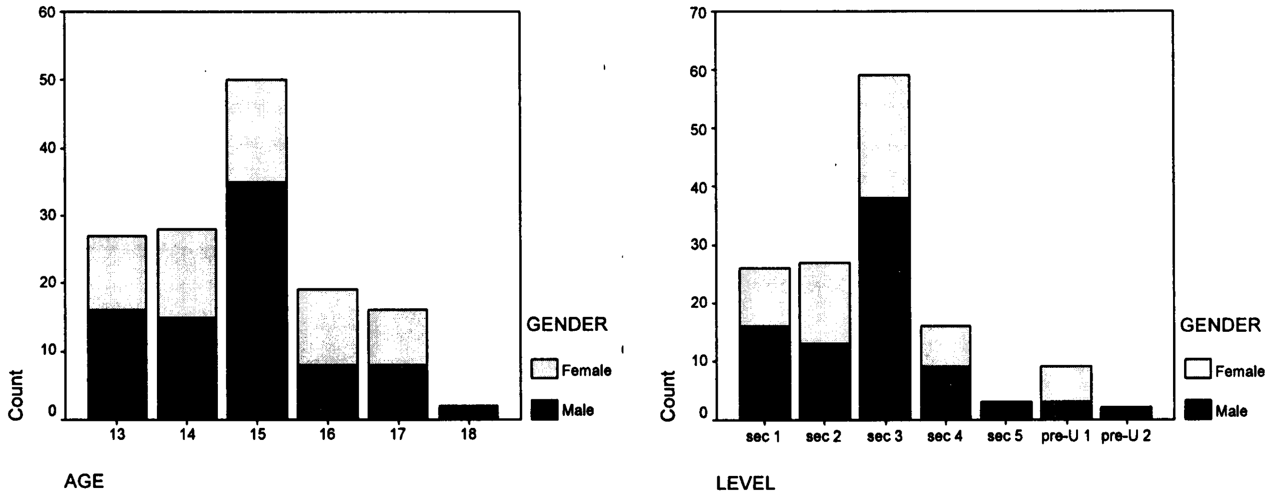

Figure 2. Constitution of participants by age and academic level

The distribution of participants by teams is shown in Table 1.

Table 1. Number of members in each team

No of members in each team	No of teams	Total no of participants
1	2	2
2	5	10
3	14	42
4	30	120
Total	51	174

We decided to limit our analyses to:

Non-GEP students. This is because GEP students undertake a significantly different curriculum than the others. The other four streams differ only in the pace of their learning and not in the curriculum. This is further justified by zero representation of female GEP students and also the small number of GEP participants (N = 13).

Secondary school students. This is because we would like to exclude the effect of pre-university education on our analyses. Also, there were only 11 entries in the pre-university category. This would also automatically narrow the age factor to 13 to 17 years.

The responses of 24 students who did not qualify into either of the two categories were excluded.

SPSS was used to analyse the survey results of the remaining 118 respondents. Table 2 displays the make-up of the 118 respondents.

Table 2. Gender and Academic level of subjects

Level	Male	Female	Total
Lower Sec	29	22	51
Upper Sec	37	30	67
Total	66	52	118

A discussion on the results of the three subscales of the survey form is now presented.

ai) Motivation

Items 1 to 11 of the survey form (Table 3) relate to the type of motivation that drives students to participate in an invention activity. The data is not unidimensional because motivation is influenced by several factors. To cater to the different factors, items 1-11 were divided into four meaningful groups:

Group I: To what extent are the students motivated specifically by extrinsic rewards?
Group II: To what extent are the students motivated by cash rewards?
Group III: To what extent are the students motivated specifically by intrinsic rewards?
Group IV: To what extent are the students motivated by extrinsic rewards as compared to intrinsic ones?

Internal reliability of this subscale of the evaluation instrument was obtained by extracting the Cronbach Alpha coefficient (Cronbach, 1951). The alpha was found to be 0.70. Nunnaly (1978) has indicated 0.7 to be an acceptable reliability coefficient but lower thresholds are sometimes used in the literature. Table 4 shows descriptive statistics for the four selected groups in relation to motivation.

Table 4. Means of grouped items from survey (motivation)

Group	Grouped Items	Number of students	Mean	SD
I	q01,q02,q03,q05,q09	118	3.01	0.69
II	q01,q02,q04	118	2.61	1.00
III	Q06#,q07#,q08#,q10#,q11#	118	2.20	0.65
IV	q01,q02,q03,q05,q06#,q07#,q08#,q10#,q11#	118	2.47	0.55

These statements were reversed.

Table 3 – Descriptive statistics of survey (motivation)

Item	Motivation to Invent	N (Total)	Min	Max	Mean (Total)	SD	Mean (Male) N=66	Mean (Female) N=52	Sig.*	Mean (Lower Sec) N=51	Mean (Upper Sec) N=67	Sig.*
1	I was attracted by the prize money.	118	1.00	5.00	2.77	1.128	2.82	2.71	0.612	2.57	2.93	0.089
2	Prize money is an important criterion to motivate me to participate.	118	1.00	5.00	2.58	1.120	2.50	2.67	0.407	2.39	2.72	0.120
3	I was attracted by the certificates of participation.	118	1.00	5.00	3.02	1.162	2.94	3.12	0.416	2.98	3.04	0.767
4	Cash prize was more attractive to me than the acknowledgement in the form of the certificate.	118	1.00	5.00	2.47	1.027	2.50	2.44	0.763	2.31	2.60	0.138
5	Having a well-known organization as a sponsor (eg DSO National Laboratories) was an important factor for me to participate.	118	1.00	5.00	2.92	1.091	2.83	3.02	0.360	3.00	2.85	0.464
6#	I would have participated even if there were no prizes to be won anyway.	118	1.00	5.00	2.38	0.986	2.24	2.56	0.085	2.25	2.48	0.226
7#	I am interested in invention competitions because it gives me an opportunity to make a prototype.	118	1.00	5.00	2.12	0.898	2.15	2.08	0.656	1.96	2.24	0.096
8#	I do not mind spending my own money to build a prototype even if I could end up not winning anything.	118	1.00	5.00	2.30	0.981	2.26	2.35	0.628	2.22	2.36	0.437
9	I participated to represent my school.	118	1.00	5.00	3.76	0.940	3.71	3.83	0.512	3.71	3.81	0.569
10#	I participated in this competition because I liked the opportunity to invent something.	118	1.00	5.00	2.11	0.804	2.14	2.08	0.692	2.02	2.18	0.287
11#	Even if I think my idea has no chance of winning, I would still participate in the competition.	118	1.00	5.00	2.08	0.907	2.11	2.04	0.690	2.10	2.06	0.821

Statements were reversed. *Sig. value from one way ANOVA.

Group I results show that the students are somewhat not motivated by extrinsic rewards (in this case, cash prizes, certificates, sponsor's credentials or opportunity/pride in representing their alma mater – the mean is 3.01).

The mean response to item 9 (see Table 3, mean = 3.76), however, interestingly shows that students are quite motivated to represent their school.

Group II results further reiterate the point that the students are generally not motivated by the amount of cash to be won (mean = 2.61). This is rather surprising as considering that Singapore is an economically driven society, with wealth being regarded as a general measure for success, it was expected that students would be very motivated by cash rewards.

Group III results show that the students are generally intrinsically motivated (mean = 2.19). The responses to each item in this group indicate that the spirit of innovation is very much alive among students. Responses to items 7 and 10 show that the students are very interested in having an opportunity to invent and build a prototype.

Group IV results show that the students are in general more intrinsically motivated than extrinsically motivated (mean = 2.47). This is very encouraging as again it shows that the students are more driven by the spirit of innovation rather than extrinsic rewards like cash prizes.

Univariate analysis of variance (ANOVA) was performed to identify items to which male and female participants respond differently (Fig 7). The analyses shows that there were no significant differences among their responses to items 1 to 11 at $p < 0.05$ level. This result suggests that male and female participants are motivated to a similar extent. Similar results were achieved when responses from lower and upper secondary students were compared.

2 x 2 ANOVA was also done to check for interaction between gender and academic level for Group I to IV responses (Table 5). The analyses showed that there were no significant interactions. This result also suggests that the effect of gender and academic level is statistically insignificant at $p < 0.05$ level.

Table 5 Two way ANOVA for grouped items (Motivation)*
Tests of between-subjects effects

Group	Type III sum of squares	df	Mean square	F	Sig	Partial Eta Squared
I	0.549	1	0.549	1.168	0.282	0.010
II	1.544	1	1.544	1.568	0.213	0.014
III	0.401	1	0.401	0.934	0.336	0.008
IV	0.652	1	0.652	2.198	0.141	0.019

aii) Inventor's Environment

Items 12 to 20 help us to assess the type of environment that our student inventors work in (Table 5). The data is not unidimensional because the environment is influenced by many factors, mainly the school and home environments.. To cater to these two main factors, the items were divided into two meaningful groups:

Group I: To what extent is the student's general environment conducive towards inventing?

Group II: To what extent is the school's environment conducive towards inventing?

Table 7 shows descriptive statistics for the subscale corresponding to the inventor's environment.

Table 6. Means of grouped items from survey (Environment)

Group	Grouped Items	Number of students	Mean	SD
I	q12,q13,q14,q15#,q16#,q17,q18,q19,q20	118	3.36	0.43
II	q12,q14,q17,q18	118	3.63	0.61

These statements were reversed.

Based on the students' responses, the Cronbach alpha (0.50) indicates a lower internal reliability level as compared to the previous section. Emphasis will therefore be put on the analyses of each group individually.

Group I results (see Table 6, mean = 3.36) show that the students feel that the general environment in Singapore is conducive towards inventing activities.

Group II results (mean = 3.63) indicate that the school environment seems to be a more influential factor. This result is expected since students spend a good proportion of their time in school. Individual item analysis further reflects positively on the school environment. However, this result has to be considered very carefully as the number of schools that participated in this competition is only 23 out of a possible 180. This number itself seems to reflect negatively on the schools' response to the competition. Perhaps these schools have already been committed to other projects and the schedule for the invention competition could not be accommodated in their overall plan for the year.

Table 7. Descriptive statistics of survey (environment)

Item	Inventors' Environment	N (Total)	Min	Max	Mean (Total)	SD	Mean (Male) N=66	Mean (Female) N=52	Sig.	Mean (Lower Sec) N=51	Mean (Upper Sec) N=67	Sig.
12	My school/ teacher encouraged me to participate.	118	1.00	5.00	3.89	1.052	3.83	3.96	0.513	3.78	3.97	0.344
13	My parents encouraged me to participate.	118	1.00	5.00	3.36	1.000	3.30	3.42	0.520	3.25	3.43	0.341
14	My friends encouraged me to participate.	118	1.00	5.00	3.59	0.980	3.59	3.60	0.977	3.63	3.57	0.742
15#	There are not enough invention competitions in Singapore that I could participate in.	118	1.00	5.00	2.77	0.789	2.71	2.85	0.362	2.71	2.82	0.435
16#	Apart from this competition, I do not have a good reason to invent.	118	1.00	5.00	3.17	1.032	3.12	3.23	0.569	3.31	3.06	0.186
17	My school provides opportunities to invent.	118	1.00	5.00	3.64	0.884	3.68	3.58	0.524	3.76	3.54	0.167
18	The educational environment in Singapore is conducive for inventing.	118	1.00	5.00	3.41	0.908	3.44	3.37	0.662	3.45	3.37	0.647
19	I would consider becoming a full-time inventor.	118	1.00	5.00	2.95	1.093	3.08	2.79	0.157	2.86	3.01	0.456
20	I am keen to take up inventing as a hobby.	118	1.00	5.00	3.43	0.910	3.50	3.35	0.364	3.49	3.39	0.548

Statements were reversed

Considering the response from the previous section that the students are motivated by opportunities to invent and build prototypes, it is of interest to know if their needs in this regard are catered for. Results from items 15, 16 and 17 indicate that the students feel that there are not enough invention competitions in Singapore but that their schools do somewhat provide enough opportunities for them to invent. The data shows that the participants' schools provide projects (which involve inventing opportunities) as an authentic learning experience or as part of an internal school competition.

Items 19 and 20 show that the students are somewhat not too keen to become full-time inventors but are keen to take up inventing as a hobby. The lack of interest in becoming full-time inventors is not surprising if we believe our students lack certain characteristics that are commonly associated with successful inventors. These characteristics include sheer perseverance, fearless attitude towards the unknown, not fearing failure, and so on. The necessary information is however lacking to make such conclusions, but these speculations should not be discarded. .

Univariate analysis of variance (ANOVA) was performed to identify items to which male and female participants responded differently (Table 9). The analyses showed that there were no significant differences between males and females in their responses to items 12 to 20 at $p < 0.05$ level. This result indicates that male and female participants have similar feelings about their environment. Similar results were obtained when responses from lower and upper secondary students were compared.

2 x 2 ANOVA was also done to check for interaction between gender and academic level for Group I to IV responses (Table 8). The analyses showed that there were no significant interactions. This result suggests that the effect of gender and academic level is statistically insignificant at $p < 0.05$ level.

Table 8 Two way ANOVA for grouped items (Environment) *
Figure 10 Tests of between-subjects effects

Group	Type III sum of squares	Df	Mean square	F	Sig	Partial Eta Squared
I	0.006	1	0.006	0.335	0.564	0.003
II	1.786	1	1.786	4.849	0.030	0.041

Table 9. Descriptive statistics of survey (inventive process)

Item	The Process of Invention	N (Total)	Min	Max	Mean (Total)	SD	Mean (Male) N=66	Mean (Female) N=52	Sig.	Mean (Lower Sec) N=51	Mean (Upper Sec) N=67	Sig.
21	The ability to draw well (in free-hand) is not important in the invention process.	118	1.00	5.00	2.65	1.143	2.71	2.58	0.526	2.24	2.97	**0.000***
22	For this competition, I kept records of what I did during the process of inventing (for eg, sketches, notes, etc)	118	1.00	5.00	3.56	0.948	3.64	3.46	0.322	3.53	3.58	0.766
23	The ability to write a description of the invention is more important than the invention (the physical product) itself.	118	1.00	5.00	3.23	1.059	3.35	3.08	0.164	3.27	3.19	0.682
24	I would like a coach to help me in future invention projects or competitions.	118	1.00	5.00	3.58	0.870	3.53	3.65	0.446	3.61	3.57	0.803
25	I think building a prototype is not necessary in an invention competition.	118	1.00	5.00	2.52	1.175	2.68	2.31	0.086	2.47	2.55	0.710
26	I prefer to solve the problems I faced in inventing by myself rather than as a team.	118	1.00	5.00	2.36	1.122	2.50	2.19	0.140	2.31	2.40	0.671
27	I will not hesitate to ask my mentor or teacher to help.	118	1.00	5.00	3.80	1.001	3.79	3.81	0.915	3.82	3.78	0.800
28	Making a prototype is physically demanding.	118	1.00	5.00	3.22	0.926	3.26	3.17	0.625	3.39	3.09	0.079
29	Making a prototype is financially demanding.	118	1.00	5.00	3.17	0.963	3.36	2.92	**0.013***	3.24	3.12	0.520
30	Inventing is too time consuming.	118	1.00	5.00	3.05	1.011	3.24	2.81	**0.020***	3.12	3.00	0.534
31	A good knowledge of Physics helps in the process of inventing.	118	1.00	5.00	4.05	0.866	4.18	3.88	0.064	4.00	4.09	0.580

aiii) Inventive Process

The attributes that count in the inventive process are now addressed.

Item 21 shows that students somewhat disagree that the ability to draw free-hand is not important (Fig 12, mean = 2.65). One way ANOVA further shows that there is significant difference at $p < 0.05$ level between responses from lower and upper secondary students. The analysis shows that the lower secondary students felt more strongly that this ability is important. Older students, who are perhaps more exposed to IT, probably believe that this ability is not as important.

Items 22 and 23 show that the students believe in keeping records and believe that the written description is more important than the product. The results reflect well on their inventive process. However, there was no physical evidence of these records as the competition did not require them to hand these in.

Item 24 show that the students prefer to have a coach to help them in invention projects. This shows that the students are not confident about their own inventive skills and do not seem to have an independent attitude. Their lack of confidence is further reflected in items 26 & 27.

Item 25 shows that students believe that building a prototype is a necessary step in the inventing process. However, items 28 and 29 show that the students generally feel that the making of a prototype is physically and financially demanding. These results question whether our young inventors are getting enough support. ANOVA for item 29 shows that there is a significant difference in the responses between male and female students.

Item 30 shows that male students find inventing is rather time consuming. This result questions the attitude of male students towards inventing.

Item 31 shows that students strongly believe that a good knowledge of Physics can help in the inventing process. Further research need be done to check the students perception of the importance of science in general and physics in particular in the inventive process.

ANOVA shows no significant difference in the responses for items 22 to 28 and 31 (for both gender and academic level).

b) Product Evaluation Form

The purpose of this instrument is to evaluate the invention (the Product).

Christiaans (2002) raised the question of whether creativity in product design can be judged in a valid and reliable way. He stresses that this depends on the type of product (eg design work as compared to artwork) being assessed and also the background of the judges. For this competition, the rules were well defined so that the type of inventions allowed were works of design rather than artwork, which may produce a more subjective response from the judges.

Therefore, the more pertinent concern was the level of subjectivity of the judges' responses. Although our study was meant to study the inventive mindset of the participants, we still need to investigate the reliability of the judges' responses before they can be used in tandem for our analyses of the inventions.

Interrater reliability, using Cronbach's coefficient alpha, is presented in Figure 13 for the Product Evaluation Form.

Fig 13 Cronbach Alpha coefficients of Product Evaluation Form

Subscale	Panel of judges (N = 8)	Selected judges A,B,C,H (N = 4)	Selected judges E,F,G (N = 3)
Creativity	0.90	0.84	0.75
Practicality	0.69	0.65	0.42
Prototype	0.84	0.68	0.65
Overall	0.88	0.81	0.70

- The results show high inter rater reliability for all critera, especially in Creativity and Prototype Quality, and in the overall mean as well. Although, the Cronbach alpha for Practicality is significantly lower than Creativity and Prototype Quality, the value is still quite high. These results suggest that the judges have a similar understanding of each criterion.

- It is of interest to note the Cronbach alphas for the selected group consisting of judges E, F and G (who are working in the toy industry) are relatively lower than those for the group made up of judges coming from the education sector. This suggests that they have slightly different perceptions of each criterion.

- It is especially surprising to note that inter rater reliability is highest in the area of Creativity. We would expect it to be more subjective as compared to Practicality and Prototype.

Fig. 14 shows data on the judges' mean scores for the various subscales assessed in the entries.

Fig 14 Descriptive statistics for the judges mean scores for the three criteria

Criterion	**N**	**Min**	**Max**	**Mean**	**SD**
Creativity	28	2.23	4.10	3.09	0.51
Practicality	28	2.85	4.03	3.36	0.28
Prototype quality	28	2.88	4.35	3.61	0.36

The results presented in Fig 13 show that the 28 prototypes evaluated are generally good in practicality and prototype quality. The eight judges were neutral when it came to evaluating the inventions for creativity. Considering that the 28 prototypes were the best entries of the 53 submitted, we can take it that the level of creativity is somewhat on the low side; this must, however, be tempered by the somewhat high standard deviation for these attributes.

Although the instrument has proven to be valid and reliable, the judges' scores are restricted to the 28 prototypes evaluated using the Product Evaluation Survey Form. So, the results of our analyses cannot be used to represent the student population in general

c) Invention Design Form

The Invention Design Forms submitted by the students were not used for the purpose of judging. It was more a platform for students to put their ideas in words and graphics.

The following is a general assessment of the IDFs submitted for the competition:

- A large majority of the teams did not put in much effort when completing the IDF. This could be due several reasons; 1) inability to understand the instructions when completing the IDF, 2) inability to appreciate the importance of the written description of the product, 3) no dependence on mentors/coaches for help, 4) low language proficiency, 5) unfamiliar activity, and so on.
- A large majority of the teams were not able to describe the mechanism of operation of their inventions. It seems that some of the teams felt that the mechanism is simple and therefore obvious. They probably felt that it was not necessary to explain it in detail. The use of diagrams to help in their explanation was common but their effectiveness varied widely.
- Most of the diagrams were hand drawn. Computer generated diagrams were limited to 2 dimensional ones only. Most of the hand drawn diagrams were drawn free-hand, and little effort was spent on assuring correctness of scale. Although labeling was usually done, their effectiveness was often questionable.
- Many of the participants used their knowledge from technical education to provide diagrams in more than one perspective (front, side, top, perspective). However, the overall standard of their drawing skills is not very impressive and they are also lacking in their effectiveness.

Overall, the standard of the IDFs was somewhat low. The participants did not put in enough effort in their written report. The descriptive and drawing skills were of rather low level.

Conclusion

This pilot study on exploring the inventive mindset of Singapore students based on the invention of toys is the first such systematic attempt to be carried out using a medley of validated instruments. It is clear that the process of invention affords tremendous scope to harness the creative potential of our students. The range of entries submitted testify to this, even though the judges are somewhat divided on this matter. Focusing on a toy-centric strategy to assess inventions assures a commonality of considerations which may be bereft of flexibility in an open category type of competition, where the sheer diversity of entries defy a common basis of evaluation.

Some of the interesting findings from this study are:

a) Students are motivated by intrinsic rewards when entering invention competitions,

b) The educational environment is becoming more conducive for inventors,

c) Female students are just as interested in invention competitions as male students,

d) Students are not interested in becoming full-time inventors but are willing to take it up as a hobby,

e) Students from the express stream are more predisposed towards inventing than those from the normal stream.

f) In terms of level of creativity of the entries, it appears that there is still some way to go even though some of the entries are of a high standard.

It is recommended that the competition approach used in this study be replicated on a wider scale so that more representative data can be collected. At the same time, invention competitions need to be included on a school-wide basis so that the spirit of innovation and enterprise can resonate more strongly among our students.

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Annex 1 PRODUCT EVALUATION FORM

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inventors' challenge 2004

Name of Invention	
Name of Judge	

Judges' Feedback

	Creativity					
1	**The invention uses an original idea.**	**SA**	**A**	**N**	**D**	**SD**
2	**This idea behind the invention is unique.**	**SA**	**A**	**N**	**D**	**SD**
3	**The invention uses a clever concept.**	**SA**	**A**	**N**	**D**	**SD**
4	**The operation of the toy is creative.**	**SA**	**A**	**N**	**D**	**SD**
5	**The overall design (or package) is ingenious.**	**SA**	**A**	**N**	**D**	**SD**

	Practicality					
6	**The invention is easy to operate.**	**SA**	**A**	**N**	**D**	**SD**
7	**It will be inexpensive to produce this product.**	**SA**	**A**	**N**	**D**	**SD**
8	**The invention can be a success if it were to be produced for educational purposes.**	**SA**	**A**	**N**	**D**	**SD**
9	**I was entertained by this invention.**	**SA**	**A**	**N**	**D**	**SD**
10	**If the invention were to be produced commercially, it can be a success.**	**SA**	**A**	**N**	**D**	**SD**

	Prototype					
11	**The craftsmanship of the prototype is excellent.**	**SA**	**A**	**N**	**D**	**SD**
12	**The prototype needs some improvement.**	**SA**	**A**	**N**	**D**	**SD**
13	**The prototype is user friendly.**	**SA**	**A**	**N**	**D**	**SD**
14	**I think the inventor spent sufficient time in building the prototype.**	**SA**	**A**	**N**	**D**	**SD**
15	**The prototype functions according to the inventor's objectives.**	**SA**	**A**	**N**	**D**	**SD**
16	**I am impressed with the quality of the prototype.**	**SA**	**A**	**N**	**D**	**SD**

Annex 2 INVENTION DESIGN FORM

<u>How to complete the Invention Design Form</u>

The Invention Design Form is structured based partially on the anatomy of a patent. However, when you complete the form for your entry, it does not mean that you have legally own a patent. The Invention Design Form is purely constructed for the purpose of the RJC Inventors' Challenge.

To help you understand how to complete the form, we will use the prize-winning entry of Mr Sin Tong of Raffles Junior College as an example. His entry, the Mind Matrix, was placed third in the RJC Inventors' Challenge 2003.

The completed Invention Design Form below is not the original entry form sent in by Mr Sin Tong. It is merely just a guide to show you how a good design should look like.

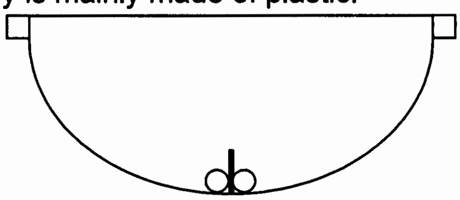
A) Background of invention.

The objective of the Mind Matrix is basically to place the 2 ball bearings into the two pockets in a specially designed plastic container.
This puzzle is suitable for children 10 years old and above. The objective is quite challenging and the solution uses centripetal force.
This toy also has the potential to be used as a demonstration of centripetal force in physics lessons.

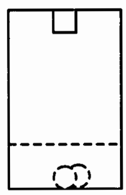
This section is just a brief description or abstract of the entry. For the purpose of clarity, you may add in more details.

B) Detailed description of the design of the toy.

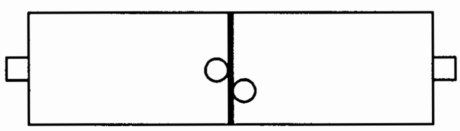
The toy is mainly made of plastic.



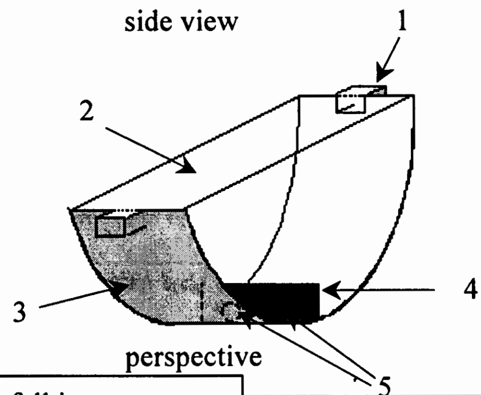
front view



side view



top view



perspective

1 – pocket for ball bearing to fall into
2 – clear plastic part of container
3 – opaque curved plastic part of container
4 – barrier to separate the ball bearings
5 – ball bearings

Free hand sketches are good enough as long as they are able to make the readers understand your design accurately. Using the working and perspective drawings are highly recommended. The working drawing is a planar representation of the object from one, two or more sides. The perspective drawing is a representation of the object if it was actually built and photographed.

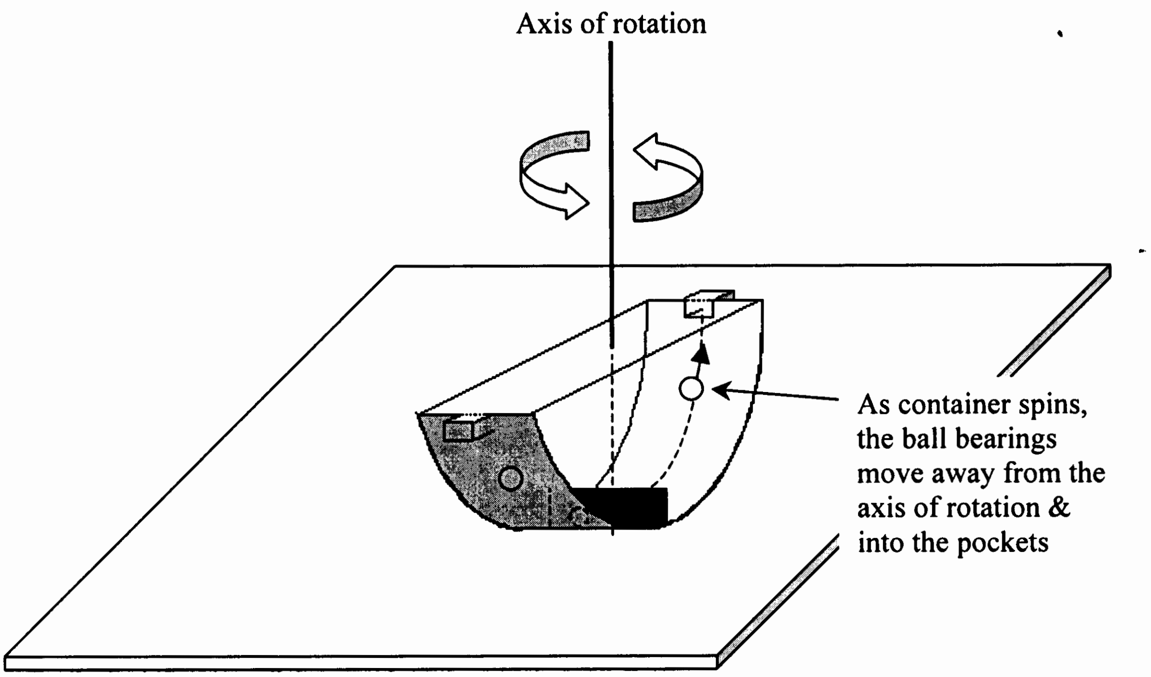
If you have built your prototype, it is perfectly fine for you to attach the photographs of the prototype.

The prototype need not be made with the intended material. You may use recycled material for the prototype. Sin Tong used a portion of a food tin can for the curved part and cling wrap for the clear part of the toy.

Well-labeled diagram is a must!

C) Detailed description of the operation of the toy.

Place the puzzle on a flat and horizontal smooth surface (eg table top), with the curved side resting on the flat surface as shown.
Flick on one end of the container so that it rotates in a smooth and horizontal manner as shown. If done correctly, the ball bearings will move away from the axis of rotation due to centripetal effect and land in the pockets as required.

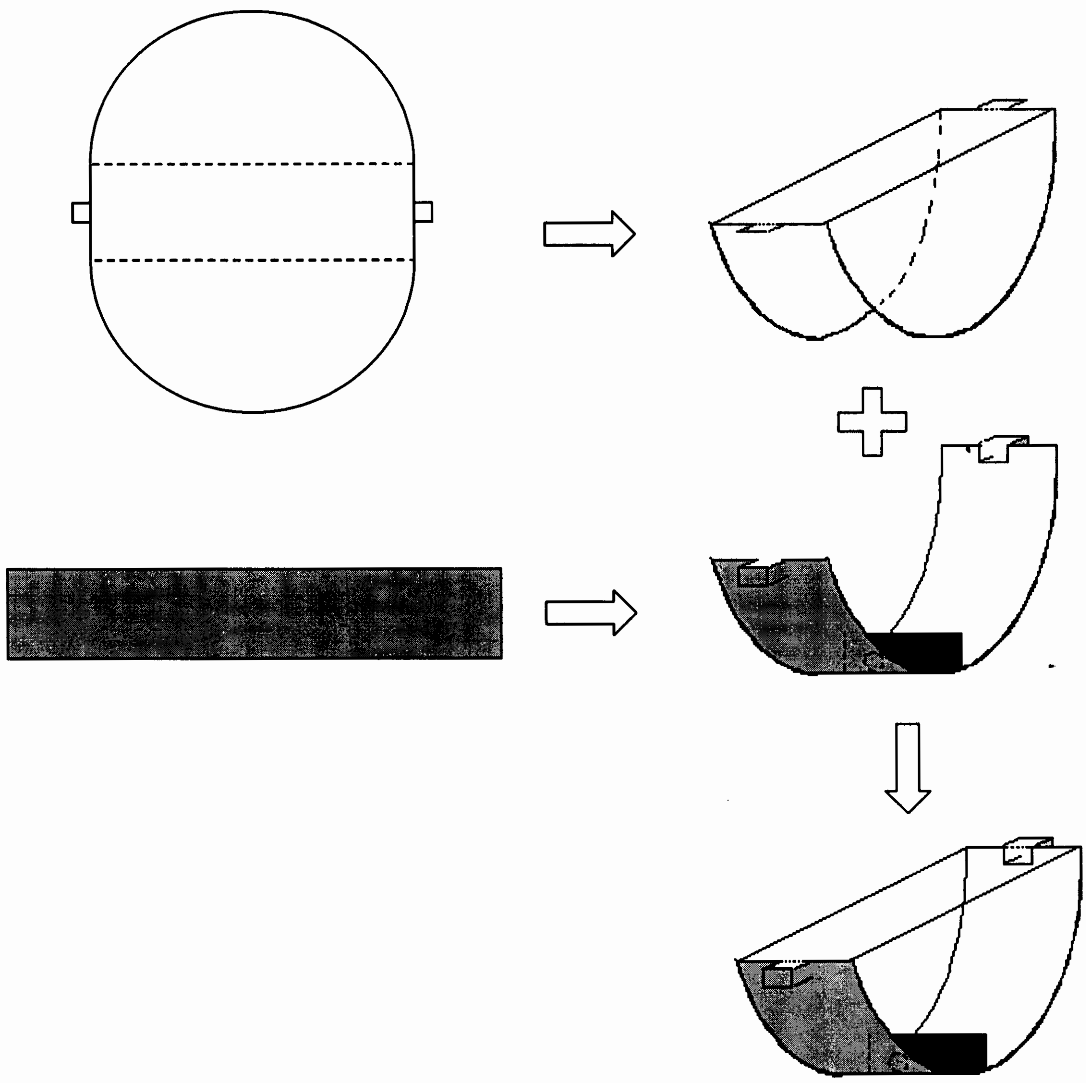


D) Reference to related inventions, if any:

E) If there are any parts of the invention that you want the judges to pay attention to please list them in point form here. For example, this could be the innovative joints or fabrication technique that you're thinking of using.

The toy may be manufactured very easily if the parts are made as follows:

Cut a clear plastic piece into the shape as shown and fold along the two dotted lines. Cut an opaque plastic piece into the shape as shown and bend it into a curve surface as shown. Use thermal process to form the pockets.



It is not necessary to show the manufacturing process in detail but it does help in spicing up the entry form.

F) Why do you think that this toy has a potential of being a hit in the toy industry?