Malaysian Journal of Library & Information Science, Vol.9, no.1, July 2004: 83-99

EPONYMOUS CITATIONS TO HOMI JEHANGIR BHABHA*

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ABSTRACT

The epoch-making research by H. J. Bhabha has gained eponymous status synonymous with his name and international fame. Out of the 427 eponymous bibliographic records for H. J. Bhabha retrieved from the Science Citation Index (1982-2002), majority of the records were for: bhabha scattering (290), angle bhabha scattering (42), small angle bhabha scattering (21), radiative bhabha scattering (17), large-angle bhabha scattering (16), resonant bhabha scattering (12), and low-angle bhabha scattering process (10). Percentage scattering of the eponyms in various bibliographic zones were: KeyWords Plus (47.16%), Abstract (26.79%), Title (22.75%), and Author keywords (3.3%). Based on terminological similarities of the eponyms, 19 clusters were formed. The keyword 'photon corrections' occurred in eight clusters whereas 'bhabha scattering', 'cross section(s)', 'gauge-theories', 'high-energies', and 'multiple bremsstrahlung' each one was common to seven clusters. Content analysis based on the presence of keywords among the clusters using number of common keywords was attempted as a pilot study and depicted as a dendrogram. Non-Indexed Eponymal Citedness (NIEC) is a significant phenomenon that should not be neglected while documenting the citations to an individual scientist.

Keywords: H. J. Bhabha; eponymous citations; non-indexed eponymal citedness; NIEC; eponyms; citation analysis; bhabha scattering; angle bhabha scattering; cluster analysis; dendrogram; Treecon.

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*This paper is dedicated to the reminiscences of Homi Jehangir Bhabha during Golden Jubilee of the Department of Atomic Energy (India).

INTRODUCTION

Eponym is the "practice of affixing the name of the scientist to all or part of what the scientist has found" (Thomas, 1992). A law, theory, theorem, hypothesis, principle, rule, formula, equation, etc. named after a person is called 'eponym' (Kalyane and Kadam, 2002). Science literature is replete with the eponyms for name(s) of inventor(s). The scientists associated with eponyms are known as eponymous scientists.

MATERIALS AND METHODS

CD-ROM version of *Science Citation Index (SCI)* 1982 – 2002 published by the Institute for Scientific Information (ISI) was used for the present pilot study on H. J. Bhabha. The bibliographic data was retrieved as follows:

a) Author/cited author bibliographic zone was searched for citations received for Homi Jehangir Bhabha. Input variants of a scientist's name in a database are very important. 'BHABHA' was used as the search term because 'bhabha' appears in various forms in *SCI:* BHABHA MJ, BHABHA HB, BHABHA HJH, BHABHA JJ, and BHABHA H. In one of the records it was even misspelt as BAGHA. Each of the retrieved records was scanned to confirm that it belongs to Homi Jehangir Bhabha. A total of 242 bibliographic records having explicit citations were related to him.

b) The Basic Index of *SCI* includes bibliographic zones: Title, Keywords (Author keywords, KeyWords Plus), and Abstract, which were searched for the term 'bhabha'. Each bibliographic record was scanned for any eponymal forms related to the work of Homi Jehangir Bhabha. Total 427 such eponymous bibliographic records related to him were included in the present study.

c) Author keywords and KeyWords Plus were merged while documenting frequency of keywords.

d) Based on terminological similarities among the eponyms, clusters were delineated.

e) Keywords common to at least three eponymous terminological clusters were used for depicting association (of thought contents of the documents having eponyms) between and among clusters, in a dendrogram using 'Treecon' software (Van de Peer, 1994-2001).

RESULTS AND DISCUSSION

Fifty-nine distinct eponyms for Bhabha were identified (Table 1) and sorted, according to their terminological similarities, into 19 clusters designated as C1 to C19. The total frequency and percentage of the 59 eponymal forms occurring in the various bibliographic zones were: KeyWords Plus 257 (47.16%), Abstract 146 (26.79%), Title 124 (22.75%) and Author keywords 18 (3.3%). But for the KeyWords Plus, which was introduced by the ISI in 1991, most of the eponymal bibliographical records would not have been retrieved.

H. J. Bhabha was well known for Bhabha-Heitler Theory (Venkataraman, 1994), also called as Bhabha-Heitler Cascade Theory, and another eponym Bhabha-Corben Theory of Relativistic Spinning Point Particles for which no bibliographic records were retrieved (obsolescence of the usage of eponyms) in the present study.

Figure 1 indicates number of *SCI* bibliographic records in the seven most frequently occurring eponymal phraseology for H. J. Bhabha: bhabha scattering (290), angle bhabha scattering (42), small angle bhabha scattering (21), radiative bhabha scattering (17), large-angle bhabha scattering(16), resonant bhabha scattering (12), and low angle bhabha scattering (process) in 10 records. 'Bhabha scattering' is the broad term for the phenomenon.

Figure 2 depicts year-wise number of bibliographic records for the topmost five eponymal forms referring to Homi Jehangir Bhabha. These eponymal forms used even today indicate the current relevance of his research (Appendix).

There were 237 distinct keywords. Most prolific 22 keywords, which were common to at least five clusters, are represented in Table 2 by bullets in the corresponding eponymous terminological clusters. Twenty-nine keywords, which were common to at least four eponymous terminological clusters, are represented in Table 3.

Table 1: Bhabha as an eponym in the number of *SCI* bibliographic records (1982 - 2002) and its occurrence in the various bibliographic zones

Clust-ers	Eponyms referring to research by H. J. Bhabha	No. of Records	Bibliographic zones			
			Abs	Ti	AK	KWP
C1	bhabha scattering	290	45	52	9	206
C1	bhabha cross section	5	4	0	1	0
C1	bhabha scattering cross section	3	2	1	0	0
C1	bhabha scattering events	3	3	0	0	0
C1	bhabha events	3	3	0	0	0
C1	bhabha scattering process	2	2	0	0	0
C1	bhabha scattering resonance	1	0	1	0	0
C1	bhabha inelastic data	1	1	0	0	0
C2	angle bhabha scattering	42	0	0	0	42
C2	small and large angle bhabha scattering	2	2	0	0	0
C3	low angle bhabha scattering (process)	10	7	7	0	0
C3	small angle bhabha scattering	21	13	10	3	0
C3	small angle bhabha scattering cross section	6	4	2	0	0
C3	small angle bhabha process	2	2	0	0	0
C3	small angle bhabha and quark-electron scattering	1	0	1	0	0
C3	small angle radiative bhabha scattering	1	1	1	0	0
C3	small angle bhabha calculation	1	0	1	0	0
C3	small angle bhabha events	1	1	0	0	0
C4	large-angle bhabha scattering (process)	16	11	10	0	0
C4	wide angle bhabha scattering	4	4	2	1	0
C4	large angle bhabha events	1	0	1	0	0
C5	radiative bhabha	1	0	0	1	0
C5	radiative bhabha scattering	17	7	11	3	3
C5	radiative bhabha and quasi-real compton scattering	1	1	1	0	0
C5	radiative large angle bhabha scattering process	1	1	0	0	0
C5	radiative wide angle bhabha events	1	0	1	0	0

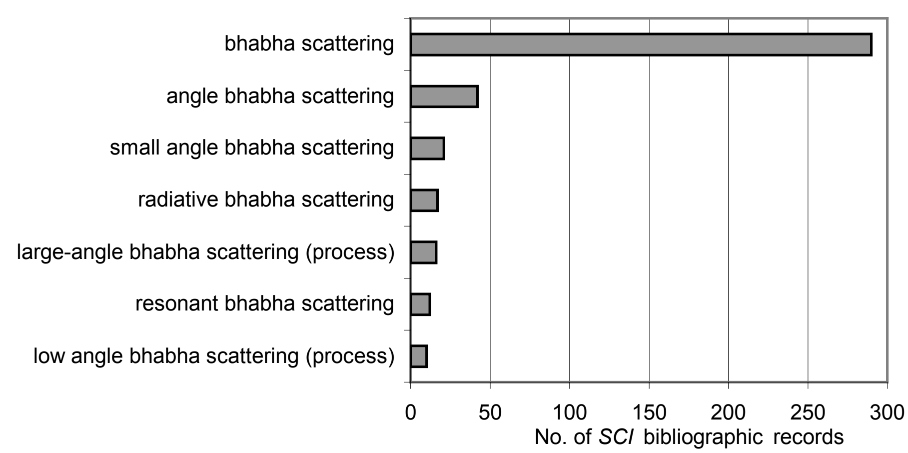
continued

(continuation of Table 1 next page)

Clust-ers	Eponyms referring to research by H. J. Bhabha	No. of Records	Bibliographic zones			
			Abs	Ti	AK	KWP
C6	resonant bhabha scattering	12	2	4	0	6
C7	bhabha and moller* scattering	5	5	0	0	0
C7	moller and bhabha scattering	3	2	1	0	0
C7	bhabha to moller cross-section	1	0	1	0	0
C7	moller-to-bhabha cross section	1	1	0	0	0
C8	bhabha equation	4	3	1	0	0
C8	half integer spin bhabha fields	2	0	2	0	0
C8	bhabha relativistic wave-equations	1	0	1	0	0
C8	bhabha-type equations	1	1	0	0	0
C9	bhabha process	3	2	2	0	0
C9	bhabha rate	1	1	0	0	0
C9	accidental bhabha coincidences	1	1	0	0	0
C9	bhabha acceptance	1	1	0	0	0
C9	bhabha bounds	1	1	0	0	0
C9	bhabha channels	1	1	0	0	0
C10	polarized bhabha scattering	3	0	3	0	0
C10	bhabha polarization scattering	1	0	1	0	0
C10	polarized bhabha and moller scattering	1	0	1	0	0
C11	bhabha moller polarimeter	1	0	1	0	0
C11	bhabha polarimetry	1	1	0	0	0
C11	new bhabha polarimeter	1	0	1	0	0
C11	bhabha spectrometry	1	1	0	0	0
C12	non relativistic bhabha first-order wave equations	1	1	0	0	0
C12	non relativistic bhabha-equations	1	0	1	0	0
C13	bhabha particle	1	1	1	0	0
C13	bhabha electrons	1	1	0	0	0
C14	bhabha-to-mott ratios	1	1	0	0	0
C14	moller-to-bhabha ratios	1	1	0	0	0
C15	high energy moller and bhabha scattering	1	0	1	0	0
C16	madhavarao-bhabha equation	1	1	0	0	0
C17	wide angle bhabha z physics	1	1	0	0	0
C18	wide angle bhabha monte carlo generators	1	1	0	0	0
C19	moller and bhabha collision cross-sections	1	1	0	0	0
	Total		146	124	18	257
	Percentage		26.79	22.75	3.30	47.16

(Abs= Abstract, Ti = Title, AK = Author Keywords, KWP = KeyWords Plus, and
*moller was misspelt as mailer in one *SCI* record)

Figure 1: High frequency eponyms referring to H. J. Bhabha in the *SCI* (1982 - 2002)



Ninety keywords (Tables 2-4) common to at least three eponymous terminological clusters (Table 1) were used to draw a dendrogram (Figure 3) using 'Treecon' software developed by Van de Peer.

Keywords (116) which were common to at least two clusters were: (un)stable w+w production; 2nd-order contributions; 2-photon processes; 2-photon production processes; 4-fermion processes; alpha(m-z(2)); angle bhabha scattering; arbitrary spin; backward asymmetry; boson decay-rate; boson mass; bounds; bremsstrahlung; calorimeter; carlo program koralz; cern pbarp collider; charge asymmetries; collider(s); collinear photons; construction; cross-section asymmetry; decays; deconvoluted and realistic observables; double bremsstrahlung; e(+)e(-) collisions; e+e-nu-nu-bar-gamma; e+e-physics; electromagnetic calorimeter; electron-positron scattering; emission; event generation; event selection; evolution; excited leptons ; exponentiation; extra dimensions; extrapolated and realistic experimental setup; fermion; final-states; forward-backward asymmetries; frautschi-suura exponentiation; generator; hadronic z-decays; hard; heavy top; helicity amplitudes; infrared and collinear divergences; initial-state radiation; interdependence; jet fragmentation; ladder-diagram contributions; language; large angles; lepton; light gravitino; light pairs; limit; linear collider; lowest-order calculations; lund monte-carlo; mediated supersymmetry-breaking; millimeter; minimal standard model; model; monte-carlo treatment; muon detector; narrow-peak structure; nnlo computations; number generators; opal jet chamber; p(p)over-bar collisions; perturbation theory; petra energies; photon production; polarized beam; pure weak corrections; qcd corrections; qed; qed radiative-corrections; quantum-chromodynamic corrections; radiation; radiative bhabha scattering; ratios; relativistic problems; resonant bhabha scattering; root-s=1.8 tev; root-s=161 gev; semileptonic neutrino scattering; singlet sector; slc; small angle bhabha scattering spectral structure; spin; square-root-s; state qed corrections; states; structure functions; supermultiplets; supersymmetric particles; supersymmetry; theoretical error; to-leading order; top quark; top-quark production; u+th collisions; w-boson mass; wide-angle bhabha scattering; w-pair production; yan cross-section; z(0) decays; z(0) peak; z0 region; z0 resonance; z-boson; z-line-shape; and z-peak.

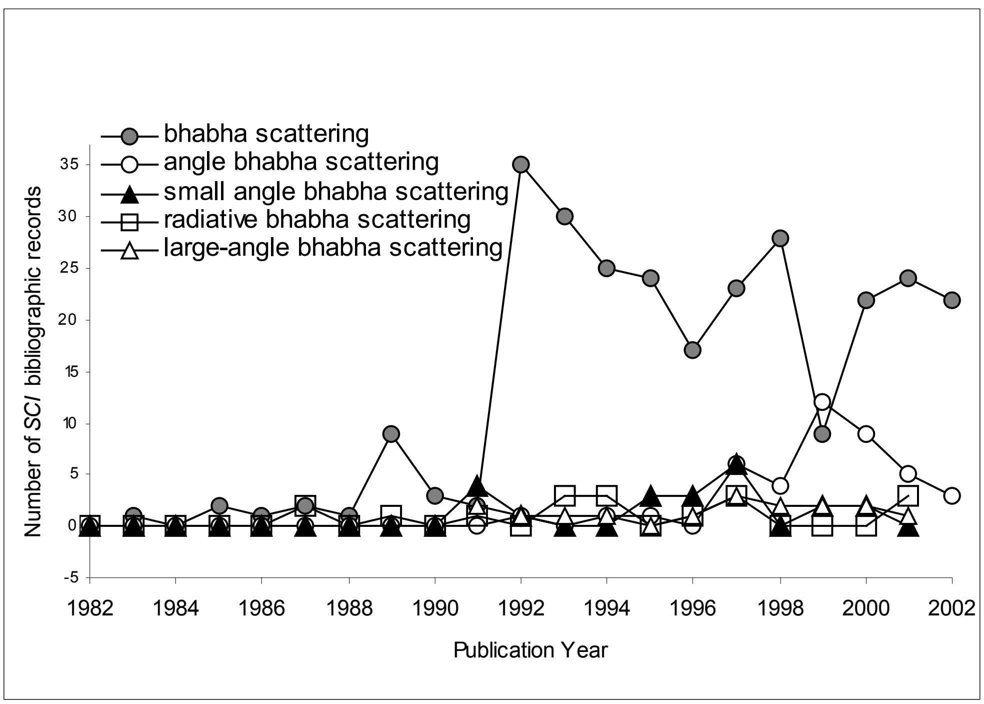


Figure 2: Year-wise number of bibliographic records for the topmost five eponymal forms referring to Homi Jehangir Bhabha

Table 2: Keywords from the bibliographic records common to at least five eponymous terminological clusters

Keywords	Eponymous terminological cluster numbers													
	C1	C3	C4	C2	C9	C5	C17	C6	C7	C18	C11	C13	C10	C14
photon corrections	•	•	•	•	•	•	•			•				
bhabha scattering	•	•	•		•			•			•	•		
cross-section(s)	•	•	•	•	•	•	•							
gauge-theories	•	•	•	•	•	•	•							
high-energies	•	•	•	•		•	•			•				
multiple bremsstrahlung	•	•	•	•	•	•	•							
e+e annihilation	•	•	•	•	•							•		
event generator	•		•	•	•	•	•							
fermion pair production	•	•	•	•	•		•							
radiative corrections	•	•	•	•	•		•							
scattering	•	•			•	•		•		•				
soft photons	•	•	•	•	•				•					
annihilation	•	•	•	•	•									
da-phi-ne	•	•	•		•	•								
electron-positron collision	•	•	•	•	•									
LEP	•	•	•	•									•	
LEP energies	•	•	•	•	•									
monte carlo	•	•	•	•	•									
monte-carlo program	•	•		•	•		•							
pair	•	•	•	•		•								
program	•	•	•	•					•					
search	•							•	•		•			•

(Presence of the keywords in a terminological cluster is represented by bullet)

Table 3: Keywords from the bibliographic records common to at least four eponymous terminological clusters

Keywords	Eponymous terminological cluster numbers											
	C1	C3	C4	C9	C2	C13	C5	C7	C10	C6	C11	C14
angle	•			•				•	•			
cmos signal processor	•	•		•		•						
collisions	•	•			•						•	
deep-inelastic-scattering	•		•	•	•							
e(+)e(-) annihilation	•		•		•		•					
e+e collisions	•		•		•		•					
electroweak	•		•	•				•				
electroweak parameters	•	•		•		•						
energies	•	•			•				•			
hard photon corrections	•	•	•		•							
inclusive muon production	•	•		•		•						
large momentum-transfer	•	•	•				•					
lepton pair production	•		•		•		•					
low angles	•	•	•	•								
low-noise	•	•		•		•						
microvertex detector	•	•		•		•						
monte-carlo approach	•		•	•	•							
one-loop corrections	•		•	•	•							
opal detector	•	•		•		•						
order radiative-corrections	•	•	•		•							
pair production	•	•	•		•							
photons	•	•	•	•								
positron-electron scattering	•							•		•		•
qcd jets	•		•	•	•							
qed vacuum polarization	•		•		•		•					
single bremsstrahlung	•	•	•				•					
small-angle	•	•		•		•						
soft	•	•	•		•							
total cross-section	•	•		•		•						

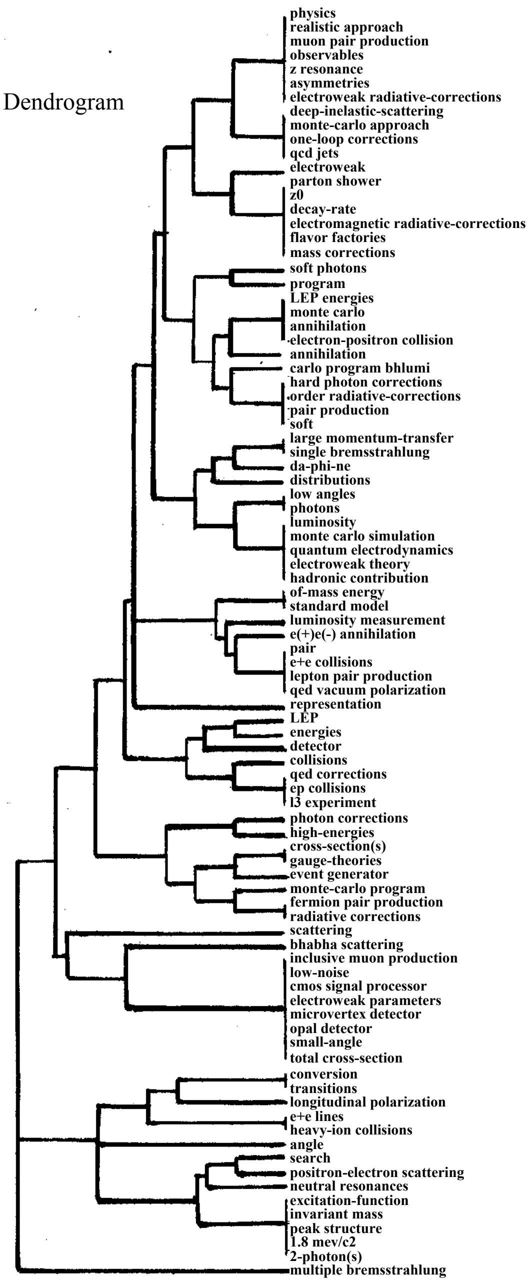
(Presence of the keywords in a terminological cluster is represented by bullet)

Table 4: Keywords from the bibliographic records common to at least three eponymous terminological clusters

Keywords	Eponymous terminological cluster numbers											
	C1	C4	C2	C3	C9	C14	C7	C6	C5	C11	C10	C8
1.8 mev/c2	•					•	•					
2-photon(s)	•					•	•					
asymmetries	•	•	•									
carlo program bhlumi		•	•	•								
conversion	•							•		•		
decay-rate	•	•			•							
detector	•		•								•	
distributions	•			•					•			
e+e lines	•				•			•				
electromagnetic radiative-corrections	•	•			•							
electroweak radiative-corrections	•	•	•									
electroweak theory	•	•		•								
ep collisions	•		•	•								
excitation-function	•					•	•					
flavor factories	•	•			•							
hadronic contribution	•	•		•								
heavy-ion collisions	•				•			•				
invariant mass	•					•	•					
l3 experiment	•		•	•								
longitudinal polarization	•								•	•		
luminosity	•	•		•								
luminosity measurement	•				•				•			
mass corrections	•	•			•							
monte carlo simulation	•	•		•								
muon pair production	•	•	•									
neutral resonances	•					•		•				
observables	•	•	•									
of-mass energy	•		•						•			
parton shower	•	•			•							
peak structure	•					•	•					
physics	•	•	•									
qed corrections	•		•	•								
quantum electrodynamics	•	•		•								
realistic approach	•	•	•									
representation	•	•										•
standard model	•	•	•									
transitions	•							•		•		
z resonance	•	•	•									
z0	•	•			•							

(Presence of the keywords in a terminological cluster is represented by bullet)

Figure 3: Dendrogram



Distance

The keywords (31), which were specific to only one cluster, were: anomalous magnetic-moment; art. no. 052001; beam modeling; bhlumi; box-diagram contributions; carlo event generator; coherent exclusive exponentiation; dafne; dose calculation; energy calibration; fermiophobic higgs; fermiophobic higgs bosons; hadronic z(0) decays; integrals; muon g-2; order qcd; photon transport; precision; qcd models; quantum chromodynamics; radiative bhabha; r-b; realistic observables; slc/lep; straggling; swift charged-particles; tagged photons; unstable heavy; vavilov distribution; z line-shape; and z-resonance parameters.

Table 5 is a matrix of the number of keywords that are common to the bibliographic records of various eponymous terminological clusters (Table 1). The eponymous terminological clusters C15 and C16 bibliographic records (one each) had no input of keywords, and C19 (one record) had no common keyword with any other cluster hence not included in Table 5. It is clear from this table that the terminological clusters C1, C2, C4, C3 and C9 are closely linked as compared to other groups because they share a fairly large number of keywords between them.

Table 5: Number of common keywords in the various terminological clusters of the eponymal bibliographic records referring to H. J. Bhabha

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C17	C18
C1	**215**	***98***	***64***	***79***	***26***	***11***	***14***	***1***	***43***	4	7	1	***10***	***10***	9	3
C2		**107**	***30***	***37***	***12***	0	2	0	***18***	4	1	0	1	0	9	3
C3			**67**	***33***	***11***	2	2	0	***26***	2	2	0	***10***	0	8	3
C4				**80**	***14***	1	3	1	***28***	1	1	0	2	0	8	2
C5					**29**	1	0	0	7	0	1	0	0	0	6	3
C6						**11**	2	0	4	0	4	0	1	3	0	1
C7							**14**	0	3	1	1	0	0	7	0	0
C8								**4**	0	0	0	0	3	0	0	0
C9									**43**	1	1	0	***10***	0	8	2
C10										**5**	0	0	0	0	0	0
C11											**7**	0	1	1	0	0
C12												**1**	0	0	0	0
C13													**13**	0	0	0
C14														**10**	0	0
C17															**9**	2
C18																**3**

A scientific research programme manifests itself in the form of a series of successively developed theories that have two elements in common: a hard core and a positive heuristic (Koester, 2002). The hard core consists of conjectures that are irrefutable within the program. The positive heuristic consists of rules that generate new and better theories within the programme. If new predictions are generated within the programme, that is called theoretical progress; if the predictions are confirmed, that is empirical progress.

SCI is a tool to determine number of citations received by a scientist. However, such citation analyses include only the references printed at the end of the text of the articles separated from the main body of the text. There are other citation typologies which are not taken into consideration for such citation analyses studies like citations appearing in the main body of the text, those appearing as footnotes and eponymal references. This type of uncitedness was recognized and accepted by E. Garfield himself as: it is easier for a physicist to achieve uncitedness of this type than for a biologist (Garfield, 1962-1973).

In the present paper we have studied the phenomenon of non-indexed eponymal citedness (NIEC). This concept refers to the appearance in scientific literature: a process, an instrument, a phenomenon which are linked with the name(s) of their creator(s) without any formal bibliographical reference. Cole and Cole (1972) have underestimated the significance of this phenomenon by stating that explicit citation is not necessary as, such scientists receive heavy citations anyway. Howeve, Szava-Kovats (1994, 1997) has shown that NIEC is a growing phenomenon and cannot be ignored. NIEC also affects obsolescence studies and eponym frequency increases with time (Pichappan and Sangaranachiyar, 1996).

H. J. Bhabha received 289 citations (in 242 records retrieved) during 1982 – 2002. But he received only 25 citations (in 427 records) retrieved with eponymal forms of Bhabha. Even considering one eponymous citation per record 402 eponymous citations to his credit would have remained unnoticed. Therefore total citations to his credit should have been at least 691 Bhabha had also received two citations in the Nobel lectures (Sen, 1969) by H. Yukawa in 1949 and P.M.S. Blackett in 1948 (Frangsmyr, 1993). This indicates relevance of his work. In addition to this, H. J. Bhabha has to his credit 131 classic-author synchronous self-references (Swarna, et al., in press) as noted from collection of his publications (Sreekanthan, et. al., 1985). It is necessary to complement eponymal citations to the indexed citations received by a scientist while evaluating his/her impact. *SCI* can fulfill this objective by including the eponyms in KeyWords Plus to enable the retrieval of such citations.

CONCLUSION

Eponyms confer recognition on a scientist. Hence when such scientists are being evaluated based on citation counts; eponymous citations too should be included. NIEC (non-indexed eponymal citedness) is a growing phenomenon. Systematic studies may prove just how significant this concept is in citation analysis. *SCI* can minimize this discrepancy by including the eponyms in KeyWords Plus. Standardisation of the eponymic vocabulary and its appropriate contextual usage, and of course error free inputs are called for to increase precision in retrieval and coherent cognition of the thought contents of the documents. Some complications encountered in this study were the variations in personal names (synonyms) and homonyms, where individuals share the same name and misspelt names. Analysts should be aware of these problems and understand the limitations of such studies based on citation counts alone.

ACKNOWLEDGEMENT

We wish to thank S. V. G. Menon, Theoretical Physics Division; T. Gopalakrishna and Anjali Bhagwat, Nuclear Agriculture & Biotechnology Division; and Manjula Mathur and Rita Mukhopadhyaya, Molecular Biology Division of the Bhabha Atomic Research Centre, for giving valuable suggestions.

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APPENDIX

Chronological Biobibliography of Research Publishing Career (1933–1954) of Homi Jehangir Bhabha

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