CHAPTER 2

REVIEW OF LITERATURE

A detailed review of literature was conducted to identify relevant studies, comprehend, evaluate and summarise various aspects of Institute–Industry Collaboration and identify research gaps.

The information collected through review of relevant literature is presented in this chapter under seven sections viz. engineering educational Institution–Industry Collaboration, stakeholder concept in university services, measurement of Institute–Industry Collaboration, enhancing and limiting factors of Institute–Industry Collaboration, models of Institute–Industry Collaboration, global practices of Institute–Industry Collaboration and practices of Institute–Industry Collaboration in India. A summary of the status of research is presented in the last section.

2.1 ENGINEERING EDUCATIONAL INSTITUTION – INDUSTRY COLLABORATION

In the wake of the quantum jump in technologies with global connectivity, the engineering educational institutions have the responsibility to provide not only the required skills and knowledge to their students, but also practical industrial experience. The recent liberalization, privatization and globalisation of the Indian economy, exposed the Indian industries to direct competition in a global market place and to become more competitive in this environment, they should improve and increase their quality and efficiency. In this situation, the industry has to respond by
a two-pronged strategy of updating their technology as well as updating their human resources, by providing new experiences and competencies. The engineering institutions on the other hand, have to involve industry in their various activities in order to catch up with the new technology.

Thus, engineering educational institutions and industries, which for long have been operating in separate domains, are rapidly inching closer to each other to create synergies. The constantly changing engineering paradigms, in response to the growing complexity of the industry environment, have necessitated these two to come closer. The intersecting needs and mutually interdependent relationship require identifying means of further strengthening Institute–Industry Collaboration.

Singh and Sharma (2008) opined that the need for effective collaboration between institute and industry is to produce an adequate and appropriate industry-needed manpower, re-orient the university curricula at different levels to meet the needs of industry, promote the research suited to the needs of industry, motivate industry to promote educational activities in the university system and vice versa, and find ways and means to enable the industries to make fuller and effective use of the university potential through multiple activities.

The Science and Technology Policy 2003 (DST, 2003) gave a vision for making India a global hub of research and development (R&D). Linkages of industry with university were given special attention. The policy document called for creation of technology transfer organizations as associate organizations of universities to facilitate transfer of know-how generated. The policy document stated that industry will be encouraged to financially adopt or support educational
and research institutions, fund courses of interest to them, create professor chairs, etc. so that science and technology endeavours can be directed towards tangible industrial goals through collaboration with industries.

In the year 2006, realising the importance of Institute–Industry Collaboration, the Department of Science and Technology (DST), India constituted a working group to submit a report to strengthen the Institute–Industry Collaboration. The working group report (DST, 2006) observed that there is a tremendous need for academia–industry collaboration in India and effective academia–industry collaboration leads to strengthening competitiveness, promoting innovation and new technology development and ensuring quality, and quantity of the human resource base. Moreover, the Indian science and technology policies over the years have placed increasing thrust in strengthening linkages of R&D activities with economic activity in general and with industry in particular.

Inzelt (2004) used different terms viz. partnership, collaboration and interaction for indicating the varying degrees of formalisation of the relationship between institutions and industries. The term partnership is an umbrella term for interaction and collaboration. The term collaboration means “working together to achieve a common goal” and the interactions are building blocks for collaboration. Inzelt also stated that collaboration can be at many different levels, that is, at individual, group, institution, sector and national levels, whilst its forms may be “intra-forms” or “inter-forms”. In spite of the fine distinction between the three terms made by Inzelt, the concept of relationship between institute and industry is basically same in all the three cases, but it differs significantly in the degree of
formalisation of the relationship and the level of mutual commitment. Currently, the term “collaboration” is widely used in India.

The collaboration arising between university and industries has different meanings for partnership. According to Natarajan (2005), the primary aim of university is to get feedback and inputs for curriculum design, obtain fund for research and infrastructure development to provide innovations and to strengthen their established academic image from the collaboration. According to Ryan (2007), the prime aim of industry is to encourage growth to get benefit of cost reduction, improve the organisation’s image, increase learning capacity of the organisation and develop human capacity from collaboration.

According to Singh and Sharma (2008), in India a number of initiatives have been taken by the various industrial associations and government agencies to promote the collaboration between the institute and industry. Many industrial associations and government agencies like Confederation of Indian Industry (CII), National Association of Software and Services Companies (NASSCOM), DST and All India Council for Technical Education (AICTE) have over the last few years launched several initiatives in partnership with academia and government. These initiatives aim to bring positive changes to the engineering educational institutions and they are described in detail.
a) CII Initiatives

- University–Industry Council initiative

It is an initiative of CII to create a platform for an effective collaboration between academia and industry to strengthen the human capital of India.

- CII–AICTE initiative

It is an initiative for promotion of quality technical education and in making available manpower with required skill and competence to suit the needs of industry.

b) NASSCOM Initiative

NASSCOM with the support of the Information Technology (IT) industry has been working on an “IT workforce development initiative” to engage academia on a sustained basis through faculty development programmes, membership of colleges, curriculum updates and regular industry–academia interface. NASSCOM has signed MoUs with UGC and AICTE to take these initiatives forward (NASSCOM, 2013).

c) DST Initiative

DST initiative for technology development is to promote collaborative research / projects and consultancy in the science and technical educational institutions (Ministry of Science & Technology, 2007).
d) **AICTE Initiatives**

- **AICTE-IIPC initiative**

  This initiative was to promote the establishment Industry–Institute Partnership Cell (IIPC) to reduce the gap between industry expectations (practice) and academic offerings (theory) by direct involvement of industry to attain a symbiosis.

- **AICTE-TEQIP Initiative**

  The Technical Education Quality Improvement Programme (TEQIP) of Government of India, a scheme of World Bank, aims to upscale and support ongoing efforts of Government of India to improve quality of technical education and enhance existing capacities of the institutions to become dynamic, demand-driven and responsive to rapid economic and technological developments occurring both at national and international levels (AICTE, 2011).

  A survey conducted by AICTE and CII (2012) on engineering educational institutions indicated lesser interactions between the institutes and industries and out of 156 engineering institutions surveyed from all the regions of Indian barely 19% had good linkages. 63% of engineering institutions had moderate linkages, while 18% of engineering institutions were rated poor. The survey also observed that there is need to establish linkage between industry, national laboratories, developmental sectors, professional bodies and engineering educational institutions.

  From above, it can be observed that though a number of initiatives have been promoted for effective collaboration between the engineering educational
institutions and industries, it has not reached the level as expected by the policymakers of India.

### 2.2 STAKEHOLDER CONCEPT IN UNIVERSITY SERVICES

Kanji and Tambi (1999) classified higher educational institution or university customers (Table 2.1) according to the criteria ‘Internal customers’ and ‘External customers’. The ‘Internal customers’ are those who maintain a close and direct relationship with a university and who work to achieve the satisfaction of the external customers; on the other hand, the ‘External customers’ establish a more indirect relationship with universities than internal customers, but they also obtain benefits from the services provided by the institution and / or support its operating cost.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal customers</td>
<td>(i) Students</td>
</tr>
<tr>
<td></td>
<td>(ii) University personnel</td>
</tr>
<tr>
<td>External customers</td>
<td>(i) Employers</td>
</tr>
<tr>
<td></td>
<td>(ii) Industrial sector</td>
</tr>
<tr>
<td></td>
<td>(iii) Public administration</td>
</tr>
<tr>
<td></td>
<td>(iv) Society</td>
</tr>
<tr>
<td></td>
<td>(v) Students</td>
</tr>
</tbody>
</table>

De Silva and Pereira (2003) added a further dimension in classifying university customers by adding ‘process’ as sub-criterion in Kanji and Tambi’s (1999) work. The types of processes are depicted in Table 2.2. Both internal and external customers have three sub-criteria namely teaching process, research process and learning process.
Table 2.2  Customer Classification with Sub-Criteria in University Services

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-Criteria</th>
<th>Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal customers</td>
<td>Teaching process</td>
<td>Teaching and research personnel</td>
</tr>
<tr>
<td></td>
<td>Research process</td>
<td>Teaching and research personnel</td>
</tr>
<tr>
<td></td>
<td>Learning process</td>
<td>Students</td>
</tr>
<tr>
<td>External customers</td>
<td>Teaching process</td>
<td>Students</td>
</tr>
<tr>
<td></td>
<td>Research process</td>
<td>Society and public administration</td>
</tr>
<tr>
<td></td>
<td>Learning process</td>
<td>Employers</td>
</tr>
</tbody>
</table>

Marzo et al. (2007) observed that universities should apply marketing approach and establish the objective of identifying and satisfying the needs of their customers. To establish the marketing approach, the first step would be to clearly determine ‘who the customers are’. In this context, they have stated that the basic, recognized functions of universities are the creation and dissemination of knowledge, which are respectively achieved through research and education. In turn, education can be divided into two sub-processes (teaching and learning). Therefore the three basic processes of a university are: ‘Teaching’, ‘Learning’ and ‘Research’. They have also stated that an ‘External Customer’ is a person or organization who, while not belonging to the institution, is “affected” by its products; in other words, a person or organization who receives results from the system. In turn, an ‘Internal Customer’ is a person or organization who works on the process. Thus, based on the combination of these two criteria, they have suggested the classification of university customers as shown in Table 2.3. This classification is a process based view of the institution’s customers and is similar to the classification of De Silva and Pereira (2003) except for the identification of all
possible customers in each case. This classification helps higher educational institutions or universities to reorient their operations with process approach.

**Table 2.3 Process Based Customer Classification in University Services**

<table>
<thead>
<tr>
<th>Process</th>
<th>Internal Customers</th>
<th>External Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching</td>
<td>Teaching staff</td>
<td>Students</td>
</tr>
<tr>
<td></td>
<td>Administrative and service personnel</td>
<td></td>
</tr>
<tr>
<td>Learning</td>
<td>Students</td>
<td>Employers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Society</td>
</tr>
<tr>
<td>Research</td>
<td>Teaching-research staff</td>
<td>Society</td>
</tr>
<tr>
<td></td>
<td>Grant holders</td>
<td>Public administration</td>
</tr>
<tr>
<td></td>
<td>Administrative and service personnel</td>
<td>Non-profit organization</td>
</tr>
</tbody>
</table>

Marzo et al. (2007) also made a detailed study to evaluate the most appropriate term for qualifying the recipients of the services provided by universities and an analysis of existing definitions led them to opt for the term of “stakeholder”, given that it is more suited to including a broader vision than the concept of the “customer”, because it not only encompasses who pays for the good or service (the customer), but also anyone who obtains a benefit. In this research study, the term “stakeholder” is used.

Dhanapal (2001) identified the stakeholders of institute–industry interaction viz. heads of the institutions, heads of the departments, heads of industry–institute interaction cell, placement officers and representatives of industries.
In the study conducted by Nagasubramanian (2001) on the effectiveness of institute–industry interactions, the stakeholders are heads of the institutions, teaching staff, students, industrial liaison officers, continuing education managers and representatives of industries.

2.3 MEASUREMENT OF EFFECTIVENESS OF INSTITUTE–INDUSTRY COLLABORATION

Calvert and Patel (2003) stated that Institute–Industry Collaboration involves a diverse set of activities and result in a variety of outputs, and no single measure is able to capture the full range of such collaborations and they have used joint scientific publications have been used as an indicator to understand the nature and extent of research collaborations between universities and firms.

Gordon (1993) has expressed that it is very essential for HEEI to establish a meaningful and permanent partnership with industry. This would facilitate in using the experience, expertise and resources available in both the systems for mutual benefit. In this context, the new economic and industrial policy of India offers both the challenge and opportunity for such a partnership. Gordon (1993) identified the possible areas of collaboration as:

(i) Faculty development
(ii) Faculty exchange
(iii) Student training and assessment
(iv) Curriculum development
(v) Management development
(vi) Resources support
(vii) Institution of chairs

(viii) Institutional evaluation

(ix) Adoption of institutions / programmes

(x) Support to sandwich programmes

According to the report of Business-Higher Education Forum (2001) on University Industry Research Collaboration Initiative, the research relationships are a subset of many different interactions between universities and businesses organizations and the Council on Governmental relations has listed six research mechanisms through which universities and companies can work together. The mechanisms are categorised as sponsored research – the most frequent form of research relationship, which involves companies directly funding university research, collaborative research – university–industry research partnerships that are encouraged through partial federal funding, consortia – groups of companies and universities engaged in various research efforts of common group interest, technology licensing – licensing of university patents (usually stemming from federally funded research) to companies for commercialization, start-up companies – usually involving university faculty, they often obtain licensing agreements to access university technologies and exchange of research materials – used to expedite the performance of research and accomplished through material transfer agreements.
As observed by Mollas-Gallart et al. (2002), university–industry research collaborations can take a number of different forms including

- Development of joint research projects
- Firm employees working within universities
- University scientists working in firms
- University scientists undertaking short-term consultancies
- Participation in formal and informal networks

and such collaboration can result in prototypes, patents, spin-offs etc.

According to Goktepe (2004), transferring the results of university research to industry may take several forms and thus can be achieved in different ways i.e. patenting, licensing, spin-off firms, etc. Although the transfer of academic research results to industry is widely accepted as a crucial factor for the industrial growth and competitiveness, this is not an effortless or simple process that flows directly from academy to industry. In this context, an empirical study has been conducted at the Lund Institute of Technology and the medical facility of Lund University of Sweden to measure the University–Industry (U–I) relations, and to find out the indicators of the successful U–I relations. In this study, Goktepe (2004) stated that U–I relations can be measured through quantitative and qualitative indicators.

The quantitative indicators consist of

- amount of measurable intellectual property, patents, number of patent licensing agreements and

- income derived from licensing.
The qualitative indicators include

- level of partnerships between the university and industry
- relationship between university people and industry engineers (who talks to whom) and
- “long term” exchange of people.

Butcher and Jeffery (2005) have observed that in the process of formal interaction, there are four basic forms to establish the dialogue between the university and industry viz. codification (e.g. scientific publications and patents), cooperatives (e.g. joint enterprises and workforce exchange), meeting and internet networks and agreements (e.g. license agreements and collaboration contracts).

Higher education institutions contribute not only skilled human resources to business, but also in various intangible ways. The intersecting needs and mutually interdependent relationship requires identifying means of further strengthening academia–industry partnerships. In this context, Rizvi and Ashita (2005) attempted to explore how institutions can work closely with industry, study the dimensions of academia–industry partnership and identify possible areas where industry’s contribution to academia would be most effective. The most preferred modes of collaborations and least preferred collaborations were concluded as follows.
The most preferred modes of collaboration with industry are:

(i) Guest lectures
(ii) Training and internship of students
(iii) Including industrial personnel into governing councils and boards of studies
(iv) Industry inputs in curriculum design
(v) Executive education programmes.

The least preferred modes of collaboration with industry are:

(i) Faculty selection
(ii) Financial support for academic activities
(iii) Providing incubator services for start-up ideas
(iv) Helping industry in training and selection of their staff
(v) Joint community development services.

Sabat et al. (2005) presented different modes of interactions in technical education between the stakeholders. Individual interaction initiatives of institutes and industry as well as joint initiatives of industry and institutes together are listed below:

(1) Institute’s initiatives

(i) Industrial visit of students
(ii) Industrial tour of students
(iii) Practical training / student internship
(iv) Student project in industry
(v) Teacher deputation to industry
(2) **Industry’s initiatives**

(i) Deputation of industrial personnel for higher studies

(ii) Continuing education for industrial personnel

(iii) Consultancy jobs

(iv) Sponsored R&D projects

(v) Sponsored short-term course

(vi) Adjunct faculty

(vii) Expert lectures

(3) **Industry–Institute joint initiatives**

(i) Training programmes

(ii) Seminars and symposia

(iii) Awareness programmes

(iv) Adoption of institute / programs.

Severson (2004) observed that transfer of knowledge and technology from universities to industry occurs through a number of pathways, but the best known and most prominent pathways are the training of students, the publication of research results in the scientific literature, consulting arrangements by faculty, research in the university laboratory that is sponsored by a company, research consortia that bring together university scientists and industry scientists to conduct collaborative research, the licensing of inventions created at the university to companies for further development and commercialization, and the exchange of research materials between laboratories.
Department of Science and Technology of Government of India (2006) reported that a strong academia–industry interface is critical to the national development. In this context, the following priorities are identified for strengthening institute–industry interface.

1) Creation of enabling environment
   a) Creation of corpus fund by the institutions from more than one industry
   b) Incentives in the form of tax exemptions for R&D and technology transfer

2) Facilitating right skills
   a) Creation of centres of relevance and excellence at the institutions in the select areas of science and technology (S&T), which are of direct relevance to industries
   b) More internships for students to expose them to industrial practices

3) Creation of new interface structures such as consortia, partnership research institutions, etc. for basic and applied R&D

4) Enhancing mobility of S&T professional through internship programmes for young faculty and active participation of industrial resource persons in teaching or research at the institutions
5) Promoting movement of technology from laboratory to marketplace through technology transfer and new venture creation.

According to De’Este and Patel (2007), university researchers interact with industry through a variety of channels that are grouped into nine types of interactions under five broad categories, each reflecting largely non-overlapping modes of interaction (Table 2.4).

<table>
<thead>
<tr>
<th>Groups</th>
<th>Types of Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meetings and conferences</td>
<td>Industry sponsored meetings</td>
</tr>
<tr>
<td></td>
<td>Conferences</td>
</tr>
<tr>
<td>Consultancy and contract research</td>
<td>Consultancy</td>
</tr>
<tr>
<td></td>
<td>Contract research</td>
</tr>
<tr>
<td>Creation of physical facilities</td>
<td>Spin-off companies</td>
</tr>
<tr>
<td></td>
<td>New physical facilities</td>
</tr>
<tr>
<td>Training</td>
<td>Postgraduate training in company</td>
</tr>
<tr>
<td></td>
<td>Training company employees</td>
</tr>
<tr>
<td>Joint research</td>
<td>Joint research</td>
</tr>
</tbody>
</table>

They have also found that in explaining the variety and frequency of interactions, the individual characteristics of researchers have a stronger impact than the characteristics of their departments or universities.

Karthikeyan et al. (2008) have opined that the co-curricular activities and R&D are to be concentrated for improving interaction between the industry and institute. They have also identified the various factors in the co-curricular and R&D activities for the continuous improvement. The co-curricular activities include placement, career guidance, publication in international and national journals,
publication in international and national conferences, in-plant training, industrial visit, management skills development program, software certification and computer proficiency, industrial project, student internship and special lectures. R&D activities cover academic research, sponsored research, collaborative research, publication of books, patent, sabbatical fellowships, infrastructure development, staff internship and consultancy.

Majumdar (2008) has highlighted that the social and economic structure of various countries in Asia and the Pacific region has moved from labour-intensive and industrial-based to knowledge-based and globalised economies and the role of academic institute has been intensified more than ever, institutes possess the optimum resource base to supply new ideas, innovation and analysis of the trends in the labour market in a holistic and pedagogic approach. In this context, the different forms of Industry–Institute linkages that have been started in various countries in Asia and the same are enumerated below:

(i) Problem solving interaction, which includes collaborative industrial projects, contract research, technology transfer initiatives, solving intricate problems through R&D

(ii) Curriculum development and teaching & learning system, which includes industrial representation in formulating curriculum, industrial personnel involvement, and in teaching & learning systems

(iii) Scholarship and placement, which includes the development funds in the form of scholarships & stipends by the industry, job fairs and placement activities
(iv) Industrial tour and study visits

(v) Faculty and staff exchange

(vi) Industrial apprenticeship

(vii) Incubation centre

(viii) Joint evaluation system.

Nanda and Singh (2008) identified the different types of interactions for an effective industry–institute bonding viz. involvement of industrial personnel in the boards or academic committees, involvement of industrial personnel in the curriculum development, deputation of faculty members at industry to work on specific projects, internships for students, project semester for students (UG students are to be sent one full semester to the industry), visiting / adjunct faculty from industry, joint research and developmental activities, continuing education programmes for industrial personnel to update and upgrade knowledge, industries as technology partners with institutions (nominal fee for the industrial personnel to use library, to attend seminars, conferences, etc.), sponsored research, consultancy and utilization of specialized database and equipments available in the institutions.

Sadagopan (2009) described five levels of industry–institute interaction on the lines of five levels of software engineering institute capability maturity model and they are:
First level - Supplier–Buyer relationship where the primary focus is on recruitment

Second level - Donor–Donee relationship where corporate invests in the form of scholarships and sponsorships for student events (cultural fest and technological fest)

Third level - User relationship where corporations utilize faculty by way of consulting projects (short duration projects)

Fourth level - Sponsor–Receiver relationship where large projects (with multiple faculty members and multiyear projects) are endowed at the institute

Fifth level - The faculty members are invited to sit on the boards of corporations and senior executive board level positions in the university senate / board.

Sadagopan (2009) concluded that the institute–industry relationship ultimately should lead to intellectual gains such as Turing award and Academy award, wealth creation for individuals and corporations, generation of amazing products and services (iPod, iPhone like products), creation of marquee companies that create jobs (Next Generation, Infosys Ltd.) and research-led institutes like Stanford University.

According to Salaka et al. (2009), internship is a valuable approach of identifying talent early on, enriching their technical skills, nurturing them with the requisite domain knowledge and subsequently hire them into the organization and internship results in development of direct knowledge potential for both institute and
organization. He classified the various forms of Industry–Institute Collaboration as detailed below:

(i)   Academic – Projects
      Guest lectures
      Higher learning
      Internship

(ii)  Non-Academic – Academic chair sponsorship
      Generic funding
      Event sponsorship
      Placement

De Fuentes and Gabriela (2010) conducted a research study on the patterns of interactions for researchers and firms and its impact on benefits for both the agents, Public Research Organization–Industry (PRO–I) interactions are seen as one of the key elements of the National System of Innovation (NSI) and they classified the forms of interaction into four knowledge channels (Table 2.5).

Table 2.5  Knowledge Channels of Interactions

<table>
<thead>
<tr>
<th>Knowledge Channels</th>
<th>Forms of Interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information and training (information channel)</td>
<td>Publications</td>
</tr>
<tr>
<td></td>
<td>Conferences</td>
</tr>
<tr>
<td></td>
<td>Informal information</td>
</tr>
<tr>
<td></td>
<td>Training</td>
</tr>
<tr>
<td>R&amp;D projects and consultancy (project channel)</td>
<td>Contract R&amp;D</td>
</tr>
<tr>
<td></td>
<td>Joint R&amp;D</td>
</tr>
<tr>
<td></td>
<td>Consultancy</td>
</tr>
<tr>
<td>Intellectual Property Rights (IPR channel)</td>
<td>Technology licenses</td>
</tr>
<tr>
<td></td>
<td>Patents</td>
</tr>
<tr>
<td>Human Resources (HR channel)</td>
<td>Hiring graduates</td>
</tr>
</tbody>
</table>
They have also stated that once collaboration starts different flows of knowledge occur through the four channels of interaction and the project channel, IPR channel and HR channel play a key role for longer-term benefits for firms associated with increasing R&D and non R&D capabilities.

2.4 ENHANCING AND LIMITING FACTORS OF INSTITUTE–INDUSTRY COLLABORATION

Lee (2000) conducted a survey to identify the enhancing factors that motivate the participants of university–industry partnership ventures and they are listed below:

1. Acquiring research funding
2. Acquiring new laboratory equipments
3. Access to new research
4. New products development
5. New patent acquisition
6. Solving specific technical problems
7. Sustaining a stronger industry–institute relationship.

Mohnen and Hoareau (2003) observed that the high absorption capacity, firm openness and professionalism of the senior management are the significant factors in establishing collaboration with universities. The absorptive capacity is a three-staged management behaviour that, in context of a learning organization, determines the need of knowledge transfer that will add value from sources outside
the institution, assimilates and transfers the information, and with the information, discovers new knowledge and turns it into economic work results.

According to Australian Government’s Department of Education, Science and Training report (2004), the barriers to collaboration occur at the structural, organizational, career-related and geographic levels and the same is described below:

(a) **Structural level**

Structural barriers are those that are imposed through legislation, regulation, procedural rules, or physical constraints (such as security policy). For example, the rules relating to research funding by granting bodies can become barriers to research collaboration by prescribing how funds are to be used or limiting the transfer of funds from grantees to partners.

(b) **Organizational level**

The culture and values of an organization can present a barrier to collaboration. For example, collaboration between researchers may not be supported by a particular organization or its management. Collaboration might not be adequately resourced through, for example, recognizing the time commitment required by researchers for collaborations. The operational policies of organizations, reflecting culture and values, can sometimes place restraints on how researchers interact with others.
(c) Career-related level

The report has identified that the promotion or advancement practices appear to vary across organizations, which may impact on the way a researcher’s contribution to a collaborative project is assessed. For example, the desire of an individual researcher to publish research outcomes may be constrained by the organization’s need to protect the potential commercial outcomes.

(d) Geographical level

The inadequate access to infrastructure, facilities and communication mechanisms are clear barriers to collaboration, although email was noted as a positive influence. For example, researchers in rural and regional locations often experienced difficulties in accessing infrastructure, facilities or working with collaborators because of the distances and associated costs. Submissions also cited the lack of access to high speed communication technology for data transfer and tele and video conferencing.

Casey (2004) identified the following barriers in the university–industry collaboration.

(a) Communication is a major barrier to collaboration. Communication skills differ between and within universities and industry. Needs and expectations are often different between the parties and the failure to communicate them compounds the problem.
Universities have mixed missions, particularly when it comes to establishing start up companies. The establishment of start up companies with faculty at the centre is, in some people’s eyes, a significant departure from education, teaching, service and research. Reasonable minds can differ on this topic, but in the end, mixed mission can be problematic in dealing with industry partners.

Cultural differences are a major barrier to collaboration. Not only is there the basic legal distinction between non-profit educational institutions and for profit companies, but there are also cultural differences within universities and industry that have nothing to do with this legal difference.

Secrecy or public dissemination of knowledge is a major difference between universities and industry. By their very nature, universities desire to publish and disseminate the results of their work. Companies, on the other hand, are often more secretive about the results of research in the search for competitive advantage and ultimately profit.

Fear factor among both the parties that is both parties either through culture, prior experience or stereotyping, often fear doing work with the other.

Lack of trust occurs within universities and industry and often between these parties. This is particularly evident in areas of legal
issues and contract negotiation and can be exacerbated by the departure of key personnel in establishing the relationship.

(g) Financial risk for universities is high when they work with industry rather than government as the federal government in particular is seen as a stable source of research money.

(h) Universities lack consistency; by their very nature, universities are fluid organism. Administration and faculty come and go, making long-term partnership difficult.

Basant and Chandra (2007) have identified lack of funding, the absence of institutional and policy incentives for researchers, the lack of research orientation among local firms, inappropriateness of research undertaken for industry and absence of appropriate infrastructure at the institutions as the factors contributing to the absence of collaboration between academia and industry.

According to Arvanitis et al. (2008), the differences between universities and industry, such as aims, culture, bureaucratized structure and human resources profile, create a variety of problems that will be encountered in the implementation of joint projects.

Joseph and Abraham (2009) explored the reasons and factors inducing as well as limiting industry–university interactions (Table 2.6) as considered by the firms.
Table 2.6 Factors and Reasons for Interactions

<table>
<thead>
<tr>
<th>Factors</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inducing factors</td>
<td>To help in quality control</td>
</tr>
<tr>
<td></td>
<td>Make use of the testing equipments and other facilities available with industries</td>
</tr>
<tr>
<td></td>
<td>Contract research (helpful to the innovative activities)</td>
</tr>
<tr>
<td></td>
<td>Information on trends in R&amp;D field</td>
</tr>
<tr>
<td></td>
<td>Recruitment of excellent students</td>
</tr>
<tr>
<td></td>
<td>State of the art technological information</td>
</tr>
<tr>
<td></td>
<td>Consulting advice in solving production-related problems</td>
</tr>
<tr>
<td></td>
<td>Technology transfer</td>
</tr>
<tr>
<td>Limiting factors</td>
<td>Universities do not understand industries line of business</td>
</tr>
<tr>
<td>(Cultural)</td>
<td>Universities concerned only with big science (and not in tune with the requirements of industries)</td>
</tr>
<tr>
<td>Limiting factors</td>
<td>Contractual agreements are difficult</td>
</tr>
<tr>
<td>(Transaction costs)</td>
<td>Lack of trust</td>
</tr>
<tr>
<td></td>
<td>Intellectual properties issues</td>
</tr>
<tr>
<td>Other limiting factors</td>
<td>Quality of research is low</td>
</tr>
<tr>
<td></td>
<td>Geographic distance</td>
</tr>
</tbody>
</table>

Salter (2009) identified the academician’s view of the barriers to university–industry collaboration as university’s technology transfer offices having a low profile, absence of established procedures for collaboration with industry, potential conflicts with industry regarding Intellectual Property Rights (IPR), industry imposing delays in dissemination of research outcomes and publications, mutual lack of understanding about expectations and working priorities, high personnel turnover and lack of continuity in companies’ research strategies, rules and regulations imposed by university or government funding agencies, the nature of research not linked with industry interests or needs, lack of suitable government funding programmes for university industry joint research in specific areas,
difficulty in finding companies with appropriate profile, and short term orientation of industry research.

Bruneel et al. (2010) stated the barriers of University–Industry Collaboration (UIC) are important in the design of effective policy to build and to support UIC and the types of barriers were identified as orientation-related barriers – those related to differences in the orientations of university and industry and transaction-related barriers – those related to conflicts over intellectual property, and dealing with university administration and reasons for the barriers in collaboration are listed in Table 2.7. An important finding from this study was that inter-organization trust is one of the strongest mechanisms for lowering the barriers of interaction between universities and industries.

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Reasons</th>
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<tbody>
<tr>
<td>Orientation related</td>
<td>University research that is extremely oriented towards pure science</td>
</tr>
<tr>
<td></td>
<td>Long-term orientation of university research (concerns over lower sense of urgency of university researchers compared to industry researchers)</td>
</tr>
<tr>
<td></td>
<td>Mutual lack of understanding about expectations and working practices</td>
</tr>
<tr>
<td>Transaction related</td>
<td>Industrial liaison offices tend to oversell research or have unrealistic expectations</td>
</tr>
<tr>
<td></td>
<td>Potential conflicts with university regarding royalty payments from patents or other intellectual property rights and concerns about confidentiality</td>
</tr>
<tr>
<td></td>
<td>Rules and regulations imposed by universities or government funding agencies</td>
</tr>
<tr>
<td></td>
<td>Absence or low profile industrial liaison offices in the university</td>
</tr>
</tbody>
</table>
De’Este and Perkmann (2011) conducted a survey to study the factors that motivate academics to engage with industry using both informal collaboration and formal modes of interaction. They identified four main motivation factors viz.

1. Commercialization – source of personal income, seeking IPRs

2. Learning – information on industry problems, information on industry research, applicability of research, feedback from industry

3. Access to in-kind resources – access to materials, access to research expertise, access to equipments

4. Generation of income for research activities.

According to Kaymaz and Eryigit (2011), the academics perceive that bureaucracy, subject interests, proximity to field studies, previous experience, government policies, publicity and the functionality of collaboration centres are negative factors in the collaboration process.

Nangia and Premanik (2011) observed the barriers of interaction from the academia and industry points of view as described below:

a) Academia as represented through universities is generally rigid when dealing with collaborative projects and typically present additional levels of restrictive internal policies and procedure that hinder innovation. Academia is largely unaware of the real industrial and national needs and unable to market its strength to industry adequately. Other inhibiting factors are lack of appropriate incentive to faculty and
specialized technical infrastructure (R&D laboratory), absence of proper recognition from practicing faculty as compared with pure academics worshipper, bureaucratic hiccups in utilization of consultancy funds, absence of exclusive & university–industry interaction cell in campus.

(b) Industry during its interaction with academia, industry’s desired time frames are instant and investment is guided by efforts that yield result-oriented solutions. The other factors which hinder its interaction with academia are insensitivity to or lack of cognizance of the tons of resource potential of the academia, much dependence on easily available foreign know-how; an unhealthy obsession with expensive, eminent professional consultants; earlier bitter experience of interactions with the academia; obligations to keep secret information of failure or success; and confidentiality for fear of losing the competitive edge.

2.5 MODELS OF INSTITUTE–INDUSTRY COLLABORATION

Swaminadhan (1995) developed a model for university–industry interaction (Figure 2.1). In his model, he attempted to relate the country’s economic development with the interactions between universities, industries and R&D organizations. He also mentioned that improvement at technological university systems in curriculum development, exchange of faculty, training of students, consultancy and R&D collaboration will serve the needs of the industry. The industry in turn improve based on the inputs received from the institutions in R&D,
cost effectiveness, improved and new technology, quick adaptation of technology and training programmes. The continuous improvement of institutions and industries helps the country’s economy to develop.

Figure 2.1 Swaminadhan’s Model for University–Industry Interaction
Ghatol et al. (2004) presented a three phased integrated model for industry–institute interaction activities with a view to strengthening the economy of the nation at different phases as described below.

Phase 1 – To integrate the environmental challenges to the competitive system
Phase 2 – To overcome hurdles and constraints while developing the industry–institute interaction
Phase 3 – To develop strategies and policies for industry–institute interaction

They finally concluded that this model is a phased form of industry–institute interaction activities where industry–institute interaction is taken as a result of mutual cooperation and collaborative activities that require an act of balancing the interests of different segments.

Krishnan (2006) presented a model for industry–academia partnerships (Figure 2.2) by creating an ecosystem for innovation in the Indian IT industry between the service companies, academic research, venture funds, start-ups, domestic consumers, global customers for R&D collaborations and fundamental innovation. He concluded that fundamental innovation should be primarily lead by academia and supported by industry with a detailed review process at regular interval.
Figure 2.2 Industry–Academia Partnership Model through Ecosystem of Innovation

Connectivity to Global Innovation Ecosystems
- Enable more researchers from India to attend, present and speak at international conferences
- Get more international conferences in India
- Get more researchers to do sabbaticals in India, and vice-versa

Research Talent Pool
- Enable greater rotation from industry to research and vice-versa
- Make a research and teaching career in India to be as attractive as an industry job in India or elsewhere

Access to Capital
- Replicate institutions such as the Stanford Research Institute.
- Invite more venture and private equity capital into fundamental innovation in India

Industry Linkages
- Sabbaticals to and from industry
- Students projects in industry
- Research sponsorships
- Agenda-setting meetings and conferences
- Grand challenges to be set by industry

(Reference – Krishnan, 2006)
A joint project conducted at U.S.A. by the National Council of University Research Administrators and the Industrial Research Institute (2006) reported Hewlett Packard’s model (Figure 2.3) for university–industry partnership. In this model, the development of a strategic collaboration between universities and industries proceeds along a continuum and the successful partnership at different phase depends on satisfying the fundamental needs of an institution (i.e. safety and security) and trust & transparency. In the model, Accreditation Board of Engineering and Technology is represented as ABET, National Science Foundation as NSF, National Aeronautics and Space Administration as NASA, Educational Institute as EDU and University Relations as UR.
Figure 2.3 Hewlett Packard’s Model for University–Industry Partnership

(Reference – National Council of University Research Administrators and the Industrial Research Institute, 2006)
The triple helix model is a multi reciprocal relationship among institution sectors (university, industry and government) at different points in knowledge capitalization process. Bhattacharya and Arora (2007) presented the various types of the triple helix configuration are described below:

(a) Triple helix I configuration (also termed as elastic model) is characterised by government control of university and industry. Government primarily directs the relation between university and industry. Figure 2.4 illustrates triple helix I configuration.

(b) Triple helix II configuration (also termed as laissez-faire model) is distinguished by separate institutional spheres (university–industry–government) with strong borders dividing them and highly circumscribed relations between the three strands. Figure 2.5 illustrates triple helix II configuration.
Figure 2.5 Triple Helix II Configuration

(c) Triple helix III configuration is characterised by a high degree of collaboration leading to creation of overlapping institutional spheres with each taking the role of the other and with highbred organisations (such as spin-off university firms) emerging at the interface. Figure 2.6 illustrates triple helix III configuration.

Figure 2.6 Triple Helix III Configuration
Bhattacharya and Arora (2007) concluded that highly industrialized economies are closer to triple helix III configuration. Interactions of universities with industry and government participation in developing economies like India are in different stages of evolution.

Karthikeyan et al. (2008) proposed a novel Special Interest Group (SIG) model (Figure 2.7) to improve academia–industry relation for the improvement of placement activities in engineering institutions.

(Reference – Karthikeyan et al., 2008)

**Figure 2.7 Special Interest Group Model for Quality Education**

In the proposed SIG model, the inputs are faculty, infrastructure and students. By improving the Teaching and Learning Process (TLP), Research & Development (R&D) and Industry–Institute Interaction (III), the output “quality excellence in an engineering education” can be enhanced.

Rieger (2008) identified four primary academic-driven partnership models from the set of interactions (Figure 2.8), namely research based, student based, subscription based and program based. While each model dictates a primary approach, they can also evolve to encompass all other approaches to varying degrees.
Focus on academic-based case study or survey research approaches oriented toward strategic issues within industry and the dissemination of results to as broad a base as possible, in order to attract sponsoring companies or grants.

Focus on direct placement of students into industry positions utilizing a combination of industry-specific education and internships with sponsoring companies.

Focus on academic-driven programs oriented toward showcasing the specific expertise of the researcher or research center, with the intent of attracting sponsoring companies.

Focus on academic-based case study or survey research approaches oriented toward strategic issues within industry and the dissemination of results to as broad a base as possible, in order to attract sponsoring companies or grants.

Focus on maximum membership of industry companies at varying levels of sponsorship fees in order to fund research activities of the professor or the research center.

(Reference – Rieger, 2008)

Figure 2.8 Academic-driven Partnership Model
Thomas and Jayasankar (2009) presented an industry–institute interaction model that includes four levels of interactions as illustrated in Figure 2.9 are described below:

**Level 1 interaction (Basic interaction)**

This includes ‘incidental’ interactions for recruitment of the graduates and for supply chain management of the IT Companies. In countries like India where there has been a giant leap forward in the economy through the process of software outsourcing, the need of this interaction was heavy and it went way ahead in the volumes of people recruited and a fight for getting the best talents. However, this interaction had a limitation in quality – in terms of the people recruited not being able to catch up with the immediate needs of the industry. This necessitated the shift from a very low level transactional kind of interaction to one of an interactive and mutually beneficial one.

**Level 2 interaction (Secondary interaction)**

This includes more systematic interactions between the industry and institute such as patronizing the academic projects, students and faculty development programs, internships and forums to discuss academics in organization and this leads to capacity building and supply chain management enhancement. But even at this level, the focus at the end of the day remains getting the best students for the company.
Level 3 interaction (Tertiary interaction)

This includes higher level interactions such as conduction of executive programs, sabbatical programs for the institute employees, customized curriculum for the students, training programmes for industrial personnel at the institutes, offering specialized electives to the students who hold offers from a particular company and this leads to competency building and enhancing employee competency.
Level 4 interaction (Collaborative interaction)

This includes advanced level interactions such as research and development, joint collaborations, sharing intellectual property rights, sponsored research, innovation model attracting young talent to go beyond jobs and empowering the young entrepreneurs to be entrepreneurial and this takes the level of education to heights of commercial success as well as maintaining the fundamental purpose of exploration of knowledge.

Datta (2009) found that the pattern of university–industry linkages in India differs considerably from that in Britain and USA. He also observed that the universities in India share meaningful inter-relationships with industry in limited ways. Theories such as national system of innovation, triple helix model and national innovation capacity can provide valuable insights to policymakers in India to develop innovative capacity of their societies and making universities a more potent instrument for fulfillment of this goal.

Nangia and Premanik (2011) observed that the world has moved from industrial revolution to knowledge revolution and from industrial economy towards knowledge economy and India, with its economy pool of technical graduates, has a great opportunity to grasp the global economy. They also stated that in the state of the art era of knowledge-driven economy, a productive interface between academia and industry is a critical requirement. In this context, they presented an integrated model (Figure 2.10) of several new collaborative approaches that are mainly possible in the Indian scenario to strengthen academia–industry interface. In the proposed model, an attempt has been made on knowledge sharing, knowledge transfer and transfer of experience & technology between academia and industry to strengthen their interface.
**Figure 2.10 Integrated Model for Academia–Industry Interface**

### Mutually Beneficial Goals of the Stakeholders

<table>
<thead>
<tr>
<th>Industry</th>
<th>Government</th>
<th>Academia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit &amp; Prosperity</td>
<td>Generation of tax base for revenues</td>
<td>Marketing of its strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More freedom &amp; avenues for exploration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of knowledge</td>
</tr>
</tbody>
</table>

### Interface

**Community**
- Socio-economic development
- Conservation & sustainable development of environment
- Human resource development

**Evolution of Knowledge**
Giving rise to leading edge & useful products, technology, processes, services high skills & high wage to face the challenges of the global economy

**Output**

**Academia**
- Community of students, faculty & scholars.
- Universities,
- Research Organizations,
- Institutes of Technology & Vocational Schools

**Industry**
- Any type of economic activity producing goods or services Large,
- SMEs

- **Encouragement of efficient work flow**
  - Creation of “chair”
  - Provision of incentives.
  - Foundation of center of excellence & relevance
  - Reformation of student internship
  - Celebration of annual S & T festival
  - Diffusion of Knowledge through interaction of peers.
  - Involvement of alumni as mentor of students.

- **Bilateral programme of mobility of S&T professional**
  - From academia to industry.
  - From industry to academia.

- **Facilitating flow of technology from laboratory to market access**
  - General policy of technology transfer.
  - Enhancement of technology transfer towards commercialization.
  - Creation of research park.
  - Setting up of venture funds to support innovative entrepreneurship.

- **Setting up of interface structures**
  - Center of applied research & interface
  - Academia –industry R&D lab consortia.
  - R&D center for common facilities.
  - Entrepreneurship Development & Technology Incubation Centre
  - National Knowledge network to connect intuitions.

- **Fostering public-private partnership**
  - Growth of technology clusters.
  - Funding mechanism
  - Regulations & policies.

**ACHIEVEMENTS**

- Intensifying collaboration in research
  - Convergence of interests towards applied research
  - Diffusion of skill of conceptualization.
  - Acceleration of research interaction
  - International academic cohesion & industrial collaboration

### IMPACT

(Reference – Nangia et al., 2011)
Salivahanan and Kamaraj (2011) stated that all technological innovations are multi-disciplinary requiring a lot of collaboration and are happening rapidly. In this context, the common models available for industry partnership may not be suitable for the developing economies and they proposed a hexagonal multi-net model for Institute–Industry Collaboration (Figure 2.11) accommodating all sectors.


2.6 GLOBAL PRACTICES OF INSTITUTE–INDUSTRY COLLABORATION

2.6.1 United States of America

Carayannis and Alexander (1999) noted that there is an increasing consensus among academic scholars, policymakers and industry practitioners alike that the present and future secret of business survival and prosperity lies in strategic
partnering and co-operating successfully rather than outright competition. This is particularly so in knowledge-intensive, highly complex, and dynamic environments such as all higher technology industries (semiconductors, aerospace, software, telecommunications, etc.). They have also observed that the lessons learned from government–university–industry strategic partnerships for research and technological development show that there are distinct skill sets that firms must develop if they are to derive the full benefits of the alliances from participation.

Was (2005) observed that three paths for industry interaction are most commonly existing in USA and the three paths are (i) Single and multiple – Principal Investigator (PI) grants, which range from a few to ~50% of total industry support (ii) Federally funded centers, which provide a strong vehicle with which to attract industry support and (iii) Industry consortia, which constitute a large number (>20) of companies providing modest level of support ($15–$50K) and the main objective of the interactions is to provide access to students and to showcase research at the institution. He concluded that successful university–industry collaboration depends on institutional commitment to work with industry, active development of programs to attract industry and construction of partnerships at many levels.

Klawe (2004) noted that the increased collaboration between industry and higher education has brought the creative engine of the knowledge economy to rest on the shoulders of academic researchers. The rise in “real-world” research and education in colleges and universities has generated exciting opportunities with the potential to shift higher education’s culture, for example, by embracing the
opportunity for faculty to move back and forth between industry and academia. The shift, however, is not without risks to fundamental principles such as the freedom of inquiry that undergirds higher education.

Reichlmayr (2006) observed that developing an undergraduate software engineering curriculum that provides the opportunity for students to experience the challenges and dynamics of professional software product development is a daunting task. Even the best written text books and most well designed laboratory exercises on their own cannot account for the preparation needed to become effective members of professional software development teams. In this context, taking the example of the practice of the Rochester Institute of Technology, Reichlmayr (2006) outlined the following strategies, which were adopted to immerse the students in real world software projects at varying levels of their academic careers.

- **Collaborating through cooperative education**

  Opportunities are made available through direct employment as part of the student’s cooperative education (co-op) requirement.

- **Commercially sponsored senior capstone projects**

  Participation on a student team undertaking a senior capstone project with a commercial sponsor and the option to participate in the department’s research efforts with the industrial partners. At each of the levels, the companies they are collaborating will obtain mutual benefit. Capstone projects and research partnerships create similar opportunities for companies to execute meaningful projects and work with prospective employees.
• Collaborative research with industry

The faculty partnerships through shared research are a vehicle for companies to explore and implement advancements in best software engineering practices.

Genheimer and Shehab (2009) conducted a survey on industry advisory board operation and effectiveness in engineering education. The study has shown that the majority of engineering program directors and board members view the advisory board as a significant asset to the engineering program, beyond just a tool for meeting ABET accreditation requirements, and view their own involvement positively. The study has shown that effective boards have a clear understanding of their role and limitations in influencing curriculum, encourage engagement with students, have formal procedures for involvement in ABET accreditation and are well coordinated with the large educational institutions. In this context, advisory boards composed largely of members with close ties to the institution, generally alumni will be more engaged as advocates of the program and will contribute more financially.

Pertuze et al. (2010) conducted a survey to identify the best practices that the companies should follow to enhance the capability of industry–university collaboration that have positive impact on company products and process (Table 2.8).
Table 2.8 Best Practices for Collaboration – Companies

<table>
<thead>
<tr>
<th>Activity</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define the project’s strategic context as part of the selection process</td>
<td>Use your company research portfolio to determine collaboration opportunities</td>
</tr>
<tr>
<td></td>
<td>Define specific collaboration outputs that can provide value to the company</td>
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<tr>
<td></td>
<td>Identify internal users of this output at the working level; executive champions are not a substitute for this requirement</td>
</tr>
<tr>
<td>Select boundary spanning project managers</td>
<td>In-depth knowledge of the technology needs in the field</td>
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<tr>
<td></td>
<td>The inclination to network across functional and organizational boundaries</td>
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<tr>
<td></td>
<td>The ability to make connections between research and opportunities for product applications</td>
</tr>
<tr>
<td>Share with the university team the vision of how the collaboration can help the company</td>
<td>Select researchers who will understand company practices and technology goals</td>
</tr>
<tr>
<td></td>
<td>Ensure that the university team appreciates the project’s strategic context</td>
</tr>
<tr>
<td>Invest in long term relationships</td>
<td>Plan multiyear collaboration time frames</td>
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<tr>
<td></td>
<td>Cultivate relationships with target university researchers, even if research is not directly supported</td>
</tr>
<tr>
<td>Establish strong communication linkage with the university team</td>
<td>Conduct face-to-face meetings on a regular basis</td>
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<td></td>
<td>Develop an overall communication routine to supplement the meetings</td>
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<td></td>
<td>Encourage extended personnel exchange, both company to university and university to company</td>
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<tr>
<td>Build broad awareness of the project within the company</td>
<td>Promote university team interactions with different functional areas within the company</td>
</tr>
<tr>
<td></td>
<td>Promote feedback to the university team on project alignment with company needs</td>
</tr>
<tr>
<td>Support the work internally both during the contract and after, until the research can be exploited</td>
<td>Provide appropriate internal support for technical and management oversight</td>
</tr>
<tr>
<td></td>
<td>Include accountability for company uptake of research results as part of the project manager role</td>
</tr>
</tbody>
</table>

According to Cathy and Pinelli (2012), the internship experience provides many benefits to students; a well developed internship can aid universities
in providing academic challenges, active and collaborative learning, supportive
learning environment, and an enriching educational experience for students and it
can also serve to provide feedback to educational institutions and students about the
skill sets needed in the workplace. They have also noted that the internship
experience offers a key role in knowledge acquisition for students and a chance to
try out their chosen field, and it gives industry an opportunity to engage with future
employees. In the summary, they have concluded that the supporting collaborative
work experiences among universities, students and industry are definitely a win for
everyone involved.

2.6.2 Europe

According to the European commission report (2006), a strategy was
launched on mobility of researchers between academia and industry to foster a
favourable environment to attract, develop and retain the necessary human resource
in research and innovation and stop the brain drain of qualified scientists. As a result
of the above strategy, a framework involving experts from industry, institutions,
research institutions from European Union member states and state associated with
the research and technological development framework was created. These expert
groups jointly put forward a coherent and powerful set of recommendations for
improving mobility of researchers between academia and industry, as a means of
enhancing a culture of longer-term structured interaction and cooperation between
both sectors in terms of knowledge transfer and development of cross-sector skills
and competence. The following are recommendations to academia and industry.
1. Develop joint training programmes in order to better answer to future employers’ need

2. Prepare early stage researchers for a career in both sectors with awareness on key employment skills. Experienced researchers should be offered entrepreneurship, and research management training

3. Researchers should be followed by two supervisors with adequate training, one from each sector

4. Increase inter-sectoral mobility possibilities for both early stage and established researchers, particularly through consultancy and internships. Advertise vacancy positions and provide access to researchers’ industry relevant expertise online

5. Provide incentive to inter-sectoral mobility through adequate evaluation criteria, a fair and transparent career evaluation process, including trained evaluates and researchers from both sectors in the evaluation committees

6. Recruit more staff with experience from the other sector on permanent positions

7. Remove administrative barriers and provide the necessary autonomy to public sector institutions enabling them to undertake the above-mentioned recommendations, especially with regard to recruitment
8. Set the framework conditions for academia–industry partnerships by favouring co-location, collaboration through jointly funded research grants and fellowships and the establishment of codes and interface offices between academia and industry.

9. Include academia–industry collaboration as a criterion when appraising institutions, including when academia involves industry representatives in its organization.

10. Develop informal networks between small and medium enterprises (SMEs) and academia.

11. Provide funding for training to further professionalize academic staff at all levels to become “on a par to industry” (administration, technology transfer officers, supervisors, evaluators, career appraisal, etc.).

Boccheta (2008) observed that in Europe 35 major projects have been identified for the next 10–15 years representing an investment of 13.5 billion euro and a significant fraction of this investment is associated with synchrotron light sources, free-electron lasers, heavy ion and photon facilities. Many of these projects will be developed in parallel and there will be competition for resources for their realization. Collaboration between institutes and industry is essential for successful completion of these infrastructures. In this context, Boccheta (2008) concluded that the effectiveness of Institute–Industry Collaboration depends on relationships,
mutual trust, appreciation of cultural differences between institutes and industry and project focused, highly motivated and trustworthy people.

2.6.3 United Kingdom

Fontanna et al. (2006) presented an empirical analysis of the determinants of research cooperation between firms and Public Research Organizations (PROs) for a sample of innovating SMEs. The results of their analysis pointed to two major phenomena. First, the propensity to forge an agreement with an academic partner depends on the ‘absolute size’ of the industrial partner. Second, the openness of firms to the external environment, as measured by their willingness to search, screen and signal, significantly affects the development of R&D projects with PROs.

Perkmann and Walsh (2008) presented a conceptual framework of academic consulting and explored its impacts on universities and the benefits to innovating firms. They identified three types of academic consulting: opportunity-driven, commercialization-driven and research-driven and evaluated the varying impacts of different consulting activities on universities and firms.

1) The commercialization and research-driven consulting are likely to enhance research productivity

2) Opportunity-driven consulting activities might not do so. Their analysis also suggested that universities should look more closely at what type of consulting activities they should promote.
De’Este and Perkmann (2011) conducted a survey to obtain information from the university researchers who received grants from the UK’s engineering and physical sciences research council between 1999 and 2003 on their interactions with industry and thereby to understand what motivates academic scientists to engage with industry. The results suggest that research policy should refrain from overly focusing on monetary incentives for industry engagement and consider a broader range of incentives for promoting interaction between academia and industry.

Perkmann et al. (2011) explored how the quality of university faculty is related to their industry engagement via collaborative research, contract research and academic consulting. They contend that university–industry relationships are the outcome of a voluntary matching process between academic and industry partners, shaped by three forces. First, academics’ decisions to work with industry are informed by considerations of complementarity with academic research. Second, resource considerations play a role as academics can use the funding gained from industry contracts to supplement grants from public sources. Third, firms are interested in working with high-quality academic researchers because, in addition to seeking project-specific inputs, they are attracted by more generic benefits such as accessing students, ‘windows’ on emerging technologies, and enhancing their knowledge bases. They have concluded that the relational involvement between universities and industry can be seen as a matching process in which partnerships involve academics interested in research complementarity and resources, and firms seeking skilled and competent partners.
2.6.4 China

Huang et al. (2010) observed that UIC in engineering education plays an effective role in building students into innovative talents and also plays a significant role in nurturing high level talents for the university research.

Shanchaowu and Jin (2011) examined the issues on integrating R&D globalization, national innovation system, university–industry knowledge transfer, and international UIC. The research provided a framework to analyze the process of international UIC. The international UIC could be used as a bridge to connect the strategies of open innovation and R&D globalization with the national innovation system. He has concluded that through the international UIC, foreign companies and foreign universities contribute to the national innovation system building of host countries and the UIC could be recognized as one method of international education. This research provided a method of science and technology internationalization and practical suggestions to the management of UIC.

According to Microsoft Research Corporation (2012), collaborative research institutes have been established in the government universities of China to support basic academic to advance state-of-the-art research in the areas of computing and computational sciences. These collaborative research institutes play an important role in academic exchanges through workshops, seminars, summer camps for the faculty members and students and joint publication of papers with the university researchers.
2.6.5 Japan

Nezu (2005) of Fujitsu Research Institute in Japan observed that formal UIC dates back to 1983, when joint research projects with the private sector were first approved, but after the changes made in the Japanese science and technology policy in the year 1999, full recognition was given to UIC. He also stated that in Japan, the number of university spanned ventures has been looked at as a key indicator for measuring the overall effectiveness of UIC.

Kazuyuki and Shingo (2012) studied Japanese patent data and provided a quantitative analysis of how UIC has changed since UIC policies were introduced in the late 1990s. In doing so, they examined not only joint patent applications filed by universities and industry but also patents resulting from UIC by tracing the path back to the inventors. This is due to the severe restrictions set by the national universities regarding the ownership of intellectual property before their incorporation in 2004. In many cases, companies ended up filing patent applications alone, even when the results were obtained through UIC. They have also analyzed how these UIC changed in nature after the introduction of policy measures, what differences resulted from corporate partners of varying sizes, and whether the changes led to specific problems. They also compared these differences with the traditional process of patent applications by companies alone, even in cases where universities were involved in the invention process. Based on the above mentioned analysis, they concluded that the US-style contractual UIC system introduced in the late 1990s has helped the research results at universities, often financed by tax money, to contribute to development of economy and society as a whole.
Furthermore, while UIC have primarily involved major and large companies, participation by SMEs carries great value.

2.7 PRACTICES OF INSTITUTE–INDUSTRY COLLABORATION IN INDIA

2.7.1 Strategies to Improve Institute–Industry Collaboration

Kamala (1991) stated that institute–industry interactions are vital for economic development of developing countries and so far it has been a weak activity in these countries due to limited appreciation and action at both the ends. She has mentioned that emphasis should be not only on research and development strategies but also on marketing and management strategies and presented some of the marketing strategies (Table 2.9) for academic consultancy that facilitate development of industrially relevant research and development.
Table 2.9 Marketing Strategies of Academic Consultancy

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<th>Strategy</th>
<th>Implications</th>
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| Managing consultancy at its own pace | • No special efforts done, wait for opportunity, match capability with requirements.  
• A passive development strategy with limited opportunities, lacking dynamism and growth prospects. |
| Market mode | • Envisages a high contact system between the academia and industries with high degree of awareness of each others’ needs and capabilities.  
• The environment in developing countries is not yet fully ready for such a mode. |
| Cuts and compulsions | • Regulation of academia-industry interactions through budgetary and fiscal instruments and regulations.  
• Under this mode, academic institutions may face financial hardships and may be forced to solicit projects without much scope for exercising selectivity. |
| Dynamic market search | • Dynamic market search referred to voluntary approach towards promotion of academia–industry relationship, introduction of change through creating awareness, educating the client on the new value collaborative R&D and initiation of change, effective coupling of S&T/R&D needs of industries. |

Achintya and Rai (2007) suggested the following strategies to strengthen the Institute–Industry Collaboration such as encouraging the sponsorship for the students projects by the industries in order to reduce the financial burden of engineering institutions, involving the students in the real shop-floor experiences at industries, exchanging engineers from industries and faculties from engineering institutions for short period, instituting awards and cash prizes for the best students and faculty members by the industry, providing proper training facilities with regard to emerging technological innovations for the engineers of the industries by the engineering institutions, promoting quality improvement programme for faculties with industries, encouraging a close liaison with the industries to place the students.
The Education Promotion Society of India (2008) suggested the following strategies to improve Institute–Industry Collaboration.

- To identify the specific needs of the industry and involve industry in curriculum development, particularly in courses which have integral relationship with industrial process
- To design of research plans, training, field study and other academic activities with partnership with the industry
- To encourage the professors from institutes to go on sabbatical to industry to update themselves
- To contribute for the development of the skilled manpower by both institutes and industry
- To nominate the industry experts in the accreditation bodies.

Federation of India Chamber of Commerce & Industry (FICCI) and Narsee Monjee Institute of Management Studies (NMIMS) (2006) conducted a study on industry–academia convergence “bridging the skill gap” and suggested a holistic approach for reforms in the higher education sector to acquire the important human resource for successful commercialization and industrial competitiveness. These strategies range from identification of skills, shortfall which may occur, efforts to impart required skills, and adapting existing skills by orienting to new demands.
1. Improve governance of academic institutes and industry linkage

Establish a process for mandatory registration of institutions with a sector specific professional body that includes representatives from the industry, academia and the government to ensure quality in higher education and training in the country. This body should be empowered to grant recognition to the institutions meeting the standards set with reference to qualified and trained teaching staff, infrastructure, adequately equipped laboratories, etc., that are essential for a focused education. The accreditation process should be mandatory and consequential. Self-regulation and transparency in the Indian higher education system is critical to ensure quality delivery of education and training.

2. Build centers of excellence

- Impart quality training to the scientific and professional pool
- Invest in the shared facilities like “National Resource Center”. Build private and government funded time-share facilities with leading edge infrastructure & repositories of knowledge
- Promote research translation centers in India. These centers will be useful in translation of academic research into industrial products
- Upgrade the existing research centers to become centers of excellence / innovation hubs. Each institute may focus on specific areas for research
- Ally with leading foreign institutes. International linkages should be increased to strengthen the Indian capabilities to transfer the new R&D work at national laboratories to the market.
3. Effective industry involvement

- Ensure participation of industry for discussion on major policy issues directly related to its concept to commercialization. Active industry executives may be nominated on the governing board of leading academic institutions

- Hold business plan competitions jointly sponsored by industry and academia

- Renewal of research grants should be made to the academic institutions contingent on industry linkages

- Help academic researchers commercialize their research findings by encouraging academic institutions to interact with an industrial partner to promote their products.

4. Attract top talents to the faculty pool

- Provide additional incentives to promote industrial cooperation to increase output of faculty / scientists from tier I research institutes

- Attract high-performing Indian scientists / technocrats back to India

- Allow faculty to earn royalty on patents

- Place no limit on earnings from industry funded projects

- Allow scientists to hold part-time positions in the private sector in order to have the right blend of theory and practice.
2.7.2 Institute–Industry Initiatives in India

In the ever-changing world of technology and innovation the different initiatives are being taken to strengthen Institute–Industry Collaboration in India. Department of Science and Technology, Govt. of India (2006) reported that the main objectives of the Institute–Industry Collaboration initiatives taken in India by the Department of Science and Technology (DST) and All India Council for Technical Education (AICTE) are to exchange ideas on various policies, processes, procedures, practices and programmes, to customize study programmes of AICTE recognized institutions as per industry’s expectations, to encourage joint innovative programme, to exchange of knowledge resource, to adopt global best practices and to encourage beneficial partnerships with foreign institutions and industry.

Murthy (2002) prescribed the case study from India with reference to the Indian Institute of Technology Institutions (IITs). He has stated that a strong link exists between the academia of IIT and industries of India through the industrial consultancy and sponsored research centre. The centre undertakes various programmes as given below.

I. Consultancy

Industries from different sectors take the help of the faculty members and the facilities of the institute to get their problems solved through the specialized knowledge of the faculty using the institute facilities.
(a) Research based industrial consultancy

An industry or group of industries can jointly sponsor a project for a period of six months to two years after which the know-how generated by the project is to be shared by both the parties.

(b) Retainer consultancy

Expertise of the IIT faculty is utilized by the industries as retainer consultants for advice and guidance on any aspect of interest to the industry.

II. Sponsored projects

These are R&D projects funded by government departments and agencies, industries or other institutes with a view to generate new knowledge or new technology or new products required for nation building.

III. Industrial associateship scheme

The institute provides facilities such as library and information services, short-term courses, technology appreciation programmes and get-together programmes.

IV. Special educational programmes

Special graduate and post graduate programmes with syllabus relevant to industrial application are conducted like M.Tech. programme in computational engineering for Tata Consultancy Services, B.Tech. Engineering Physics programme to meet the needs of industries that are in search of engineer-scientists for their R&D activities.
V. Technology development mission

In this programme, four higher institutes of technology and science namely IIT at (i) Madras (ii) Delhi (iii) Kanpur and (iv) IISc, Bangalore work on the generic areas of magnetic materials, polymers and composites and metals matrix composites.

These programmes link the faculty members, staff and students of the institute to work on the live, unsolved problems of user agencies. This also helps the students to get an exposure and an opportunity to tackle practical problems.

Infosys launched a unique academia–industry initiative called Campus Connect (CC) to architect the education experience (Infosys, 2012). The goal of the CC was to build a sustainable partnership with engineering education institutions in India for mutual benefit; producing “industry ready” recruits and to help to increase India’s competitiveness in the knowledge economy. CC aims at evolving a model through which Infosys and engineering institutions can partner for competitiveness, enhance the pool of highly capable talent for growth requirements in (IT) space. It is aimed at creating an effective means of backward integration into the supply chain by going into the college campuses from where the IT industry gets the people for its growth. Currently, they have more than 300 engineering colleges under their wing. CC initiative includes
(i) Seminars and training for colleges faculty: This will give an industry perspective to the faculty, aligning the college curriculum with industry requirements and working with educational bodies for implementing it, and

(ii) Publishing Infosys courseware on the web: This will give students and faculty access to courseware designed by Infosys. The courseware adds to the existing college courseware and highlights the integrated, systems way of looking at hitherto discrete topics.

WIPRO launched a faculty development programme called MISSION 10X (Wipro, 2014) in India. WIPRO’s Mission 10X aims to increase employability of engineering graduates through a deep faculty enablement programme that empowers engineering faculty members with innovative teaching techniques using which they can help learners in imbibing higher level of understanding of subjects, application of concepts learned and development of key behavioral skills. Since its inception, Mission 10X has been able to reach out to over 10,000 faculty members from over 700 colleges across 20 states.

According to Texas Instruments (TI) India (2014), the main aim of the university relation initiatives at India, is to reach out to the educators and the engineering student community for helping them to achieve more in their research and their learning on the latest development in the field of semiconductors. The various university–industry initiatives by TI at India are listed below.
• **UniTI newsletter**

The newsletter aims to bring together the engineering academic community in India closer to TI. They provide interesting and useful articles on latest technologies of interest to TI, product information, information about events organized through the UniTI program.

• **Teaching materials**

TI provides educational CD-ROMs to educators with "ready to teach" content such as foilware and experiments around TI experimenter kits. These educational materials have been prepared by Professors from reputed universities. Faculty members from India can download the same with free of cost.

• **Analog design contest**

The contest aims at promoting analog integrated chips based-hardware system design in engineering institutions.

According to IBM Research - India (2014), the main objectives of Institute–Industry Collaboration in India by IBM is to develop a long-term, mutually beneficial relationships with the faculty and students of the Indian academia by fostering advanced research, promoting university–industry exchanges, providing infrastructure and technology support, and cultivating tomorrow's world-class researchers. In this context, they offer numerous resources to academia under the umbrella of such collaborations such as faculty research awards, equipment grants, sabbatical opportunities, conference sponsorships, student internships, student project training and Ph.D. fellowships. Presently, IBM India is collaborating with
few HEEI viz. Indian Institute of Technology (IIT) at Bombay, Madras & Kharagpur, Indian Institute of Science (IISc), Bangalore, TATA Institute of Fundamental Research (TIFR), Bombay and International Institute of Information Technology-Hyderabad (IIIT-H).

2.7.3 Spin-off University Firm

Flores (2006) presented a case study on university–industry collaborative networks for new product development in IIT Madras, Chennai, India. According to Flores, for a country like India, universities have had teaching as main objective, but in order to develop new advanced technologies to enable the development of societies, advanced knowledge and skills are required and in many cases are not present in entrepreneurs who just want to start a new business. Therefore the universities should play a more active role in these developments. In this context, IIT Madras and the Telecommunications and Computer Networks Group (TeNeT) closely collaborated to enable the creation of new businesses to develop new technologies that can be affordable to the rural areas in India mainly communication. This collaboration has resulted in the first spin off of the TeNeT group called “Midas Company” and followed by Nexge and Vortex. Figure 2.12 illustrates the spin-off case study.
The key findings for the successful spin-off university firm at IIT Madras are:

- **Product innovation**

  The targeted products are either new to the global markets or new to India.

- **Competencies**

  Skills both from professors and entrepreneurs are available. The transfer of knowledge is not only from IIT Madras to the companies, but bilateral. New knowledge is created and shared in and by all the TeNeT groups. TeNeT entrepreneurs have working experience in other companies which facilitates the commercialization of the new products to the market as professors usually don’t have industrial working experience. Companies take advantage of IIT Madras laboratories and overall infrastructure.
• **Informal contacts**

Professors from the TeNeT group started the spin-offs by contacting their ex-students and integrating them to the network. These contacts facilitated the network to take-off and to develop the new products.

• **New product development process**

The TeNeT defined a clear methodology to develop new products, where all the members contribute for the generation of ideas, for their assessment and selection. Professors from TeNeT also look for venture capital in the USA.

• **Market**

The market focus is clear and shared by all the members. Members of the TeNeT group are also highly motivated to be competitive in international markets and their technologies are being sold in several countries with similar business opportunities in Asia, Africa and Latin America.

• **Trust**

There is a high level of trust between IIT Madras professors and entrepreneurs from the TeNeT group. The strong leadership from IIT professors to hold the group together and target one specific need to develop India has made the group to work towards a common vision and goal.
2.7.4 Innovation Centers

Today the industry recognizes innovation as the need of the hour and the primary means of ensuring sustainable competitive advantage. Research and innovation could well happen within the confines of an organization or a research institution. Natarajan (2008) reported that the various initiatives taken by the Indian HEEI to establish the innovation centres viz. society for innovation and development at IISc, Bangalore, foundation for innovation and technology transfer at IIT, Delhi, cell for technology innovation, development and entrepreneurship support at IIT Madras and society for innovation and entrepreneurship (SINE) at IIT, Bombay are to promote national level innovation with a mission to act as a bridge between the institutions and the corporate worlds, to add commercial value to the intellectual activities of the faculty members and research scholars and to create a purposeful and effective channel to help and assist industries and business establishments to compete and prosper in the face of global competition, turbulent market conditions and fast-moving technologies.

In this context, Natarajan (2008) also reported on the initiative taken by IIT Madras to establish a research park to promote R&D in partnership with the industry to nurture innovation, to assist in the growth of new ventures and to promote economic development.
The salient features of the research park are:

- It is an independent company with the board of directors comprising distinguished academicians, leading industry professionals and government representatives

- It is a world-class facility with a built-up space of 1.6 million sq.ft. and it houses about 100 R&D companies and 10,000 research personnel

- It connects industry personnel to the innovation inputs of knowledge, people, and resources that will unleash the power of innovation in organizations.

2.8 SUMMARY

The review of literature on the collaboration of HEEI with industries points out the importance of a continuous, long-term effort in the setting up of a relationship, which is of mutual benefit. It is evident from the critical review of literature that in India research on Institute–Industry Collaboration is still in its infancy and with possible exception of a few studies, it remains an unexplored area. The research studies carried out are general in nature. No research study has been carried out to determine the effectiveness of Industry–Institute Collaboration in HEEI in specific to deemed to be universities, which have full academic freedom and can award their own degree. This creates a lot of scope in increasing Industry–Institute Collaboration in these institutions. The review of literature provided a deep insight, which enabled the formulation of an appropriate design to carry out the study. The following are the salient points brought by the review of literature.
1. In the present scenario when globalization is round the corner, it has become essential for HEEI to establish collaboration with the industries and this collaboration has become the need of the hour for overall economic development of the country. The basic principle of a long-term and sustainable collaboration is symbiosis or achievement of mutual benefits by using the experience and resources available in both the systems.

2. For a successful Institute–Industry Collaboration, institutions must apply a marketing approach and establish the objective of identifying and satisfying the needs of their stakeholders. In this context, the stakeholders of Institute–Industry Collaboration are academic administrators, placement coordinators, faculty members, students and representatives of industry.

3. The process of knowledge transfer between institutes and industries occurs through multiple channels and one of the methods for measuring Institute–Industry Collaboration is by means of surveys.

4. Various types of collaboration occurred between institute and industry and these collaborations are from primitive forms to advanced types in which long-term relationships are developed.

5. Institute–Industry Collaboration involves a diverse set of activities and result in a variety of outputs and no single measure is able to capture the full range of such collaborations.
6. The effectiveness of Institute–Industry Collaboration between HEEI and industries can be measured with the parameters such as organizing workshops, conferences and seminars with joint participation of the faculty members and the industries, encouraging engineers from industry to visit engineering institutions to deliver guest lectures, involving the experts from industry in curriculum design and teaching process, involving the industrial personnel in various committees, encouraging the industrial experts in evaluating the students, encouraging joint publication of papers by the faculty members and people from industries, conducting human resource development programmes by faculty members for industrial personnel, encouraging collaborative degree programmes with industries, sponsoring R&D laboratories by the industries at the institutes, participating in the infrastructure development of institutions by the industries, contributing funds to attend workshops by the industries, donating instructional resource materials by the industries, utilizing the state-of-the-art laboratory facilities at the institutes by the industries, short-term assignments to the faculty members in industries, participating in the professional consultancy work and conducting testing at the site or laboratory by the faculty members to the industries, encouraging the joint projects and research at the institute with the industries, encouraging the filing of joint patents by the faculty members and industrial personnel, sponsoring the professional chairs by the industries at the institutes,
arranging industrial visits and project works for the students, arranging internships and practical training for the students at the industries and instituting the scholarship / fellowship for the students by the industries at the institutes.

7. The effectiveness of the Institute–Industry Collaboration is closely related to the enhancing and limiting factors.

8. The factors that enhance Institute–Industry Collaboration are acquiring research funding, acquiring new laboratory equipments, access to new research, new products development, new patent acquisition, solving specific technical problems, sustaining a stronger industry–institute relationship, source of personal income, generation of income for research activities, maintaining quality standards, using testing equipments and other facilities, information on trends in R&D fields, state-of-the-art technological information, consulting advise in solving production related problems and technology transfer.

9. The factors that limit Institute–Industry Collaboration are lack of understanding, lack of mutual trust, geographic distance, absence of dedicated manpower such as industrial liaison officers / placement officers, lack of appropriate incentives, lack of specialized technical infrastructures, lack of communication, cultural differences, conflicts in IPRs and rigid rules and regulations.

10. An Institute–Industry Collaboration model is a planned flow of activity in sequence for the benefit of institute and industry.
11. The Institute–Industry Collaboration cannot be explained with some stipulated laws or by establishing a static model and there is no widely accepted model was developed as the type and the intensity of Institute–Industry Collaboration are not same throughout the globe.

12. The most of the models were presented with need based criteria and emphasis on macro level aspects.

13. The pattern of Institute–Industry Collaboration in India differs considerably from that in other countries.

14. In India, some specific initiatives jointly implemented by universities and industries / government like creation of science parks, technology parks, research parks, entrepreneurship development centers, incubation centers and innovation centers in the universities campuses to promote the activities of Institute–Industry Collaboration.

To conclude, there is lots of evidence on growing interest among HEEI and industry on Institute–Industry Collaboration and the collaboration between HEEI and industry have become a topic of increasing attention for researchers in recent years. Hence there is a need for specific research studies to investigate the collaboration between HEEI and industry especially in developing countries like India.