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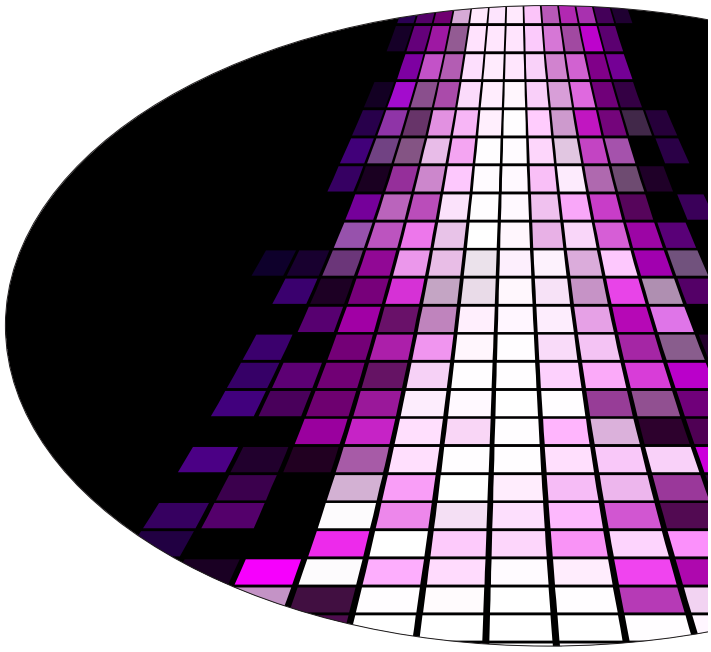

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Understanding Interactions Between Research Institutes and Industry : Indian Perspective

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Abstract

The tangible potential benefits of interactions between public research institutes and industry are often not realized in practice due to many complexities underlying these interactions. As the interaction is between two diverse organizations, it needs considerable management effort at all stages to make it successful and to get the maximum benefit. Therefore, there is every need to study these interactions, and critically examining different dimensions and identifying key factors that matter in institute-industry interface. This will provide an insight into effective management of their interactions. The present study attempts to assess the situation existing in Indian context. It tries to understand the interactions from the perspective of actual researchers and managers of these interactions at research institutes. The study resulted in identifying key factors at different stages of interaction which if managed correctly, increase the probability of effective and successful interactions leading to development of good technologies. The study also tries to explore whether there is any difference in the perception of researchers across the experience levels and disciplines, and also between researchers and managers.

Keywords: *Public research Institute; institute industry interactions; technology transfer; survey of researchers; modes of institute industry interaction; research collaborations*

INTRODUCTION

Public funded R&D institutes, hereinafter referred to as "research institute' and 'institute' in the paper, generate and disseminate knowledge, typically drawing on national and international, industrial and scientific knowledge in order to support the industry. They have their own technologies and technology related services which the industry needs but can't access. They carry out tasks helping the industries to develop a strategic approach towards technology (Nath and Mrinalini, 2000, Rath, 1998). The interactions between these research institutes and industry hereinafter referred to as "interactions" in the paper, are witnessing growth worldwide and there are number of studies that have analysed them. It will provide research institutes more exposure towards application oriented research, which may also lead to the development of new commercially potential technologies. It is a means for industries to advance technologically at lower cost and with less inherent risk than would normally be possible through internal development (Siegel et al. 2003; Katz et al. 1997; Rogers et al. 1998; Jacob et al. 2000; Marceau 2002; Santoro et al. 2002; Rama

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Mohan et al. 2005; Lee 2000; Levy 2009). Research institutes can supplement funds for research, test the practical application of their research, develop and transfer new technologies earning critical revenues through interactions. Industries can solve their specific technical problems, develop new products and processes, conduct research leading to new patents and improve their technologies and products through interactions (Lee 2000, Rama Mohan and Ramakrishna, 2003).

Growing social pressure demanding useful research and shrinking academic research budgets are influencing research institutes to interact with the industry (Blumenthal et al. 1986; Martinez et al. 1999). It can also result in the exchange of technological information, sharing of R&D costs and risks, accumulation of new skills and expertise, cross-fertilisation of ideas, broadening the effective scope of activities, access to funding and R&D facilities, participation in research of high-technology areas and transfer of research into useful products (Scott, 1998; Forest and Martin, 1992; Bloedeon and Stokes, 1994; Katz and Martin, 1997; Rogers et al., 1998; Ingham and Mothe, 1998; Ruppert et al., 1999; Hagedoorn et al., 2000; Jacob et al., 2000; Bozeman and Dietz, 2001; Marceau, 2002; Santaro and Betts, 2002; Rama Mohan and Ramakrishna, 2005; Owen-Smith and Powell, 2001; Arvanitis et al., 2008; Lee, 2000). Industries are realising that in-house R&D facilities and resources are not enough for the development of the new products and are showing interest in interactions (Bloedeon and Stokes, 1994; Ingham and Mothe, 1998; Hagedoorn et al., 2000; Chiesa and Manzini, 1998; Rama Mohan and Ramakrishna, 2005). The active participation of industry is also an important component to support the successful outcome of academic research for commercial purposes (Lopez, 1998). Interactions expose industry to basic fundamental research, provide access to the newest technologies and reduce product-process development time and cost (Lee, 2000; Meyer-Krahmer et al., 1998; Scott, 1998).

Industry looks for high quality researchers, senior management commitment, customer focus, clearly defined research goals, effective project planning and management, supportive and flexible organizational culture and access to complementary skills in research institutes (Davenport et al., 1999). Additional funds and knowledge exchanges are the main advantages whereas short term orientation of the research and restrictions to publications are the disadvantages from interactions with industry (Meyer-Krahmer and Schmock, 1998; Starbuck, 2001). Researchers choose interactions with industry for getting access to additional funding for research, applicability of research, access to

industry skills and facilities, keeping abreast with industry problems and getting recognition within the scientific community (Meyer-Krahmer and Schmock, 1998; D Este et al., 2005; Siegel et al., 2003; Numprasertchai and Igel, 2005; Hoye and Pries, 2009).

Industry sponsored meetings and conferences, consultancy, contract and joint research projects, creation of new companies and new physical facilities and training relationships are some of the interaction modes. Creation of spin-offs was the least preferred form of interaction, and joint research and training were moderately important. Consultancy, contract research and collaborative research are the most preferred modes of interaction (D Este and Patel, 2007). Industries prefer a few publications, conferences, informal interactions and consulting compared to patents and licenses (Cohen et al., 2002). Interactions occur through personnel mobility, informal contacts, consultancy collaborative research projects, patenting and spin-offs (Roessner, 1993; Schartinger et al., 2001; Faulkner and Senker, 1995; Arundel and Geuna, 2004; Sequeira and Martin, 1997; Hoye et al., 2009). Preferred modes of interaction are collaborative research, informal contacts, education of personnel, seminars for industry and membership of committees (Meyer-Krahmer, 1998).

Lack of understanding regarding organizational cultures, insufficient rewards for researchers, inflexibility of administration, insufficient resources devoted to technology transfer, unrealistic expectation regarding the value of technology and public domain mentality of academic institutes are barriers for successful interactions with industry. Institutes and industry have different perspectives and goals with respect to Intellectual Property Rights also (Siegel et al., 2003). Different strategic goals, lack of commitment, not defining structure of interactions, not adhering to the terms of the agreement and incompatibility of partners are some of the reasons for failure of the interactions (Blumenthal et al., 1996; Forest and Martin, 1992). Differing interests and attitudes, fear to lose scientific independence or neglecting basic research and scientific publication activities seem to be the most relevant impediments for researchers to get engaged in interactions. These are primarily because of cultural differences between institute and industry. These can be partly traced back to the different goals pursued by the institute and the industry and the lack of knowledge of the problems and interests of each other, is responsible for this situation (Arvanitis et al., 2008; Millson et al., 1996). Research institutes need to improve their understanding of the needs of the industries, adopt a more flexible stance in negotiating agreements and streamlining policies and

procedures They must increase the rewards for researchers for participation in interaction by valuing patents and licenses in promotions and tenure (Siegel et al., 2003).

The tangible potential benefits of interactions are often not realized totally in practice due to many complexities underlying these interactions. It needs considerable management effort at all stages in order to make it successful and to achieve the maximum benefit (Barnes et al., 2002). Unfortunately, there are no clear cut models for managing interactions (Geuna and Muscio, 2009). The importance of better interactions has increased over the past few years which necessitated productive and effective interface and in this context, it is necessary to critically examine and understand the interactions throwing light on different dimensions and identifying key factors at different stages for its effective management. It was understood from the literature that no study has been done in Indian context earlier to understand these interactions. There is a need for studies which dwell on interactions in Indian context and the present study attempted to work in that direction. It attempts to find out the perception of researchers towards key factors at various stages of interaction process which, if managed properly, can make the interactions successful. The present study also explores whether there is any difference in the perception of researchers across different disciplines and at different experience levels. Also it tries to identify whether there is any difference in perceptions of researchers and managers towards the interaction process at research institutes.

RESEARCH STUDY AND APPROACH

Aim of the study

The main aim of the present study is to understand interactions in Indian context so that it can be managed effectively. It implies any type of relation between institute and industry and does not confine to any one specific interaction. The study focuses on the individual level of experience i.e. at the individual researcher level since they are the key persons who work along with industry personnel for longer durations during the project period. Also, in almost all research institutes, there will be a separate division that looks after facilitating the interactions. The approach adopted in the study involves identifying key factors at different stages of the interaction process by gauging the perceptions of the researchers and managers working in the research institutes. Identified factors if managed correctly, increase the probability of effective and successful interactions. It was expected that

the outcome of the study will give an insight to the management of the Indian research institutes about the concept of interaction between actual researchers and managers and how such interactions can be managed for effective technology development. It presents and discusses opinions that arose from a survey of researchers and managers, regarding the interaction process, working in Indian public funded research institutes.

The study aims to understand the perceptions of actual researchers and managers at various stages of interaction process viz.

- Search channels used by industry and influencing factors for choosing research institutes for interactions
- Advantages of interactions
- Motivation and demotivation factors for researchers
- Motivation for research institutes and industry,
- Most preferred forms of interaction
- Essential factors and barriers for successful interaction.

The study also aims to find out whether there is any variance in the perceptions of researchers across disciplines wise and at different experience levels. The study also attempts to find out whether there is any difference in the opinion among actual researchers and managers about this interaction process.

Research Study

India's largest scientific establishment and one of the world's largest chain of public R&D institutes was considered in the study. It is an autonomous body with a mission statement to provide scientific industrial research and development that maximizes the economic, environmental and societal benefit for the people of India. The underlying emphasis is that R&D provides traceable and tangible benefits to the economic, environmental or societal welfare systems. A survey was designed and carried out in the study to gain insights into perceptions of the researchers' working in various research institutes about various aspects of interactions. The population of the study includes researchers working in India's largest chain of public R&D, institutes working in the area of chemical sciences, engineering sciences and biological sciences. The sample for the study was drawn from these researchers' who belong to different disciplines and have different experience levels randomly. Every research institute belonging to the chosen chain has an exclusive division, working for facilitating interactions. Further in this study, the term 'Manager' refers to the personnel who are incharge of this interaction process and are working in those divisions. Sample for surveying the

managers' perceptions was drawn from these divisions. The results and recommendations are based on structured and personal interviews with these researchers and managers. The interviews consisted of a series of questions that were designed to determine how researchers viewed the different aspects of interactions; thereby, trying to identify the important factors that have to be managed for successful initiation and management of the interactions. The identified factors, if managed correctly, increase the effectiveness of the interactions.

Questionnaire was prepared incorporating the key factors identified in the literature at different stages of the interactions and was administered to one hundred and sixteen researchers and forty five managers personally or through mail. Since the sample contains researchers across different disciplines and with different experience levels, the conclusions can be drawn from the broad spectrum of researchers. Researchers in the sample were drawn from Chemical Sciences (CS), Engineering Sciences (ES), and Biological Sciences (BS). Responses were received from sixty four researchers with a response rate of fifty five percent and the response rate for the managers was fifty two percent. All the received questionnaires were structured and analysed. The author and also had personal discussions with some of them to arrive at requisite conclusions. Details of the sample of the researchers are given in Table 1. The researchers and managers were asked to assess whether the mentioned factors are important or not in the questionnaire.

Table 1(a): Details of sample researchers (Experience wise)

S.No.	Sample	Percent(%)
1	Senior researchers	43
2	Middle researchers	37
3	Junior researchers	20

Table 1(b): Details of sample researchers (Subject wise)

S.No	Sample	Percent(%)
1	Chemical Sciences	40
2	Biological Sciences	34
3	Engineering Sciences	26

RESULTS AND DISCUSSION

Search channel used by industry

Research institutes can chalk out effective publicity strategies, to attract and initiate interactions, if they know the search channel used by industries

in identifying the research institutes which pursue research in their areas of interest. It helps in devising ways for getting good exposure to the capabilities of the institute. As the researchers and managers were actively in touch with the personnel of the industry for long durations during their collaborations, they had adequate information about how that particular industry approached the institute for interactions. So it was decided that utililising their experience in understanding the search channel used by industry for identifying research institutes will contribute to the understanding of the issue. The results obtained were presented in Table 2.

Ninety six per cent of the researchers felt that industry will come to know about research institutes through its patents and by participating in interaction meets, exhibitions, workshops and seminars. By participating in industry interaction meets and trade exhibitions arranged by other agencies, industry will become aware about the capabilities of institutes and also will get a chance to interact and have technical discussions with researchers of the institute. Research institutes often organize conferences, seminars and workshops in their areas of expertise covering latest R&D in that field. Through these workshops and seminars, researchers can contact the industry personnel and it is the best way to exchange knowledge on research opportunities and to stimulate ideas for new research. Also, it is one of the best way for institutors to showcase their R&D capabilities. Informal discussions between researchers and industry personnel, most of the times, lead to research interactions.

Interactions often develop formally and informally through personal contacts of researchers and industry personnel. Ninety two percent of the researchers felt the same. Research institutes some times do not have sufficient resources to penetrate the market for business generation/development. They engage experts as consultants to help them in identifying clients for their knowledge base. Similarly, industries also engage consultants who identify the institutes for carrying out research in their R&D areas. Another approach that the industry adopts for identifying research institutes is by conducting web search. R&D managers at industries, when they want to know the potential institutes having expertise and capabilities in specific technology or R&D area, search internet and analyze the information and further, approach the institute for further discussions. Institutes have to update their success stories regularly on their website. Eighty five per cent were of the opinion that their publications in reputed journals will help in attracting industry and only sixty three percent felt that the print media is effective in present days.

Senior researchers are of the opinion that industries are coming to research institutes because of researchers' personal contacts with them and through patent portfolio of the institute. Participating in interaction meets and exhibitions is also a good idea according to them. Middle level researchers felt that industries will come to institutes by identifying them through web, their patents and by participating in interaction meets, exhibitions, workshops and seminars. Junior researchers felt that publications, personal contacts, consultants and organization of workshops and seminars are driving industries through the research institutes. F ratio at 0.05 α level yields 0.77 which is less than the critical value of F i.e.3.46 gives a conclusion that there is no significant change in the perception of researchers at different experience levels.

Researchers from engineering sciences and biological sciences are giving importance to filing patents and participating in interaction meets and exhibitions whereas researchers from chemical sciences are opting for organizing workshops and seminars. F ratio at 0.05 α level yields 0.57 which is less than the critical value of F i.e.3.46 indicates that there is no significant change in the perception of researchers across the disciplines. Managers felt that industry will know about the institutes through its publications also. Participating in interaction meets and exhibitions and organizing workshops and seminars are also important to showcase the capabilities of the institutes. Personal contacts between the researchers and industry personnel also play a key role in finalizing research interactions. t ratio at 0.05 α level yields 0.44 which is less than the critical value of t i.e.2.14 gives a conclusion that there is no significant change in the perception of researchers and managers.

Table 2: Search channels used by industry

S.No.	Search Channel	Researcher across experience (%)			Researcher across discipline(%)			Researchers (%)	Managers (%)
		S	M	J	ES	BS	CS		
1	Print media	70	41	34	71	66	54	63	40
2	Publications	88	83	100	85	70	90	85	100
3	Personal contacts	100	83	100	85	100	90	92	100
4	Consultants	94	75	100	100	100	81	92	60
5	Web search	88	100	68	100	88	90	92	80
6	Patents	100	100	68	100	100	90	96	100
7	Interaction meets and exhibitions	100	100	68	100	100	90	96	100
8	Workshops and seminars	94	100	100	100	88	100	96	100

S=Senior researchers, M-Middle level researchers, J=Junior researchers

ES-Engineering Sciences, BS-Biological Sciences, CS=Chemical Sciences

Influential Factors for industry

Industry will look for technical and scientific expertise existing in the institutes, its past track record in different aspects, leading edge work done or appropriate technology and facilities available while deciding to interact with research institutes. This was the percpetion of researchers as presented in Table 3. Industry looks for quality people having excellent track record and good expertise in their area of interest. Institutes have to identify their priority R&D areas, based on goals and objectives of the institute, and see that it has good expertise available in those areas as the capability of an institute is reflected in its command over a scientific knowledge base. Industry examines the performance of the institute in its earlier collaborations regarding deliverables, timeliness, clarity in reporting and project management. The industry gives priority to available facilities and also examines whether the core R&D area work done in the institute is aligned with the industry's objectives or not.

Senior researchers feel that industry will give priority to: technical and scientific expertise existing in the institutes, availability of appropriate technologies, demonstrated capabilities and past track record, facilities available and management of the institute. Management of the institute has the capabilities to identify performance gaps and opportunities in time and resolve them. Middle level and junior researchers feel that almost all the factors mentioned are important. F ratio at 0.05 α level yields 1.77 which is less than the critical value of F i.e.3.55 indicates that there is no significant change in the perception of researchers at different experience levels. Researchers from engineering sciences and chemical sciences that almost all the factors identified are important. F ratio at 0.05 α level yields 1.26 which is less than the critical value of F i.e.3.55 indicates that there is no significant change in the perception of researchers across the disciplines also. Managers also feel that almost all the factors are important. t ratio at 0.05 α level yields -1.49 which is less than the critical value of t i.e.2.17 gives a conclusion that there is no significant change in the perception of researchers and managers.

Table 3: Factors influencing research institutes

S.No	Influential factors	Researcher across experience(%)			Researcher across discipline(%)			Researchers (%)	Managers (%)
		S	M	J	ES	BS	CS		
1	Technical and scientific expertise	100	100	100	100	100	100	100	100
2	Leading edge work or appropriate technology	100	100	100	100	100	100	100	100
3	Demonstrated capabilities	100	100	100	100	20	100	66	100
4	Past track record	100	100	100	100	100	100	100	100
5	Facilities avaailable	94	100	100	100	88	100	96	100
6	Management of the institute	100	100	100	100	100	100	100	100
7	Business fit	82	100	100	71	88	100	88	100

S=Senior researchers, M-Middle level researchers, J=Junior researchers

ES-Engineering Sciences, BS-Biological Sciences, CS=Chemical Sciences

ADVANTAGES OF INTERACTION

Almost all the researchers surveyed in the study felt that interactions will result in improvement in technology and cost savings for the industry and will also lead to patents with great commercial potential as presented in Table 4. Ninety six percent felt that interactions results in exchange of knowledge and ninety two percent felt that it will pave way for access to market needs and development of new products. Senior researchers are mainly forecasting technology improvements and cost savings from the interactions, whereas middle level researchers are of the opinion that it will give access to market needs and good patents. Junior researchers are of the opinion that interactions will lead to knowledge exchange, technology improvement and new product development. F ratio at 0.05 α level yields 0.17 which is less than the critical value of F i.e.3.88 which points out that there is no significant change in the perception of researchers at different experience levels. It was observed that researchers from engineering sciences hope that for all the advantages mentioned and researchers from chemical sciences and biological sciences expect technology improvement and patents. F ratio at 0.05 α level yields 2.06 which is less than the critical value of F i.e.3.88 points out that there is no significant change in the perception of researchers across the disciplines. Managers also expect all the advantages mentioned from industry institute interactions. t ratio at 0.05 α level yields 0 which is less than the critical value of t i.e.2.36 gives a conclusion that there is no significant change in the perception of researchers and managers.

Table 4: Advantages of interactions

S.No.	Advanatges	Researcher across experience(%)			Researcher across discipline(%)			Researchers (%)	Managers (%)
		S	M	J	ES	BS	CS		
1	Knowledge exchange	94	91	100	100	100	90	96	80
2	Access to market needs	94	100	64	100	88	90	92	100
3	New product development	94	91	100	100	88	90	92	100
4	Technology Improvement and Cost saving	100	100	100	100	100	100	100	100
5	Patenting	94	100	100	100	100	100	100	100

S=Senior researchers, M-Middle level researchers, J=Junior researchers

ES-Engineering Sciences, BS-Biological Sciences, CS=Chemical Sciences

DEMOTIVATION FACTORS

Researchers in this study were asked to identify the factors that discourage them from interacting with industry and the obtained results were presented in Table 5.Seventy percent of the researchers surveyed are hesitant to interact with the industry because of administrative problems that they come across within their organisation. Fifty two percent are not enthusiastic because

the work will be short term in nature. Forty four per cent felt that they dont prefer to work with the industry as that might restrict the changes of publishing the work in journals. Researchers would like to publish their research work in reputed international journals as it will give them good recognition among peers. When they work with the industry on some project, they can only publish their results subject to the contractual obligation. When the findings are analysed based on the experience of the sample, it is observed that, most of the senior researchers oppose it for the reason of facing restriction in publications and short term nature of research work. Researchers at middle level oppose it for administrative problems and junior researchers fear that they might get less interesting topics and might face administratives problems. F ratio at 0.05 α level yields 0.17 which is less than the critical value of F i.e.4.25 points out that there is no significant change in the perception of researchers at different experience levels.

Researchers from engineering sciences are expecting restrictions in publishing the work whereas researchers from biological sciences thought that the work may be short term oriented. Researchers from chemical sciences are fearing for administrative problems and less interesting topics. F ratio at 0.05 α level yields 1.41 which is less than the critical value of F i.e.4.25 points out that there is no significant change in the perception of researchers across the disciplines. As managers largely favour interactions with the industry, most of them dont feel that any mentioned factor is a disadvantage. Only forty percent felt that short term orientation may act as a hindrance to interactions. t ratio at 0.05 α level yields 3.9 which is greater than the critical value of t i.e.2.44 points out that there is significant change in the perception of researchers and managers.

Table 5: Demotivation factors

S.No.	Demotivation factors	Researcher across experience(%)			Researcher across discipline(%)			Researchers (%)	Managers (%)
		S	M	J	ES	BS	CS		
1	Short term orientation	65	41	34	57	66	36	52	40
2	Restrictions to publications	70	50	34	85	20	54	44	20
3	Less interesting topics	41	41	68	42	33	72	52	20
4	Administrative problems	53	75	68	57	44	100	70	20

S=Senior researchers, M-Middle level researchers, J=Junior researchers

ES-Engineering Sciences, BS-Biological Sciences, CS=Chemical Sciences

MOTIVATIONS FOR RESEARCHER, INSTITUTES AND INDUSTRY

Ninety two percent of the researchers felt that recognition within scientific community and additional funding for research would

motivate them to undertake industry R&D work as presented in Table 6. Ninety three per cent are interested in this as it provides a platform to discover new knowledge that can be applied commercially. Seventy seven percent are interested as it serves as a reference to get other projects also. Middle level researchers opt for interactions to get additional funding whereas junior researchers said that all the mentioned factors will motivate them. Senior researchers considered recognition within scientific community and additional funding as the main motivational factors. F ratio at 0.05 α level yields 3.25 which is less than the critical value of F i.e.4.25 points out that there is no significant change in the perception of researchers at different experience levels. Researchers from chemical sciences and engineering sciences are interested in interacting with industry as it gives them recognition within the scientific community and additional funding and biological researchers are interested in discovering new knowledge. F ratio at 0.05 α level yields 5.98 which is greater than the critical value of F i.e.4.25 points out that there is significant change in the perception of researchers across the disciplines. Managers of the interaction process opine that apart from all the factors it will act as a reference point for researchers to get other projects also. t ratio at 0.05 α level yields -2.99 which is less than the critical value of t i.e.2.45. This points out that there is no significant change in the perception of researchers and managers.

Table 6: Motivations for researcher

S.No.	Motivation for researchers	Researcher across experience(%)			Researcher across discipline(%)			Researchers (%)	Managers (%)
		S	M	J	ES	BS	CS		
1	Discovery of new knowledge	94	91	100	100	88	90	93	100
2	Recognition within scientific community	94	90	100	100	77	100	92	100
3	Additional research funding	94	100	100	100	77	100	92	100
4	References for other projects	88	75	100	85	66	82	77	100

S=Senior researchers, M-Middle level researchers, J=Junior researchers

ES-Engineering Sciences, BS-Biological Sciences, CS=Chemical Sciences

Motivation for research institutes

Venturing into new ambitious R&D areas and upgrading latest R&D expertise is essential for any institute to survive in the present competitive and dynamic research landscape. Complementary expertise, facilities and new skills available with the industry helps the institutes in achieving this task. Researchers felt that this is the major motivation for the institutes to enter into interactions. It will give an opportunity for institutes to accumulate

new skills and broaden the scope of their activities. Researchers felt that interacting with industry helps research institutes in getting access to expertise and facilities which are not available at the institute. Results obtained were presented in Table 7. Eighty eight percent of the respondents felt that it will also help in accumulating new skills. Pressure for useful research from the federal agencies as well as society also compells the research institutes to interact with industry. Eight five percent felt that need for cross fertilization of ideas also motivates institutes to partner with industries. It is interesting to note that researchers do not think that institutes are going to the industry for the reason revolving around shrinking research budgets. Only seventy four percent felt that getting additional funds motivates the institutes for partnering with industry.

Researchers from all experience levels are of the opinion that getting access to new expertise and facilities is the major motivation for the institutes to partner with industry. Most of the senior and junior researchers felt that it helps in accumulating new skills. Middle level researchers felt that pressure for useful research is also directing institutes to partner with industry. Researchers at all experience levels felt that institutes are not highly motivated to partner with industry only for funds. F ratio at 0.05 α level yields 0.12 which is less than the critical value of F i.e.3.88 indicates that there is no significant change in the perception of researchers with different experience levels. Researchers from biological sciences and chemical sciences are thinking that getting access to new expertise and facilities is the major motivation for the institutes to partner with industry whereas researchers from engineering sciences opted for accumulating new skills, getting access to facilities and expertise and for cross fertilization of ideas. Only fifty five percent of biological researchers opted that institutes will interact with industry for getting additional funds. F ratio at 0.05 α level yields 0.81 which is less than the critical value of F i.e.3.88 indicates that there is no significant change in the perception of researchers across the disciplines. Managers who are coordinating the interaction process suggest that the motivation for institutes to interact with industry is to get access to new facilities, skills and expertise. Only twenty percent felt that institutes will go to industry for cross fertilization of ideas. t ratio at 0.05 α level yields 0.629 which is less than the critical value of t i.e.2.30 gives a conclusion that there is no significant change in the perception of researchers and managers.

Table 7: Motivations for research institutes

S. No.	Motivation for research institutes	Researcher across experience (%)			Researcher across discipline (%)			Researchers (%)	Managers (%)
		S	M	J	ES	BS	CS		
1	Pressure for useful research	76	100	100	85	77	90	85	100
2	Access to funds	70	75	68	85	55	81	74	60
3	Accumulation of new skills	94	83	100	100	77	90	88	100
4	Access to facilities and expertise	100	100	100	100	100	100	100	100
5	Cross fertilization of ideas	88	91	64	100	77	81	85	20

S=Senior researchers, M-Middle level researchers, J=Junior researchers
ES-Engineering Sciences, BS-Biological Sciences, CS=Chemical Sciences

Motivations for industry

Industry will usually encounter many technical problems during the production and also during its R&D. Researchers felt that getting solution for these technical problems would motivate the industry for coming to the research institutes. Ninety six percent of the surveyed researchers felt that industry would come to the institutes to observe latest scientific developments, getting access to facilities, expertise and new scientific knowledge as presented in Table 8. Industry wants to improve their technologies to cut down cost of production. So it will approach institutes with an eye to explore this possibility as well. Working with internationally reputed institutes will also enhance the image of the industry in business circles.

Senior researchers believe that industry would come to institutes mainly for getting access to new scientific knowledge and to get solution for their technical problems. Middle level and junior researchers feel that all the mentioned factors motivate the industry to come to institutes for interactions. F ratio at 0.05 α level yields 1.8 which is less than the critical value of F i.e.3.88 points out that there is no significant change in the perception of researchers at different experience levels. Most of the researchers across the disciplines also felt that all the mentioned factors motivate industry to come to institutes for interactions. F ratio at 0.05 α level yields 0.09 which is less than the critical value of F i.e.3.88 indicates that there is no significant change in the perception of researchers across the disciplines. All the managers surveyed felt that all the mentioned factors motivate industry to come to institutes for interactions. t ratio at 0.05 α level yields -4 which is less than the critical value of t i.e.2.30 demonstrates that there is no significant change in the perception of researchers and managers.

Table 8: Motivations for industry

S.No.	Motivation for industry	Researcher across experience(%)			Researcher across discipline(%)			Researchers (%)	Managers (%)
		S	M	J	ES	BS	CS		
1	Solution for technical problems	100	100	100	100	100	100	100	100
2	Access to facilities and expertise	94	100	100	100	88	100	96	100
3	Access to new scientific and technical knowledge	100	91	100	100	100	90	96	100
4	Technology improvement	94	100	100	100	100	90	96	100
5	Business stature enhancement	94	100	100	85	100	100	96	100

S=Senior researchers, M-Middle level researchers, J=Junior researchers
ES-Engineering Sciences, BS-Biological Sciences, CS=Chemical Sciences

MODES OF INTERACTIONS

According to the present research, preferred modes of interaction for researchers with industry inculde licensing of patents/knowhow, sponsored research and collaborative research, as presented in Table 9. They would like to take up sponosored projects and joint collaborative research projects with industry. Collaborative research implies flow of knowledge from both sides. Sponsored projects are the projects wholly funded by the industry. They have specified R&D objectives and well defined results. Eighty five percent surveyed are willing to undertake consultancy assignments also which involves scientific, technical or other advise/assistance based on available expertise of the institute. An explanation, supported by the interviews, is that licensing of patents/know how, sponsored research, collaborative research and consultancy projects attract the researchers more that the fact that receive funding for carrying out their research and it exposes them to application research and market trends.

Informal contacts facilitate exhange of knwoledge and fertilisation of new ideas which may finally lead to new research collaborations. Eighty one percent preferred this mode of intercation. On the same note, organisation of conferences jointly by industry and institutes is considered beneficial to both. It provides industry an access to latest R&D happenings in that particular area and also for institutes it is a stage to showcase its R&D capabilities in that particluar area. Conferences present the possibilities of a quick presentation of recent research results and informal discussion. Seventy seven percent of the respondents also opt for technical services. They are meant to render to the clients, assistance based on available knowledge, expertise, skills, infrastructure and facilities of the institute. It shall thus comprise: testing and analysis, routine training and technical assistance of advisory nature.

Some of the institutes conduct training programmes for the industry in their area of expertise and on the operation of sophisticated instruments and facilities. Only seventy four percent of the researchers preferred this

mode. Exchange of personnel however is considered helpful in cross fertilisation of ideas and may also lead to further new projects. Only fifty five percent of the respondents evinced interest in this mode. Industry will offer to the researchers memberships in their scientific advisory boards and board of directors. It would help the industry in getting experienced scientific advise and also provides researchers exposure in the R&D areas of industry which may lead to future collaborations. But, only fifty five percent show interest in this mode.

Researchers across the experience levels preferred licensing of patents/knowhow, sponsored research and collaborative research projects with industry. Junior researchers are interested to be in committees which is not preferred by senior and middle level researchers. Only thirty four percent of the junior researchers prefer informal contacts, exchange of personnel and conducting training programmes to industry. F ratio at 0.05 α level yields 0.32 which is less than the critical value of F i.e.3.35 gives a conclusion that there is no significant change in the perception of researchers at different experience levels. Researchers across the discipline levels preferred licensing of patents/ knowhow, sponsored research and collaborative research projects with industry. Researchers from engineering sciences also prefer informal contacts, undertaking consultancy projects and conducting training programmes which does not entice researchers from other disciplines. Only thirty three percent of the biological researchers are express interest in memberships in committees. F ratio at 0.05 α level yields 0.86 which is less than the critical value of F i.e.3.35 points that there is no significant change in the perception of researchers across the disciplines.

Preferred modes of interaction for managers are licensing of patents/ knowhow, sponsored research, collaborative research and consultancy. They are of the opinion that exchange of personnel and joining of researchers as members in committees also go a long way in strengthening the interactions with industry. t ratio at 0.05 α level yields -1.32 which is less than the critical value of t i.e.2.1 indicating that there is no significant change in the perception of researchers and managers.

Table 9: Modes of interaction

S.No.	Modes of interaction	Researcher across experience(%)			Researcher across discipline(%)			Researchers (%)	Managers (%)
		S	M	J	ES	BS	CS		
1	Collaborative research	100	100	100	100	100	100	100	100
2	Informal contacts	88	75	34	100	77	72	81	60
3	Sponsored research	100	100	100	100	100	100	100	100
4	Consultancy	94	75	100	100	77	81	85	100
5	Technical services	65	92	100	85	66	82	77	80
6	Exchange of personnel	58	75	34	42	77	45	55	100
7	Organisation of conferences	77	92	68	100	66	85	81	80
8	Training programmes for industry	70	83	34	100	77	54	74	80
9	Membership in Committees	58	58	100	57	33	72	55	100
10	Licensing of patents/knowhow	100	100	100	100	100	100	100	100

S=Senior researchers, M-Middle level researchers, J=Junior researchers
ES-Engineering Sciences, BS-Biological Sciences, CS=Chemical Sciences

ESSENTIAL FACTORS FOR SUCCESSFUL INTERACTIONS

Almost all the researchers felt that communication and good personal relations, trust and commitment, focus on quality, clarity in terms of agreement, good project planning and adherence to agreement terms are essential for interactions to be fruitful, as presented in Table 10. Better communication and good personal relations helps for resurrecting weak partnership. Respecting each partner's abilities and building a good communication channel between partners are crucial elements for successful interactions. Trust and commitment also aid for interactions to be successful and a way of establishing future collaboration. It diminishes transaction costs, increases organizational productivity, facilitates attainment of results higher than those expected, enhances communication, improves transparency and limits dissension. Commitment infers dedication to a course of action. New partners should be introduced through smaller projects, thereby providing the opportunity to develop trust in a situation where a greater degree of one to one contact is possible (Barnes et al ,2002). The existence of trust reduces coordination costs and facilitates conflict resolution. It is brittle if damaged and can be difficult to reestablish. Poor communication can create an atmosphere of mistrust. Good communication ensures transparency, minimizes misunderstanding, reduces uncertainty and encourages sustained cooperation (Kelly et al. ,2002). Effective management of institute-industry interactions needs the development of a clear communication strategy. Role of each partner and their responsibilities must be clearly communicated and agreed upon, from the very beginning in the interactions.

Objectives of the proposed work have to be defined clearly based on

established areas of common interest, mutual strategic importance and benefit. Without clearly defined objectives, projects can become broad and unwieldy, yielding results which are not expected. Clearly defined objectives provide the basis for robust and focused research process. It is very essential as there are inevitable differences in the perspectives of partners and hence partners bring with them their own specific objectives and expectations. Without clearly defined objectives, the project can be subject to a considerable amount of misinterpretation and unrealistic expectations. It must involve harmonisation of different expectations of partners, in order to set manageable boundaries around a project and to eliminate conflicting goals (Barnes et al. 2002). The objectives of interaction need to be in line with partners' mission, strategies and innovation objectives, therefore conflicts between the partners must minimized (Bidault and Cumings, 1994; Rama Mohan and Ramakrishna, 2005; Santoro and Betts, 2002).

Responsibility of each partner should be spelled out clearly during negotiations. It is possible that industry perceived researchers as the experts and therefore didn't expect to make a substantial contribution beyond financial and occasional technical support. As the sponsors, industry may have had the perception that they were paying the researchers to do the work ie as a form of contract research. Such issues can be readily dealt with by ensuring that the role of each partner in collaboration and their responsibilities are clearly communicated and agreed from the very beginning (Barnes et al., 2002). Clarity in terms of the agreement is very crucial. Deliverables must be spelled out clearly in the agreement, it is better to define quantifiable deliverables. The aspects to be taken care are scope of work, targets, milestones, deliverables, time frame for completion of activity, IPR, financial terms and conditions, effective date of starting the work, input to be provided by each partner and periodicity of reporting. Written agreements can provide clear direction and describe factors such as objectives of the interaction, deliverables, interaction structure, sharing of research personnel, equipment and Intellectual Property Rights, ongoing interaction management practices, conditions for termination and dispute resolution. Terms and conditions in agreements have to be flexible enough to allow for a revision of objectives if partners are faced with unexpected evolutions (Bloedon and Stokes, 1994; Ingham and Mothe, 1998; Chiesa and Manzini, 1998). Phased relationships introduce flexibility into interactions by providing logical decision points at which strategy and goals can be reassessed (Slowinski et al. 1993).

Effective project planning and management system is needed. The

development of a mutually agreed project plan is very important. Without good project monitoring and management, institutes are unable to inspire confidence in the industry due to inappropriate delivery mechanism, resulting in time and cost overruns. There has to be progress monitoring to see that the proposed activity is adheres to terms spelt in the agreement. Experienced project manager required for this and ninety six percent of the respondents expressed the same opinion. Project manager, as the manager with responsibility for the project as a whole should encourage the development of trust by taking a lead role in creating conditions conducive to its development. Such conditions may be achieved by treating all partners equally and fairly, encouraging frank communication, meeting commitments and informing partners of problems as soon they arise. Each organization should be receptive to the problems of other organizations and both the organizations should have integrity, cooperation and commitment to continue interactions further.

Ninety six percent of the respondents felt that periodic review of the project is very essential for successful interactions. It is to be mentioned in the agreement whether monthly reports or quarterly reports have to be submitted depending on the duration of the project. There is need of measures to encourage the development of a clear communication strategy and setting out frequency of meetings. The reports can be sent through emails also. If necessary, teleconferences can also be planned depending on the progress of the project. If the project touches a roadblock for any scientific and technical reason, brainstorming through these types of teleconferences will help in overcoming the blocks.

Eighty five percent of the respondents opined that arranging face to face meetings are necessary for effective project review. The physical distance between the partners, which made it difficult to schedule face to face meetings and to follow up, cause communication problems (Kelly et al. 2002). The review has to be planned periodically and it has to be once in every six months if the project is of longer duration. Face to face meetings will help in establishing communication and good trust between partners. It helps in effective project monitoring to reach the agreed targets or milestones. It also helps in overcoming technical and scientific difficulties that arise during the progress of work. Eighty one percent suggested that complementary aims and expertise play a crucial role in making the interactions successful.

Middle level researchers feel that face to face meetings and complementary aims and expertise are also very important for successful interactions while senior and junior researchers do not stress on the same.

Junior researchers are also preferring experienced project manager and balanced priorities. F ratio at 0.05 α level yields 1.466 which is less than the critical value of F i.e.3.35 indicates that there is no significant change in the perception of researchers with different experience levels. Researchers from engineering sciences and chemical sciences opine that almost all the mentioned factors are very important for successful relations. Researchers from biological sciences do not give importance to face to face meetings, complementary aims and balanced priorities. F ratio at 0.05 α level yields 5.88 which is greater than the critical value of F i.e.3.35 point out that there is significant change in the perception of researchers across the disciplines. Managers suggested that communication and good personal relations, trust and commitment, focus on quality, clarity in agreement, face to face meetings, peroidic review, good project planning and aadherence to agreement terms are very important for successful relations. t ratio at 0.05 α level yields 0.493 which is less than the critical value of t i.e.2.1 give a conclusion that there is no significant change in the perception of researchers and managers.

Table 10: Essential factors for successful interaction

S.No.	Essential factors	Researcher across experience(%)			Researcher across discipline(%)			Researchers (%)	Managers (%)
		S	M	J	ES	BS	CS		
1	Communication and good personal relations	100	100	100	100	100	100	100	100
2	Trust and commitment	100	100	100	100	100	100	100	100
3	Focus on quality	100	100	100	100	100	100	100	100
4	Clarity in agreement	100	100	100	100	100	100	100	100
5	Face to face meetings	88	100	68	100	66	90	85	100
6	Peroidic review	100	100	34	100	88	100	96	100
7	Complementary aims and expertise	82	100	68	100	77	100	81	80
8	Good project planning and adherence to agreement terms	100	100	100	100	100	100	100	100
9	Experienced project manager	94	90	100	100	88	100	96	80
10	Balanced priorities	94	80	100	100	77	100	92	80

S=Senior researchers, M-Middle level researchers, J=Junior researchers
ES-Engineering Sciences, BS-Biological Sciences, CS=Chemical Sciences

BARRIERS FOR SUCCESSFUL INTERACTION

Ninety six percent of the respondents felt that bureaucracy and inflexibility of administration and difference in organizational cultures will hamper successful interactions as presented in Table 11. Fundamental differences in the relative priorities, prospectives and time horizons of researchers and industry are major obstacles towards successful relations. Industries do not want researchers to publish their results and share information with colleagues and the general public. Instead they view technology as something to be kept proprietary and to be used for the strategic advantage in the pursuit of profits. A balance between

the requirements must be achieved. This requires that each party understands the needs of the other and constraints placed upon them and to strives towards a solution which would benefit all partners equally (Barnes et al., 2002). Minor irritations and repeated miscommunications caused by cultural differences can lead to total break down of relationship (Kelly et al., 2002). The expectations of both academic and industrial partners need to be managed throughout. There will be inevitable differences in the requirements and expectations of the partners, which must be balanced if the interaction has to be successful. Researchers want to publish their research results in academic journals and feel that the industry's short term orientation, confidentiality and restriction to publications were being satisfied at the expense of academic progress. Institute would value patents not only as a revenue producing resource, but also a tool in the advancement and dissemination of knowledge (Hall et al., 2001). Eighty eight percent felt that insufficient rewards to researchers and unrealistic expectations regarding technology are the hindrances. Senior researchers felt that bureaucracy and inflexibility in administration as the main stumbling block. Middle and junior researchers suggested that difference in organizational cultures act as hinderance. F ratio at 0.05 α level yields 0.55 which is less than the critical value of F i.e.4.25 points out that there is no significant change in the perception of researchers at different experience levels.

Researchers from engineering sciences are not happy about the rewards they receive during interactions with industry. F ratio at 0.05 α level yields 0.31 which is less than the critical value of F i.e.4.25 gives a conclusion that there is no significant change in the perception of researchers across the disciplines. As per the managers' perception, insufficient rewards to researchers and unrealistic expectations regarding technology value act as impediments towards successful relations. Difference in organizational cultures is the other factor contributing to the failure in interactions. t ratio at 0.05 α level yields 5.19 which is greater than the critical value of t i.e.2.44 points out that there is significant change in the perception of researchers and managers.

Table 11: Barriers for successful interaction

S. No	Barriers	Researcher across experience(%)			Researcher across discipline (%)			Researchers (%)	Managers (%)
		S	M	J	ES	BS	CS		
1	Difference in organizational cultures	88	100	100	85	100	100	96	80
2	Insufficient rewards for researchers	82	100	68	100	77	90	88	80
3	Bureaucracy and inflexibility of administration	94	100	100	100	88	100	96	80
4	Unrealistic expectations regarding technology value	88	75	68	71	100	90	88	60

S=Senior researchers, M-Middle level researchers, J=Junior researchers
ES-Engineering Sciences, BS-Biological Sciences, CS=Chemical Sciences

MAIN FINDINGS AND CONCLUSIONS

The main aim of the present study is to understand interactions between research institutes and industry in Indian context so that it can be managed effectively. It tried to gauge the perceptions of researchers' vis-à-vis managers on various aspects of interaction process. Identified factors at different stages if managed correctly, increase the probability of effective and successful interactions. The study also aims to find out whether there is any variance in the perception of researchers across discipline and with different experience levels. A survey was designed and carried out in the study to gain insights into perception of the researchers' working in various Indian research institutes, about various aspects of interactions with industry.

Industry will come to know about research institutes through its patents and by participating in interaction meets and exhibitions. Organizing workshops and seminars will also provide a chance for the institutes to showcase their capability thereby attracting industries. Managers felt that publications and patents are also key to attract industries. Industry will examine factors like technical and scientific expertise existing in the institutes, its past track record in different aspects, leading edge work done or appropriate technology and facilities available at the institute while deciding to interact with research institutes. Interactions between industry and institutes will result in improvement in technologies and gaining patents with great commercial potential. Researchers are not highly enthusiastic to interact with industry because of administrative problems that they come across within their own organization, short term nature of work and less interesting research topics. Researchers felt that recognition within scientific community and additional funding for research motivates them to undertake industry R&D work. Apart from these factors, managers are of opinion that it will help the researchers to get involved in other projects also from the same industry.

Venturing into new ambitious R&D areas and upgrading R&D expertise is essential for any institute to survive in the present competitive and dynamic research landscape. Chance of getting exposure to complementary expertise and accumulation of new skills motivates the institutes to enter into interactions with industry. It is interesting to note that researchers are not of opinion that institutes are not looking towards additional funds only. Managers who are coordinating the interaction process suggest that the motivation for institutes to interact with industry

is to get access to new facilities, skills and expertise. They feel that demand for useful research from federal agencies and society is also driving institutes to industry. Getting solution for the technical problems that arise during production and R&D mainly motivate the industry for interacting with the research institutes. Preferred modes of interaction for researchers with industry are licensing of patents/knowhow, sponsored research and collaborative research. Managers prefer undertaking consultancy projects also.

Communication and good personal relations, trust and commitment, focus on quality, clarity in terms of agreement, good project planning and adherence to agreement terms are essential for interactions to be fruitful. Effective project planning and management system is needed. Periodic review of the projects is very essential for successful interactions. Managers also think that face to face meetings are essential for effective project monitoring and thereby for successful interactions. Bureaucracy and inflexibility of administration and difference in organizational cultures will hinder successful interactions. Minor irritations and repeated miscommunications caused by cultural differences can lead to total break down of relationship. Managers also feel that insufficient rewards to researchers and unrealistic expectations regarding technology value also come in way of successful relations.

Summary of the findings and suggested actions for management of the research institutes is presented in Table 12. There is no significant difference in the perception of researchers with different experience levels and across the disciplines regarding search channels used by industry, influential factors for selecting research institutes, advantages of interactions, demotivating factors for researchers for interactions, motivational factors for institutes and industry, preferred modes and barriers of interaction. Though no significant difference is observed in perceptions of researchers with different experience levels regarding motivation for researchers and essential factors for successful interactions, significant difference is observed in perceptions of researchers across the disciplines. There is no significant difference in perceptions of researchers and managers except for demotivation factors and barriers for successful interactions.

Table 12: Findings and conclusions of the study

S. No	Item	Researchers	Managers	Suggested actions	Remarks
1	Industry comes to institutes through	*Patents *Exhibitions and Interaction meets *Seminars and conferences	*Publications *Patents *Exhibitions and Interaction meets *Seminars and conferences	*Filing patents having potential commercial applications *Participating in exhibitions and interaction meets *Organising seminars and conferences *Publishing work in Internationally reputed journals	*No significant difference in perceptions of researchers at experience levels and across the disciplines *No significant difference in the perceptions of managers from that of researchers
2	Influential factors for selecting institutes	*Expertise *Past track record *Work done *Facilities available	*Expertise *Work done *Demonstrated capabilities *Past track record *Facilities *Management *Business Fit	*Enrichment of expertise in latest R&D areas having potential commercial application *Maintaining good track record in existing projects *Pursuing R&D in latest areas having good industrial applications *Establishing latest state of art research facilities	*No significant difference in perceptions of researchers at experience levels and across the disciplines *No significant difference in the perceptions of managers from that of researchers
3	Advantages of interaction	*Technology improvement *Cost savings *Patents	*Access to market needs *New products *Technology improvement *Cost savings *Patents	*Pursuing R&D for improving existing technologies and on new technologies *Filing joint patents with industry	*No significant difference in perceptions of researchers at experience levels and across the disciplines *No significant difference in the perceptions of managers from that of researchers
4	Demotivation factors for interaction	Administrative problems	Short term orientation	*Taking necessary actions to ensure that administrative procedures are flexible and researcher friendly	*No significant difference in perceptions of researchers at experience levels and across the disciplines *Significant difference in the perceptions of managers from that of researchers
5	Motivations for researcher	*New knowledge *Recognition *Funding	*New knowledge *Recognition *Funding *Reference to other projects	*To see that there will be chance for researcher to update his knowledge and get recognition while taking up the project	*No significant difference in perceptions of researchers at experience levels *Significant difference in the perceptions of researchers across the disciplines *No significant difference in the perceptions of managers from that of researchers
6	Motivation for institute	Access to expertise and skills	*Access to expertise and skills *Pressure for useful research	*To see that the institute will get a chance to venture into new R&D areas and accumulation of new expertise and skills while interacting with the industry	*No significant difference in perceptions of researchers at experience levels and across the disciplines *No significant difference in the perceptions of managers from that of

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