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Correlates of divergent thinking among secondary school physics students

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Recent studies have reported a decline and lack of creativity across many nations, raising concern about low status of divergent thinking - the basis of creativity. The purpose of this study was to explore some correlates of divergent thinking that would be utilized to enhance creativity. Its objective was to determine correlations between divergent thinking and: project work, creative attitude, critical thinking, originality, and interaction with toys and science materials. The study employed a correlation design and targeted a population of 2,236 12th grade secondary school physics students in Nairobi Province; while the sample comprised 763 respondents, obtained through stratified and random sampling techniques. Data were collected using Questionnaire for Physics Students, which was constructed by the researcher and validated by three experts in psychometric measures from Maseno University. The instrument had a reliability of .837; and significance of correlations was tested at p = 0.05 and p = 0.01 levels. Significant correlations were observed between divergent thinking scores and: creative attitude, critical thinking, extent of play with toys, and originality. The study recommends (1) use of supplementary print and audiovisual scientific materials in schools to inspire creativity and (2) further research aimed at establishing causative relationships involving divergent thinking.

Keywords: Creativity, divergent thinking, physics, secondary education

INTRODUCTION

The cultivation of high-order thinking skills in general and divergent thinking abilities in particular is recognized as one of the most important goals of education globally (Robinson, 2007; Chien, 2010; Craig, 2001). In a world that experiences rapid transformation, creative problem solving skills are viewed as the essential all-time ability needed to effectively address unforeseen challenges that demand innovative solutions (Duch et al., 2001; Osborn and Mumford, 2006; Shefield, 2011; Tan, 2010). Accordingly, calls by educators to focus educational efforts on creativity and innovativeness have intensified over the years (Merris, 2008; Sahlberg, 2009). Some scholars perceive creativity and independent thinking as key ingredients of the success of developed nations, arguing that such nations capitalized on the power of thinking by integrating creativity and technology with discipline, hard work and integrity to become the major economic and technological power they are today (Josu and Dion, 2008; Kimani, 2008; Mangena, 2007; Maseau, 2008; and Ogot, 2007).

While building the case for creativity, Koray (2003) observes that science education in particular is widely accredited in many countries, including the US, as a major source of discovery and economic development and therefore tasked to maintain the country's competitiveness in the twenty-first century. This is to be achieved by cultivating skilled scientists and engineers needed to create tomorrow's innovations (DeHaan, 2009; National Research Council, 2007). Elsewhere, emphasis on creativity continues to grow, with many countries such as the European Union (EU) member countries and Indonesia having declared 2009 as the Year of Creativity to mark the beginning of a global transformation led by creativity in all spheres of life; while China, Hong Kong, Taiwan, Japan, Singapore and Malaysia have already embarked on major programmes for promoting creativity

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in schools. Indeed creativity and its associated basic skill, divergent thinking, are now a serious theme of engagement for UNESCO (Tan, 2010).

Divergent thinking continues to gain currency not only because it provides the basis for generating new ideas but because of its ability to enhance learning in a more economical way (Jackson, 2000). Taylor (2008) and Tsui (2001) document an overwhelming consensus among science teachers on the need to teach the construct for the purpose of encouraging independent thinking. Nobel laureate Albert Einstein, as cited in Isaacson (2007), warned that accumulation of material should not stifle student's independence of thought, for learning becomes much more interesting, meaningful and effective when people are given the opportunity to be creative by exercising their thinking abilities. Children, in particular, learn better and often faster using creative methods rather than by memorizing information (Goff and Torrance, 1990; Puccio, 2001). But such methods require a curriculum that promotes independent thinking, original work, self-initiated projects and experimentation that assist in stimulating growth in creative behaviours.

Although creativity enjoys a wide consensus as an important goal of science education, available literature points to its stifling and general neglect in the teaching-learning process. According to Ishaq (2008) and Gale (2001), educational systems penalize divergent thinkers as much of the classroom discourse is biased towards learning styles that promote convergent thinking and uniformity of responses while discouraging divergent thinking. This observation is consistent with the findings of Bronson and Marryman (2010) who, in what they consider as a creativity crisis, have reported a declining level of creativity in America. However, low status of creativity appears to be widespread globally (Hechinger, 1993; Kenya Institute of Education, 2010; Okeke, 2010; Okere, 1986; Robinson, 2010). In Kenya, the grim picture is painted against a background in which some skills are prescribed in the school curriculum to enhance creativity and provide holistic education to children; and these include critical thinking, project work, and science congress participation among other co-curricular activities. The reported low status of creativity therefore raises doubts about the relationships between these activities and divergent thinking, for there can be no influence unless a correlation exists between variables. The purpose of this study was therefore to explore some correlates of divergent thinking that could be utilized to enhance creativity. The study not only aimed at verifying presumed correlations but extended the search to other areas of the curriculum not specifically aimed at creativity enhancement but which nonetheless might help in achieving this purpose, considering that each learning experience may achieve many more educational outcomes than originally intended (Tyler, 1949). The objective was to determine correlations between divergent thinking and selected factors, namely: participation in project work, creative attitude, critical thinking, originality and extent of childhood interaction with toys and scientific materials.

RESEARCH METHODOLOGY

This study adopted a combination of ex-post-facto and correlation designs. The ex-post-facto component was incorporated since the study sought information on the extent of respondents' previous exposure to certain treatments in their normal school programme and at home, such as participation in project work, participation in Students' Congress on Science and Technology, and extent of interaction with toys and science materials; while correlation design facilitated the determination of correlations between these variables and divergent thinking. These designs were also based on ethical considerations. First, the respondents had already been exposed to childhood interaction with toys, whose overall long-term effects were unknown and consequently would not be manipulated on respondents. Other variables such as originality and critical thinking, not only had ethical implications but were likely to require prolonged exposure before they could have any significant impact on divergent thinking, rendering them unsuitable for experimental designs. No treatment was administered but the researcher applied statistical analysis of covariant data to determine pre-existing relationships.

Study Population

The population for this study consisted of 2,236 Form 4 (12th grade) secondary school physics students in Nairobi Province, Kenya. These were students who followed the local 8-4-4 curriculum and had opted to study physics upto the Kenya Certificate of Secondary Education (KCSE) level. Further, the population was hosted by schools that had consistently achieved a mean physics score of at least 6.0 (Grade C) on a 12-point scale in the national examinations (KCSE), during the three years preceding research. This selection criterion was to maximize the probability that the targeted population would retain the same performance category of 5.0 and above during the 2010 and 2011 national examinations. The decision to limit the population to this performance range (6.0-12.0) was based on the componential theory of creativity which recognizes good mastery of relevant knowledge domain, beyond a certain threshold level of competence, as a prerequisite for any meaningful divergent thinking and creative output (Amabile, 1996; Asha, 1980; Karimi, 2000; and Mahmodi, 1998). These schools fell into various categories, including public, private, boarding, day, co-educational and single-sex schools. Students in this population came from diverse socio-economic backgrounds, with virtually all the 43 ethnic communities in Kenya represented. Nairobi was selected for its technology-rich environment which was perceived as having a unique influence on the scientific creativity of its residents.

Sample and Sampling Procedure

The study sample consisted of 763 physics students drawn from 18 secondary schools. This sample comprised students who had actively participated in the Students' Congress on Science and Technology (SCST) and those who had not. Sampling was carefully done to include all the subgroups targeted; and this was achieved through stratified and random sampling techniques at different stages. First, stratified sampling was done, in which the population of schools was divided into performance strata according to their physics performance in national examinations the previous year. Further sub-stratification was carried out within each stratum to categorize schools by gender to guarantee equitable gender representation and, more importantly, to facilitate the matching of schools with respect to particular characteristics in the sample. From the strata, purposive sampling was used to select schools so that each district received proportional representation, ensuring that both boys' and girls' schools were fairly represented.

At the school level, all Form 4 physics students who had participated in the Students' Congress on Science and Technology (SCST) by presenting physics exhibits or Talks were nominated, with the assistance of physics teachers, to participate in the study. Then, other Form 4 physics students, who had not participated in SCST, were randomly selected from the rest of the class to top up the sample to 40 students. However, this number varied slightly from one school to another, depending on physics enrolment. Schools with bigger enrolments contributed larger samples to cater for those whose enrolments fell below the target. The same procedure was applied to all the 18 sampled schools, giving a total of 763 student respondents, comprising 386 girls and 377 boys.

Research Instrument

One instrument, Questionnaire for Physics Students, was used in the study and this consisted of four parts each of which targeted a different skill or information. The four parts targeted relevant background information, attitude towards creativity, and divergent and critical thinking abilities of physics students. It therefore consisted of four parts, namely: Background Information, Creative Attitude Scale, Test of Divergent Thinking, and Test of Critical Thinking respectively.

The section on Background Information was basically a component of the Torrance's Test of Creative Thinking, adapted by the researcher to make it suitable for use with secondary school students. It was used to collect data from respondents on gender, extent of involvement in physics project work, participation in Students' Congress on Science and Technology, and childhood interaction with toys, and science materials. Bull and Davis (1980) recognize statements of past creative activities by respondents as an important behavioural assessment of divergent thinking abilities. The second section, Creative Attitude Scale, was used to collect data on the attitude of respondents towards creative thinking and creative work. It comprised sixteen (16) items designed to elicit responses on selected elements of creative attitude identified by Amabile (1996), Murphy (2007) and Ozden (2004). These elements included (1) curiosity (2) optimism (3) perseverance and high motive effort (4) constructive discontent (5) belief in one's creative ability (6) seeing problems as interesting (7) confronting challenges (8) willingness to take risk (9) seeing room for creativity and new discoveries (10) interest in physics (11) strong liking for positive uniqueness (12) commitment, (13) high level self-confidence, (14) interested in new, mysterious and complex things and (15) determination to make a contribution in physics and technology. It was based on the Likert five-point summative rating scale of 1 to 5.

The third section consisted of six (6) items designed to measure divergent thinking abilities in physics. The instrument was constructed, based on the design principles applied in the development of Torrance's Test of Creative Thinking, and guided by the scientific expressions of divergent thinking. Divergent thinking abilities were measured by quantifying ideational fluency and cognitive flexibility. Throughout the instrument, items were deliberately ill-defined not only to correspond to problems encountered in real life situations but also to allow ample room and flexibility in generating alternative solutions or responses. On the other hand, they were sufficiently clear to render them solvable (Torrance, 1998).

These items aimed at eliciting and quantifying the components of ideational fluency, namely: adaptive fluency and spontaneous fluency as well as cognitive flexibility as finer aspects of divergent thinking. Items which specifically targeted adaptive fluency asked the respondent to provide many alternative solutions while those assessing spontaneous fluency were silent on the number of responses expected. The same items were used to obtain the measure of cognitive flexibility by considering the number of domains of physics knowledge engaged by the respondent when generating solutions to a given problem.

The last section of the instrument was designed to measure critical thinking; and the items included targeted the ability to identify deficiencies in given physics statements, recognizing inadequacy in the information required to solve a physics problem, identifying errors in an experimental set-up, recognizing unstated assumptions and the ability to evaluate a given set of alternative solutions to a problem to determine the most suitable creative option (decision making). The items were creatively designed to avoid any direct relationships with the achievement test items normally met by students in books or examinations. It was an attempt to guard against previous exposure, which would otherwise be a major threat to validity of the instrument.

Validity of Instruments

The instrument was validated to ensure it met the criteria to elicit the information targeted; and a number of measures were taken to achieve this. First, face validity was ascertained by three experts on Research Methods at Maseno University, who evaluated each item on the instrument to establish its, relevance, clarity and suitability and verify adequacy of item samples for all the variables targeted by the study. The Questionnaire for Physics Students (QPS) was then given to six (6) experienced physics teachers in different schools within the study area, who were requested to (1) identify any divergent and critical thinking items that were similar to those normally used in knowledge tests, (2) compare and comment on the relative difficulty levels between the items targeting adaptive fluency and spontaneous fluency respectively, and (3) verify appropriateness of language to the level of their students. Based on teachers' feedback, unsuitable items were eliminated or rephrased accordingly ensuring that items for divergent thinking and critical thinking were themselves unique, and that adaptive and spontaneous fluency items had similar strengths and range of responses.

Reliability of the Instrument

To obtain reliability, the students' questionnaire (QPS) was piloted on a sample of 224 Form 4 students in 5 schools, which represented 10 per cent of the study population. The quantitative data obtained were used to compute separate reliability coefficients for the various sections of the instrument. This computation yielded Cronbach's alpha values of .842 for quantitative items on Background Information, .826 for Creative Attitude Scale, .831 for Test of Divergent Thinking, and .853 for Test of Critical Thinking.

Data Collection Procedure

The investigator first sought research approval from the School of Graduate Studies, Maseno University, and proceeded to obtain research authorization from the National Council of Science and Technology (NCST). This facilitated access to the latest records, at the Provincial Director of Education's office Nairobi, regarding physics enrolment by district, school and gender for the purpose of sampling schools. The researcher then visited the sampled schools to explain the purpose and make arrangements with the principals and concerned physics teachers for the administration of instruments. A follow-up was made through telephone calls to confirm the appointments. During the visit, students were sampled, and this was followed by the administration of the study instruments. This exercise was conducted in early October, 2010 – two months before the respondents completed their secondary education course.

Analysis of Data

Scoring of the attitude items was done by assigning the values 5, 4, 3, 2, and 1 to the checking points SA, A, U, D, and SD respectively for all the positively worded statements. For negative statements, the awards were reversed, with SD and SA corresponding to 5 and 1 respectively. A mean score of 3 represented neutral creative attitude, above 3 indicated positive creative attitude, while scores below 3 were interpreted as negative creative attitude on the part of respondent. The scores obtained were used to compute correlations between attitude and participation in physics project work, grade level and divergent and critical thinking abilities. Responses pertaining to divergent thinking were scored in terms of number of acceptable solutions to a given problem situation and the scores were tallied separately to reflect participants' abilities on various components: adaptive fluency, spontaneous fluency, cognitive flexibility as well as fluency on problem finding, problem solving and design of scientific device; and originality. The same treatment was given to responses on various components of critical thinking.

To analyze the responses for originality, the researcher applied the rubric developed by Osborn and Mumford (2006) and based on the considerations of unexpectedness, newness and distinctiveness. In rating unexpectedness, the researcher sought to determine the extent to which the response was novel, imaginative unpredictable or innovative. While judging the newness, consideration was given to whether the response went beyond the stimulus and included additional materials and experiences; while distinctiveness involved evaluating the extent to which a response was unusual and distinct from other answers; that is, statistical infrequency. The BI and CAS data were then coded; and the coded information, together with all the corresponding scores obtained for each participant were fed as data set into the Statistical Package for Social Sciences (SPSS) Version 17.0. Through this analytical package, multiple correlations between measures were determined, and the significance of any observed correlations was tested at $p \leq .05$ and $p \leq .01$ levels of significance on two-tailed tests.

RESULTS AND DISCUSSION

The relationship of divergent thinking was tested against a number of independent variables which included project work, creative attitude, critical thinking, originality, and extent of interaction with science materials and involvement with toys during childhood. Correlation analysis was extended to components of divergent thinking for the purpose of gauging the contribution of each component to any observed relationship.

Project work

The factor of project work, which was envisaged to contribute to the development of divergent thinking, was investigated to determine the status of its implementation at various grade levels: from Form 1 to 4. However, the obtained project wok participation index ranged from .96 to 2.0 on a scale of 0 to 4, which can only be described as "very little" to "just a little" as defined in the rating scale used in the data collection. In fact, at the individual level, 28 per cent of respondents indicated that they had not done project work at any grade level while 7 per cent had done it at only one level, in most cases Form 4. Even then, participation index varied between 1 and 2 only. Project Work Participation Index was mainly determined by teachers, as students relied almost entirely on project work assigned by them.

To explore possible implications of this trend, an analysis was performed to determine whether there was a correlation between divergent thinking and extent of participation in project work. The tests revealed only a weak and insignificant correlation between overall project work participation index and overall divergent thinking score on a two-tailed test ($r = .029$, $p > .05$). In the light of this observation, the investigator extended the search to individual components of divergent thinking but the same situation replicated with remarkable consistency for both boys and girls (Table 1). On the basis of these findings, it was concluded that there was no significant correlation between divergent thinking and the extent of participation in project work.

Creative attitude

As a factor investigated in this study, creative attitudes of respondents were measured using the Creative Attitude Scale. Correlations between the obtained scores and scores on divergent thinking were then computed to quantify the relationship between the two constructs. This investigation was motivated by the assumption that creative attitude could be an important factor necessary in sustaining divergent thinking and efforts towards translating divergent ideas into creative production. A summary of results for the correlations between creative attitude and various components of divergent thinking are presented in the last three columns of Table 1.

The statistical analysis revealed significant and strong positive correlations between creative attitude and adaptive fluency ($r = .173$, $p < .01$), cognitive flexibility ($r = .157$, $p < .01$), problem solving ($r = .196$, $p < .01$), and overall divergent thinking score ($r = .163$, $p < .01$) on a two-tailed test. However, no significant correlations were observed between creative attitude and other components of divergent thinking, namely: spontaneous fluency, problem finding and design of scientific device. The observed correlations could therefore not be generalized to all the components of divergent thinking. Accordingly, it was concluded that creative attitude was significantly correlated to divergent thinking with a reduced canonical factor loading of three components, viz: adaptive fluency cognitive flexibility and problem solving. It may also be inferred from these findings that various components of divergent thinking can exhibit

Table 1: Summary of correlations between divergent thinking (DT), project work and creative attitude

DT Component	Pearson correlation (r) between DT component and:					
	Project Work			Creative Attitude		
	Girls	Boys	Overall	Girls	Boys	Overall
Adaptive fluency	.081	.025	.052	.102	.252**	.173**
Spontaneous fluency	.017	.047	.028	.053	.091	.080
Cognitive flexibility	.036	.023	.031	.029	.250**	.157**
Problem solving	.111	.005	.053	.133*	.267**	.196**
Problem finding	.006	.022	.007	.033	.095	.054
Design of sc. device	.027	.015	.005	.010	.048	.034
Overall DT	.038	.022	.029	.075	.237**	.163**

* Correlation significant at p ≤ .05; **Correlation significant at p ≤ .01

Table 2: Correlation between divergent thinking and creative attitude by components

DT Component	Pearson correlation (r) between DT component and:					
	Originality			Critical Thinking		
	Girls	Boys	Overall	Girls	Boys	Overall
Adap. fluency	.206**	.442**	.331**	.271**	.234**	.247**
Spont. fluency	.026	.273**	.212**	.071	.356**	.250**
Cog. flexibility	.279**	.456**	.394**	.190**	.350**	.278**
Problem solving	.169**	.461**	.327**	.170**	.246**	.203**
Problem finding	.008	.143*	.064	.220**	.180**	.196**
Design	.127*	.236**	.203**	.173*	.335**	.261**
Overall DT	.193**	.453**	.342**	.301**	.372**	.337**

* Correlation significant at p ≤ .05; **Correlation significant at p ≤ .01

correlations with creative attitude, and probably other factors, independently of one another. But, curiously, correlations were generally significant for boys but not girls, signifying possible mediating effect of gender in the relationships. However, correlation with overall divergent thinking conformed to the perception of creative attitude as an important non-cognitive factor in the creative process (Suparna, 2007).

Originality

The data pertaining to the test of correlation between originality and components of divergent thinking are presented in the first three columns of Table 2.

This test revealed strong positive correlations between originality and all components of divergent thinking except problem finding, which was insignificant ($r = .064$, $p > .05$). Original ideas were therefore more likely to come from more divergent thinkers than less divergent thinkers. This finding supports the widely held view that the ability to produce unique and novel ideas lies in the ability to generate multiple solutions (Robinson, 2010). Except for spontaneous fluency and problem finding, the correlations were fairly consistent between boys and girls. It also appears that originality is not a preserve of highly divergent thinkers. Though significant, a Pearson correlation of only .342 suggests that original ideas can also come from moderately divergent or even low divergent thinkers. In fact, some 8 per cent of the original ideas were contributed by respondents who scored within the lower quartile of the divergent thinking performance range.

Critical thinking

To quantify critical thinking ability, measurement was carried out on its various components, which were the ability to: identify deficiencies in a given physics statement, identify error in a statement, recognize unstated assumptions, recognize inadequacy of information required to solve a problem and to make appropriate decision. The combined scores from these measures constituted the overall critical thinking scores, which then reflected the overall critical thinking ability. The last three columns of Table 2 show the computed correlations between critical thinking and various components of divergent thinking.

These results indicate significant positive correlations between critical thinking ability and all components of divergent thinking; and this generally applies to both boys

Table 3: Correlation between divergent thinking and various components of critical thinking

Components of CT	**Correlation between overall DT and component of CT**		
Ability to:	**Girls (*N* = 377)**	**Boys (*N* = 386)**	**Overall (*N* = 763)**
Identify deficiencies in physics statement	.120	.187**	.422**
Identify error in physics statement	.095	.298**	.361**
Recognize unstated assumption	.273**	.378**	.522**
Recognize inadequacy of information required to solve a problem	.346**	.347**	.494**
Make appropriate decision	.189**	.053	.630**
Overall CT	.301**	.370**	.337**

**Correlation significant at $p \leq .01$

and girls. All the observed correlations were quite strong, at p-values below .001 on a two tailed test, which were suggestive of causative relationships. Some scholars, including Scriven (1979) and Scott et al. (2004) believe that efforts to enhance creative capacity should begin with establishing the relationship between critical thinking and divergent thinking, arguing that the understanding of such correlations would build the confidence of educators and underscore the need for emphasis on critical thinking. Yet literature on creativity is devoid of studies documenting such relationships. This finding is therefore not only consistent with the theoretical position of Scriven that the two constructs go hand in hand with creativity but is also an important step towards filling the gap concerning the relationship between divergent thinking and critical thinking in physics.

However, the foregoing analysis failed to indicate whether specific components of critical thinking accounted for the observations more than the others; and for this reason, separate tests were run to directly correlate overall divergent thinking with individual critical thinking components. The results for this analysis constitute the content of Table 3.

Each component of critical thinking was found to be strongly correlated to overall divergent thinking ability and these correlations were of magnitudes that could be indicative of causality. Components of critical thinking that exhibited strongest correlation with overall divergent thinking, in a descending order of strength were: making appropriate decision ($r = .630$, $p < .001$), ability to recognize unstated assumptions ($r = .522$, $p < .001$), ability to recognize inadequacy of information required to solve a problem ($r = .494$, $p < .001$) and the ability to identify deficiency in a given physics statement ($r = .422$, $p < .001$). Divergent thinking components were strongly correlated to overall critical thinking, just as critical thinking components were also strongly correlated to overall divergent thinking ability. Further analysis to investigate whether correlations between these constructs could apply to the two gender subgroups yielded fairly high correlations for girls ($r = .301$, $p < .01$) and boys ($r = .375$, $p < .01$).

These findings support the theoretical assumption that other than divergent thinking, creativity exercises elements of critical thinking; so creative individuals are expected to demonstrate high abilities in both critical and divergent thinking skills. The strong correlations suggest mutual interaction of components between the two constructs. It appears that a creative mind is dissatisfied with the prevailing situation and this state of affairs arises from the critical ability to recognize deficiencies, faults, inadequacies, inefficiency, errors and the rational ability to synthesize available observations and arrive at untold facts about a phenomenon. This state of disequilibrium motivates the search for order and harmony and exercises the divergent thinking process that culminates into multiple tentative solutions. Such solutions are then screened through the convergent thinking dimension of critical thinking to obtain the most suitable, workable and appropriate option. Through this process, it seems, critical thinking grows in sympathy with divergent thinking, and vice versa.

Table 4: Correlation between divergent thinking and interaction with science materials

Factor	Correlation with divergent thinking					
	Overall (*N* = 521)		Girls (*N* = 274)		Boys (*N* = 247)	
	Pearson r	p value	Pearson r	p value	Pearson r	p-vale
Watching sc. mov.	.103*	.05	.084	.169	.109	.078
Reading stories about great sc. disc.	.111*	.05	.066	.278	.146*	.018
Listening to sc. news	.114**	.01	.051	.404	.161**	.009
Overall Int.	.161**	.00	.093	.129	.202**	.001

* Correlation significant at p ≤ .05; **Correlation significant at p ≤ .01

Interaction with science materials

The extent of respondents' interaction with some selected scientific materials, namely: reading stories about great scientific discoveries and inventions, listening to science news and watching scientific movies was investigated to determine (1) the extent of interaction and (2) whether these interactions were correlated with divergent thinking abilities. The extent of interaction with each of the selected science materials was rated on a five-point scale of 0 to 4. Of the three selected materials, the highest rating was observed on watching scientific movies (2.59) followed by reading stories about great scientific discoveries and inventions (2.02). The overall mean rating was 2.13, which suggests that learners generally have little interaction with the selected materials, as this practically corresponds to point 2 on the rating scale. Correlation between divergent thinking and the interaction with each of the stated science materials was computed and the results were as presented in Table 4.

The test revealed weak positive correlations between divergent thinking and extent of watching scientific movies (r = .103, p < .05) and also between divergent thinking and extent of reading stories about great scientific discoveries and inventions (r = .111, p < .05). Correlation between divergent thinking and extent of listening to science news was found to be stronger (r = .114, p = .01). Overall, there was a strong correlation between divergent thinking and interaction with science materials (r = .161, p < .01). Despite this, differential analysis by gender showed that the correlation between overall divergent thinking and interaction with science materials applied to boys but not girls. This is perhaps a reflection of sex-differentiated cultural influence, in which the society prescribes certain expectations to boys different from those of girls. Kim (2010) has demonstrated the tendency of girls to conform to social expectations of "being like everyone else" rather than associating with new ideas by engaging in divergent thinking, while boys are encouraged to explore. It is however, instructive to note that interaction with the science materials under investigation was voluntary and based on student's interest; so its possible link with natural creative potential cannot be ruled out.

Involvement with toys in childhood

Toys are some of the materials commonly used to occupy children and to engage them in play, providing them with a medium to interact with both the physical and social world. They constitute a major part of play, the most important method by which children learn. Older children not only play with toys but demonstrate creative instinct by making their own. It was curious to explore (1) how much physics students were involved in making toys during childhood (2) the extent to which they played with toys and (3) the relationship between divergent thinking and (a) extent of making toys and (b) extent of playing with toys.

The mean rating on "playing with toys" stood at 3.12, which corresponded to "much involvement" in the activity. Although a slightly lower mean of 2.66 was reported on making toys, this fell at practically the same point of much involvement on the rating scale (of 0-4). Therefore respondents had experienced comparable degrees of involvement in making and playing with toys. Tests for correlation with divergent thinking scores were run independently for playing with toys, making toys and overall interaction with toys, the results of which are summarized in Table 5.

A weak positive correlation was obtained between divergent thinking and extent of play with toys (r = .087, p < .05) but not between divergent thinking and extent of making toys (r = .082, p > .05). Clearly, the observed overall correlation of .087 was attributable to boys only, since no significant correlation featured in the case of girls; in which sense the observations are similar to the results presented in Table 4. Making of toys, however, did not seem to have any significant impact on divergent thinking among boys or girls; so this activity does not necessarily translate into divergent thinking or creativity of children. This is expected where children's interactions

Table 5: Correlation between divergent thinking and interaction with toys

Factor	Correlation with overall divergent thinking					
	Overall (*N* =763)		Girls (*N* = 386)		Boys (*N* = 377)	
	Pearson r	p-value	Pearson r	p-value	Pearson r	p-value
Playing with toys	.087*	.045	.005	.934	.162**	.000
Making toys	.082	.056	.108	.079	.049	.430

* Correlation significant at $p \leq .05$; **Correlation significant at $p \leq .01$

merely involve imitation of existing objects and doing what they have seen others do. Moreover, the influence may be domain-specific, and depend on the type of toy made or played with. Further analysis to correlate various components of divergent thinking to the extent of interaction with toys during childhood revealed no significant correlation between play with toys and any component of divergent thinking (not shown in the table). Similarly, making of toys did not correlate significantly with any component of divergent thinking, except for problem solving ($r = .087$, $p < .05$).

CONCLUSION

This study provides support to some of the long-held theoretical viewpoints regarding correlations between divergent thinking and critical thinking, creative attitude and interaction with science materials; but points to some degree of independence among various components of the construct. Moreover, the activities aimed at enhancing creativity do not necessarily have a direct influence on divergent thinking but their correlations seem to involve a complex interplay of meditating variables such as gender. The results have implications for school, and out-of-school environments as having important contributions in the development of this construct. The study has also demonstrated that divergent thinking is important, but not sufficient for creative work, which also seems to depend on non-cognitive factors such as creative attitude and motivation.

RECOMMENDATIONS

This study has generated a number of useful findings that can inform educational practice and further work on creativity. Based on these findings, the report makes policy recommendations where the findings, combined with relevant information in the existing literature, are reasonably comprehensive to guide the practice. However, in other cases, further investigations are necessary before recommendations for action can be made. The study therefore recommends as follows.

1. Based on the strong correlations observed between divergent and critical thinking, the study recommends that suitable strategies to enhance critical thinking be incorporated in the teaching-learning process, not only for its own value but also to enhance divergent thinking abilities.

2. Considering the observed correlations between divergent thinking and interaction with scientific materials, print, digitized and broadcast materials with captivating literature on great scientific innovations, discoveries and inventions should be made available to pupils to inspire their creativity.

3. Further to the scientific materials investigated, studies should focus on the effects of other scientific materials, types of toys, and childhood plays to determine their potential for enhancing divergent thinking of pupils.

4. Following the strong positive correlations exhibited between divergent thinking and most of the tested independent variables, future studies should aim at establishing causative relationships involving divergent thinking to expand knowledge of the range of factors that may be manipulated to enhance creativity.

5. In view of the limitations associated with recall of past experiences, on which this study partly relied, further investigations should involve actual observations to determine the effects of various types and extent of play on the development of divergent thinking ability.

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Appendix A

Appendix A: Questionnaire for Physics Students

Introduction

The aim of this questionnaire is to gather information for research purposes; and your participation by providing valuable information is crucial to the success of the study. It is hoped that the results of this study will be useful to educational planners in their efforts to provide quality and relevant education to our nation.

You are expected to complete the questionnaire by indicating your own independent opinion against each item. Feel free for there is no wrong or correct answer - **just your honest opinion** and true experiences**.** The information given will be treated in strict confidence; but you need not write your name on the paper.

SECTION A

Please complete this section by filling in the blank spaces and placing a tick (√) in each appropriate bracket.

1. Gender: Girl ( ) Boy ( )

2. Indicate how much you have been involved in physics Project Work from Form I upto your present class.

Form I: Not at all ( ) Very little ( ) Little ( ) Much ( ) Very much ( )

Form II: Not at all ( ) Very little ( ) Little ( ) Much ( ) Very much ( )

Form III: Not at all ( ) Very little ( ) Little ( ) Much ( ) Very much ( )

Form IV: Not at all ( ) Very little ( ) Little ( ) Much ( ) Very much ( )

3. Indicate which of the following statements is true about the project work you have done so far.
A. All projects the were assigned by the teacher ( )
B. All the projects were self-initiated ( )
C. Some of the projects were self-initiated ( )

4. (a) Have you had an opportunity to present a physics exhibit or talk at a Students' Science Congress? Yes ( ) No ( )
(b) If no, give reason(s)……………………………………………………………

(c) If yes, indicate the level(s) at which you have participated.
District ( ) Provincial ( ) National ( )

For items 4 to 8, indicate the degree to which you have been involved in each.

No	Item	Response				
		Never	**Very little**	**Little**	**Much**	**Very much**
5	Making toys (during childhood)					
6	Playing with toys (during childhood)					
7	Reading stories about great scientific discoveries and inventions					
8	Listening to science news					
9	Watching scientific movies					

Appendix A cont.

SECTION B

In the table below, indicate your feeling towards each of the following statements by circling: **SA** if you strongly agree, **A** if you agree, **U** if you are undecided, **D** if you disagree, and **SD** if you strongly disagree with the statement.

No.	**Statement**	**Response**				
10	I am usually curious about physics phenomena (events) happening around me.	**SA**	**A**	**U**	**D**	**SD**
11	It seems to me that there is very little room for new discoveries in physics.	**SA**	**A**	**U**	**D**	**SD**
12	I feel inspired by the works of great physicists of the past.	**SA**	**A**	**U**	**D**	**SD**
13	The society may not need any more discoveries in physics, if only the existing knowledge could be properly utilized.	**SA**	**A**	**U**	**D**	**SD**
14	Whenever I get a new physics idea, I usually get so much absorbed in it.	**SA**	**A**	**U**	**D**	**SD**
15	It is not really my dream to make a unique contribution in physics one day.	**SA**	**A**	**U**	**D**	**SD**
16	There are many physics explanations which do not satisfy my curiosity, even if I clearly understand them.	**SA**	**A**	**U**	**D**	**SD**
17	I hardly feel challenged by inventions made in physics.	**SA**	**A**	**U**	**D**	**SD**
18	Given time, I believe I would be able to solve some of the problems in real life through creative application of physics.	**SA**	**A**	**U**	**D**	**SD**
19	I lack the desire to learn about physical phenomena that are not in the physics syllabus.	**SA**	**A**	**U**	**D**	**SD**
20	As I learn physics, I generate many questions which I feel eager to investigate.	**SA**	**A**	**U**	**D**	**SD**
21	I hardly feel interested in everyday life problems that require physics solutions.	**SA**	**A**	**U**	**D**	**SD**
22	I often think of how to use my knowledge of physics in new and novel ways.	**SA**	**A**	**U**	**D**	**SD**
23	I think there is very little room for improvements in the existing devices based on physics.	**SA**	**A**	**U**	**D**	**SD**
24	I feel a strong desire to devote my efforts in coming up with new physics-based solutions to some of the problems facing the society.	**SA**	**A**	**U**	**D**	**SD**
25	I would not be willing to undertake an invention project if it has a chance of failing.	**SA**	**A**	**U**	**D**	**SD**

The next two sections, **C** and **D**, consist of items 26 to 37; and you are advised to **spend 3 to 4 minutes per item.** While responding to the items, you are encouraged not only to apply the relevant physics knowledge you have acquired but also to think beyond what you have learnt, seen or heard, and trying to give unique responses that other people may not have thought of. Feel free to include even what you only imagine would work, provided it is realistic. However, try to be **brief** and **clear**. For items which do not specifically ask for many responses, you may give one or more responses, whichever you prefer.

Appendix A cont.

SECTION C

26. Fig. 1 represents a rectangular glass container partitioned with a glass plate, and holding some water.
SPACE FOR YOUR RESPONSE

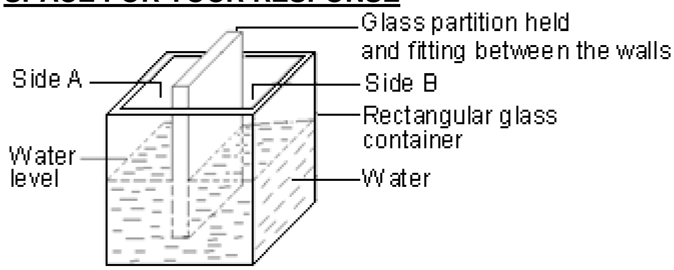

Fig. 1

List as **many** ways as you can, of increasing the level of water in side **A** slightly. (Explanation is **not** required.)

27. It is estimated that the world oil reserve would last no more than two centuries if it continues to be consumed at the present rate. Suggest as **many** alternative sources of energy as you can, but exclude **solar** and **electrical** energy, **wind**, water **waves**, **biogas**, **hydroelectric** power, **coal**, **geothermal** energy, **nuclear** energy and **bio-fuel**.
……
…………………………………………………

28. An engineer wishes to design a train that can move at a high speed of 600 km/hr, which would be the highest so far. Its weight, length and engine power are already fixed. Suggest how this speed can be achieved.

……
…………………………………………………

29. One common problem with a car (or bicycle) wheel is that it sustains a puncture fairly frequently. Suggest a new design of a wheel that would prevent the problem of punctures.
……
…………………………………………………

30. To an observer, a beaker containing water appears shallower than it actually is. What should the observer do so that the beaker becomes less shallow than it appears?

31. Fig. 2 represents thick smoke emerging from a burning heap of rubbish. Ask physics questions that you would wish to find answers for, about the behaviour of smoke shown in the diagram. **SPACE FOR YOUR RESPONSE**

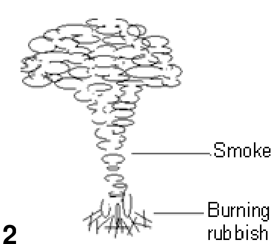

Fig. 2

32**.** Fig. 3 shows the path taken by a lightning discharge (flash). State what you would wish to find out, within the area of physics, about the behaviour of the lightning discharge shown on the diagram. **SPACE FOR YOUR RESPONSE**

Appendix A cont.

Fig. 3

SECTION D

33. The following are statements of observations and conclusion in a certain experiment.

Observations: When a mixture of water and suspended dust particles is illuminated with a strong beam of light, the dust particles are observed to move continuously in all directions. The speed of this movement increases when the mixture is warmed.

Conclusion: Particles of liquids and gases are in continuous random motion. This movement is caused by heat.

Give as **many** reasons as you can, why this conclusion may not be fully convincing.

34. The set-up, observations and conclusion drawn from a certain experiment were as shown in Fig. 4 and the accompanying information.

Set-up: Three holes were poked with nails at different heights on a plastic bottle. The bottle was then quickly filled with water.

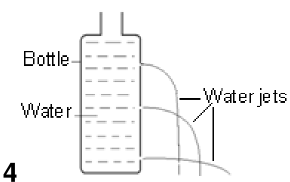

Fig. 4

Observations: The liquid jet emerging from the hole near the base landed the farthest while the jet from near the top of liquid column landed near the bottle as shown in Fig.4.

Conclusion: Pressure in liquids increases with depth.

If the conclusion is a correct scientific statement, give reasons why the experiment (set-up and observation) fails to fully verify it? **SPACE FOR YOUR RESPONSE**

35. A physics class was given the following question. *Fig. 5 shows two wooden blocks, A and B, placed on a table. Identify the block which is easier to move.*

SPACE FOR YOUR RESPONSE

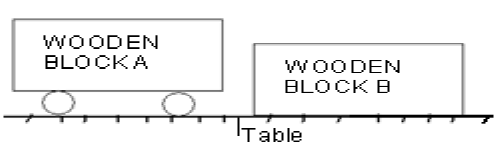

Fig. 5

Appendix A cont.

Study the question THEN comment on it. (Give only comment(s), but **not** the answer to the question.)

36. A student located the centre of gravity of a rectangular metallic plate by drawing its diagonals and marking their point of intersection. What did the student assume?

37. A certain external component of an aircraft can be easily damaged by heat. However, it can be effectively protected by any of the methods A to F given in the table below.

A. Using cold circulating water	B. Using a stream of air
C. Keeping the component in a small refrigerating compartment	D. Immersing the system in a cold water bath
E. Providing a large surface area	F. Enclosing the component in a small vacuum flask

Rank in order of preference, the best two options you would recommend.

Best:……….. Second best:………………………………………