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THE MAKING OF SCIENTISTS: A REVIEW OF STUDIES

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This study is an attempt to identify psychological characteristics of the typical scientist. It is a review of fairly recent researches. From the review it appears that, in general, scientists have high intelligence and visuospatial abilities, are critical thinkers, creative, objective in approach, curious and motivated, introverted in social interactions and unconventional. This study will help in identification and nurture of scientists of the future.

Introduction

Understanding the importance of STEM education, in India, Science is ordinarily a compulsory subject in school till the Secondary level of education. At the Higher Secondary level Science may be studied by choice. The Science pass-outs of the Higher Secondary level may take up any subject in Science at the Undergraduate level and then go on to the Post-Graduate level followed in some cases by Doctoral work. At the same time after Higher Secondary level there are some students who branch out into Technology, Engineering, Medicine, Pharmacy and Mathematics education. STEM education in all its forms nurtures scientists.

Scientists are treasured by every society. Selection of appropriate persons for scientific work is useful for advancement of science. The characteristics of a scientist is often a matter of speculation. Comprehensive treatment of the "nature" of scientists are rare. Piecemeal work focusing on one or two traits of scientists abound. But understanding the network of relationships among different characteristics of typical scientists prompted this review of pertinent (often piecemeal) treatments. It is hoped that this study based on more recent research will help us familiarize ourselves about the traits of scientists in general. The characteristics of scientists evidenced in research are the following:-

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Cognitive Characteristics

Intelligence : It is widely known that scientists have high intelligence but it still merits research.Charlton[1] reiterated the fact. He was supported by recent findings by Kaufman et al.[2] and Sato[3] among others. Halpern et al.[4] had earlier spoken of abstract intelligence, numerical abilities and visuospatial abilities in connection with high attainment in science. Scientists are regarded as rational when they select a theory more precise than all the others[5]. This is endorsed by most recent research finding which say that logic is twined with science[6].

Criticality and Creativity

The nature of science is such that its theorists and practitioners (be it students or scientists) have to think critically[7,8,9]. Creativity is as important as science itself because the former drives the latter. According to authors in STEM education, scientists produce creative and workable ideas and practices for the advancement of knowledge and technology. These ideas are creative to the extent that these are original and socially useful[2,3,10-14]. A study has stressed on the originality, knowledge generation and comprehension aspects of science[15]. At the root of all ideas critical and creative is cognitive flexibility[16].

Visuospatial Ability

It has been opined that visual spatial thinking encompasses volitional developing of mental imagery[17].

Halpern et al. gave examples of visuospatial abilities necessary for success in science. The examples, in brief, are visualizing data and models as well as converting words into visuospatial formations[4]. It has been stated that visual aids to understanding scientific concepts help scientists communicate and think about complexities in science[18]. Similarly findings from a longitudinal study say that space related capability has an important role in developing proficiency in science and technology as well as mathematics[19]. Visuospatial ability evidently has important contribution in learning and problem solving in Chemistry, Physics, Geology and Geography[20-23].

Noncognitive Characteristics

Big Five Personality Factors: The Big Five factors are Openness to Experience, Conscientiousness, Extroversion, Agreeableness and Neuroticism. According to this formulation individuals scoring high on Openness to Experience are imaginative, creative, original, curious and liberal while the low scorers are down-to-earth, uncreative, conventional, uncurious and conservative. People scoring high on Conscientiousness are conscientious, hardworking, well organized, punctual, ambitious and persevering, low scorers are negligent, lazy, disorganized, late, aimless and non-persistent. Persons who are high on Extroversion are affectionate, talkative, active, fun-loving and passionate whereas those with low scores are reserved, quiet, passive, sober and emotionally unreactive. Those persons high on Agreeableness are soft-hearted, trusting, generous, acquiescent, lenient and good-natured, persons scoring low are ruthless, suspicious, stingy, antagonistic, critical and irritable. People scoring high on Neuroticism are worrying, temperamental, self-pitying, self-conscious, emotional and vulnerable, those persons who score low are calm, even-tempered, self-content, comfortable, unemotional and hardy[24,25]. After a large scale study on 2015 scientists and 78,753 nonscientists it was reported that the scientists were more open, less conscientious, lower on emotional stability and extraversion[26]. Sato in 2016 similarly reported that a sample of scientists were more open (e.g. more curious) and self-directed as manifested through creativity and autonomy[3]. This has received support from another study with the Big Five. It has been found in that study that the participants in international science competitions and nonparticipants differed in investigative, social enterprising and networking activities[27]. In 2020 Meyer-Rochow counted curiosity, enthusiasm and perseverance among qualities necessary to become a scientist[28].

Curiosity and Motivation

In a similar vein, it has been reported that curiosity, enjoyment of problem solving and independence are among the characteristics of future research scientists[29].

It has been opined that intellectual curiosity drove scientific revolution in the Western world[30]. It was contended that curiosity drives research particularly in science[31]. It has been opined by Jirout in 2020 that children are curious and their curious questioning helps develop thinking and motivation needed in science[32]. It has been found that scientists in a state run research institute were intrinsically motivated, they were not motivated by extrinsic rewards like pay rise[33]. Another study found scientists participating in a science fair to be motivated by the urge to popularize science. The senior scientists also felt a sense of duty while the juniors experienced satisfaction and joy[34]. In 2020, a representative sample of Americans,were respondents in a study to find out public perception of scientists' work. It was reported by the authors that intrinsic rewards (e.g. helping society and people) rather than extrinsic ones motivated typical scientists[35].

Unconventionality

It has been reported that more creative scientists were less conventional than those who were deemed less creative[36]. According to an author, as a person a scientist could be rational but be unconventional for the scientific community[37]. It was noted by researchers that even for getting financial sponsorship for unconventional investigations scientists were compelled to present unconventional ideas in conventional usage[38]. Similarly, interdisciplinary scientists reduce professional hazards associated with unconventional work by display of proficiency and dedication[39].

Objectivity

Science has to be objective in epistemic terms i.e value neutral. The echelon of science is its precision. But

Table 1: Cognitive Characteristics of An Ideal Scientist

High on Abstract Intelligence
High on Numerical Ability
High on Visuospatial Ability
Rational
Logical
Critical Thinker
Creative

social constraints have to be looked into. Moral values are also to be considered (*for example ethical treatment of study animals*). Scientists are therefore in a dilemma over which value (epistemic or nonepistemic i.e. social) to give importance to. They usually pay more attention to epistemic ones but can not ignore the social values[40,41,42].

Table 2: Non-Cognitive Characteristics Of An Ideal Scientist

Open to experience (e.g. Curious)
Motivated
Persevering
Unconventional in ideation
Objective

Conclusion

The present review reveals interrelationships or coexistence of psychological characteristics of the typical scientist. Abstract intelligence, mathematical ability and visuospatial abilities go together[4]; critical and creative thinking are based on cognitive flexibility[16]; unconventionality in thinking and creativity coexist[36]; openness to experience and motivation are tied with curiosity[3,28] etc.

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