INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Correlates Of Creativity In R&D Scientists

Nishi Misra
Scientist 'E', Defence Institute of Psychological Research, Lucknow Road, Timarpur, Delhi, India
Amool Ranjan Singh
Ranchi Institute of Neuropsychiatry and Allied, Sciences (RINPAS), Kanke, Ranchi, Jharkhand, India

Abstract:

Objectives: Present study was conducted to (i) determine gender, discipline and age differences in scientific creativity. Barriers to creativity at the workplace were also determined. Sample comprised 100 R&D scientists; aged 25 to 55 years. 't' test and multiple regression analysis were computed. Results revealed non-significant differences on gender and age and significant discipline-wise differences on creative output. Scientists reported more number of organizational barriers and lesser number of personal barriers that affected their creative output at the workplace. Directions for future research are discussed.

Key words: *Creativity, workplace, barriers, scientists*

1.Introduction

In the modern age, progress is exploding in a logarithmic fashion. The revolutionists are the creative scientists and engineers, responsible for turning "impossible" into "possible". It has been argued by scientists and researchers that the process of R&D is basically giving expression to the creativity of the scientist's mind. Creativity has been defined in various ways. According to Random House Webster's unabridged dictionary, "creativity is the ability to transcend traditional ideas, rules, patterns, relationships and create meaningful new ideas, forms, methods and interpretations". Scientific creativity covers thinking skills needed to carry out scientific activities, such as convergent and associational thinking as well as divergent thinking. It includes scientific knowledge content as well as scientific inquiry skills (Park, 2004).

Factors influencing creativity

The traits which have been found common in a productive scientist are: a high degree of autonomy, self sufficiency, self-direction, a preference for mental manipulations involving things rather than people, a somewhat distant or detached attitude in interpersonal relations and a preference for intellectually challenging situations rather than socially challenging ones, a liking for method, precision, exactness and the like. Personality variables such as tolerance and psychological mindedness has been found to explain up to 20% of the variance in addition to potential and intellect (Feist & Barron, 2003). Commitment to work has been reported as the strongest predictor of creativity (Busse & Mansfield, 1984).

Gender differences in scientific creativity exist if one focuses on the highest level of creative accomplishment. Male professors produce more creative work in research publications than female professors (Axelrod, 1988; Ajzenberg-Selove, 1994) and men earn more degrees, produce more works of arts, and produce more contributions in professional fields (Callahan, 1979; Ochse, 1991; Piirto, 1991; Reis, 1987). Thus, the general notion is that male performance on creativity measures is generally better than females (Stoltzfus et al., 2011).

Creativity has been found as a curvilinear function of age. Some fields are characterised by early peaks, usually around the early 30's or late 20's, like lyric poetry, pure mathematics, and theoretical physics (Adams, 1946). A comparatively late peak in the late 40's and 50's is noticed for endeavours like, novel writing, history, philosophy, medicine and general scholarship (Fulton & Trow, 1974). Potential and intellect at age 27 predict life-time creativity at age 72 (Feist & Barron, 2003).

Barriers to Creativity: Barriers inhibit creative thinking that may be both personal as well as situational and prevent innovative ideas from being implanted. Situational factors like mood, reward, motivation and attention exert less influence than personal factors like knowledge, skills and attitudes (Davis, 2000). Some of the common blocks include fear of the unknown, fear of failure, reluctance to exert influence, frustration avoidance, resource myopia, custom boundedness, reluctance to play and let go, impoverished emotional life and over-certainty (Christiano &Ramires, 1993).

As creativity has been defined in various ways in literature, in the present study creativity was defined as the knowledge of an R&D scientist, displayed in the form of creative output, such as publications of scientific papers, oral presentations, patents, development of new instruments and products.

2.Aims Of The Study

The study was conducted with the aims to determine (a) gender differences in scientific creativity (b) discipline-wise differences in scientific creativity (c) differences in manifestation of scientific creativity among various age-groups (d) barriers to scientific creativity.

3.Method

Sample: R & D scientists from University and Institutes of India comprised the sample (N=100, men=68, women=32). The age of the scientists ranged from 25-55 years with a mean age of 36 years. The minimum qualification of the scientists was Post Graduation and maximum Ph.D. (mean education=19 years). These scientists worked for different R&D organizations situated in Northern and Southern parts of India. Major disciplines represented by the scientists were (a) Engineering and computer sciences and (b) Physical, chemical and life sciences.

Creative and less creative scientists were delineated on the basis of the ratings of the judges, on a scale of 1 to 5, with 1 denoting least creative and 5 denoting most creative. Three judges, who had more than 20 years of experience, rated the creativity of scientists on the following information provided to them (a) the awards, medals and honours won by the scientist, (b) number of completed projects to his credit, (c) number of ongoing projects to his credit, (d) number of publications, both national and international, (e) number of oral presentations, both national and international, (f) number of patents, both national and international, (g) number of new instruments/ methods/ systems developed.

Correlations between the judges' ratings were calculated for finding the internal consistency of the measure. The ratings of the judges were further validated by comparing the ratings with the grades obtained by the scientists on Torrance Tests of Creative Thinking.

4.Measures

Socio-demographic data sheet (prepared by the researcher): A data sheet for ascertaining the particulars of scientists, like their name, age, gender, marital status, number of children, type of residence, hobbies, educational qualification, area of specialization, year of joining organization, number of promotions received, significant professional achievements in terms of awards, medals and honours, significant scientific achievements during the last three years, like number of ongoing and completed projects, number of Indian and US patents granted, number of publications in National and International journals, number of oral presentations, both National and International, new instruments/ methods/compounds developed and number of training programs developed.

Barriers to creative thoughts at the workplace: prepared by the scholar. 100 male and female scientists were contacted and asked to write the various barriers (both personal and organizational) encountered by them at the workplace that prevents them from producing creatively. The list of barriers was thereafter categorized. 18 factors emerged as prominent ones out of a list of 30 factors. Each factor, included in the scale was followed by a response category of "Yes" and "No".

Torrance tests of creative thinking, verbal and figural (Torrance, P.E., Ball, O.E., Safter, 1965): helps in understanding the constellation of general mental abilities that is responsible for creative achievements. It has two forms: figural and verbal. This test was selected for determining the type of abilities: convergent, divergent or associational that are involved in the process of creativity, specifically of a creative scientist.

5.Procedure

Scientists from various disciplines were contacted following the procedure of stratified random sampling. Stratification was done for discipline, gender and age of scientists. Scientists were selected from physical, chemical, life sciences, computer science and engineering disciplines from various Universities and Institutes of India. In all, 150 scientists were contacted. Only 100 completed the questionnaires fully. Therefore, data

of only 100 scientists was taken into consideration. They were further categorized into three age groups: 25-35 years, 36-45 and 46 to 55 years.

These 100 scientists were further categorized into most and least creative on a five point continuum, with 1 denoting least creative and 5, most creative. The categorization was done by three experienced scientists above the age of 55 years, for the productivity of each scientist i.e., the number of awards, medals and honours won by him/her, number of completed and ongoing projects, number of national and international publications, number of patents filed-both national and international, number of oral presentations, national and international, number of new products, systems and methods developed.

6.Statistical Analysis

Descriptive statistics like mean, SD were used and group comparisons using t-test was computed for finding differences between creative and less creative scientists in terms of gender, age-group and discipline. The SPSS package (Version 16) was used for analyzing the data. Analyses were also carried for the types of barriers encountered at the workplace by finding the percentage of scientists who experienced each of the eighteen factors listed as barriers to creativity at the workplace. Multiple regression analysis was computed for finding the predictors of scientific creativity.

7.Results

Gender	**N**	**Mean (creativity score)**	**S.D.**	**t**	**P value**
Men	68	2.18	0.94	0.28	0.78 ns
Women	32	2.12	1.04		

Table 1: Gender Differences In Creativity Of R&D Scientists

The difference between men and women scientists was non-significant.

Age group	N	Mean creativity score	S.D.	t	P value
25-35	43	2.01	0.88	0.77	0.44
36-45	30	2.18	0.98	0.71	0.14
46-55	27	2.38	1.06	1.49	0.48

Table-2: Differences in creativity between the young, middle and senior group of Scientists

Dependent Variable: Creativity Score

Age differences between the young, middle and senior group of scientists on creativity revealed non-significant differences.

Discipline	N	Mean creat. Score	S.D.	t	P value
PCL	58	2.33	0.99	2.09*	0.03
EC	42	1.93	0.89		

Table 3: Differences in creativity between the physical, chemical and life scientists and engineering and computer scientists

*(Note: *p<0.05, PCL= Physical, Chemical & Life Sciences, EC.= Engineering & Computer Sciences)*

Significant differences were obtained on creativity scores of physical, chemical and life sciences scientists vis-à-vis engineering and computer scientists.

Model	Variables entered	R	R2	Adjusted R2	F	Unstand.coeff. B	Stnd. E
1	PINJ	0.54	0.33	0.101	12.06**	1.97	0.106
2	PINJ &Edu Q	0.74	0.42	0.157	10.10**	-.791	1.02
3	PINJ, Edu Q &Hons	0.85	0.47	0.197	9.01**	-.548	1.00

Table 4: Stepwise Multiple Regression Analysis

*(Note: **p<0.01, PINJ= Publication in International Journal, Edu Q= Educational Qualification, Hons.= Honours)*

Note: Predictors in the model (Constant)

- Predictors in the Model: PIJ
- Predictors in the Model: PIJ & Edu Q
- Predictors in the Model: PIJ, Edu Q, Hons.
- Dependent Variable: Creativity Score

Name of Barrier	% Reported by Scientists	Name of Barrier	% Reported by Scientists
Bureaucratic structure	65	Conformity Pressures	32
Short-sightedness of authorities	55	Expectation to behave in a non-innovative way	30
Non-supportive office policies	55	Fear of Criticism	30
Lack of Infrastructure	55	Fear of taking risks	28
Shortage of manpower support	50	Fear of Superiors	27
Non-academic atmosphere in office	40	Shaky self-confidence	25
Favouritism	40	Fear of failure	25
Being low in the hierarchy	40	Fear of Rejection	23
		Fear of being different	20

Table 5: Scientists' perceptions regarding barriers to creativity at workplace

Stepwise multiple regression analysis was computed in order to determine the variables which contributed significantly to creativity of scientists. Publication in national journals contributed to 33% of the variance in creativity scores, publication in national journals and educational qualification together contributed to 42% of the variance in creativity scores. Publication in National journals, educational qualifications and Honours, all three together contributed to 47% of the variance in creativity scores.

Bureaucratic structure was the barrier that was perceived most by the scientists (65%), followed by short-sightedness of authorities (55%), non-supportive office policies (55%)

and lack of infrastructure (55%). Personal barriers like timid nature of self (20%) and fear of being different (20%) were reported least by most of the scientists as barriers to creativity at the workplace.

8.Discussion

In the present study, women scientists were found to be more creative than men. Women scientists form a very small proportion of women in India and also a minor proportion of all working women. Although creativity for females means diversified activities, at the scientific front, lady scientists have managed to remain at par with the men folk. Many lady scientists have started contributing significantly in the scientific field. As opposed to past, when societal constraints were there, women of the twentieth century are encouraged to engage in intellectual pursuits by their families. The once dichotomous division of the sexes at the social, intellectual and political front has been fading fast. Although faced with family responsibilities, their load is being shared by men nowadays. Their families have become supportive and even their spouse, both at the educational and emotional front.

Age differences between the young, middle and senior group of scientists on creativity revealed non-significant differences (Table-2). This shows that creativity does not decline with an increase in age and has no bearing on the creativity of scientists as far as creative scientific output is concerned. The obtained results reveal that with an increase in experience, the scientists tend to contribute more (although the differences are non significant). They are in better control of the facilities needed for making contributions. Their greater number of years of service enables them to have a wider perspective of knowledge in their respective fields. The junior scientists have not yet mastered their subject well enough to make meaningful contributions. Training and experience are needed to channel their creative potential into creative productions. The findings are in line with the empirical and theoretical literature, which says that a pessimistic conclusion about creativity declining with increasing age is unjustified (Csikszentmihalyi, 2003; Dennis, 1966; Simonton, 1991). Moreover, different creative disciplines exhibit distinct age functions (Adams, 1946; Diamond, 1986) e.g., applied mathematicians normally peak later in their careers than do pure mathematicians. Two disciplines may have identical ideation rates but disparate elaboration rates, or vice versa (Simonton, 1989). Some scientists may have original ideas more quickly than the others but fail to publish it

fast. The decline also varies from discipline to discipline (Dennis, 1966; Lehman, 1953). These interdisciplinary contrasts were not calculated in the present study.

Creative productivity in R&D is the result of teamwork where usually the senior most scientists take the lead. The young scientists are still in the learning phase and it takes time for them to come up with a novel idea that they can translate into reality. Thus, despite being the fact that they have lots of ideas, enthusiasm and zeal, they cannot publish without the supervision of senior scientists who are relatively more experienced.

Significant differences were obtained on creativity scores of physical, chemical and life sciences scientists vis-à-vis engineering and computer scientists. The former were found more creative than the latter (Table-3). R&D includes both basic and applied research. The scientists who belong to the pure sciences do more of basic research as opposed to computer and engineering scientists who carry out applied research. The former are more product oriented than the latter. Their sole aim is to produce and publish. The computer scientists also make significant discoveries but they are less interested in publishing their facts. Their products are more user-oriented. This may be one reason for the differences on creativity scores. The latter group contained more of young scientists who had not established themselves fully. They have yet to contribute in the scientific community. Their nature of work is more product-based and they have to put in number of years of research for developing a product.

Creativity in engineering is the mental process of conceptualizing and evolving a design. For being creative, the engineers need to innovate, to explore new paths towards better solutions of engineering problems, make use of new scientific advances and exploit new tools that are becoming available (Sen Gupta, 1984). Creative engineers should be able to explore and scrutinize the available data and generate novel solutions (Guilford, 1967). Today our engineering education emphasizes mastery of the known. Great stress is laid on the evaluative behaviour of judging critically what is wrong.

9.Conclusion

On the basis of overall results it can be concluded that:

(1) There are no gender differences in creativity score of scientists but still women have not been able to reach the glass ceiling as far as R&D in science is concerned. (2). There are no significant age differences in creativity of R&D scientists. There is a trend of greater productivity with an increase in age (although the differences are not significant). (3). Discipline-wise differences exist on creativity of R&D scientists. The physical,

chemical and life scientists are more productive /creative as compared to engineering and computer scientists, (4) Barriers reported by scientists pertained to the organizational front.

The study has certain limitations:

- A cross-sectional design was followed which did not allow to study the exact way in which creativity unfolds itself in the career of a scientist.
- The sample did not contain equal number of women scientists as compared to men.
- There was great variation in the productivity of scientists, with some of them contributing significantly and others very sparsely, which could have vitiated the obtained findings.
- The ratings of judges were used as the criteria for determining the productivity of scientists. The productivity of a scientist was taken on the basis of his response. It was not confirmed through other sources.

Future research is needed to determine the exact way in which creativity unfolds in the career of a scientist and what are the factors that facilitate and inhibit it. This is possible by undertaking more of longitudinal research. The cultural factors should also be taken care of. Establishment of an objective criterion for assessing creativity of a scientist, both at individual and at group level is needed. Moreover, confirmation of productivity/ creativity of a scientist through other sources should also be adhered to. Psychologists need to come up with more recent theories of creativity, particularly scientific creativity. This would prove very beneficial in carrying out researches on creativity of scientists where one is clear as to what constitutes scientific creativity.

10.Reference

1. Adams, C.W. (1946). The age at which scientists do their best work. Isis, 36, 166-169.
2. Ajzenberg-Selove, F. (1994). A matter of choices: Memoirs of a female physicist. Brunswick, NJ: Rutgers University Press.
3. Axelrod, T. (1988). Patently successful. Ms., 16(10), 44-45.
4. Busse, T.V. & Mansfield, R.S. (1984). Selected personality traits and achievement in male subjects. The Journal of Psychology, 116, 117-131.
5. Callahan, C.M. (1979). The gifted and talented,.Chicago, National Society for the Study of Education, 421-423.
6. Cristiano, S.J.E. & Ramires, M.R. (1993). Creativity in the classroom: special concerns and insights, in Frontiers in Education Conference, IEEE, Washington DC.
7. Csikszentmihalyi, M. (2003). The domain of creativity. Runco & Albert Eds.
8. Encyclopedia of Creativity.
9. Davis, S & Palladino, J.J. (2000). Psychology. Prentice Hall, New York.
10. Dennis, W (1966). Creative productivity between the ages of 20 and 80 years. Journal of Gerontology, 21, 1-8.
11. Diamond, A.M., Jr. (1986). The life cycle research productivity of mathematicians and scientists. Journal of Gerontology, 41, 520-525.
12. Feist, G.J. & Barron, F. (2003). Predicting creativity from early to late adulthood. Intellect, potential and personality, Journal of Research in Personality, 37, 62-88.
13. Fulton, O. & Trow, M. (1974). Research activity in American higher education. Sociology of Education, 47, 29-73.
14. Guilford, J.P. (1967). The nature of human intelligence. Mc Graw Hill, New York.
15. Lehman, H.C. (1953). Age and achievement. Princeton: Princeton Univ Press.
16. Ochse, R. (1991). Why there were relatively few eminent women creators? Journal of Creative Behaviour, 25 (4), 334-343.
17. Park, J. & Kim, I. (2004). Classification of students' observational statements in Science. In Progress in Education Research, New York: Nova Science Publishers, Inc.
18. Piirto, J. (1991). Why are there so few? (Creative women: Visual artists, mathematicians, musicians). Roeper Review, 13, 14

19. Reis, S.M. (1999). Women and Creativity. Encyclopedia of Creativity, Vol. 2, Academic Press.
20. Sen Gupta, M. (1984). Psychology of Engineering Creativity. Cosmo Publications, New Delhi.
21. Simonton, D.K. (1989). The swan song phenomenon: last work effects for 172 classical composers. Psychology & Aging, 4, 42-47.
22. Simonton, D.K. (1991). Career landmarks in science conferences and interdisciplinary contrasts. Development, 27, 119-130.
23. Stoltzfus, G., Nibbelink, B.L., Vredenburg, D. & Thyrum, E. (2011). Gender, gender-role and creativity. Social Behaviour and Personality, 39 (3), 7.
24. Torrance, E.P. (1965). Rewarding Creative Behaviour Experiments in classroom creativity. Englewood Cliffs. New Jersey, Prentice Hall.