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## **INDIA'S COLLABORATION IN SCIENCE AND TECHNOLOGY WITH SOUTH EAST ASIAN COUNTRIES**

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### **ABSTRACT**

*The collaboration in science and technology (S&T) is fast emerging in the scientific world. India recognized the importance of international scientific collaboration in S&T quite early and has signed a number of S&T agreements with South East Asian countries. In this paper, the collaboration is presented through the analysis of co-authored research papers published during the period 1996 to 2000 in the journals covered by the Science Citation Index. The study covers the nature and the areas of S&T collaborations, institutions involved, and the impact of these collaborations on their individual fields. It is revealed that a total of 329 co-authored papers were published during the period. Out of these, 214 were published through bilateral and 115 through multilateral efforts. The priority areas vary with the nature of collaboration as well as with the collaborating country. The institutions involved in these collaborations are also indicated. The research papers analyzed reflect the present status of India's collaboration in S&T with the South East Asian countries. Such a study will help decision-makers to identify the potential S&T areas for future international cooperation.*

**Keywords:** S&T Collaboration, International Collaboration, India, South East Asian countries; Publication productivity, Scientometrics.

### **INDIA'S COOPERATION WITH ASEAN COUNTRIES**

The Association of South East Asian Nations (ASEAN) was established in 1967 and comprises Indonesia, Malaysia, the Philippines, Singapore, and Thailand. Brunei Darussalam joined the association in 1984, Vietnam in 1995, Laos and Myanmar in 1997 and Cambodia in 1999. It became a conglomerate of ten nations having a total population of 523 million (8.6% of world's population), and a total area of 4.5 million square meters. It has a combined GDP of USD737 billion with a total trade of USD720 billion per year. The ASEAN members range from some of the world's wealthiest nations to the least developed countries (LDCs).

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India has recognized international collaboration in S&T as a mechanism to (a) facilitate interaction among scientific researchers of various countries to update and refine their knowledge base, (b) develop advanced technologies, high-tech equipments and new materials for the economic growth of the participating countries, and (c) share scientific and technological capabilities among the participating countries. The existing mechanism of cooperation includes exchange of scientists as well as technical information; and conduct of joint training, research and development programs. At present, India's S & T collaboration with South East Asian countries is being undertaken through multilateral, regional and bilateral agreements (TAIFAC, 1995; *Science and technology*, 2001; *Joint statement...*, 2002; *Suggested remarks ...*, 2002).

**(a) Multilateral cooperation**

India's multilateral cooperation with South East Asian countries is undertaken under the umbrella of international cooperation, through the United Nation agencies, such as UNESCO, ILO, WHO, UNEP, FAO, UNIDO, IAEA and the World Bank.

**(b) Regional Cooperation**

India's S&T cooperation with ASEAN countries at regional level has made considerable progress in fields such as advanced materials, information technology, biotechnology, space technology and technology management. The ASEAN-India Working Group on Science and Technology constantly reviews the on-going cooperation and the Technology Information, Forecasting and Assessment Council (TIFAC), under the Department of Science and Technology, India has been coordinating India-ASEAN projects (*6<sup>th</sup> ASEAN Science and Technology week...*, 1998)

Under advanced materials research, two projects on "rare earths (NdFeB) permanent magnets" and "wear resistant coatings (surface engineering)" have been initiated on a cost-sharing basis. This involves bringing industry from both sides to commercialize the technology, possibly through joint ventures.

Under information technology, an "ASEAN-India Digital Archive Project" (AIDA) was completed in the first half of 1999 on a cost-sharing basis. The responsibility for the project was given to "ERNET India" under the Department of Electronics. This project has produced a multi-lingual, multi-cultural archive of fonts, texts, voice, pictures, video-clips of common words, phrases or events from India and the ASEAN member countries. These are made available to software developers, teachers, and students who may want to create multi-media presentations, animation and courseware. In the year 2000, the National Institute of Information Technology (NIIT), India, provided training programmes in advanced software techniques for 94 ASEAN scientists, indicating India's desire to share expertise in these areas (TAIFAC, 2000).

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In biotechnology, cooperation projects include plant and animal biotechnology and the establishment of an ASEAN-India Bio-informatics Network. In space technology, the areas identified for cooperation include capacity-building, training, exchange of scientists and use of Indian remote sensing data for environmental management. Other areas of cooperation includes, training courses at Indian institutions, expert study on human resource development, establishing linkages between Indian universities with the ASEAN university network, attachment of ASEAN students at Indian Institutes of Technology and organizing public lectures by Indian and ASEAN eminent personalities to strengthen economic, political, cultural and security ties (*Asean-India*, 2002).

#### **(c) Bilateral cooperation**

India has signed a number of bilateral agreements in S&T, in general as well as in specific fields with many of the South East Asian countries. With Malaysia, a memorandum of understanding (MOU) was signed between Antrix Corporation (the commercial wing of ISRO) of India and Maxstar, a private sector Malaysian consortium for assistance to Malaysia's micro-satellite program including hardware development, technical support and personnel training. A bilateral agreement on cooperation in the field of science and technology between India and Malaysia was signed in Kuala Lumpur in 1998 (*India Malaysia Relations [Discover India]*, Dec 2002).

A bilateral agreement between India and Singapore on S & T cooperation was signed in 1991, involving the setting up of joint working groups to promote ventures in the telecom sector, and establishing an India-Singapore Biotechnology Park in 2002. This park is expected to boost R&D and commercialization in areas as diverse as pharmaceuticals, agriculture, food, beverages, and environmental technology. Both the countries are also exploring the possibilities for exchange of scientists and utilizing facilities in the field of nuclear sciences (*Singapore India Business Forum [Discover India]*, April 2002).

Thailand-India bilateral cooperation programs in the field of S&T takes shape in the cooperation between Thailand Institute of Scientific and Technological Research and with the Asian Institute of Technology, both in Bangkok. Under this agreement technologies developed in the either country in such areas as pollution control, waste management and environment management will be mutually exchanged and joint R&D programs will be launched (*India Thailand pledge to boost ties [Discover India]*, 5 April 2002; *India Thailand to exchange ...*, 2002).

In the case of the Philippines, a bilateral agreement on scientific and technological cooperation was signed in 1987, followed by other MOUs on cooperation in the utilization of atomic energy for peaceful purposes (1991),

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agricultural science and technology (1991), renewable energy research (1996), and R&D on pharmaceuticals (1997). The cooperation in agriculture includes study visits, training, consultancy, joint research projects and transfer of technology (*Bilateral relations between India and the Philippines [Discover India]*, April 2002).

With Vietnam, India signed a bilateral agreement in 1976 and which was renewed in 1996. Under this agreement, a Joint Committee on Science & Technology was constituted in 1997 to oversee the implementation and progress of the collaboration. Cooperation was established in areas such as nuclear energy, agriculture, fisheries, animal husbandry, computer hardware, computer software (including applications), pharmaceuticals, remote sensing, water resources, biotechnology and information technology (*India Vietnam bilateral relations [Discover India]*, March 2002).

Indonesia and India agreed to a joint cooperation in S&T especially in the area of remote sensing as early as 1982. This collaboration gradually extended to areas such as space research, telemetry tracking command and network, peaceful uses of outer space, biotechnology, sources of renewable energy, medical sciences, science policy, science popularization, information technology, agriculture and marine sciences (*India Indonesia relations [Discover India]*, 27 April 2002).

India and Laos signed a memorandum of understanding on cooperation in the areas of agriculture and allied sectors. (*Lao People's Democratic Republic [Discover India]*, September 1998).

India's collaboration with South East Asian countries has led to joint co-authored publications, which helps to map India's relationship with different South East Asian countries, as well as their impact on the development of different S&T fields. A number of studies had investigated the linkages of Indian S&T fields with partner countries (Nagpaul, 1999; Basu and Vinu, 2000). However, most fail to analyze collaboration profile at bilateral and multilateral levels with different countries or regions. The present study attempts to reveal the status of the India's collaboration with the South East Asian countries, based on joint publications.

## **OBJECTIVES**

The aim of this paper is to study the research collaborations of India with the South East Asian countries, based on joint co-authored publication data. The main objectives are: (i) To study the nature of Indian collaboration in S&T with South East Asian countries, (ii) To identify the broad subject areas of these collaborations, (iii) To study the impact of these collaborative research efforts in

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different S&T fields, and (iv) To identify the major institutions in India and South East Asian countries that are involved in these collaborative research programmes.

### **METHODOLOGY**

The data for the study consisted of joint publications resulted from India's collaboration with selected South East Asian countries. These co-authored publications were derived from the CD-ROM version of *Science Citation Index* (SCI), for a period of five years, from 1996 to 2000. This SCI database covers around 5000 significant journals of the world in all major fields of science and technology. The journals covered by SCI represent the mainstream science publications. As a result, this study is restricted to co-authored articles published mainly in international and refereed journals. The articles are classified under 10 major disciplines and 51 sub-disciplines, according to the scheme suggested by Computer Horizon Inc. (CHI), USA. Each article is classified into a main discipline and a sub-discipline using the subject classification of the journal in which it was published. The impact factor referred in this study was taken from the *Journal Citation Report* (ISI, USA), published annually.

The nature of collaboration was defined as bilateral and multilateral, depending upon the number of countries participating in it, as reflected in the affiliations of the authors. A research paper would indicate a (i) bilateral collaboration, when there was participation of only two countries (India with any one South East Asian country), and (ii) multilateral collaboration, when the participation was of three or more countries (India with two or more South East Asian countries).

### **RESULTS**

#### **(a) S&T Research Output of India and Selected South East Asian Countries**

The status of India's collaboration in S&T with the selected South East Asian countries indicates that there exists a wide gap between the research output of India and the South East Asian countries (Table 1).

Table 1: Research Output of India and Selected South East Asian Countries

Country	Number of papers covered in SCI in different years				
	1996	1997	1998	1999	2000
India	11,177	11,067	12,128	12,521	12,127
Singapore	1,407	1,701	2,038	2,520	2,925
Thailand	642	698	905	880	1,057
Malaysia	479	489	574	784	679
Philippines	253	280	289	311	326
Indonesia	259	344	289	322	364
Vietnam	193	209	205	209	290

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The average number of publications per year for these countries from 1996 to 2000 was 11804 (India), 2118 (Singapore), 836 (Thailand), 601 (Malaysia), 292 (the Philippines), 270 (Indonesia), and 221 (Vietnam). Each country had a different growth rate in terms of its publication outputs. A comparatively faster growth rate was observed in the case of Thailand and Singapore.

#### **(b) Research priorities**

The priority areas of research in India during 1995 and 1997 were; chemistry (27.3%), physics (20.2%), biomedical research (13.6%), clinical medicine (12.3%), and engineering and technology (11.1%). For the South East Asian countries, the active research areas were as follows; (i) Singapore – engineering and technology (25.3%), clinical medicine (18.4%), physics (16.1%), chemistry (12.2%) and biomedical research (10.2%); (ii) Malaysia – chemistry (30.2%), clinical medicine (21.2%) and biology (17.4%); (iii) Thailand - clinical medicine (43.4%), biology (16.6%) and biomedical research (12.3%); and (iii) the Philippines – biology (54.8%) and clinical medicine (11.7%) (National Science Board, 2000).

#### **(c) Collaboration Profiles of India and the South East Asian Countries**

The share of India's total international co-authored papers has increased from 9.5% in 1986-88 to 15.7% in 1995-97. The share of total international co-authored papers of the South East Asian countries was also increasing from 1986-88 to 1995-97 as follows: Indonesia, from 65.5% to 86.2%; Thailand, from 48.4% to 62.9%; Philippines, from 45.6% to 65.3%; Malaysia, from 34.5% to 42.9% and Singapore from 23.7% to 29.6% (National Science Board, 2000).

The number of India's collaborative partners has also increased from 84 countries in 1986-88 to 109 countries in 1995-97, as reflected in co-authored papers published. For the South East Asian countries, the number of collaborative partners as seen in co-authored papers has increased from 49 to 94 for Thailand; 44 to 75 for Philippines; 42 to 65 for Singapore; 39 to 84 for Indonesia; and 32 to 76 for Malaysia.

The increment in India-South East Asian collaboration as reflected by the number of joint co-authored papers produced from 1986-88 to 1995-97 was as follows: Singapore (from 0.4% to 0.8%), Malaysia (from 0.1% to 0.8%), Philippines (from 0.3% to 0.4%), Indonesia (from 0.1% to 0.3%), and Thailand (from 0.5% to 0.3%). The priority assigned to India in co-authored papers from South East Asian countries was much higher. India's share of papers in South East Asian countries has increased for Malaysia (from 1.6% to 6.9%), Philippines (from 2.8% to 4.0%) and Indonesia (1.4% to 2.0%) and decreased in the case of Singapore (from 3.5% to 3.2%) and Thailand (from 2.6% to 1.3%).

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**(d) Indian Collaborations with South East Asian Countries in S&T**

Table 2 indicates that India and the South East Asian countries produced a total of 329 co-authored papers. The maximum contributions of 142 papers (49.2%) were through the collaborations between India and Malaysia, followed by Singapore (90 papers), Philippines (55 papers), Thailand (41 papers), Indonesia (25 papers) and Vietnam (21 papers). There was only one co-authored paper by India and Laos. This means that on an average, 66 papers were published per year (Table 2).

Table 2: Joint Co-Authored Papers of India with South East Asian Countries

Year	Number of papers under different collaborations		
	Total joint co-authored papers	Bilateral collaboration	Multilateral collaboration
1996	34	19	15
1997	41	23	18
1998	55	35	20
1999	110	82	28
2000	89	55	34
Total	329	214	115

**Types of Collaboration**

The collaboration pattern indicates that a total of 214 papers had bilateral collaboration (one India and one South East Asian country) and 115 had multilateral collaboration (one India and at least one South East Asian country, with minimum of three countries). Table 3 indicates that a strong bilateral collaboration existed between India - Malaysia and India - Singapore, which accounted for 83.09% and 75.50% of all bilateral co-authored papers respectively.

Table 3: S & T Collaboration between India and the South East Asian Countries

Countries	Number of papers under different collaboration		
	Number of co-authored papers*	Bilateral papers	Multilateral papers*
India-Malaysia	142	118	24
India-Singapore	90	68	22
India-Philippines	55	16	39
India-Thailand	41	8	33
India-Indonesia	25	-	25
India-Vietnam	17	4	13
India-Laos	1	-	1

\* Includes multilateral papers, where more than one South East Asian country is present along with India in each paper

In contrast, the proportion of India’s bilateral co-authored papers with Thailand, Vietnam, Indonesia and Laos was very small. India’s collaboration with these four countries were mainly through multilateral collaborations, and accounted for 80.48%, 61.90%, 100%, and 100%, respectively of all India’s co-authored papers.

**Priority Areas of S&T Cooperation**

To find the priority areas of S&T collaboration between India and each South East Asian country, the total output of 329 collaborative papers was classified under 10 major disciplines. Table 4 shows that chemistry received the maximum priority with a contribution of 34.3% papers, followed by engineering and technology with 17.9%, biology with 14.3%, and clinical medicine with 12.1%. Health sciences received the least priority, with contribution of only 0.27% papers.

The breakup of these publications by subjects and types of collaborations reveals that mathematics had all its publications in bilateral mode followed by chemistry with 95.6% share, engineering and technology with 83.0% share and physics with 57.9% share. The priority areas in multilateral publications were biology, clinical medicine and biomedical research with a share of 82.5%, 70.2% and 57.7% of the total co-authored publications in these fields respectively.

Table 4: Co-authored Papers by Types of Discipline

Disciplines	Number of co-authored papers		
	Total	Bilateral	Multilateral
Chemistry	113	108	5
Engineering & Technology	59	49	10
Biology	47	14	33
Clinical Medicine	40	7	33
Biomedical Sciences	26	11	15
Physics	19	11	8
Earth & Space Sciences	10	5	5
Mathematics	6	6	-
Multidisciplinary Sciences	6	2	4
Health Sciences	1	-	1
Unassigned	2	1	1
Total	329	214	115

Table 5 shows the distribution of co-authored papers by subjects from India with different South East Asian countries. The table shows that India’s collaboration with individual South East Asian countries had different focus and priorities. With Malaysia, India had collaborated actively in chemistry (73.24%); mathematics, engineering, technology and clinical medicine (7.75% each). With Singapore, India collaborated actively in engineering, technology (46.67%), physics (12.22%), chemistry (8.89%) and clinical medicine (7.78%). India’s



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collaboration with the Philippines was focused on biology (56.36%) and clinical medicine (21.82%). With Thailand, Indonesia, and Vietnam, the focus has been on clinical medicine and biology.

Table 5: Co-authored Papers by India and Individual South East Asian Countries

S&T Disciplines	Malaysia	Singapore	Philippines	Thailand	Indonesia	Vietnam	Laos	Total
Chemistry	104	8	1	1				114
Engineering & Technology	11	42		5		1		59
Clinical Medicine	11	7	12	17	10	5		62
Biomedical Research	6	5	5	3	5	2	1	27
Biology	4	4	31	8	7	4		58
Mathematics	1	5				4		10
Physics	3	11		1	1	1		17
Earth & Space Sciences		5		2	2			9
Public Health				1				1
Multi-disciplinary Sciences	2	3	4	2				11
Unassigned			2	1				3
<b>Total</b>	<b>142</b>	<b>90</b>	<b>55</b>	<b>41</b>	<b>25</b>	<b>17</b>	<b>1</b>	<b>371</b>

**(e) Bilateral S&T collaborations: India and the South East Asian countries**

**Subject-wise distribution of papers**

The 214 bilateral co-authored papers resulting from India's collaboration with the South East Asian countries are classified into 9 broad subject fields (Table 4). The distribution across broad subject fields is skewed in favour of chemistry, engineering and technology, accounting for 50.47% and 22.90% of all the co-authored papers, respectively. The other broad subject disciplines receiving less attention were biology (14 papers, 6.54%), physics (11 papers, 5.14%), biomedical research (11 papers, 5.14%), clinical medicine (7 papers, 3.27%), mathematics (6 papers, 2.80%), and earth and space sciences (5 papers, 2.34%).

**Impact of bilateral co-authored papers**

The impact of the bilateral co-authored papers on different disciplines was analyzed based on the impact factor (IF) of journals in which these papers were published. The impact of all co-authored papers and the mean average impact factor per paper was observed to be 0.876. The average impact factor per paper

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in terms of ranking was 2.639 for biomedical research, 2.045 for clinical medicine, 1.202 for physics, 1.079 for biology, 0.728 for engineering & technology, 0.712 for chemistry, 0.470 for multi-disciplinary sciences, 0.451 for mathematics, and 0.320 for earth & space sciences.

### **Bilateral Collaborations with Individual South East Asian Country**

Table 3 indicates the subject and country distribution of bilateral co-authored papers of India and South East Asian countries, their impact on different fields and the extent of institutional.

#### ***Indian-Malaysia Collaboration***

The Indian-Malaysian collaborative activities resulted in 118 bilateral co-authored papers, which were distributed in 8 broad subject disciplines. This distribution was highly skewed in favour of chemistry, accounting for 84.74% (100 papers) of the total co-authored papers. The remaining 18 papers were distributed among seven other subject disciplines. The impact of these papers varied from 0.155 to 4.858, and the average value of impact factor (IF) per paper was computed as 0.676. The majority of these papers had low impact factor value. Only 6 out of total 118 papers had IF value greater than 1.5. A total of 30 Indian and 11 Malaysian institutions participated in collaborative research. The leading collaborating institutions from India were: University of Madras (54 papers), Indian Institute of Technology, Kharagpur (27 papers), Anna University, Madras (23 papers), Bengal Engineering College, Howrah (10 papers), Pondicherry University (5 papers), Indian Institute of Technology, Madras (5 papers), and SPIC Foundation, Madras (5 papers). The major collaborating institutions from Malaysia were: Science University of Malaysia (101 papers), University of Malaya (4 papers), University Telekom (3 papers) and University Putra Malaysia (3 papers). The 11 Malaysian institutions involved in collaborative research had 156 collaborative linkages with Indian institutions. Of these 156 collaborative linkages, 91 were linkages with Indian institutions located in Tamil Nadu. This may be due to the large Indian (mainly Tamil speaking) population in Malaysia, which makes collaboration conducive.

#### ***India-Singapore Collaboration***

The 90 bilateral co-authored papers under this collaboration were classified in 8 broad subject disciplines and focused on engineering & technology, which accounted for 46.66% of all the co-authored papers. The remaining 48 papers were in physics (11 papers), chemistry (8 papers), clinical medicine (7 papers), biomedical research (5 papers), mathematics (5 papers), earth, space sciences (5 papers), biology (4 papers) and multi-disciplinary sciences (3 papers). The impact of these papers varied with the IF values ranging from 0.177 to 4.890, and the average IF per paper was computed as 1.089. Only 11 out of 68 papers had IF values above 1.5. A total of 25 Indian and 5 Singapore institutions participated in collaborative research. The 5 Singapore institutions had 76 collaborative linkages

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with 25 Indian institutions. The leading collaborative institutions from India were: Indian Institute of Technology, Madras (12 papers), Indian Institute of Science, Bangalore (11 papers), R.V. College of Engineering, Bangalore (9 papers), Anna University, Madras (7 papers) and Regional Engineering College, Rourkela (5 papers). The major collaborating institutions from Singapore were: National University of Singapore (53 papers) and Nanyang Technological University (13 papers).

#### ***India-Philippines Collaboration***

The 16 bilateral papers resulting from Indian - Philippines collaboration were distributed in 4 broad subject fields, with focus on biology, which accounted for 56.25% of all co-authored papers. The remaining 7 papers were in biomedical research (3 papers), multi-disciplinary sciences (2 papers), and chemistry (1 paper). The impact of bilateral co-authored papers varied from 0.376 to 2.749, and the average IF per paper was 1.42. Only 6 out of 16 co-authored papers had IF values above 1.5. A total of 13 Indian and 1 Filipino institution were involved in the bilateral research. In the Philippines, the International Rice Research Institute, Manila (16 papers) had 18 collaborative linkages with 13 Indian institutions. The major collaborating institutions from India were GB Pant University of Agriculture and Technology, Pantnagar (3 papers), N D University of Agriculture and Technology, Faizabad (3 papers), and Indian Agricultural Research Institute, New Delhi (2 papers).

#### ***India-Thailand Collaboration***

The eight bilateral co-authored papers under this collaboration were distributed in 4 broad subject fields, and their distribution was skewed in favour of engineering and technology, accounting for 62.50% of total co-authored papers. The three remaining papers were in clinical medicine (1 papers), biology (1 paper) and biomedical research (1 paper). The impact of these bilateral co-authored papers varied from 0.187 to 3.579, and the average IF per paper was 1.032. Only 2 out of 8 total co-authored papers had an IF per paper above 1.5. A total of 10 Indian and 6 Thailand institutions are involved in this bilateral research. These 6 Thailand institutions had 14 collaborative linkages with 10 Indian institutions. The leading institutions from India and Thailand were Indian Institute of Technology, Kanpur (5 papers), Asian Institute of Technology, Bangkok (4 papers) and Electricity Generating Authority, Bangkok (2 papers).

#### ***India-Vietnam Collaboration***

The four bilateral co-authored papers under this collaboration were classified into 3 broad subject fields, physics (2 papers), engineering & technology (1 papers) and biology (1 paper). The impact of these bilateral co-authored papers ranged from 0.393 to 0.889, with an average IF per paper was 0.659. The impact was high in physics (0.774), biology (0.694) and engineering & technology (0.393).

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A total of 3 Indian and 7 Vietnam institutions were involved in bilateral collaborative research.

**(f) Multilateral Collaboration: India and the South East Asian Countries**

There were 115 multilateral co-authored papers, involving Indian and South East Asian scientists.

**Distribution of Papers by Fields of Study**

The 115 multilateral papers were classified under 10 broad subject fields and were highly skewed towards biology and clinical medicine, accounting for 28.69% each of the total co-authored papers. The other disciplines getting comparatively less attention were biomedical research (15 papers, 13.04%), engineering & technology (10 papers, 8.69%), and physics (8 papers, 6.95%).

**Impact of multilateral research**

The average impact factor (IF) per paper of these multilateral papers was found to be 2.39. The 22 and 24 co-authored papers resulting from India-Singapore and India-Malaysia multilateral collaboration received the highest impact of 2.975 and 2.905, respectively. India-Thailand, India-Philippines, India-Laos and India-Vietnam multilateral collaborative papers registering the IF per paper as 2.70, 1.945, 1.610 and 1.521, respectively. The highest impact of co-authored papers between Malaysia-India was in physics (2.503) and chemistry (0.744). India-Singapore collaboration received the highest impact of 2.697 and 1.04 in biology and engineering & technology, respectively. India-Philippines papers registered the highest impact of 3.851 in clinical medicine and Indo-Indonesian co-authored papers registered the highest impact of 4.961 in biomedical research.

**Multilateral Collaboration by Country**

Analyses of multilateral co-authored papers by country gave the following results:

***India-Philippines Multilateral Collaboration***

The 39 multilateral co-authored papers were in 5 broad subject disciplines. The emphasis was in biology and clinical medicine, which accounted for 56.41% and 30.77% papers, respectively of all the co-authored papers. The remaining 5 papers were in biomedical research (3 papers), and earth & space sciences (2 papers). The impact of these papers varied from 0.397 to 16.135, and the average IF per paper was 1.945. The impact was high on clinical medicine (3.851), followed by biomedical research (2.64) and biology (0.915). A total of 22 Indian institutions collaborated with 21 institutions in Thailand. The active Filipino institutions involved were International Rice Research Institute, Manila (20 papers), De La Salle University, Manila (4 papers), and University of Philippines, College of Public Health, Manila (3 papers).

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### ***India–Thailand Multilateral Collaboration***

The 33 co-authored papers were classified into 5 broad subject disciplines, and the focus was on clinical medicine and biology, which account for 48.48% and 21.21% of all the co-authored papers. The remaining 10 papers were in biomedical research (2 papers), earth and space sciences (2 papers), multidisciplinary science (2 papers), health sciences (1 paper), chemistry (1 paper), physics (1 paper), and unassigned (1 paper). The impact of these papers varied from 0.391 to 23.872, and the average IF per paper was 2.70. Only 8 out of 33 papers had an IF value above 1.5. The impact value was high on multidisciplinary sciences (17.33), public health (3.269) and clinical medicine (2.426), followed by biomedical research (1.959), physics (1.222), biology (0.713), and chemistry (0.557). A total of 31 Indian institutions collaborated with 21 institutions in Thailand and the active Thai institutions were: Mahidol University, Sirira Hospital, Bangkok (7 papers), Khon-Kaen University (5 papers), and Asian Institute of Technology, Bangkok (3 papers).

### ***India-Indonesia Multilateral Collaboration***

The 25 multilateral co-authored papers were distributed into 5 broad subject disciplines and were active in clinical medicine, biology and biomedical research, accounting for 40%, 28% and 20% respectively of all the co-authored papers. The remaining collaboration was in earth and space sciences (2 papers) and physics (1 paper). The impact of these papers was in the range 0.629 to 21.738, and the average IF per paper was calculated as 2.19. The 18 co-authored papers out of 25 had an IF above 1.5. The impact was high in biomedical research (4.961), followed by clinical medicine (2.086), physics (0.964), biology (0.918), and earth & space sciences (0.844). A total of 25 Indian institutions collaborated with 16 Indonesian institutions and the most active Indonesian institutions were Universitas Indonesia, Jakarta (3 papers), and Universitas Udayana, Bali (3 papers).

### ***India-Malaysia Multilateral Collaboration***

The 24 multilateral co-authored papers were distributed in 7 broad subject disciplines, which comprised clinical medicine (7 papers), chemistry (4 papers), engineering and technology (4 papers), biology (3 papers), biomedical research (3 papers), multidisciplinary science (2 papers) and physics (1 paper). The impact of these papers range from 0.187 to 23.87. The average IF per paper was 2.905. Only 9 papers out of 24 had IF of above 1.5. The impact was high in the multidisciplinary sciences (17.33), followed by clinical medicine (2.776), physics (2.503), biology (1.605), biomedical research (0.946) and chemistry (0.744). A total of 10 Malaysian institutions collaborated with 22 Indian institutions and the most active Malaysian institutions were University of Malaya, Kuala Lumpur (6 papers), and Science University of Malaysia, Penang (5 papers).

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***India-Singapore Multilateral Collaboration***

The 22 multilateral co-authored papers were classified into 7 broad subject disciplines comprised engineering and technology (6 papers), clinical medicine (5 papers), physics (4 papers), multidisciplinary science (3 papers), biology (2 papers), biomedical research (1 paper), and chemistry (1 paper). A total of 12 Indian institutions collaborated with 6 Singaporean institutions and the active Singapore institutions were National University of Singapore (10 papers), and National Institute of Education, Center of Tropical Forest Science, Singapore (3 papers).

***India-Vietnam Multilateral Collaboration***

The 13 co-authored papers were in 6 broad subject disciplines: Clinical Medicine (5 papers), Biology (3 papers), Biomedical Research (2 papers) and Physics (2 papers). The focus was on the following sub-fields: fertility (2 papers) and agriculture and food science (2 papers). The impact of these papers ranged from 0.470 to 3.531, and the average IF per paper was computed as 1.521. The 7 papers out of 13 had an IF above 1.5. The impact was high in Clinical Medicine (2.351), followed by Biomedical Research (1.322), Biology (1.038), Physics (0.817) and Earth & Space Sciences (0.629). A total of 13 Indian institutions collaborated with 14 Vietnamese institutions and the later institutions were Vietnam-Vietnam Cuu Long-Rice-Research Institute, Onon (3 papers).

***India-Laos Multilateral Collaboration***

The sole multilateral co-authored paper resulting from this collaboration was in biomedical research.

**Clusters of Collaborating Countries in the Multilateral Papers**

All 83 countries, including India and the South East Asian countries, were involved in this multilateral research. Since the minimum requirement of three countries was essential for multilateral collaboration, it was found that maximum (59) papers (51.3%) were published through 3-country collaborations. The number of collaborating countries was as high as 25 per paper. These are listed in Table 6. The cluster formed by 3 to 5 countries accounted for 73.04% of all the co-authored papers and 11 to 25 countries shared about 10.43% papers.

Table 6: Number of Collaborating Countries in Multilateral Research

Cluster of countries	No. of papers published	Cluster of countries	No. of papers published
3	59	9	3
4	12	10	6
5	13	11-15	10
6	3	16-20	1
7	3	21-25	1
8	4	Total	115

### *India's Collaboration in Science & Technology with South East Asian Countries*

The United States, was the leading country as a collaborating partner in multilateral research involving India and the South East Asian countries, appearing in 41.73% (48 papers) papers. It was followed by China (24.3%), Japan (22.6%), the United Kingdom (16.5%), Brazil (11.3%), Australia (11.3%) and The Netherlands (10.4%).

#### **Cluster of Participating Institutions in Multilateral Papers**

Academic and research institutions from the collaborating countries in multilateral research collaborated in clusters of varying sizes from 3 to 60 institutions per paper. The cluster formed by 11 to 60 institutions account for 20.87 %, while those of 3 to 5 institutions accounted for 56.52% of all the multi-authored papers (Table 7).

Table 7: Institutions Participating in Clusters in Multilateral Research

<b>Cluster of institution</b>	<b>No. of papers</b>	<b>Cluster of institutions</b>	<b>No. of papers</b>
3	43	9	2
4	12	10	3
5	10	11-20	21
6	10	21-30	2
7	7	51-60	1
8	4	Total	115

The results indicate that India's collaboration with the South East Asian countries resulted in 329 co-authored papers during 1996 and 2000. This was mainly bilateral collaboration, which accounted for 65.04% of all the co-authored papers. The rest of the joint papers were multilateral in nature. Chemistry, engineering, technology and biology were the priority areas of collaboration, contributing about 34.35%, 17.93%, and 14.28%, respectively. The priorities assigned to different subject fields had different emphasis under bilateral and multilateral research. The bilateral research efforts focused on chemistry, engineering and technology, accounting for 50.47% and 22.90% of all the co-authored papers, while the priority of multilateral research was on biology, clinical medicine and biomedical research (28.69%, 28.69%, and 13.04% respectively) of all the co-authored papers.

Looking at the individual South East Asian countries, the subject priorities in collaboration with India differed from one country to another. Under bilateral research, the dominant areas of collaborative research was chemistry with Malaysia, engineering and technology with Singapore and Thailand, biology with the Philippines and physics with Vietnam. Under multilateral research, the dominant areas of collaborative research were biology and clinical medicine

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with Philippines as well as Thailand, biology, clinical medicine and biomedical research with Indonesia and Vietnam, and engineering & technology, clinical medicine and physics with Singapore.

The study of impact of these collaborations revealed that the average impact of multilateral co-authored papers was much higher (2.39) than that of bilateral co-authored papers (0.876). Under bilateral research, Indo-Philippine co-authored papers registered the highest impact per paper (1.42), followed by India-Singapore (1.089), India-Thailand (1.032), India-Malaysia (0.676) and India-Vietnam (0.659). This provides some evidence of the importance of multilateral collaboration to achieve significant research output.

The 83 countries participating in multilateral research were found to collaborate in groups of different sizes varying from 3 to 25 countries. The United States was the leading collaborating countries in multilateral research, followed by China, Japan, the United Kingdom, Brazil, Australia, and The Netherlands. A large number of academic and research institutions, which collaborated in multilateral research, appeared in clusters ranging from 3 to 60 institutions.

## **CONCLUSIONS AND FUTURE TRENDS**

The study reveals that although India had S&T collaborations with the seven South East Asian countries during the period of study, the one with Malaysia was the strongest especially in chemistry. It indicates that both India and Malaysia have a strong base in this field, probably because of the rich natural resources in these countries. There was a strong dominance of bilateral agreements indicating that both countries jointly possess sufficient infrastructure and human resources to conduct research in the areas of collaboration without involving a third country. With the issue of Intellectual Property Rights becoming increasingly important, it would be in the interest of these countries to jointly register their rights to research outputs. The second strongest collaboration was with Singapore and bilateral agreements dominated, especially in the field of engineering, technology, physics and chemistry. India's S&T collaboration with the five other countries, viz. Philippines, Thailand, Indonesia, Vietnam and Laos was mainly through multilateral agreement mainly in clinical medicine, biology and biomedical research. The weakest collaboration has been found with Laos with an output of only one paper during the period. Perhaps opportunities for further collaboration with this country would be the focus in future. The strong cooperation in the fields of clinical medicine and biomedical research, indicated with all the seven countries is expected to grow in strength as the world's attention is being currently on these areas in an attempt to solve health problems. Other potential areas of collaboration with South East Asian



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countries are environment and medicine to protect their interests in the regime of intellectual property rights.

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