JOINT R & D PROJECTS AS TECHNOLOGY TRAINING VENTURES

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Joint R&D Projects As Technology Training Ventures

ABSTRACT *This paper presents an empirically derived model of the process through which firms, that typically lack the resources and/or expertise in a particular technology area to implement certain strategic R&D projects of their interest on their own, initiate and implement them in the form of* technology training ventures *jointly with not-for-profit technology institutions. These firms are keenly interested in training themselves and acquiring the resources required for future R&D in that technology area and do so simultaneously and rapidly while completing the project. Joint R&D projects implemented as* technology training ventures *can be more effective than formal technology training programmes for technology institutions to transfer their advanced technical knowledge to the industry. Firms can also see the application of new knowledge in a context of their immediate interest, thus helping them absorb it rapidly for future applications in their search for sustainable competitive advantage. The process model has been developed by drawing from and synthesizing several in-depth case studies of such joint R&D projects. Apart from contributing to theory, this model can enable practitioners in both firms and technology institutions to understand the effective processes required for initiating and implementing such* technology training venture *projects for mutual benefit.*

Introduction

Technology based firms often find that they internally lack the adequate infrastructure or technical expertise required to implement certain strategic R&D projects in technology areas that are new to them and are emerging as important for their growth and survival. Finding that they cannot out-source such technology from potential competitor firms at an advantage, they realize that they have to meet the challenge of rapidly training themselves in these new technology areas, while simultaneously establishing new technological facilities of their own to implement such R&D projects. Some firms meet this challenge by implementing such strategic R&D projects jointly with not-for-profit technology institutions in the form of *technology training ventures.* (Technology institutions [TIs] for the purpose of this research are independent, autonomous not-for-profit institutions involved in technological R&D including government laboratories, technological universities, technology education institutes, industry association laboratories and research foundations.) TI-firm joint R&D projects allow these firms to exploit the facilities and expertise available at the TIs to rapidly implement their immediate project in a non-competitive environment, as well as simultaneously learn the new technology from the TI, and build their own facilities with the TI's help, for future work in that technological area.

Seen from the TI's point of view, joint R&D projects in new technology areas implemented in this way can be more effective than formal technology training programmes, in transferring their technical knowledge to the industry. It can also help the TI learn from the practical application of their theoretical knowledge in the technology area while implementing the project in the industry environment. Firms can see the immediate application of the new technology in a context of their interest, thus helping them absorb the basic knowledge rapidly and effectively for future application in their search for sustainable competitive advantage.

Joint R&D projects represent an intense form of interaction between firms and TIs. A joint R&D project arises when the firm approaches the TI with a technological problem (and the TI accepts it) for which (a) the TI has no ready transferable solution or access to such a solution and (b) the TI and firm both have complementary expertise and capabilities required to solve the problem. The joint R&D project involves simultaneous or sequential R&D work by both the TI and the firm working either independently (reporting progress to each other) or together.

Though the apriori requirements with which the firm and TI agree to a joint R&D project are important, such projects can also lead to unanticipated benefits for the participating organizations which often do not enter into apriori cost-benefit analyses. Though initiated as time bound project based interactions, they may lead to long term relationships if the project interaction is fruitful and therefore can impact both the firm and the TI in their immediate and future technological and commercial activities. Collaborative arrangements can facilitate the process of technology transfer which is a complex and subtle process. Tyler and Steensma[1] propose that the greater the tacitness of technology, and the greater the complexity of technology (variety and diversity of technologies that must be incorporated into the development process), the more likely executives will consider technological collaboration as a mode of technology development. Intense TI-firm interactions in joint R&D projects can also lead to both anticipated and unanticipated learning within and across participating organizations which can widen the scope of their technological and commercial activities.

This paper presents a model of the process through which firms initiate and implement joint R&D projects with TIs in the form of *technology training ventures* in an attempt to rapidly and simultaneously train themselves, acquire resources and complete a project in a technology area that is new for the firm. It traces the web of interlinked project processes and indicates their anticipated impacts on firm and TI activities. The model has been developed by drawing from and synthesizing in-depth case studies of such joint R&D projects.

Literature Review

Dodgson[2] defined technological collaboration as any activity where two or more partners contribute differential resources and technological know-how to agreed complementary aims. Bonaccorsi and Piccaluga[3] identified from an extensive literature review that technology based firms enter into relationships with TIs for four basic reasons: (a) to get access to scientific frontiers, (b) to increase the predictive power of science, (c) to delegate selected development activities and (d) to compensate for lack of resources. However, the role of TI-firm joint R&D projects as *technology training ventures,* though falling in their fourth category above, has not been specifically identified or described in the literature.

Some studies however do give indications of this role. Examining the outcomes of university - industry relationships, Berman[4] found that university students are trained through collaborative projects with firms and the application of the new knowledge by the firm is often left to recently hired students who have been trained in this manner. The firm's scientists gained work access to the university laboratories. He also found that direct industry funding of university R&D was associated with subsequent increases in industrial R&D expenditure with a shorter time lag than that found for undirected academic research. He therefore argues that universities which collaborate with firms increase the utilisation and transfer of academic knowledge by providing informal access to their students and professors.

Though literature on technological collaboration in the university -firm or TI-firm joint R&D context exists (e.g. Bird, Hayward and Allen[5]; Bonaccorsi and Piccaluga[6]; Bower[7]; Berman[8]; Lopez-Martinez et.al.[9]; Rosenberg and Nelson[10]), the focus of these studies, according to Bailetti and Callahan[11] 'have been on the strategy and the reasons for entering a collaboration rather than its management.' According to Alter and Hage[12] 'there are no studies of problem solving in collective research involving multiple business firms and universities.'

Recent literature reviews have emphasised the role of intangible, invisible organisational assets such as organisational routines, organisational learning and capabilities as a factor of production and a source of competitive advantage, and the role of technology in creating such assets (e.g. Schendel[13]; Bettis and Hitt[14]). These reviews indicate the importance of understanding the micro-level processes of organising and implementing technological development activity both within and across organisations. However, content studies dominate in this field. These lead to research outputs usually in the form of lists of success or failure factors.[15] While such lists of factors are indicative they do not depict the process by which these factors can combine synergistically to produce successful new technological products. On the other hand, the few process studies which exist in this field have given interesting insights which connect and combine some of these factors (e.g. Bailetti and Callahan[16]; Hausler, Hohn & Lutz[17]). These studies indicate the potential of process studies to give insights which complement the more common content studies in technology development.

As previous research has largely concentrated on identifying the antecedent conditions for initiating TI-firm joint R&D activity and their consequences, there is a lack of adequate empirical research which gives insights into the *process* of initiating and implementing such activity. Further there is no clear theory linking the identified antecedent conditions to the process of initiation and implementation of joint activities and to their identified consequences. This research attempts to fill this gap by developing an empirically based model of the process of initiating and implementing TI-firm joint R&D projects that are implemented in the form of *technology training ventures.*

Methodology

Given the research gap identified and the lack of adequate process research in this area, it was necessary to conduct a process study, using qualitative research methodology, to build an empirical base for theory development. Process questions are essentially of *the how did it happen?* nature but they also include the *what happened?* and *why did it happen?* questions relevant to the context of the study. Grounded theory building[18] using the case study method[19] is considered an appropriate and valid[20] approach for studying process issues.[21] The longitudinal processual method of case research[22] was adopted as it answers the *what?, why?* and *how?* questions together within a relatively short research time span.

Multiple qualitative process case studies of TI-firm joint R&D projects were developed in this research. Multiple cases provide greater scope for attempting analytical generalisation[23] compared to a single case and provide a useful vehicle for understanding the complexity and richness of the joint R&D project initiation and implementation process, considering the paucity of previous work. The broad research approach adopted was in the holistic tradition[24] of strategy process research in attempting 'to track simultaneously over time, multiple contextual factors, strategies, decision processes, administrative systems and outcomes' while focusing on a 'narrow strategic problem'. This approach has not been adopted for research in multi-organisational contexts so far, but is recommended.[25]

In this research the TI-firm joint R&D project was taken as the fundamental unit of analysis. Projects were selected from a list of TI-firm joint R&D projects made available by a financial institution which was funding such projects under a special technology development financing scheme. Given that taxonomic samples could not be identified apriori, a variety of projects were selected (as suggested by Bhave[26]; Eisenhardt[27]; Leonard-Barton[28] and Van de Ven and Poole[29]) to reflect a range of investment quantum and project sizes, a variety of technologies and industrial sectors, differences in technology levels between firms and TIs, types of R&D (basic, commercial, incremental, radical and reverse engineering), types of firms and types of TIs. A variety of cases were chosen in an effort to develop richer theory and provide an opportunity for replication and comparison, thus building external validity[30] and expanding the domain of generalisation.[31]

The data collection was primarily through in-depth semi-structured and open-ended interviews of key project participants in multiple hierarchical levels and departments in both organisations. As far as possible, all project participants were interviewed, some repeatedly, for varying periods from about an hour to two and half hours. The process questions raised in the interviews traced the project process from inception to completion. Apart from this, information was sought from participants on their organisations, the relevant industry, and the environment faced by the firm and the TI. Other topics covered were: the importance of the project's product category to the firm; governance structure of the project; characteristics of the project and technology which affected project implementation; problems encountered and their resolution; monitoring of projects; meetings; co-ordination; communication; capability development; and changes in plan over the duration of the project. As the attempt was to gather as much of the richness of the project process as possible, new topics which emerged during the interviews were opportunistically explored, and new questions were added for subsequent interviews.[32]

Participants mentioned their background and experience, areas of professional interest, the history and experience of their interaction with firms or TIs and its importance. They were also asked to describe and evaluate: their individual role in the project; formal and informal relationships; help given and received; technology transfer and training; uniqueness of the project; learning from the project; and the project's likely impact on their organisations in both technical and managerial spheres. The interview schedules also covered the non-project routine activities of project participants and its impact on their involvement in the project. Based on the respondent's answers, and if additional information was necessary, probing questions were asked. The open ended questions gave respondents considerable leeway in giving descriptive answers and elaborating wherever necessary.

Participants were also asked to assess the success or failure of the project, to give their opinion on its likely causes and suggest possible improvements. They were also requested to suggest what firms and TIs could do to facilitate such projects and to develop long term relationships. Apart from their content, these suggestions and opinions also gave useful insights into aspects of the project process which were not elicited through direct questions. Interviews were completely transcribed. Interview data was . supplemented by observations, communications, records and reports.[33] Through the multiple projects, themes and issues gradually re-occurred and over the set of projects there was repetition of process details indicating that theoretical saturation had been reached. When sufficient repetitions occurred to ensure external validity[34] no further projects were studied.

The Miles and Huberman[35] 'categorisation and theme analysis' technique was used to develop cases from the interview and background data. First, the background data and the interview statements in each transcript were thematically classified. Based on this classification, a common case writing format was developed with a logical and chronological sequence for presenting the data. All transcripts related to a project were then combined within this common format. The various sections were then logically connected and edited to facilitate readability. The common format ensured reliability in the data collected and also provided within case analysis.[36] While structuring the cases, the focus was on the development of causal patterns over time within cases and on the development of patterns across cases. This analysis served as inputs for the inductive development of the proposed process model.

The project case studies traced the life of the project from conception to completion. The case writing was kept as objective and close to the data as possible. As far as possible, only factual statements were converted to third person. Wherever they could stand independent of their context in the interview, direct quotations of statements and opinions made by project participants were presented without interpretation. Where the context was important it was mentioned along with the statement. The extensive use of quotations was essential as, apart from factual 'hard data', the statements of projects participants contained 'soft data' on their thoughts, opinions, beliefs and assessments about themselves, their partners and the projects. This 'soft data' was considered important and valid in this research as, apart from technological capabilities, these can play an equal if not more important role in the selection and assessment of potential partners, in the initiation and implementation of the joint activity, and in the development of the propensity to interact in future. Draft cases were read, corrected and cleared by the firm in consultation with the TI.

Eisenhardt[37] has presented a framework for building theory using case study research. This research is set in Eisenhardt's framework. Steps on selection of cases, crafting data collection instruments, entering the field, analysing data, shaping hypothesis and reaching both case and research closure, closely followed this framework. Since all cases could not be equally well developed due to differences in the background and interview information made available to the researcher, therefore in the analysis, some cases developed into central cases contributing to the development of generalisations, while other less developed cases supported the generalisations built from the central cases. As this research was of an exploratory nature, it stopped after using the empirical base to identify the project process and to conceptually build on it in developing a proposed theory in the form of a process description and model. Further research is required for testing the adequacy of the variables included in the process model and the completeness and accuracy of the process description and model.

Process Description and Model

The process model presented in Figure 1 and the general process description presented in this section are synthesized from those TI-firm joint R&D project cases developed as described in the methodology section above, where: (a) the project involved the use of some skills, technology and equipment which were not available with the firm in-house but were available with the TI, (b) the firm wished to acquire these skills, technology and equipment, both for the project and for its future work, (c) the firm therefore contracted the TI for assistance on a consulting basis for teaching it these skills and acquiring the technology and equipment, through regular intensive interaction, while simultaneously and jointly implementing the project. The general description of the *technology training venture* project process is in the form of a set of interconnected proposition like statements covering: (a) the project antecedent conditions and joint project initiation process, (b) the project implementation and learning process, and (c) evaluations across organisations and perceived consequences of the project. Important aspects of the process description are summarized at the end of the description in two tables - Table 1 which covers the project antecedent conditions and joint project initiation process; and Table 2 which covers the project implementation, learning from the project and evaluations across organisations.

Figure 1 about here

Project Antecedent Conditions and the Joint Project Initiation Process

The project antecedent conditions, the firm's project implementation mode choice process, and the joint project initiation process are described in this section. Interspersed with the description, examples and quotations drawn from a typical *technology training venture* project is presented in *italics* to illustrate some important aspects of the process description. This example of an R&D project between GMT, a small machine tool manufacturing firm and IIT, a not-for-profit advanced technology training and research institute, for jointly designing and developing a sophisticated machine tool, is followed through in the subsequent sections also.

Importance of the Project for the Firm: The *technology training venture* project is of strategic importance to the firm in the sense that it is linked to the firm achieving its strategic goals. It is usually the only one, or one of the few projects, being implemented by the firm. The project individually holds great importance for the firm both for itself and for its potential to contribute to the technological resource base of the firm. Apart from developing the new project, the firm needs to learn the technology required for it, to meet immediate and future needs.

This is shown in the GMT-IIT case. GMT, a small machine tool firm contemplated designing and developing a sophisticated machine tool. This project was technologically very important to GMT as, without such a machine, they had reached a bottleneck in their growth both in terms of production capacity and in terms of quality standards required for exports. GMT lacked the resources to purchase expensive machine tools developed abroad which could do similar functions and there are no manufacturers of such machines in the country. They therefore decided to design and develop the required machine on their own at a much *lower cost, both for their own immediate use as well as for sale in future.*

Technology Involved in the Project: The technology required for the project is largely unfamiliar to the firm. The firm also lacks the knowledge and the appropriate manpower and/or equipment required to implement the R&D project on its own. The basic technology required for implementing the project is however not new. Though not yet known widely within the industry, it is relatively familiar to the TI and therefore, for the TI, the project requires customised application of a known technology to a real life industrial problem.

In the GMT-IIT case, GMT found that they needed to robustly test the machine design theoretically prior to construction, for which a simulation analytical technique was essential. While this technique was known and proven abroad, firms in the country had not yet used it in a significant way. GMT lacked both the knowledge of this technique and the analysis software required to use it. Also the software was extremely expensive for GMT to afford. They needed to learn the technique to implement this project and future projects of this nature.

Options for the Firm: Given this scenario of technological unfamiliarity and project requirements, the firm explores three options: (a) *Technology acquisition from a firm abroad.* This option is time consuming and has the risk of failing during adaptation. It is usually very expensive and there is low opportunity for learning. Often outdated technology is received which leads to no capability building. On the other hand, it involves one time payment and comparatively low internal human resource investment. (b) *Acquire new manpower and equipment and do internal R&D with self learning and experimentation.* This is time consuming, very expensive, has high risk and requires high investment. The firm also has low confidence in its ability to do the project entirely on its own. (c) *Do a joint R&D project with a TI and learn the new technology while implementing the project.* This is more rapid, has high learning with easy learning transfer from TI to firm, is low in cost and has lower risk. The firm also has higher confidence in the TI's ability to do the project, since it is more familiar with the technology area. On weighing the three options the firm decides to choose the option of a TI-firm joint R&D project implemented as a *technology training venture.*

In the words of the CEO of GMT -- 'We needed the machine to achieve quality standards. We identified this as a gap in our achieving the targets in the market. Through this development we have come to know the latest technology and improved our knowledge base. It has also opened a new area for us in making this and similar machines for the market -

either domestic or abroad. We are doing this development on our own instead of importing it, not only for the cost saving but also because we are learning a lot and developing capabilities which can open a new line of activity for us in future. For this the large amount of time spent in development is worthwhile.'

Project Contract and Implementation Structure: In the *technology training venture* project implementation process, the firm contracts a suitable TI, which has the skills, technology and equipment, to assist it during project implementation. The TI is essentially on a consulting contract. It teaches the new technology, demonstrates its use and advises the firm on purchase of equipment. The firm works with the TI's guidance. The contract could also call for use of the TI's equipment till the firm acquires them. As such projects require very high interaction between the two organisations during project implementation for the transfer of know-how from the TI to the firm, the firm usually considers a TI in its immediate vicinity (same city) as its first choice. The TI is usually one with which the firm has had a long and fruitful interaction and developed a personal and professional rapport. The firm typically does not go through an elaborate search process and only contacts the local TIs working in that technological area.

In the GMT-IIT case, GMT did not have the required skills and equipment to implement the project on its own and it was difficult for it to learn to do so on its own. For its future growth it was essential for GMT to develop its design capabilities. Without the new machine, GMT was facing difficulty in meeting export quality requirements on their main product. They therefore approached IIT, a local not-for-profit advanced technology training and research institute, which was familiar with the simulation analytical technique and had the required simulation software. They wanted IIT to teach them the technique while simultaneously implementing the project with them jointly. They also needed the IIT professors to give them technical advice on certain design aspects which they were handling for the first time, as well as for the selection and specifications of some imported components. In the words of GMT's CEO -- 'We were aware of the facilities at IIT. Also its proximity to our unit was important. They are knowledgeable sources and so we decided that IIT will be our consultants.'

Feasibility and Viability of the Project Implementation Structure: The *technology training venture* project implementation structure is feasible if the project technology and knowledge is transferable from TI to firm through teaching and the project interaction and implementation process. It is viable if the TI has the required, clearly superior expertise and capability to teach the required skills, and guide the firm, compared to the firm learning these on its own, through trial and error.

Motivations of the Firm: The firm identifies a project with a clearly definable end result, but does not have some of the skills, technology and equipment required for implementing it, as these are a level above that known to the firm. The choice of implementing the project as a *technology training venture* is closely linked to the availability and willingness of a suitable TI. The firm needs to learn the technology, both for the contemplated project and for future projects in that area. The firm's motivations are that the required skill and technology is available with the TI, rapid learning by doing is possible, it knows the TI well through fruitful previous contact and frequent interaction is possible. As the project is in a known technology area for the TI and the firm has the knowledge that similar projects have been done by the TI in the past, the risk of failure associated with the project is low.

Constraints of the Firm: The firm's constraints are that the required skills and equipment are not available within the firm and it is difficult for it to learn the technology on its own. For its future growth it is essential for the firm to acquire the skills, technology and equipment to implement future projects in this area, but it perceives difficulty in doing so on its own. Alternatively the firm, facing high competitive pressure, wants to get the first project involving the new technology implemented as early as possible and therefore cannot spare the time to experiment and learn the technology on its own before implementing the project.

Firm's Choice of TI: The project is usually initiated as a consequence of a history of casual to intensive interaction between the TI and the firm, for a variety of reasons conferences, student projects and training, testing of equipment, consultancy and earlier projects. As TI and firm are located in the same city, this long interaction is both facilitated and sustained. Over time the TI and firm personnel develop professional respect for, and friendly personal relations with, each other. The firm's choice of TI is based on whether past interaction has been fruitful, whether the required facilities are available at the TI, whether regular and close interaction is possible, the perceived ease of interaction and interpersonal rapport.

The choice process is shown in the GMT-IIT case: GMT has been in contact with IIT for over twenty-five years. It was one of the closest TIs for them (apart from a local engineering college) which worked in the machine too. (metrology) field. As the project required regular *and close interaction - GMT wanted to be close to the TI. Since IIT was based in the same city, it was their first choice. GMT had developed a very good rapport with the head of the metrology department at IIT. Said the head of the metrology department at IIT - 'We have known GMT for a long time. Our interaction goes back to about twenty five years - when we were involved in the calibration of their equipment for the manufacture of surface plates which they were exporting in the 1960s. There were several small projects of a consultancy nature after that. So when they went in for a new machine, IIT was their obvious choice.' Another TI based in a major city 300 kilometres away was not considered even though it was specialised in machine tool technology.*

TI's Considerations: On being approached, the TI examines the project primarily in terms of its usefulness for training its students or junior scientists to apply their knowledge and to use it as a learning opportunity. The TI accepts the project if it broadly falls within their current or future areas of research and their experience base, and if the work has some unique and challenging components. The TI can also use the firm's plant as an experimental base to try out new design ideas and modifications, which are beneficial to the firm and are within the limits of the firm's proposed project, usually as a peripheral mutual benefit.

On the other hand, the TI scientists may be time constrained due to their teaching workload and other concurrent projects. Since it has the required equipment and expertise that the firm lacks, the TI may, considering its charter, be obliged to accept the project. The TI may also be obliged to support a local firm which has no alternative source for technical support. Such obligation may be partially guided by its charter and partially due to obligations created by earlier interactions and friendly relations that have developed between the firm and the TI.

Importance Level of Project to the TI: The project is more than of just commercial importance to the TI. The TI considers the project as important in terms of supporting the industrial firm in upgrading its skills, while simultaneously developing a new product. The TI also sees the project as an opportunity to apply and demonstrate their knowledge in industrial practice, earn revenue, and to some extent advance work in its areas of interest. As the TI has typically had a long and fruitful interaction with the firm in the past, it sees this project as one of the series of ongoing interactions with the firm, and wishes to continue the interaction which it considers mutually beneficial. The project is in a familiar technology area for the TI and it may be interested in disseminating the technology to the industry so that the industry can gain practical benefits and the TI can see the practical application of the technology (and also gain practical experience for itself). The TI may also be interested in training the firm so that they can manage such projects on their own in future, and so that the new technology spreads in the country.

In the GMT-IIT case, IIT's primary reasons for taking up industrial consulting projects were: (a) testing of research areas in practice, (b) obligation to develop technological capability in industry, (c) training for students and (d) additional source of revenue. 'From my side I was interested in my students getting industry experience and in disseminating knowledge to the industry.' - said a professor of IIT. 'We may not learn much from this project as this is only an applicable of technology to a job requirement and not an innovation. We are only applying our knowledge to a context. But we have a lot of scope in experimenting and studying the performance of the finished machine' - said another professor of IIT. 'The problem for us is that we are preoccupied with other things - student projects and teaching hold greater priority and this is not a priority item for us as much as it is for them (GMT).' - said a third professor of IIT.

Familiarity of TI with Technology Area: The technology area is familiar to the TI and it has done R&D for similar projects before. The earlier experience is useful for, though not directly applicable to, the project.

Technological Nature of the Project: The project does not involve a major technological leap, but is largely a developmental application of a known technology to a new industrial problem. Therefore much of the work involved is of customised, non-patentable nature.

Regarding the GMT project, a scientist of IIT said - 'We went for this project primarily because we have the expertise here at IIT. We have been working in this area for a long time (eight years). We are getting some benefits and we are giving some benefits to the industry. Also we have had earlier contact with them over a long time.' For IIT, the work required application of a technique known to them to an industrial application. For them therefore, it was a developmental project and not something entirely new and unfamiliar.

Project Implementation and Learning Process

The project implementation and learning process in a *technology training venture* project is described in this section and illustrated through the GMT-IIT case example. In a *technology training venture* project implementation process, the project moves interactively between work at the TI, TI to firm teaching interaction, and work at the firm, as described below and depicted in the process model. Work at the firm and at the TI go on throughout the project duration (though its nature changes over the project duration). Also there is constant back and forth movement of information and TI to firm teaching interaction, throughout the project duration.

Work at the TI: The initial work at the TI is in testing the designs developed by the firm, developing new designs if required, and holding demonstration classes for the firm's participants. A major part of this work is delegated to its students or junior scientists as a form of job training for them. The overall guidance and some consulting and training is provided by the senior scientists. At a later stage, work at the TI involves checking interim design changes and the results sent by the firm and making modifications as required.

TI and Firm Working Together: The initial work done together by the firm and the TI, involves planning of the project and discussions for taking decisions on the choice of design and the choice of equipment. The TI also assists the firm in their negotiations for getting project financing and for purchase of equipment related to the new technology. The latter is required as the firm is entering a new and unfamiliar technology area. Since the TI has experience in setting up its own laboratory in that specialised field, it is familiar with the requirements and can support and advice the firm in planning and developing its own laboratory or plant. At the later stage in the project, the work and the interaction process continue as earlier, with greater work being done by the firm as it learns the new technology and applies it. The TI gets involved in checking results sent by the firm and they work together in experimenting on the completed product and in setting up the new laboratory at the firm.

Work at the Firm: At the firm, the initial work is for checking on the production feasibility of the TI's designs and their market suitability. At a later stage, work at the firm involves applying the new technology and using the new equipment to develop the product or process.

The project implementation process is illustrated in the GMT-IIT case: The IIT professors first went through GMT's initial design drawings and engineering drawings and suggested basic improvements. The work involved application of the simulation analysis to check the designs for meeting quality requirements, robustness on performance parameters and economy. It also involved computer aided design and computer numerical control *programming. These sub-projects were carried out by students under the supervision of the IIT professors. Said the head of the metrology department at IIT - 'This project was of a consultative nature and not hands on development. We were only assisting them in technical aspects and were not involved in direct design.' In computer numerical control technology, the firm can buy subsections from various suppliers and integrate them. GMT needed help from IIT in the selection of subsystems as they were purchasing some of such components for the first time. IIT provided such assistance as required over different stages of project execution. At GMT, the work involved developing design drawings for each part of the machine, with suitable modifications to suit special requirements and quality of material available. At each technical stage in the project, the steps were: (a) IIT confirmed the design for the particular part, (b) GMT fabricated the part, (c) GMT called IIT professors over to GMT, (d) the professors checked the part and suggested improvements if necessary, (e) they then went to the next stage.*

Interaction: In a *technology training venture* project, the firm's major objective is to learn a new technology while implementing the project. Usually there is a high tacit component in this technology and its transfer requires constant interaction, demonstration and teaching. Therefore being in close vicinity of the TI is important for the firm. The TI acts as a consultant and guides the firm in a number of technical areas in the project and in the purchase and use of equipment in the new technology area. The TI's technical knowledge is transferred to the firm through the formal and informal teaching and intensive interaction throughout the project duration. Though some parts of the project are carried out separately at the firm and TI, they consult each other at every stage throughout the project.

This interaction is described in excerpts from interviews in the GMT-IIT case: 'Two or three of GMT's people met us regularly and informed us of their progress. Whenever they completed a phase we went there, looked at the work done, discussed and calculated the specifications. More often they came over here with their design.' - said the head of the metrology department at IIT. 'We met GMT people very often and went through their reports. We gave advice, revised them, looked into their calculations. The meetings were formal - we asked them to come over and spend some time (two to three hours) discussing on all aspects. We also went there a number of times to see things for ourselves. We met their suppliers of special equipment and were involved in discussions with them.' - said another professor of IIT. 'They came over to meet us regarding other technical problems also. Interaction was *informal - they could walk in any time and clarify their doubts.' - said a third professor of IIT. 'IIT provided us guidance on all aspects. Whenever we had any problem we contacted them and they helped us. Recently we had some difficulty in some specialised area, we contacted the concerned professor. He asked us to attend a class he was conducting in that area. We are in regular contact with people there.' - said an engineer of GMT.*

Learning Process within the TI: In the *technology training venture* project, learning within the TI during the project is through high interaction between the scientists. They learn from each other and also learn through the process of teaching the technology to the firm. They learn to apply their knowledge to practice and gain in practical experience. For the students or junior scientists from the TI, the learning is in developing practical skills in applying theory to practice in an actual industrial problem. This also leads to their gaining confidence in the usefulness of their theoretical technical knowledge.

This is depicted in statements in the GMT-IIT case: 'The youngsters involved in the project had an opportunity to understand the working of an organisation and product development activities within it.' - said the head of the metrology department at IIT. 'In my view this was a good *problem - a practical, realistic and technically large problem. It was a good problem for the technical and practical training of our students - it gave them a feel for an industrial problem - to see the application of their course work to practice. The project required expertise of different people - a mix of expertise. Four of us (professors) were involved - it led to faculty coming together, cross fertilisation of ideas, learning across departments and joint solution of problems.' - said another professor of IIT. 'We have learnt about the applications of concepts in practice and seen the validity of our design assumptions. This exposure will be helpful to us in new products and new machine designs.' - said a third professor of IIT. 'Though each of us in our project group at IIT was handling a sub-project, we used data across persons in the group as co-ordination and feedback was required across our specialised sub-segments of the project. We often met and sought solutions to problems from faculty in other departments outside our field of study.' - said a fourth professor of IIT.*

TI to Firm Teaching and Knowledge Transfer: The technology and knowledge transfer in a *technology training venture* project is embodied in the frequent formal and informal interaction and technology demonstrations during visits to each other's premises. This happens throughout the project duration. A major part of this technology transfer is from the

TI to the firm, though the TI does learn a little from the firm - specially in the practical and commercial aspects of applying technology to practice. There is TI to firm teaching through frequent interaction, communication, formal, informal training and technology demonstrations at the TI or firm, and through the practical experience of jointly setting up a new laboratory or equipment at the firm. The initial work is done by the TI participants as a demonstration for the firm's participants. Simultaneously they conduct formal training in the new technology. Over time, as training proceeds, the firm does most of the new technology related work on its own under the TI's guidance.

In the GMT-IIT case, the IIT professors organised several short term training programmes for GMT both at the IIT campus and at the GMT factory. These were for training GMT engineers on the simulation analysis technique, computer numerical control programming and computer aided design. 'The IIT training courses for GMT started when we could not follow some of the analysis results. So they offered a course for us here at GMT.' - said the CEO of GMT. 'For training, sub-groups were formed for different training aspects. The training was an important component of our project. It was there in the MOU (memorandum of understanding) and was a joint initiative.' - said the head of the metrology department at IIT. 'Our aim was to disseminate knowledge to the industry.' - said another professor of IIT.

<u>Learning Process within the Firm</u>: In the *technology training venture* project, the learning for the firm is of advanced techniques useful to their industry and for their future work, while applying them to their immediate practical problem. The learning process within the firm is by instruction and by doing, as they learn to apply advanced technology to their industrial practice. They also gain practical experience during the joint purchase and use of the new equipment required for setting up their laboratory or plant for using the new technology.

In the GMT-IIT case, after the training on the analysis technique, GMT started applying this learning while designing new components for their machine. Through this they could send IIT more advanced drawings correct in the basics, and therefore avoid the first round of corrections, thus shortening the total design cycle time. According to the head of the metrology department at IIT - 'We have trained the people at GMT so that the next time such a requirement arises they can do it on their own. They have also enhanced their technical capabilities and changed their thinking pattern. They have now realised the need and usefulness of looking at design in a new and systematic manner. It will also improve their *confidence level.'*

Interest and Relationship: The *technology training venture* project is characterised by a medium level of personal and organisational interest in both the firm and the TI. CEOs of both organisations are usually involved in supporting the project, but initiative and interest in the project emerge from the next level - the R&D or production functional head. The TI-firm relationship is primarily relational (personal and trust based) and to some extent contractual.

Problems and their Resolution: Problems in the *technology training venture* project process are usually related to communication gaps and project delays. Given the frequent interactions and amicable relations between project participants across organisations, these are resolved as soon as possible through amicable discussions.

Evaluations and Consequences of the Project

This section covers the parameters on which the firm and the TI evaluate each other after the project is completed. It also covers their vision of the consequences of the project for future interaction between the two organisations. These are synthesized from cases of the *technology training venture* projects studied.

Evaluation of the TI by the Firm: On completion of the project, evaluation of the TI by the firm is against its initial motivations and perceived benefits. It is also based on its perception of the knowledge base of the TI project participants in the technology area, the quality and ease of interaction with them, and their ability to teach the new technology in an interesting and effective manner, apart from effectiveness in implementing their part of the project. The firm is positive about interacting with the TI in future if these expectations are met.

Evaluation of the Firm by the TI: Similarly, evaluation of the firm by the TI is against its initial motivations and perceived benefits. It is also based on the firm's clarity in communicating its requirements and expectations, adequacy of the firm's participants' prior knowledge base, their interest and ability to absorb the new technology, and the ease of interacting with them. The TI is positive about accepting future contracts from the firm, if these expectations are met.

Expected Consequences: In a *technology training venture* project, if evaluations of the TI and the firm regarding each other and their mutual learning interaction are positive, then continious future interaction is expected by both firm and TI. This usually holds even if the project does not meet all its technical expectations. Though the firm and TI have a long history of interaction, there is a tacit understanding that the firm would not repeatedly approach the TI with the same or similar problem, but would learn during the course of the project to solve that class of problems on its own in future. Future interaction is expected to be on new problem areas which the firm has not brought to the TI before.

Tables 1 and 2 about here

Discussion And Conclusions

This paper contributes a mapping of the process of initiation and implementation of TI-firm joint R&D projects, that are initiated by firms which typically lack the infrastructure or the technical expertise required for implementing them on their own, and hence approach TIs that have the required expertise and infrastructure. As shown, TI-firm joint R&D projects implemented as *technology training ventures* can be a viable technology acquisition option for firms, under certain initial and process conditions. Firms can examine the process model and description to draw lessons on creating appropriate ground conditions for TIs which facilitate the initiation of joint R&D projects, and therefore gain the synergies available from such projects. However, such synergies can only be gained if the firm develops the capacity to absorb the technology with adequate in-house R&D resources. TIs can also examine the model to learn how to create appropriate ground conditions for firms, so that they initiate joint R&D projects with them, and therefore gain the synergies available from such projects.

This research complements the more common large sample survey based studies of TI-firm joint R&D projects which, while providing an overview of the firm and TI motivations and explaining the existence or nonexistence of joint R&D projects, are not designed to describe the initiation and implementation *process*, which is key to developing policy mechanisms that initiate and facilitate such projects. Directions for future research are: (a) testing for the accuracy and completeness of the developed process model and its identified stages and sub-processes, (b) comparison of the model with models of joint activity between organisations of various types, (c) developing scales and operationalizing the various components of the model.

While providing empirically grounded theory development in this field, this research can also enable practitioners and policy makers in first, understanding effective processes for initiating and implementing *technology training ventures* for mutual benefit, and second, modifying structural conditions to initiate an effective implementation and learning process in them. The process model is useful in understanding how factors at the individual, organizational and inter-organizational level combine to initiate and implement such joint R&D projects. It can also provide insights aiding understanding and decision making by firms, TIs and policy makers in facilitating and strengthening TI-firm interaction, and in initiating, executing and sustaining a progressive programme of such projects.

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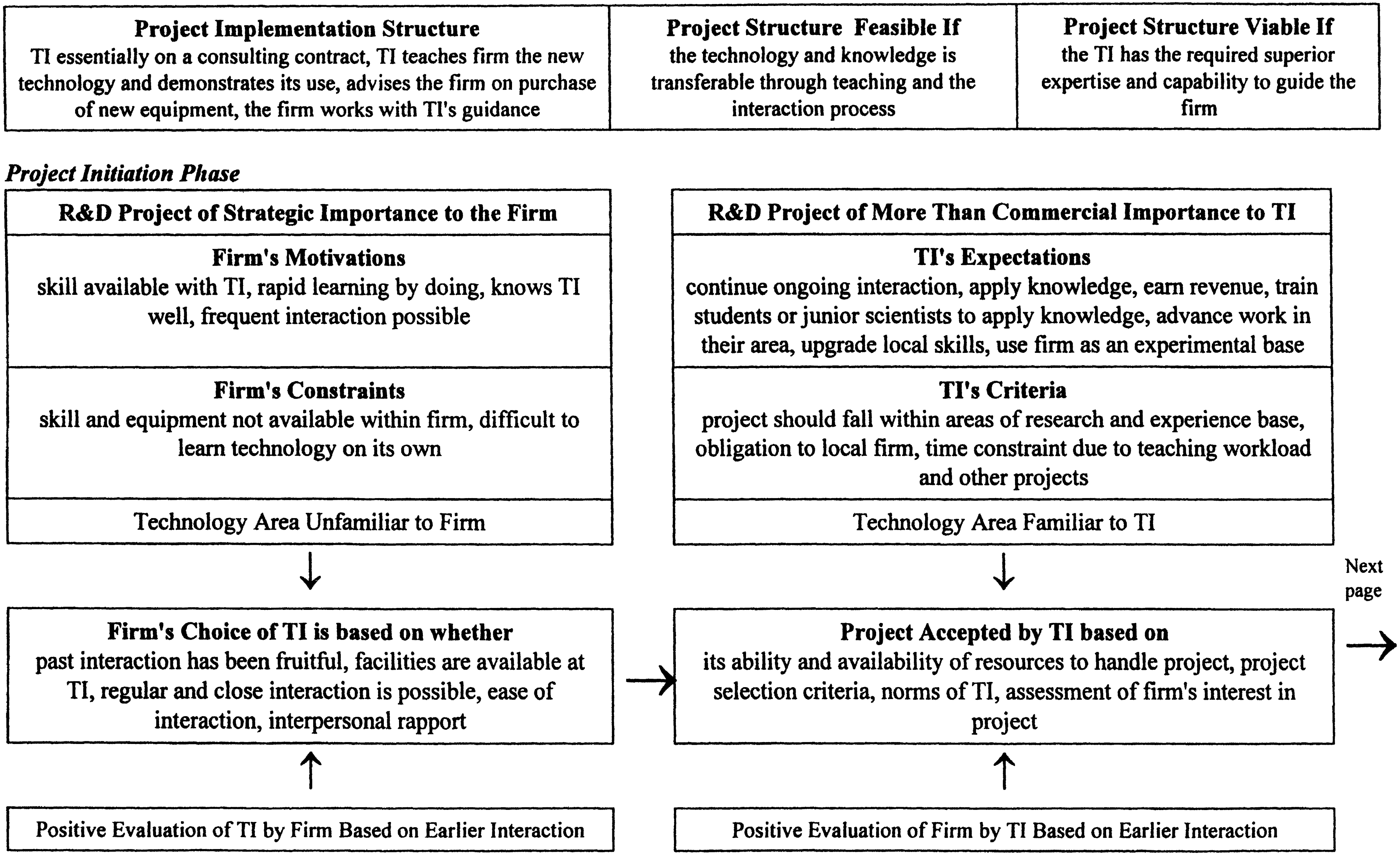

Figure 1. Process diagram of technology training venture project

Project Implementation Phase and Outcomes

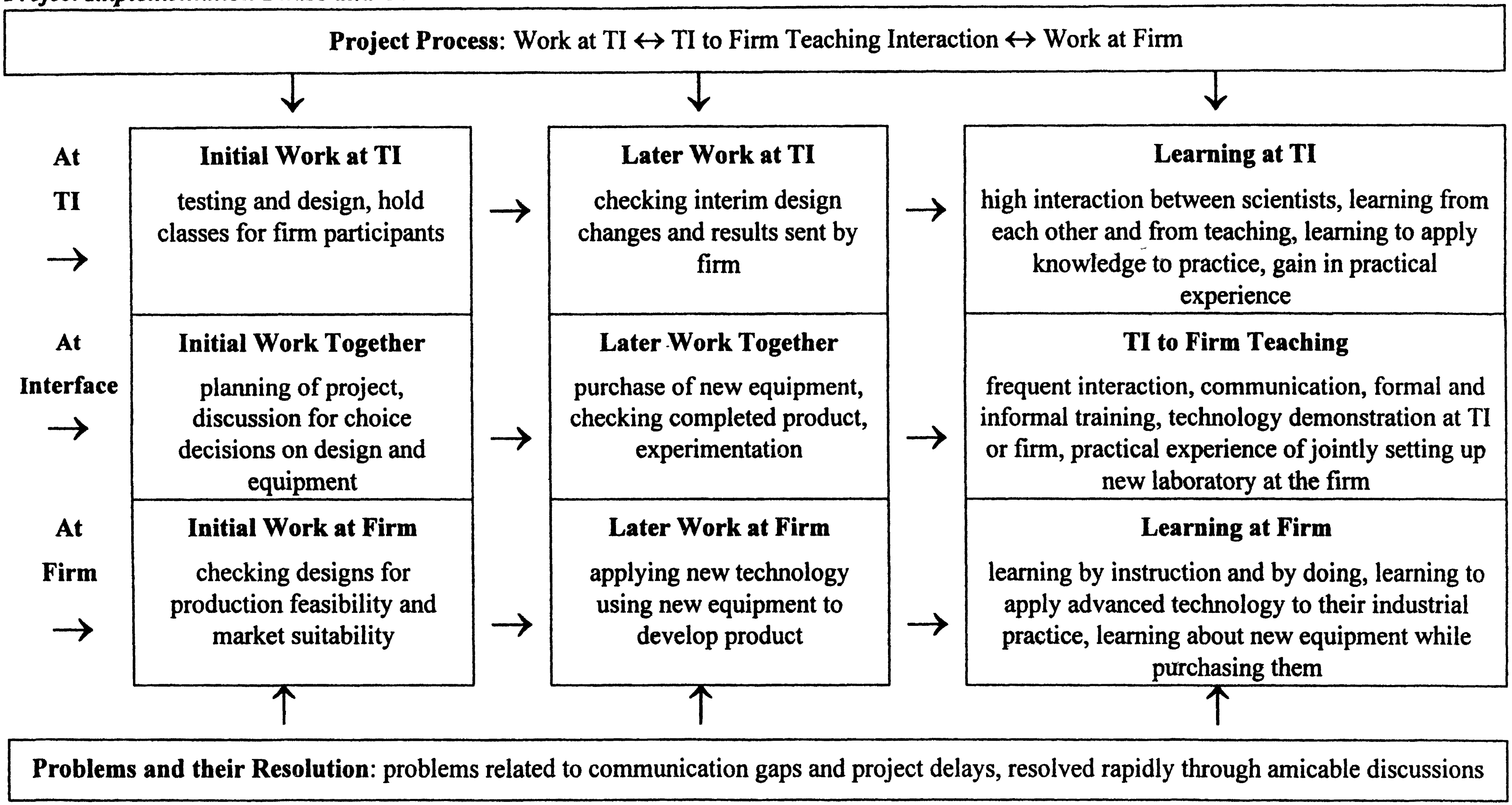

Figure 1 (*continued*). Process diagram of technology training venture project

Table 1. Antecedent conditions and joint project initiation process

Project Features	Technology Training Venture Joint R&D Project
Importance level for firm	Strategic importance; firm needs to learn the technology to meet export and future domestic market needs
Familiarity with technology area	Technology area unfamiliar to the firm
Need for firm to outsource technology	Firm lacks the knowledge and appropriate manpower and/or equipment to do project on its own
Firm's major motivations	Skill is available with the TI, rapid learning by doing is possible, knows the TI well, frequent interaction is possible
Firm's major constraints	Skill and equipment not available within the firm, it is difficult to learn the technology on its own
Firm's choice of TI primarily based on	Fruitful past interaction, rapport, ease of interaction, facilities are available at TI, regular and close interaction is possible
Importance level for TI	Project is of more than just commercial importance to the TI, it is seen as one of a series of ongoing interactions with the firm
TI's familiarity with technology area	Technology area is familiar to the TI
TI's considerations	To continue ongoing interaction, apply knowledge, earn revenue, train students or junior scientists to apply knowledge, advance work in their area
TI's criteria	The project should fall within its areas of research and experience base, obligation to local firm, fall within time constraint due to teaching workload and other projects
Project process mode is feasible if	Required technology and knowledge is transferable through teaching and the interaction process
Project process mode is viable if	The TI has the required superior expertise and capability to guide the firm
Project structure	The TI is on a consulting contract, TI teaches new technology and demonstrates its use, advises firm on purchase of equipment, firm works with TI's guidance

Table 2. Project process, learning and evaluation

Project Features	Technology Training Venture Joint R&D Project
Project process	Work at TI - interactively moving with TI to firm teaching interaction - interactively moving with work at firm
Initial activity at TI	Testing and design, holding classes for firm's participants
Initial activity together	Discussion for choice decisions on design and equipment
Initial activity at firm	Checking designs for production feasibility and market suitability
Technology transfer activity	Occurs throughout the project duration
Later activity at TI	Checking interim design changes and results sent by firm
Later activity together	Purchase of new equipment, checking completed product, experimentation
Later activity at firm	Applying new technology using new equipment to develop product
Problems and their resolution	Related to communication gaps and project delays, resolved rapidly through amicable discussions
Learning at TI through	High interaction between scientists, learning from each other and from teaching, learning to apply knowledge to practice, gain in practical experience
Learning during technology transfer	Through frequent interaction, formal and informal training, demonstrations, practical experience, tacit knowledge transfer
Learning at firm	Learning by instruction and by doing, learning to apply advanced technology to practice, learning about new equipment while purchasing them
Evaluation of TI by firm based on	TI's knowledge base, against initial motivations and perceived benefits, quality and ease of interaction, ability to teach effectively, effective project implementation
Evaluation of firm by TI based on	Clarity in communicating requirements, against initial motivations and perceived benefits, ease of interaction, interest and ability to absorb new technology, adequate knowledge base