

Differences in Divergent Thinking among Secondary School Physics Students

Joseph Achieng'Rabari; Francis Chisikwa Indoshi and Tony Okwach Omusonga

Department of Educational Communication, Technology and Curriculum Studies,
Maseno University, Kenya

Corresponding Author: Francis Chisikwa Indoshi

Abstract

Viewed as the basis of creativity, divergent thinking is recognized for its role in improving quality of life generally and through scientific innovations, which involve creative application of principles of basic sciences, such as physics. However, besides its general neglect in curriculum implementation, differences in students' creative abilities appear to be another important challenge to address. The purpose of this study was to explore differences in divergent thinking abilities between various subgroups of physics students. Its objective was to determine if there were significant differences in mean divergent thinking scores when students were categorized by gender, grade level, participation in science congress, pre-school entry points, type of toys played with in childhood, socio-economic status and inclination for group work. The study targeted a population of 4,324 Form 4 (12th grade) and Form 3 (11th grade) secondary school physics students in Nairobi Province. The sample comprised 1019 respondents, consisting of 515 girls and 504 boys and these were obtained through stratified and simple random sampling techniques. Data were collected using a Test of Divergent Thinking (TDT), which was constructed by the researcher and validated by three experts in research methods from Maseno University. The instrument had a reliability of .846; while significance of observed differences was tested at $p = 0.05$ and $p = 0.01$ levels. Girls registered superiority over boys in problem finding ($t = 3.180, p < .01$) while boys outperformed them on spontaneous fluency ($t = -3.782, p < .01$) and cognitive flexibility ($t = -2.062, p < .05$); but there was no significant gender difference on overall divergent thinking. Other significant differences were registered between participants and non-participants in Students' Congress on Science and Technology on adaptive fluency ($t = 3.197, p < .01$) in favour of congress participants (but not on other components of divergent thinking), and between Form 3 and Form 4 on adaptive fluency ($t = -2.004, p < .05$) in favour of Form 4. However, no significant differences were observed when participants were grouped by types of toys they played with in childhood, pre-school entry points in education, or socio-economic class. The study recommends further research to investigate the influence of other scientific materials, types of toys, and childhood plays on divergent thinking.

Keywords: creativity, divergent thinking, gender, grade level, socio-economic status, differences

INTRODUCTION

The development of high order cognitive abilities is considered as a key function of education. Divergent thinking ability, in particular, is emphasized for its role in creative problem solving, preparing the learner to effectively address unforeseen challenges of the future. The desire to develop this ability is evident in secondary school science curriculum, which encourages activities and teaching methods that enhance creative skills of the learner as important efforts towards achieving the goal of industrialization (Republic of Kenya, 2002). Moreover, experiences from industrialized nations suggest a strong link between scientific creativity and technological advancement (Kimani, 2008). Viewed in this light, physics has a critical role to play in the realization of this goal, given its status as a key basic science whose principles are widely applied in technology.

Calls by educators to focus educational efforts on creativity and divergent thinking have intensified

over the last decade. Mangena (2007) and Ogot (2007) perceive basic science research and an education that encourages creativity, innovativeness and independent thinking as the key ingredients of the success of developed nations, arguing that commitment to self reliance in technology is an essential ingredient of economic development. Accordingly, they advocate for a science education that prepares children to be divergent thinkers, innovators and creators of technology rather than mere consumers of existing technologies. DeHaan (2009) and Koray and Mustafa (2009) recognize the need for people to improve their creative thinking in order to develop technological improvements and utilize them in today's continuously changing world, arguing that this ability is necessary to create new products and to find effective solutions to potential problems as the world develops.

However, although divergent thinking is emphasized, there is evidence of intervening factors whose effects

become clearly manifest when learners are categorized into various subgroups, based on certain characteristics. Regarding the factor of grade level, for example, Chi et al. (2005) explored performances on three types of creativity tasks; that is, real-world problem, figural, and verbal tasks among 6th-grade students and university students in Hong Kong. The findings of this study indicate significantly higher scores on the real-world problem by university students, compared to 6th graders. While this was expected, the groups, curiously, did not differ significantly on verbal task, while 6th graders outperformed university students on figural task. This finding corroborates the study by Diakidoy (2001) which explored creativity in problem solving within the domain of physics and its relation to fluency of responses, originality and type of task. It also draws further support from a study by Kim (2010), in which grade level groups not only differed on mean scores but also on factor structures. But perhaps more provocative is the observation regarding 6th graders' superior performance over university students on a creativity task (Chi et al., 2005). This finding suggests that some of the creative skills in specific areas are unending, peak early and decay as students progress to higher grade levels. Jones (2002) reported a similar finding in which medical college students were outperformed by secondary school students on some aspects of creative skills. In view of these reports, some components of divergent thinking appear to grow with grade level as others weaken.

Substantial research efforts have also been devoted to gender differences in creativity and divergent thinking. However, most studies have revealed no consistent gender differences, while majority of those which have reported any differences suggest girls' superiority over their male counterparts and the findings have been observed to vary considerably from one field to another. Gender differences have also been reported on creativity in biology education (Ndeke, 2003). Males have been observed to surpass females on certain aspects of creativity but females are generally better than males on others (Ai, 1999). Habibollah et al. (2009) found no gender differences on the overall factor scores. But females scored significantly higher on environmental sensitivity than males, while males scored significantly higher on initiative. This is consistent with the findings of Palaniappan (2000) which supported the view that there were no gender differences for general factor scores, among Malaysian students. In fact some researchers contend there are more differences across grade levels than gender (Kim, 2010). However, these conclusions could have been influenced by the fact that literature on gender differences is relatively scarce (Ai, 1999). Consensus seems to have built around the proposition that although there may be no overall differences, differences on specific aspects of creativity do occur, with girls demonstrating

superiority in some areas while boys are stronger on other others.

As a learning institution, the school offers an environment consisting of factors that stimulate and those which impede creative thinking processes, otherwise referred to as *blocks* to creativity. By examining the relationship between school environment and children's creativity, Dudek et al. (1993) found that the global climate of a school, including socio-economic level and classroom factors significantly influenced students' performance on the Torrance's Test of Creative Thinking. Some specific factors at play within the classroom dynamics were student-teacher composition and interactions between them. The identified top blocks to creativity within the classroom include success orientation, sanctions against questioning, external evaluation, surveillance, competition and lack of choice (Starko, 2005; Taylor et al. (2008). Torrance (1998) points out that a misconception about young children's inability to think productively has led to overemphasis upon recall and reproduction to the neglect of problem solving, creative thinking and decision making in the early years. It is believed that these factors lead to stress and negative emotions. Sousa (2006), proposes a biological explanation, arguing that when students feel stressed, a certain hormone that activates defence behaviours in the body is released. Brain activity is then reduced to focusing on the cause of stress and how to deal with it instead of encouraging recursive thought; and this physiologically inhibits the process of meaning making and creativity.

Conversely, by shifting the focus to cooperation and collaboration from success orientation and competition, students are allowed opportunities to dialogue with each other and build an understanding of the material through recursion (Starko, 2005). Studies by Ronald (2002) lend support to this hypothesis by reporting positive effects of allowing for discussion, cooperation and collaboration within the physics classroom. Other than through discussion, divergent thinking in physics classrooms is also found to be encouraged by classroom environments which stimulate debates and allow controversy (Niaz & Rodriguez, 2002; Tao, 2001). In a nutshell, creativity is nurtured in an environment in which learners take responsibility for their own learning, with the teacher playing the role of a facilitator. Overall, a well structured classroom environment makes statistically significant and unique contributions to gains in divergent thinking above students' pre-entry levels of critical thinking. This finding applies to out-of-class environment as well and therefore supports the long held theoretical speculation that students' academic and nonacademic experiences jointly influence change in divergent thinking abilities (Preckela et al., 2005).

Despite significant research efforts made so far, findings regarding differences in divergent thinking are relatively scarce and inconclusive. Moreover, most of them are not specific to the domain of physics, while influence of factors such as participation in science congress and length of pre-school attendance are undocumented. Furthermore, such differences are influenced by the culture (Kim, 2010), hence the need to verify them in the context of Kenyan cultural environment. In view of this situation, the purpose of this study was to explore the differences in divergent thinking abilities when respondents are categorized into subgroups based on various characteristics. The objective of this study was therefore to determine if there were significant differences in mean divergent thinking scores when respondents are grouped by gender, grade level, participation in science congress, length of preschool attendance, type of toys played with in childhood, school, socio-economic status and group and independence orientation.

Theory of Divergent Thinking

Divergent thinking is considered as one of the key psychological abilities that are essential for creative processes. Consensus among researchers has built around divergent thinking as the basis for generating many alternative solutions to a given problem, which are then processed into creative solutions through evaluative thinking (Gabor, 2005; Jaffar, 2004; and Schick, 2004). Voluminous productivity is perceived as the rule and not exception among individuals who have made some noteworthy contributions. Its major components are ideational (creative) fluency, cognitive flexibility and originality. Cognitive flexibility, which is the ability to discontinue an existing pattern of thought and shift to new patterns of thinking, is seen not only as another important component of divergent thinking but as one that enhances practical significance of solutions generated. In this model, divergent thinking is hypothesized to be influenced by gender, grade level, childhood interaction with toys, socio-economic class, length of pre-school education, and participation in science congress. Fluency and cognitive flexibility are displayed in problem solving, problem finding and design of scientific device.

METHODOLOGY

Study Design

This study adopted a combination of survey and ex-post-facto designs. The ex-post-facto component enabled respondents to report on their previous exposure to science congress, interaction with toys, and length of preschool attendance. The approach employed was quantitative to enable collection of numerical data that would be used in computing differences in mean scores on various components of divergent thinking. The choice of quantitative approach was based on the desire to arrive at

objective outcomes that are value-free and not influenced by possible subjective preferences and biases of the researcher (Kealey & Protheroe, 1996), ensuring precision, statistical power and high reliability of data gathered.

Study Population

The population for this study consisted of 4,324 Form 4 (12th grade) and Form 3 (11th grade) secondary school physics students in Nairobi Province. These were students who followed the local 8-4-4 curriculum and had opted to study physics up to 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. The decision to limit the population to this performance range 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 & Hennessey, 1996; 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 sample comprised 1019 respondents, consisting of 515 girls and 504 boys and these were obtained through stratified and simple random sampling techniques. 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 at 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 Form 3 and again to all sampled schools (18), giving a total of 1019 student respondents.

Research Instrument

One instrument, Test of Divergent Thinking (TDT), was used to collect data in this study. The instrument included a biodata section which collected information on various characteristics of respondents such as gender, grade level, participation in science congress, length of preschool attendance, type of toys played with in childhood, school, socio-economic status and group and independence orientation. The Divergent Thinking Test consisted of six (6) items designed to measure divergent thinking abilities in physics, and these were constructed by the researcher, 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. Different items targeted different components of divergent thinking, namely: adaptive fluency, spontaneous fluency, cognitive fluency, problem solving, problem finding and design of scientific device. 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 (Torrance, 1998).

Validity of the Instrument

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 instrument was then given to six (6) experienced physics teachers in different schools within the study area, who were requested to identify (1) 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 its reliability, the instrument (TDT) was piloted on a sample of 244 Form 3 and 4 students in 5 schools, which represented 10 per cent of the study population. The quantitative data obtained were used to compute reliability coefficient of the instrument; and this computation yielded a Cronbach's alpha value of .862.

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 Education 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 students completed their respective grade levels.

Analysis of Data

Scoring of responses was done as per the guidelines developed by Torrance (1998), considering the number of acceptable responses generated for each item. Responses were then tallied to reflect adaptive fluency, spontaneous fluency, cognitive flexibility, problem solving, problem finding, design of scientific device and overall divergent thinking score. These data, together with the corresponding coded biodata for each participant were fed as data set into the Statistical Package for Social Sciences (SPSS) Version 17.0, from which differences in mean divergent thinking scores were then computed at $p = .05$ and $p = .01$ levels of significance.

RESULTS AND DISCUSSION

This section presents results pertaining to differences in mean divergent thinking scores between selected respondent subgroups. Tests for equality of means were performed to determine whether divergent thinking scores differed on the basis of some selected dichotomous variables, which include gender, grade level, science congress participation status, pre-school entry point and type of toys played with during childhood. This analysis applied the t-test for independent mean scores associated with each variable and the results are presented separately.

Gender Differences

Some differences were observed between boys and girls on specific components of divergent thinking, which include adaptive fluency, spontaneous fluency and cognitive flexibility on problem solving, design of scientific device and problem finding ability. To

determine the significance of these differences a t-test was run for grade level 4. The corresponding performance data on divergent thinking, together with the results of the t-test for equality of mean scores of boys and girls were as presented in Table 1.

Table 1: Gender differences in divergent thinking

DT Component	Girls (n = 268)		Boys (n = 271)		t-test	
	Mean	SD	Mean	SD	t-ratio	p-value
Adaptive fluency	2.03	1.522	1.96	1.454	1.335	.182
Spontaneous fluency	.06	.244	.19	.485	-3.790**	.000
Cognitive flexibility	.60	.920	.79	1.176	-2.062*	.040
Problem solving	1.95	1.542	1.97	1.460	1.267	.206
Problem finding	1.62	1.315	1.28	1.127	3.180**	.002
Design of sc. device	.48	.571	.80	.752	-5.642**	.000
Overall DT	4.88	3.240	5.00	2.805	-.391	.696

* Difference significant at $p = .05$; ** Difference significant at $p = .01$

Boys scored significantly higher than girls on the design of scientific device ($t = -5.642$, $p < .01$) and spontaneous fluency ($t = -3.790$, $p < .01$) and cognitive flexibility ($t = -2.062$, $p < .05$) while girls outperformed boys on problem finding ability ($t = 3.180$, $p < .01$). However, no significant gender differences were observed on other components of divergent thinking. The test was also extended to compare the relative abilities of girls and boys on originality but this, too, revealed no significant gender difference ($t = -1.064$, $p > .05$). To probe whether these differences could be explained on the basis of chronological age, a differential analysis was performed to compare mean chronological ages of respondents. Although it revealed significant age differences between boys and girls, further analysis showed no statistically significant correlation between age and divergent thinking scores. Neither was there evidence to back possible influence of socio-economic status as seen later in this report. Therefore, although girls were generally younger and dominated the middle-income residence bracket, it was unlikely that these demographic differences influenced the observed gender differences on divergent thinking.

Gender differences have been the focus of a number of studies. However, the picture regarding the influence of gender on divergent thinking has not been consistent (Ai, 1999; Nori, 2002). While Ndeke (2003) reports gender differences on creativity in biology education, most studies have revealed no consistent gender differences in various disciplines. Majority of studies which report differences suggest girls' superiority over their male counterparts, although this finding is observed to vary considerably from one field to another (Ai, 1999). Habibollah et al. (2009), for example, found no gender differences on the overall factor scores; but females scored significantly higher on environmental sensitivity than males, while males scored significantly higher on

initiative. This is consistent with the findings of Palaniappan (2000) which revealed no gender differences on general factor scores, among Malaysian students. The findings of the current study complement the growing evidence that gender differences occur on some specific components of a given discipline, rather than the discipline as a whole.

Grade level differences

Grade level was considered as a complex variable that combined chronological age or maturity, amount of physics content covered and the length of exposure to physics content. Consequently, grade levels were expected to differ in terms of these stated aspects. The foci of this analysis were grade level as a combined factor and the exposure to physics content in terms of length of "time on physics content" or amount of material covered. The first stage of the analysis involved probing the influence of grade level as a combined factor by comparing unfiltered Form 3 and 4 respondents on their performance on various components of divergent thinking. The corresponding results were as shown in Table 2. The test revealed small but significant grade level differences on adaptive fluency and design of scientific device. While the difference on adaptive fluency was in favour of Form 4, ($t = -2.004$, $p < .05$), Form 3 respondents scored higher on design of scientific device ($t = 2.277$, $p < .05$). Grade level differences on all other components, including overall divergent thinking, were insignificant. The difference on adaptive fluency may be attributed to differences in the amount of physics content learnt. Although all the concepts on which TDT items were constructed had been taught to both grade levels, Form 4 respondents had an advantage of having covered more physics content and a corresponding wider domain of knowledge to draw solutions from. Indeed, some educators subscribe to the view that divergent thinking is dependent on content mastery (Ai, 1999; Karimi, 2000; Mahmodi, 1998), which involves both

Table 2: Grade level differences on components of divergent thinking

DT Component	Performance on component				Test for equality of means	
	Form 3 (n = 149)		Form 4 (n = 212)		t-ratio	p-value
	Mean	SD	Mean	SD		
Adaptive fluency	1.66	1.132	1.93	1.389	-2.004*	.046
Spontaneous fluency	.10	.330	.08	.295	.609	.543
Cognitive flexibility	.43	.746	.54	.855	-1.210	.227
Problem solving	1.66	1.155	1.93	1.407	-1.940	.053
Problem finding	1.42	1.237	1.40	1.354	.157	.876
Design of sc. Device	.71	.756	.55	.626	2.277*	.023
Overall DT	4.34	2.853	4.53	3.200	-.553	.581

* Difference significant at p = .05

depth and scope of knowledge. Some of the specific areas of comparative advantage noted were: thin lenses and Bernoulli's effect.

To isolate the factor of exposure to physics content, maturity was eliminated from the twin factor of age-and-grade through paired matching of respondents by age across the two grade levels: Form 3 and 4. In the matching procedure, Form 3 respondents who had no age matches in Form 4 and vice versa were filtered

off from the sample. The filtered or matched samples in Form 3 and 4 had equal mean ages of 17.22 years with a standard deviation of .551. This screening was considered crucial in eliminating possible influence of the interaction between maturity and amount of syllabus content covered. A t-test for equality of means was then applied to determine whether the screened samples of Form 3 and 4 differed on their mean divergent thinking measures. The results of this analysis were as presented in Table 3.

Table 3: Grade level differences in divergent thinking for samples matched by age

DT Component	Performance on component				Test for equality of means	
	Form 3 (n = 98)		Form 4 (n = 98)		t-ratio	p-value
	Mean	SD	Mean	SD		
Adaptive fluency	1.69	1.143	1.88	1.308	-.806	.422
Spontaneous fluency	.10	.330	.08	.295	.609	.543
Cognitive flexibility	.43	.746	.54	.855	-1.210	.227
Problem solving	1.67	1.190	1.88	1.308	-.865	.390
Problem finding	1.42	1.237	1.40	1.354	.157	.876
Design of sc. device	.84	.745	.45	.662	2.939**	.004
Overall DT	4.42	2.830	4.44	2.976	-.042	.966

** Difference significant at p = .01

Matching participants by age across grade levels seemed to have amplified the difference in mean scores on the design component. The observed difference (t = 2.939, p < .01) on this component was still in favour of Form 3 but at a lower level of significance, implying an increased probability of being reflected in the entire population. One possible interpretation is that the ability to design a scientific device is stifled by greater exposure to curriculum content.

It should also be appreciated that the observed mean age of 17.22 years associated with the filtered subgroup fell between the overall mean ages of Form 3 and 4 respectively, implying that Form 3 respondents who were generally older than their classmates were compared with Form 4 respondents who were younger than their classmates. These subgroup characteristics are often associated with differences in IQ and socio-economic factors; so it may be reasonable to argue that the matching process

amplified possible influence of such factors. However, considering that the difference was in favour of Form 3, it is unlikely that IQ and socio-economic differences as well as other characteristics of subgroups that share the same age but are at different grade levels influenced the results. No statistically significant difference on originality scores was observed between grade levels either (t = .292, p > .05).

The higher performance on creativity registered by Form 3 respondents on the design component tallies with the observations by Chi et al. (2005) who reported a higher score by 6th graders on a figural task than university students. It is further evidence that the levels of some creative skills decay with advancement to higher grade levels. All the other investigated components of divergent thinking seem to stagnate, a finding, which supports the popular belief that the education system hampers creativity.

Differences between Science Congress Participants and Non-Participants

Respondents who had participated in students' science congress at any level (district, provincial or national) were compared with non-participants on the

basis of their scores on various components of divergent thinking. The results for this analysis were as presented in Table 4.

Table 4: Differences in divergent thinking between science congress participants and non-participants

DT Component	Mean scores on components				Test for equality of means	
	Science congress participants (n = 86)		Non-congress participants (n = 672)		t-ratio	p-value
	Mean	SD	Mean	SD		
Adaptive fluency	2.51	1.709	1.95	1.425	3.197**	.001
Spontaneous fluency	.19	.448	.11	.374	1.608	.108
Cognitive flexibility	.90	1.117	.65	1.047	1.949	.052
Problem solving	2.33	1.665	1.99	1.462	1.913	.056
Problem finding	1.60	1.246	1.42	1.230	1.233	.218
Design of sc. device	.66	.716	.64	.680	.782	.313
Overall DT	5.77	3.886	4.78	3.444	2.390*	.017

* Difference significant at $p = .05$; ** Difference significant at $p = .01$

The analysis revealed significant differences between science congress participants and non-participants on adaptive fluency ($t = 3.197, p < .01$) and overall divergent thinking ($t = 2.390, p < .05$) in favor of participants. However, no significant differences were observed on any other component of divergent thinking. A comparison based on measures of self-reported creativity also revealed no significant difference between these subgroups on originality of own ideas ($t = 1.912, p > .05$), number of shortcomings identified in physics statements ($t = 1.316, p > .05$) and number of self-generated ideas that were later found to be established knowledge ($t = .325, p > .05$), all of which were consistent with null hypothesis. These results suggest that students who participate in science congress display similar levels of creative abilities as those who do not, except on adaptive fluency. Perhaps the adaptive fluency is stimulated in congress participants by this unique forum and the preparations that precede congress presentation.

Although congress participants were presumed to be curious and self-motivated in their search for solutions, the results negate the general expectation regarding spontaneity, as the test failed to reflect any significant differences on spontaneous fluency. However, when compared on their creative attitude measures, science congress participants were found to hold stronger positive creative attitudes than non-participants ($t = 2.990, p < .01$). Besides, from an examination of the responses, many of the non-congress participants cited lack of confidence in the subject and in their creative abilities as the reasons they had never participated in science congress. The two subgroups, however, did not differ significantly on their extent of liking physics ($t = .826, p > .05$). These findings suggest that divergent thinking is not sufficient for creativity and that non-cognitive factors

such as attitude, motivation and confidence may be important for translating ideas into creative outputs. This argument is consistent with the ideas advanced by Goodstein, Casden and Rothschild (1985) and Suparna (2007) in support of the role of high motive effort in a creative process. Nevertheless, the search for literature pertaining to comparisons between participants and non-participants in science congress was, unsuccessful - a feature that reflects underinvestment in creativity research as observed by Sternbeg and Lubart (1996). When asked to disclose the source of ideas for their projects, most participants indicated that they borrowed but modified previous projects or existing designs. This partly explains the observation that participants and non-participants registered comparable mean scores on most components. On the other hand, this participation seem to have presented greater freedom and opportunity to exercise independent thought as the learner evaluated an existing idea before instituting appropriate modifications and improvement, leading to the enhanced ability on adaptive fluency observed in the study.

Differences between Kindergarten and Pre-Unit Entry Points

In analyzing for differences in divergent thinking abilities, participants were also categorized by the stages at which they joined the education system; that is, Kindergarten and Pre-Unit entry points. This was to probe for any differences attributable to length of pre-school education. This analysis was motivated by the expectation that children who begin education early in life and therefore have a longer exposure to pre-school education probably have a head-start in the development of creative abilities through coordinated and enhanced interaction with materials in the pre-school environment. First, it was observed that a large majority of the respondents (606), who

represented 79.82 per cent of the sample, began their education at kindergarten level while the rest joined

at Pre-Unit stage. Table 5 presents the results of analysis by point of entry into education.

Table 5: Differences in divergent thinking by point of entry into pre-school

DT component	Performance on components by entry point				Test for equality of means	
	Kindergarten (n = 606)		Pre-Unit (n = 136)		t-ratio	p-value
	Mean	SD	Mean	SD		
Adaptive fluency	2.07	1.479	2.00	1.465	.391	.696
Spontaneous fluency	.13	.410	.09	.293	.925	.356
Cognitive flexibility	.70	1.083	.66	.904	.394	.694
Problem solving	2.08	1.505	2.00	1.436	.468	.640
Problem finding	1.47	1.249	1.40	1.174	.547	.585
Design of sc. Device	.64	.702	.66	.630	-.226	.822
Overall DT	4.98	3.616	4.90	3.069	.215	.830

No significant differences in mean scores on various components of divergent thinking were observed between participants who joined school at kindergarten level (age 4-5) and those who began at Pre-Unit level (age 6). This finding suggests that, whatever the point children get into education system, they immediately find themselves in water-tight programmes in which all activities must proceed as planned without giving room for creativity and divergent thinking. In the observation of Assouline and Lupkowski-Shoplik (2005), although young children often demonstrate interest in mathematical concepts, this interest is discouraged by the standardized rigid kindergarten curriculum that requires them to accomplish certain predetermined tasks, such as counting from 1 to 100. The door to curiosity, exploration and individualization is immediately shut. In fact, a t-test run to compare reported extents of childhood play between the two subgroups revealed a significant difference ($t = 3.050, p < .01$) in favour of those who joined education system at the Pre-Unit level, an indication that there is more play at home than in kindergarten.

Differences between Subgroups by Type of Toys Played With in Childhood

In this study, information was also gathered on the types of toys used by participants during their childhood play. The two major categories were: commercial and locally made toys; and on this basis, participants were categorized into four subgroups for the purpose of analyzing for any differences associated with the type of toys. The subgroups were labelled: *commercial toys only*, *locally made toys only*, *both commercial and local toys*, and *no-toy* subgroups. The mean scores of various subgroups on divergent thinking components were then subjected to t-test to determine whether there were significant differences between them. However, no significant differences were observed between any two subgroups with regard to any divergent thinking component. Table 6 presents the results pertaining to *commercial toys only* and *local toys only* subgroups but these are similar to those obtained in all other such two-group comparisons.

Table 6: Differences in divergent thinking by type of toys played with in childhood

DT component	Performance on components by entry point				Test for equality of means	
	Commercial only (n = 134)		Local only (n = 41)		t-ratio	p-value
	Mean	SD	Mean	SD		
Adaptive fluency	2.00	1.407	2.13	1.795	-.422	.674
Spontaneous fluency	.15	.438	.10	.305	.505	.614
Cognitive flexibility	.65	1.070	.73	1.413	-.332	.532
Problem solving	1.94	1.405	2.23	1.212	.947	.346
Problem finding	1.46	1.250	1.13	1.196	1.249	.214
Design of sc. device	.67	.753	.50	.630	1.118	.266
Overall DT	4.83	3.610	4.67	4.054	.211	.833

A comparison between *local-toys-only* and a combination of *commercial-and-local toys* subgroups on overall divergent thinking scores yielded t-ratio of .539 ($p = .590$), while the difference between *commercial-toys* and *both-commercial-and-local toys* subgroups had a t-distribution value of -.491 ($p = .623$); so they were insignificant. A similar result was

obtained in the comparison between *both-commercial-and-local toys* and *no-toy* subgroups ($t = -.652, p = .515$). These observations suggest that the category of toy - whether commercial or local, is not linked to divergent thinking. One important assumption in this study was that the ability to recall past childhood experiences was equally distributed

between the more divergent and less divergent thinkers. Based on this, it could be deduced that there were no significant differences in mean divergent thinking scores based on the type of toy played with in childhood; that is, whether commercial or local. However, it should also be appreciated that the accuracy of the data depended on the ability of respondents to recall past childhood experiences. Moreover, it may not have been possible for respondents to recall their play experiences that occurred very early in childhood. In a study of college students' remembrance of their childhood play, Bergen (2007) found that most young adults were able to recall salient play experiences in the periods of their lives from 8 years old. The foregoing deduction is therefore valid to older children and only to the extent that the assumption holds true.

Differences Associated With Socio-Economic Status.

T-test were also run to compare the mean scores when participants were categorized by socio-economic status as reflected in the self-reported category of residence: high-income middle-income and low-income residences. Residents of high-income estates were compared against those of middle-income and again with residents of low-income dwellings. However, no significant differences were observed on the overall mean divergent thinking scores or mean scores on any of the components (Tables 7 and 8).

Table 7: Differences in mean divergent thinking scores between high-income and middle-income subgroups

DT Component	High-income (n=130)		Middle-income (n=298)		t-test	
	Mean	SD	Mean	SD	t-ratio	p-value
Adaptive fluency	1.92	1.295	2.04	1.441	-.547	.585
Spontaneous fluency	.15	.401	.10	.363	.852	.395
Cognitive flexibility	.64	.857	.64	.992	-.010	.992
Problem solving	1.89	1.332	2.02	1.441	-.625	.533
Prob. finding	1.54	1.324	1.41	1.099	.740	.460
Design of sc. device	.62	.734	.63	.701	-.076	.940
Overall DT	4.87	3.466	4.77	3.088	.192	.848

Table 8: Differences in mean divergent thinking scores between high-income and low-income subgroups

DT Component	High-income (n = 130)		Low-income (n = 179)		t-test	
	Mean	SD	Mean	SD	t-ratio	p value
Adaptive fluency	1.92	1.295	1.82	1.291	.444	.658
Spontaneous fluency	.15	.401	.07	.259	1.386	.168
Cognitive flexibility	.64	.857	.55	.937	.603	.547
Problem solving	1.89	1.332	1.87	1.259	.084	.934
Problem finding	1.54	1.324	1.45	1.186	.423	.673
Design of sc. device	.62	.734	.57	.607	.462	.645
Overall DT	4.87	3.466	4.46	2.753	.783	.435

The results presented in Tables 7 and 8 fail to support the ion-creativity theory proposed by Dobrochodow (2008). High-income subgroups supposedly enjoy an environment that is relatively rich in ions from the solid-free air and bath showers, especially when at home. This, taken together with greater access to new technologies and other resources was expected to give them an advantage over their counterparts in the middle and low-income settings. However, the apparent discordance may be due to a number of factors, including: the possibility that environments did not differ significantly in terms of the concentrations of ions, the effect being temporary and only felt during contact with ions, and domain-specificity of effects. These results also suggest that socio-economic factors do not significantly correlate to creativity in physics, a finding that apparently conflicts with the observations of Dudek et al. (1993). However, it is instructive to note that the cited study relate to figural tasks rather than divergent thinking in

physics. Otherwise the present finding concurs with the report by Warden and Pratt (1971) who found no significant differences related to ethnic and socio-economic class.

Group and Independence Orientation Subgroups

Group learning is advocated by creativity experts as an effective strategy of teaching creativity, expounding its important role as a forum for brainstorming, exchanging ideas, and providing an atmosphere where learners freely critique and challenge theories as they develop alternative viewpoints, thus stimulating creativity. The same view has been expressed by teachers in the present study, who rated group work higher than independent work in terms of their suitability for creativity development. In addition, most of the student respondents indicated a higher preference for group work, although a significant minority felt otherwise. Following these observations, an analysis was

performed to compare the performance of the two subgroups on divergent thinking measures, the results

of which are displayed in Table 9.

Table 9: Differences in mean divergent thinking scores between group and independence orientation subgroups

DT component	Group orientation subgroup		Independence orientation subgroup		T-test	
	Mean	SD	Mean	SD	t-ratio	p-value
Adapt. fluency	1.85	1.420	1.89	1.396	.164	.870
Spont. fluency	.08	.287	.09	.295	.334	.724
Cognitive fluency	.55	.968	.64	.942	.614	.540
Problem solving	1.84	1.419	1.96	1.467	.547	.585
Problem finding	1.22	1.122	1.40	1.166	.998	.319
Design of sc. dev.	.50	.620	.55	.667	.975	.333

There was no significant difference in mean scores on any component of divergent thinking between respondents who prefer group work and those who prefer to work independently. This observation suggests that group and independence orientations are not linked to or influence divergent thinking. In fact, a review of creative works related to physics reveals some landmark creative contributions that emanated from collaborative work, typical examples being the invention of aeroplane by Orville (1871-1948) and Wilbur (1867-1912) and the series of combustion engines designed jointly by Nikolaus Otto and Eugen Langen between 1862 and 1876. But many of the past creative geniuses such as Isaac Newton (1642-1727), Benjamin Franklin (1706-1790), Thomas Edison (1847-1931), Guglielmo Marconi (1874-1937), Albert Einstein (1879-1955) and Carl Diesel (1858-1913) worked independently (Microsoft Corporation, 2005). However, neither these observations nor the findings of the present study they support contradict the plausible argument of Fryer (1991) in favour of group work since the analysis was specific to preference to group work and not the impact of group work on divergent thinking.

CONCLUSION AND IMPLICATIONS

This study has revealed some differences between subgroups of students on specific components of divergent thinking ability. Significant differences were observed when students were categorized by gender, with boys performing relatively better on some components of divergent thinking and girls registering superiority on others, notably problem finding ability. Participation in Students' Congress on Science and Technology did not reflect in the overall divergent thinking abilities of students except on adaptive fluency which was associated with a small but significant difference in favour of congress participants. Grade level differences were also observed, in which Form 4 respondents outperformed their Form 3 counterparts on adaptive fluency, while the latter demonstrated superiority on design of

scientific device. However, no significant differences were observed when participants were grouped by types of toys they played with in childhood, pre-school entry points in education, or socio-economic class.

These findings have important implications for the growth of divergent thinking abilities of pupils. The observed lack of significant differences based on length of pre-school education shows that pre-school environment and its programmes do nothing beyond what the home environment offers towards the development of divergent thinking abilities. This calls for a review of the pre-school curriculum to incorporate elements of creativity as an integral component. The formal education system is no exception to this finding as differences between grade levels were not only inconsistent but some divergent thinking skills grow weaker as learners progress to higher grade levels, contrary to expectations. This lends support to the popular belief that the school system stifles creativity and does little to encourage divergent thinking.

Results of the comparison between participants and non-participants in science congress point to only weak links between this activity and divergent thinking ability. This, together with the generally low performance on divergent thinking tasks recorded imply that the project work students do in physics does not significantly enhance the development of divergent thinking skills, most probably because it normally comes with a prescribed procedure for learners to follow. This approach denies learners the opportunity to exercise truly independent thinking and by identify a problem, propose solutions, formulate hypothesis, design an investigation, justify the choice of materials to be used, draw conclusion, and evaluate the whole process or product for further improvement. The situation calls for a rethinking of the implementation of project work and participation

in science congress to enhance creativity generally and divergent thinking skills in particular.

That participants did not differ on divergent thinking scores when categorized by type of toys they played with in childhood is an indication of the inability of some toys, particularly those found in the participants' environment, to promote divergent thinking. This finding has implications for both pre-school and home environments where toys are extensively used. It appears there is general lack of materials that not only satisfy children's curiosity and urge to play but also arouse inspire scientific creativity and enhance divergent thinking. Also, from the observed gender differences on divergent thinking, there is need for further research to investigate environmental factors that give each gender an advantage over the other and taking advantage of these for overall development of creativity.

REFERENCES

- Amabile, T. M. & Hennessey, B. A. (1996). The motivation for creativity in children in Pittman, T & Boggiano, A. (eds.), *Achievement and motivation: A social developmental perspective*, pp. 54-74. New York: Cambridge University Press.
- Ai, X. (1999). Creativity and academic achievement: An investigation of gender differences. *Creativity Research Journal*, 12(4): 329-337.
- Assouline, S. G. & Lupkowski-Shoplik, A. (2005). *Developing mathematical talent*. 262.
- Bergen, D. (2007). *Play as the learning medium for future scientists, mathematics and Engineers*, American Journal of Play. Spring.
- Chi, H. W., Yim, C., Hoi, M. I. McBride-Chang, C. (2005). Age differences in creativity: Task structure and knowledge base, in *Creativity Research Journal*, 17: 4.
- DeHaan, R. L. (2009). Teaching creativity and inventive problem solving in science. May, 28.
- Diakidoy, I. A. and Constantinou, P. C. (2001). Creativity in physics: Response fluency and task specificity. *Creativity Research Journal*, Vol. 13, Issue 3 & 4, pp. 401-410.
- Dobrochodow, R. K. (2008). Do schools kill creativity? www.ted.com/index.php or blog.www.theamericanmonk.com
- Dudek, S. Z., Strobel, M. G., & Runco, M. A. (1993). Cumulative and proximal influences on the social environment and children's creative potential, in *The Journal of genetic psychology*. 154(4): 487-499
- Fryer, D. (1991). Qualitative methods in occupational psychology: Reflections upon why they are so useful but so little used. *The occupational psychologist*, 14, 3-6.
- Gabor, P. (2005). Scientific creativity in Hungarian context. *Hungarian Studies*, Akademiai Kiado. Vol. 19. No 2 Dec., 2005.
- Goodstein, D. L., Casden, R., & Rothschild, M. A. (1985). Harmonic motion, in P. F. Buffa, *The mechanical universe: Introductory physics series*. CA. The Anneberg/CPB Project
- Habibollah, N., Rohani, A., Tengku, A. & Jamaluddin, S. V. (2009). Gender differences in creative perceptions of undergraduate students. *Journal of Applied Sciences*, In Press.
- Jaffar, M. A. (2004). Creativity. *Bahrain Medical Bulletin*, Vol. 26, No. 2, June
- Jones, K. (2002). *Journal of Southern Agricultural Education Research*. 51(1): 211-236.
- Karimi, A. (2000). The relationship between anxiety, creativity, gender, academic achievement and social prestige among secondary school students. University of Shiraz, Shiraz, Iran.
- Kealey, D. J., & Protheroe, D. R. (1996). The effectiveness for cross-cultural training of expatriates: An assessment of the literature on the issue. *International Journal of Intercultural relations*. 20(2), 141-165.
- Kim, K. (2010). Research agenda. Relationship between Confucianism and creativity. [kkim.wmwikis.net/Research + Agenda](http://kkim.wmwikis.net/Research+Agenda).
- Kimani, N. (2008). Power of intellect key to Kenya's economic revival: The need to develop and embrace a creative economy. *The Standard*. August 21. p14.
- Koray, O. & Mustafa, S. K. (2009). The effect of creative and critical thinking based laboratory applications on creative and logical thinking abilities of prospective teachers, in *Asia-Pacific Forum on Science Learning and Teaching*. 10(1): 1. Karaelmas University.
- Mangena, M. (2007). Science: The cure for poverty, Bouzaglou (ed.), in *The Mail and Guardian Hila* , www.dst.gov.za/media-room/speeches/speech.2007-05-22.5612035654 | Johannesburg, South Africa.
- Mahmodi, M. T. (1998). Relationships between employment of mother, personality features, creativity and academic achievement among students. University of educational teacher, Tehran, Iran.

- Microsoft Corporation. (2005). Encarta Premium Suite: Offline digital encyclopedia, Disc 1-4.
- Ndeke, G. C. W. (2003). The effects of gender, knowledge, opportunities and scientific creativity among Form 3 Biology students. Unpublished M. Ed Thesis, Egerton
- Niaz, M., & Rodriguez, M. A. (2002). Improving learning by discussing controversies in the 20th century physics. *Physics Education*, 37(1), 59-63.
- Nori, Z. (2002). Gender differences in creativity and academic achievement: An investigation of gender differences. *Creativity Research Journal*, 12(4) 329-337.
- Ogot, B. (2007). Without Science, Africa is Doomed, in *The East African Standard*, June, 2007.
- Palaniappan, A. K. (2000). Sex differences in creative perceptions of Malaysian students. *Percept Mot Skills*, 91(3): 970-972.
- Preckela, F. Heinz, H. and Wiese, M. (2005). Relationship of intelligence and creativity. in *Gifted and non-gifted students: An investigation of threshold theory*. <http://www.sciencedirect.com/science>.
- Republic of Kenya, (2002). Kenya Secondary School Syllabus, Volume II, Science and Mathematics, Kenya Institute of Education, Nairobi.
- Ronald, I. (2002). Norwegian deaf teachers' reflections on their science education: Implications for instruction. *Journal of Deaf Studies and Deaf Education*, 7(1), 57-73.
- Schick, V. (2004). How to think about weird things: Critical thinking for a new age (4th ed). www.atypon.com/.
- Sousa, D. A. (2006). How the brain learns. Thousand Oaks, CA: Corwin Press.
- Starko, A. (2005). Creativity in the classroom, Mahwah, NJ: Lawrence Erlbaum.
- Sternberg, J. R. & Lubart, T. I. (1996). *American Psychologist*, 51(7), July, 677-688.
- Suparna, R. (2007). Proceedings of the 2007 Complexity Science and Educational Research Conference, February 18-20, Vancouver, British Columbia, pp. 217-224
- Tao, P. (2001). Confronting students with multiple solutions to qualitative physics problems, in *Physics Education*, 36(2): 159-190.
- Taylor, A. R., Gail, M. J., Broadwell, B. & Oppewall, T. (2008). Creativity, inquiry or accountability? Scientists' and Teachers' perceptions of science education. *Wiley Interscience*, DOI 10.1002/sc.20272: 1068-1071.
- Torrance, E. P. (1998). Torrance Test of Creative Thinking: Directions Manual and Scoring Guide, Verbal Test Booklet A, Scholastic Testing Inc.
- Warden, P. G. & Pratt, R. S. (1971). Convergent and divergent thinking in black and white children of high and low socioeconomic status. *Psychological Reports*, 36(3): 715-718.