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Investigation of Creativity in Physics in the Context of Learning in Association with Deep Approach to Study

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Abstract: *Investigation of creativity in the context of learning is receiving much attention of researchers. In this context, an approach to study is an important factor to study creativity. An approach to study is a multidimensional construct. Among those different dimensions, deep approach has been selected particularly as a factor in the present study to investigate creativity in the context of learning physics. Major objectives of the study were to investigate how different sub- dimensions of deep approach (namely deep processing, use of evidence, relating ideas, and intrinsic motivation), and also deep approach, as a whole, are related to creativity in physics- both in the bi variate and multivariate levels.*

Relationships (at bi variate level) were estimated using coefficients of correlation, and at the multivariate level using multivariate regression analyses (multiple regression and subsequent stepwise regression) considering creativity in physics as the criterion variable and four different sub- dimensions of deep approach as predictor variables.

All the four sub dimensions of deep approach were found to be significantly and positively correlated with creativity in physics. Coefficients are particularly strong in case of 'deep processing', and 'use of evidence', fair for 'relating ideas', but not so strong particularly for 'intrinsic motivation' (though significant). Deep approach as a whole was also found to be significantly and positively correlated. Results of multivariate regression analyses showed that the regression model could explain 55.7% variance of obtained scores. All the sub dimensions of deep approach, except 'intrinsic motivation', were found to predict the criterion variable strongly.

Keywords: *Coefficients of correlation, Creativity in physics, Deep Approach to Study, Multiple Regression Analyses, Sub-dimensions of Deep Approach.*

I. Introduction

Relationship between learning and creativity is introduced by Guilford (1950), one of the pioneers in the field of scientific researches on creativity. But not much work is reported in this specific field of study. Most of the researches of the past half century have studied creativity of eminent persons (Baghetto & Kaufman, 2007). Learning related creativity and creativity of eminent persons are not identical. Among these two, the former has an important role in the process of construction of new and personally meaningful knowledge and understanding of the learners and therefore is 'intrapersonal' by nature (Runco, 2004). This intrapersonal creativity of an individual may not be recognized as a creative behavior by another individual. This type of creative expression starts with an internalization or appropriation of cultural tools and social interaction, not just copying but rather a transformation or reorganization of incoming information and mental structures based on the individual's characteristics, context, and existing knowledge (Moran and John Steiner, 2003). This also significantly depends upon the way through which learners interact with a learning situation while receiving various information from surrounding and processing those (Kaufman & Baer, 2005). This is where creativity, in the context of learning, may have its relationship with study approaches of learners. Study approach is an important study behavior indicating students' involvement with study. Effective study approach helps a learner to manipulate learning environment properly, enriching his/her information processing system. A problem faced by the learner in any learning situation, challenges his/her existing cognitive structure and utilizing enriched information processing, he/she adopts suitable modification in it, and make necessary reconstruction. This may also help in adopting flexible approaches in learning, enabling him/her in coping with new situation in learning, encouraging his/her diversity. So, this may also foster his/her creativity, in general. Therefore, study approach may be an important factor to investigate creativity in the context of learning.

Among different disciplines taught in the institution, physics has enough scope of nurturing creativity within its own domain (Mukhopadhyay,2011). Its axiomatic nature, scope of applying abstract thinking, inductive approach and analytical reasoning in particular, deductive approach and synthetic reasoning in general in understanding physics etc. provides a physics learner greater opportunity in constructing knowledge actively, encouraging his/her creativity. In view of this, creativity in the context of learning physics (precisely, creativity in physics) has been selected as the focal area of present investigation.

Different approaches to study namely deep, surface, achieving, and holistic have been suggested by Entwistle and Ramsden (1983) to explain study behavior of school students. Among these, deep approach indicates active engagement in study -which also seems to be the feature of a creative learner. This similarity between creativity and deep approach raises some questions in the mind of present researchers: whether creativity and deep approach have any association in the context of physics learning, in particular? If any, what is the nature of that relationship? How different aspects of deep approach are related to creativity in physics and whether it accounts for the relationship between creativity and deep approach as a whole? Researchers feel an active urge to find solutions of these which led to selection of the present study.

II. A Brief Review Of Related Literature

Heinstrom (2000) investigated personality and approaches to learning in relation to information searching behavior of 500 university students. Questionnaire about Information Behavior, Approaches to Study Skill Inventory (ASSI: Entwistle and Tait, 1996) for students, Five Factor Inventory for Personality were used. Deep learners were found to be open, orientated to questioning and analysing arguments, showed readiness in accepting new information more flexibly. Personality trait, as well as information searching behavior of deep learners seems to be close to that of a creative person. Study, therefore indicated that strong positive relation of creativity may exist with deep approach.

Particularly in learning science, Chin and Brown (2000) investigated activities performed by deep learners. Approaches to Study Inventory (ASI) were employed. Students' activities in a chemistry unit were observed, recorded and analyzed according to 5 categories, namely: generative thinking, nature of explanation, asking questions, meta-cognitive activities, and approaches to task. Deep learners were found to generate ideas more spontaneously, give more elaborate explanations, describing mechanism and cause-effect relationship, ask questions focusing on explanation, cause, prediction or resolving discrepancies in knowledge, and found to be engaged in 'on line theorizing'. Activities performed by a deep learner in learning science may be close to creative behaviors in science i.e. generation of multiple hypotheses, elaboration, scientific prediction etc. Findings therefore lend support that; deep approach may have close association with creativity in the context of science learning.

Deep approach might encourage learners in adopting appropriate strategies even in complex situations, facilitating the learning of higher order. Few such strategies are self regulation, Meta cognition in learning etc. Abdullah (2005) conducted his study to explore the relation between creativity and self- regulation in learning. He considered 119 university students of 18-21 years of average age. Learning and Study Strategy Inventories (LASSI) and Wholetheme Learning Inventory (WLI: Dhobaiban, 2004) for measuring self-regulation, and 'Test Your Creativity Level Scale' (TYCLS: Hamradi, 1999) for measuring creativity were employed. Students showing high score on self-regulation, as measured with WLI, were found to possess also high score on creativity; WLI score was found to predict creativity significantly. Study therefore showed significant and positive relationship between creativity and self- regulation in learning. Self-regulation might be close to deep approach, as already mentioned. In fact, the construct of deep approach to study and self-regulation are similar in many respect identified by Vermunt (1996). Hence, findings of Abdullah (2005), as referred, indicated the possibility of close association of creativity with deep approach. Paul and Elder (2006) investigated the relationship between critical thinking and meta-cognition, considering university students. Significant correlation was found between Meta cognition and critical thinking, indicating creativity. Therefore these results also lend support in favor of considering that creativity and deep approach are strongly related.

All these studies also indicate the possibility that deep approach to study and creativity, in the context of learning physics, may also be strongly and positively related.

In fact, students' conception of the nature of learning influences their study approaches (Boyle *et. al.* 2003), and in view of this Mukhopadhyay (2011) effectively explained the possibility of this strong association between deep approach and creativity in physics. According to him, Physics is characterized by well organized structure of content. Several physics concepts are interrelated following a proper hierarchy. Therefore students may conceive physics learning as an active search for an 'integrated and meaningful whole' in view of those interrelationships. This conception might influence study approach of learners in physics, in general, and encourage their deep approach in learning physics, in particular. Learners may engage themselves to a thorough search in investigating the related concepts in physics, considering various aspects, in combining those following systematic and logical approach, leading to exploration of the meaningful whole, developing the insight, which, in turn, may foster his/her creativity in physics. So, students' proper conception of the nature of physics learning may lead him/her adopt the deep approach in learning physics, which may also encourage creativity in physics as a consequence. Hence creativity and deep approach to study in the context of physics learning have fair possibility to be associated closely.

But in spite of this, related studies in this field are extremely inadequate. Available studies throw indirect light in favor of the possibility only. Not only deep approach, 'approaches to study' (a comprehensive and multidimensional construct, deep approach is a part of which) is entirely ignored by researchers in investigating creativity. 'Study approaches', particularly the deep approach, is a potential factor of creativity in physics and scope is there to investigate the relationship between these two.

III. Rationale And Objectives

Hence, investigation of creativity in physics in relation to deep approach is research worthy. Present study also aims to investigate the same. Creativity in physics is considered as the dependent variable. Four different sub dimensions of deep approach (namely the deep processing, relating ideas, use of evidence, and intrinsic motivation, as considered by Entwistle and Ramsden, 1983) are considered as the independent variables. Objectives of the study are:

1. To investigate the relationship of creativity in physics with each of the four different sub dimensions of deep approach to study (and also deep approach as a whole) at bi variate level.
2. To investigate whether four sub-dimensions of deep approach can predict the criterion variable significantly in a multivariate perspective.

IV. Hypotheses

Following hypotheses were proposed to be tested in relation to the objectives as stated. These are stated in form of null hypotheses in view of lacking of sound related studies. These are as follows:

H01. There is no significant and positive correlation (at bi variate level) between creativity in physics with each of the four sub dimensions of deep approach to study (i.e. deep processing, relating ideas, use of evidence, and intrinsic motivation), and also with deep approach as a whole.

H02. Deep processing, relating ideas, use of evidence and intrinsic motivation cannot predict creativity in physics in a multivariate level.

V. Design And Mode Of Analysis

Data were analyzed at three levels namely- Univariate level, Bivariate level and Multivariate level.

5.1 Analysis at Uni -variate level

At uni variate level, Descriptive analysis was performed in terms of Mean and Standard Deviation of scores. Mean and Standard Deviation of scores in each of the selected variables were computed.

5.2 *Analysis at Bi variate level:*

At bi variate level, analysis was done by computing coefficients of correlation of creativity in physics with each of the four sub dimensions of deep approach (deep processing, relating ideas, use of evidence, and intrinsic motivation) and also with deep approach as a whole.

5.3 *Analysis at Multivariate Level:*

Multivariate analysis was done considering creativity in physics as dependent variable, and four different sub dimensions of deep approach as independent variables. Multiple regression analysis and subsequent stepwise regression were considered.

VI. Brief Operational Description Of Variables

6.1. *Creativity in Physics:*

Present study considers creativity in physics mostly in relation to divergent thinking. At the same time, it also considers adequate and proportionate convergent thinking leading to an appropriate and unique solution of a problem in physics in the same relation (as per Sen and Mukhopadhyay, 2009).

Six different dimensions of creativity in physics have been considered. Three among these are divergent and three are convergent by nature. Brief operational descriptions of these are as follows:

Fluency (divergent, ability of producing number of valid responses), Flexibility (divergent, ability of producing responses of varying categories), Originality (divergent, ability of producing valid and rare responses of low frequency). Planning and foresight (convergent, ability of foresighted planning leading to perception of a problem effectively), Conceptual correlate (convergent, ability of finding analogy), and Correct vocabulary (convergent, ability of producing appropriate words)

6.2. ***Deep Approach to Study (along with its different sub dimensions):***

Students using deep approach in study shows intention of understanding meaning of the lesson, interact actively with author's arguments, relate them to the previous knowledge and their own experience, and are motivated intrinsically.

Operational descriptions of different sub dimensions included under deep approach are as follows:

6.2.1. Deep **strategy:** active questioning in learning,
6.2.2. Relating **ideas:** relating new information to previous knowledge,
6.2.3. **Use of evidence**: relating evidence to draw conclusions, and
6.2.4. **Intrinsic motivation**: interest in learning for sake of learning itself.

VII. Sample

Secondary passed students, studying science in higher secondary section (in class-XI, under W.B.C.H.S.E), were considered appropriate for the study. Students of this group belong to formal operational stage of their cognitive development. They also have the ability to think in abstract way. Without knowing what creativity is, they have the scope of systematic exploration of all the possible solutions. Therefore, they can exhibit greater amount of creative thinking more spontaneously. At this stage, they have just appeared at the first public examination (at the end of class X). So, it is expected that they also tend to develop approaches to study, but not so stably. Only they may have specific orientation towards their study by applying specific strategy, not rigidly, but flexibly, trying one or the other. Six hundred fifty five (655) students of the above mentioned category constitute the present sample. Stratified random sampling technique was used for selecting this group.

VIII. Tools Used

Following tools were used in the present study.

1. Test on Creativity in Physics (Sen and Mukhopadhyay; 2009)
2. Approaches to Study Inventory (ASI: Entwistle and Ramsden; 1983) – only the Deep Approach part of the Inventory.

IX. Results Of Data Analysis And Discussion As Per Hypotheses

Following steps were used for analyzing data

9.1. Descriptive Analyses (Mean, Standard Deviation)
9.2. Coefficients of Correlation
9.3. Regression Analyses (Multiple Regression, Stepwise Regression).

These are discussed step by step as follows:

9.1. ***Descriptive analyses (Mean, Standard Deviation,)***

Mean and Standard Deviation (S.D) of the scores on Creativity in Physics are presented in (Table.1). Scores on different dimensions of it, as well as the overall scores of the same are considered separately, for it being the main variable under consideration (though, only the overall scores on it was used further for estimating the relationships, as discussed in the following sections). Scores on Deep Approach to Study are presented in **Table 2**. Score on Deep Approach (as a whole), as well as score on each separate sub dimension of it were considered. This is for preliminary investigation of data.

TABLE 1: Mean and Standard Deviation (S.D) Of Scores for Creativity In Physics (N= 655)

Dimensions	Mean	S.D.
1. Fluency	32.33	6.01
2. Flexibility	22.51	4.86
3. Originality	19.49	7.62
4. Perceptual Foresight	4.60	2.55
5. Conceptual Correlate	4.88	2.18
6. Correct Vocabulary	9.07	3.48
Creativity in Physics (overall)	93.89	22.48

TABLE 2: Mean And Standard Deviation (S.D.) Of Scores for Deep Approach (N= 655)

Dimensions	Mean	S.D.
1. Deep Strategy	12.61	1.51
2. Relating Ideas	11.56	1.62
3. Use of Evidence	10.95	1.04
4. Intrinsic Motivation	8.78	1.11
Deep Approach (as a whole)	42.68	6.92

7.2 Coefficient of correlation

Coefficients of correlation of creativity in physics with deep approach (deep approach as a whole, and also four different sub dimensions of it) were computed using Pearson's product moment method. Following table (Table 3) shows the results.

TABLE 3. Coefficients Of Correlation Of Creativity In Physics With Deep Approach (N=655)

Variables	**Coefficient of Correlation**
1. Deep Strategy – Creativity in Physics	0.552 *
2. Relating Ideas - Creativity in Physics	0.257 **
3. Use of Evidence - Creativity in Physics	0.447 **
4. Intrinsic Motivation - Creativity in Physics	0.133 *
5. Deep Approach (as a whole) - Creativity in Physics	0.513 **

'**' significant at 0.01 level, '*' significant at 0.05 level, N.S.- No significance

Results reveal that all the four sub scales of Deep Approach are significantly and positively correlated, coefficients are particularly strong in case of the sub-scales 'Deep processing', and 'Use of evidence'; fair for the sub dimension 'Relating Ideas', and not strong for 'Intrinsic motivation' (though significant). Deep Approach as a whole is significantly and positively correlated.

Discussion of the results:

In view of the results of significant and positive coefficients of correlation of creativity in physics with each of the four sub-dimensions of deep approach and also with deep approach, as a whole**, hypothesis H.01 is rejected.** Heinstorm (2000) has identified that deep learners are more critical in learning, preferred by complexities, ready to adopt with change in learning situation flexibly. These results lend a support to the present finding.

A deep learner, in science learning, is found to perform the activities as: generating multiple ideas, elaborating explanations, resolving discrepancies in knowledge, recognizing a problem etc (Chin and Brown, 2000). These activities are close to flexibility, elaboration and problem recognition respectively; which are the factors and abilities related to creativity in physics. This indicates that some similarity may be there between the constructs of creativity in physics and deep approach to study. Present result is also supported by this finding.

'Use of evidence' (using evidence while drawing conclusion) is the particular dimensions of deep approach which is found to have strong and positive correlation (r=0.447, Table.3)) with creativity in physics. These sub dimensions of deep approach seem to be closely associated with learning science. A science learner might be rational enough and prefers evidence for taking decision. Before concluding anything, a scientifically creative learner might also show his/her intention in verifying facts using strong logic, reasoning ability and adequate experimental evidence. Therefore the strong relationship between creativity in physics and use of evidence has justification.

The correlation between 'deep processing' (another dimension of deep approach, implying active questioning in learning to attain understanding of the text) with creativity in physics is found also to be significantly high (r=0.552, Table 3). A creative learner has flexibility which help him/her in generating multiple hypotheses viewing different perspectives of a situation. This is impossible unless he/she develops proper understanding of the subject using his/her spirit of enquiry and active questioning mind. This may account for this result.

The dimension 'interrelating ideas' (linking new information to previous knowledge) is found to be fairly correlated with the same (r= 0.257, Table.3). This behavior of deep approach also seems to be relevant in learning science. Science in general and physics in particular, consists of a number of interrelated concepts. So a student learning science, particularly a creative one, has enough scope to interrelate several scientific ideas. This might account for the fair relationship, as found.

But the sub-dimension 'intrinsic motivation' (learning driven by personal interest in learning for its own sake) is found to have comparatively low (though significant, positive) correlation with creativity in physics (r=0.133, Table 3). A learner shows strong intrinsic motivation only when the abstract beauty of the internal structure of knowledge of the respective discipline is perceived by him/her properly. The sample of the present study is students of class XI. They have introductory idea of physics in secondary level, but have started learning physics as a separate discipline after passing secondary examination. So they might not have enough exposure in the domain of physics learning. They may not have scope enough to appreciate the aesthetic value of the subject physics, which may result in this low correlation. Present scenario of teaching –learning physics (over loaded curriculum, teacher-controlled classroom, over-emphasis of mere factual knowledge in physics etc.

) may also fail to make physics learning a joy full one resulting in de motivation in learning physics, to some extent.

Except ‘intrinsic motivation’, each of the other sub-dimensions of deep approach are strongly (to fairly) and positively correlated with creativity in physics. This indicates the possibility of strong correlation between creativity in physics and deep approach as a whole, which might account for the finding (r=0.513, Table 3).

9.3. Regression Analyses (Multiple Regression, Stepwise Regression).

Relationship of Creativity in Physics with four different sub dimensions of Deep Approach was investigated using multiple regression analysis, considering Creativity in Physics as dependent variable, and, Deep Processing, Relating Ideas, Use of Evidence, and Intrinsic Motivation as independent variables. Stepwise regression analysis was also done subsequently to investigate the degree of predictability of each predictor for the criteria variable. Results are shown in Table.4.

TABLE 4: SUMMARY: MULTIPLE REGRESSION FOR (N=655)

TABLE 4A: MODEL SUMMARY

Model	R	R-Square	Adjusted R-square	Standard error of estimate	p
1	0.746	0.557	0.551	12.307	0.000

TABLE 4B: REGRESSION COEFFICIENTS

Model	Un standardized coefficients		Standardized coefficients	t	p
	B	Standard Error	Beta		
1 Constant	-19.206	9.956		-1.929	0.054
Deep Processing	0.966	0.107	0.350	9.062	0.000
Relating Ideas	0.252	0.052	0.199	5.382	0.000
Use of Evidence	0.297	0.138	0.075	2.149	0.033
Intrinsic Motivation	0.235	0.131	0.051	1.787	0.075

TABLE 5: SUMMARY: STEP-WISE REGRESSION (N=655)

Multiple Regression	Step +in/-out	Multiple R	Multiple R^2	R- square change	p-level
Deep Processing	1	0.6140	0.3759	0.3759	0.0000
Use of Evidence	2	0.7159	0.5131	0.1372	0.0000
Relating Ideas	3	0.7420	0.5506	0.0375	0.0000
Intrinsic Motivation	4	0.7462	0.5569	0.0063	0.2230

Results (Table. 4) reveals that the regression equation is found to predict 55.7% (adjusted- 55.1%) variance of the obtained scores. Stepwise independent variables entered for the dependent variable (Table 5), were deep strategy (explaining 37.59% of scores), use of evidence (13.72%), relating ideas (3.75%), and intrinsic motivation (0.63%).

Discussion of the results

Results of regression analysis (Table.4, and Table. 5) show that all the independent variables, i.e. deep strategy, use of evidence, relating ideas, and intrinsic motivation significantly predict the criterion variable. In view of this, **hypothesis H02 is rejected.**

Creative learners are driven strongly by an urge in constructing their own knowledge. Among different dimensions of deep approach, deep strategy particularly seems to be the most essential ingredient leading to such construction. It encourages learners’ active participation in learning nurturing his spirit of scientific enquiry. This might be the cause for which this sub dimension of deep is found to be the strongest predictor (explained more than 50% of the total variance of the scores). Few other dimensions of deep approach also seem to be associated with various other steps of such construction, particularly in science. ‘Interrelating ideas’ (linking new information to previous knowledge) may help him/her to integrate related concepts into a meaningful whole leading to formation of newer and newer ‘gestult’. ‘Use of evidence’ (using evidence to draw conclusion) may help him/her in testing hypotheses on the basis of results undergoing scientific experimentation leading to verification or falsification of those hypotheses ultimately. All these, together lead to knowledge construction, encouraging creativity. This might account for the result of significant and strong prediction of the scores of creativity in physics by these components of deep approach.

'Intrinsic motivation' (interest in learning for its own sake) may provide a learner joy in constructing new knowledge encouraging his/her further search for a newer knowledge. This particular dimension is found to predict the criterion not so strongly (though significantly). Deep learners have some intrinsic motivation. But might be these intrinsic motivations of deep learners are not too high to predict their scores of creativity in physics strongly.

X. Conclusion

Result reveals a strong association of creativity in physics with deep approach as a whole and result of this strong association might be attributed mostly to the results of strong correlation of creativity in physics with each of two particular sub dimensions of deep approach, namely deep strategy, and use of evidence.

These results of all the correlations indicate some study trends of creative learners in physics particularly. They are mostly meaning oriented, their learning emphasizes on their sense of logic and on reasoning ability strongly. They prefer very much to verify facts before concluding anything have active questioning mind and spirit of scientific enquiry, have some preference in relating new ideas to the existing concepts. But in-stead of having meaning orientation in learning physics, they do not have strong intrinsic-motivation towards the same. They have such potentiality, as the result indicates. But might be due to less exposure in physics learning, and various other external causes emerging in the contemporary context of teaching-learning physics, their motivation has closer association to some external criteria (as orientation to career, achievement in examination etc.). Well–exposure to several aspects of physics learning (which they may receive in due course of higher studies) , joy and pleasure in learning physics etc. may encourage their intrinsic motivation. In this regard, the present study suggests some specific roles of a physics teacher in this regard, which are as follows.

Students' overall exposure in various aspects of learning physics should be enhanced by acquainting them with various learning resources. This may orient them more strongly towards learning physics encouraging their intrinsic motivation. This also suggests improvement of infrastructural facility in school, particularly the functioning of school library. Students' may be encouraged to use library resources to solve various assignments in physics. Instead of doing all the assignments in home, few may be done in the physics class with proper use of those resources and with the co operation of the physics teacher. Freedom and autonomy of learners in a physics class might result in joy in their learning. Peer group tutoring, Co-operative learning etc. may increase the possibility of students' involvement in learning. Use of these learner centric strategies in physics class might also encourage them to learn for the sake of learning itself, increasing their intrinsic motivation towards learning the discipline. A physics teacher may also use indirect ways of instruction particularly heuristic approach in teaching in order to ensure their involvement, taking the role of facilitator- rather instructor. Reduction of the load of curriculum, over emphasis of mere memory and factual knowledge in learning etc. are also few suggestions which may encourage meaning orientation of deep learners more strongly fostering their creativity.

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