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A study of Industrial Collaboration and Technology Transfer

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ABSTRACT

A Central motive of the Engineering Research Centers (ERC) program is to form partnerships between academia and industry in systems-oriented research areas that are critical to the Nation's economic strength. Each ERC collaborates with industry from the early stages of its vision creation and strategic planning, and collaboration extends to technology development and application. By thus expanding and accelerating technology transfer and eventual commercial use, this approach bridges the traditional technology transfer gap between the single university investigator and industrial adopters of academic research results. The ERC are distinctive among NSF research centers in this embracing of industry throughout the entire cycle technology creation, development, and implementation. Each ERC team envisages and plans technology development with its industrial partners from the outset. Each center's strategic plan, developed with industrial members, helps identify areas for joint projects and experimental test beds for validating research results in practical applications. NSF holds ERCs responsible for tracking their research results through commercial implementation. ERCs must build large research programs with considerable financial support from industry. While some support may be in the form of contractual agreements with deliverables, in many centers an equivalent or greater sum consists of unrestricted industrial grants to the center. Special emphasis is often place on attracting small and medium-sized companies to ERCs because of their more rapid acceptance of new technologies and rapid growth potential. ERCs are not discouraged from involving foreign-owned companies as long as reciprocity of information, expertise, and people is emphasized. In 1999-2000, 10% of ERCs' industrial members were foreign-owned companies.

1. Introduction

According to the gathered by individual centers and by NSF, ERCs have been very successful in attracting and providing benefits to industry. In 1999-2000 there were 439 industrial memberships in 18 centers, or an average of 24 companies per center. The total number of companies involved was 326, since many companies are members of two or more ERCs. Of these companies, 25% were small businesses, 10% medium-sized and 65% large. Equally impressive is the large number of technologies that have been invented by ERCs and implemented by their industrial partners. For example, as of fall 2000, a total of 347 patents had been awarded to 30 ERCs, 1,422 software licenses had been issued to companies, and 68 companies had been formed as spin-offs of ERC research. In addition, hundreds of discrete innovations had made their way into use in industry.While all ERCs are expected to plan, create, validate, and transfer new technologies, some of the activities inevitably receive greater emphasis at different stages in a center's life cycle. New "start-up" centers (years 1-3) necessarily focus on strategic planning with industrial members, attracting new members to their efforts, and developing forums for interaction. Mid-term centers (year 4-7) must focus on demonstrating successful industrial collaboration and technology transfer results, promising more to come beyond the sixth-year review. Mature centers (year 8-10/111) are putting new technologies into play while attracting new companies and finding new ways of teaming with industry without NSF support, including generating industrial endowments. Successful centers engage in long-term planning jointly with industrial members beginning in the early stages.Experience shows that the enthusiasm and appeal of a start-up center is very effective in attracting industry involvement; but as centers mature, industrial collaboration requires more work, as sponsors become more demanding. On the other hand, age confers the advantages of experience and credibility. In the early stages, centers need to set modest membership fees, focus research on knowledge and technology development, and use industry as a partner in identifying problems. In later stages, centers may shift their base to large contracts with specific companies; research then should include a focus on applications and field-scale development based on the knowledge and technology developed, while maintaining a base of new and exploratory work.

Another way of viewing the center's life cycle is to consider that, in the first few years, NSF acts as a venture capitalist, funding a build-up of infrastructure and providing substantial leverage to industrial support. By year 6, the center has "gone public," establishing a certain amount of credibility with regard to its benefits to industry, and begins to face a new set of challenges. With the infrastructure in place, the center matures, and the issue of delivery becomes preeminent.Industrial collaboration with ERCs extends beyond the development and transfer of technology. Industrial members become involved not only in strategic planning and collaborative research, but also in many educational activities. Industrial members give practical experience to ERC seminars. Members also participate at the center in hands-on courses, seminars, and co-advising graduate students.Industrial involvement in the early stages of technology planning and development provides substantial payoffs when ERC students graduate. Member companies employ a large fraction of ERC graduates. Many of the hiring companies have noted that ERC graduates, by virtue of their systems-oriented training, are more skilled at technological innovation and product/process development than their non-ERC counterparts. They also are capable of integrating knowledge across disciplines, working in teams, understanding industrial needs, and addressing problems from an engineering systems perspective. Industrial sponsors typically comment that ERC students "land on their feet running" and 1 ERCs established between 1985 and 1997 have 11-year terms of support by NSF; with the Class of 1998, this term was reduced to 10 years.

"Do not require the usual 12 to 18 months to come up to speed." Many ERCs and their industrial members agree that students are the best and most lasting form of technology transfer. The ERCs' relationships with companies are experiments. Each one is unique, depending on the nature of the research undertaking, the scope and type of the industries involved, and the strategic direction of the center. Within this diversity there are common issues, which each center must resolve to create a functioning partnership with industry. The objective of an ERC should be to establish a very broad industrial constituency. Emphasis on dollar amounts of support should be balanced by a focus on the intellectual and economic potential of a collaborative effort.Ultimately, the ERCs are test beds for broader cultural change in university-industry collaborative research. They are pioneering new ways of bringing research results to market, breaking down many traditional barriers that have hindered cooperation between universities and industry. Every lesson they learn makes it easier for those who follow to work together productively, as the working partnership of university administrations and faculties with corporate researchers develops. This is perhaps even truer of the centers that have graduated from NSF support, since those centers operate without federal subsidies and therefore must justify their benefits to both their host universities and their industrial members.Case studies are used to illustrate some effective approaches. At the end of the chapter is a summary of the main lessons that have been learned; most of the sections also have a listing of specific lessons learned.

2. Establishing An Industrial Affiliates Program

Start-up Systems Development: A critical start-up activity in any center is to establish the vision and infrastructure that are required for an effective industrial collaboration and technology transfer program, including systems for tracking interactions with industry. The Director and senior leadership of the center typically form the vision and strategic plan for industrial interaction during the center's proposal development process. The infrastructure required to affect this vision and strategic plan must be developed with post-NSF survival in mind. One ERC had existed as a University/Industry Cooperative Research Center before becoming an ERC and had already established the basic foundation for their industrial collaboration, but found they had to adapt that model to the more strategic, systems-oriented ERC approach. Other new centers have surveyed existing ERCs during their initial development phases, to benchmark the strategic plans and infrastructure that were effective for the existing centers.

In the months after the formation of a new center, it is important to work with the university and its technology transfer office to establish internal support and work out an ERC membership agreement for the program. NSF requires each ERC to develop its own generic membership agreement, governing the participation of industrial and practitioner members and specifying the forms of industrial cash and in-kind contributions that constitute membership in the center. In multi-institutional ERCs, where university/industry research centers may already exist, it is essential to examine and compare the existing membership structures, fees, and terms and conditions and involve all key personnel at the universities from the start in drafting the new ERC agreement. Support for the ERC is generally high immediately after the award of the cooperative agreement and the climate for negotiating long-term university support is good. Some centers have negotiated long-term university support is good. Some centers have negotiated return of overhead from grants received by faculty doing center-related research. In most universities the return of intellectual property revenue is divided according to a certain formula that includes the inventor, the university, the originating unit (the ERC), and other parties.

An important component of the strategic plan for industrial interaction is a clearly defined marketing strategy for recruiting industrial sponsors. A well-developed marketing strategy typically includes an analysis of the industry sectors by the center's research and of the value drivers that industrial sponsors will find attractive in a research and technology transfer relationship. The marketing plan includes financial and technology transfer goals, specific actions and timelines needed to reach those goals, and a budget for the Industrial Affiliates Program. This plan includes strategies not only for recruiting new members, but also for retaining existing ones, through customer service activities such as communications on center research activities and results, faculty interactions with sponsor companies, and regular visits to sponsors' sites.

Membership Structure and Fees: All ERCs expect substantial financial support from industry. ERCs have annual memberships, with responsibilities and benefits governed by a membership agreement. Across all ERCs, annual membership fees range from $2,000 to $250,000, usually encompassing two or three membership categories with corresponding fees and benefits of membership. For small companies (often defined as fewer than 500 employees or less than $30 million in annual sales), fees are generally $2,000 to $10,000, and may be graduated. Many centers allow larger firms to affiliated either in limited ways (by research area or by specific contractual projects), with annual fees typically ranging from $6,000 to $30,000, or in a broader way (full membership with maximal rights), with fees usually ranging from $25,000 to $100,000. Industry-specific differences are important in establishing a fee structure. For instance, the computer software industry usually pays higher fees than others do. Some centers include university overhead on membership fees, while others do not. Policy on indirect costs must be negotiated with the university administration at the inception of the center and established in writing. Membership fees are pooled and allocated to center functions according to the strategicand operational plans established by the center's leadership. Industrial members may provide additional support above the membership fees for activities such as sponsored research projects, equipment donations, intellectual property donations, or educational grants. Potential industrial members that have not joined the center but contribute support for projects that fall within the scope of the ERC's strategic plan and are included in the Center's annual report, are not considered members but may be given another designation, such as "affiliates." Some centers use all fees to support research; some use them exclusively for support of student interns; others use membership fees for all operations.Centers' policies vary on how fees are paid – in cash, in kind, or a combination. Single institution ERCs may find that in-kind contributions are valuable in the early stages, when equipment is needed and relationships require nurturing, but later, when the facility becomes more fully equipped and working relationships are established, cash contributions may be required of new members.In multi-institutional ERCs with pre-existing industrial consortia, the needs and cultures at the different institutions and industries may vary. Thus, it is important to maintain, at least initially, the flexibility to negotiate and the willingness to make changes, to arrive at a membership structure that is acceptable to all parties involved.

Membership Rights: During its first year, each ERC develops a standard membership agreement that governs members' participation and sets out the forms of cash and in-kind contributions that constitute membership. Organizations that can be considered as members include private firms and local and Federal agencies. Organizations contributing research and educational participants in the center, such as other universities, institutes, and hospitals, should not be counted as members. An ERC should be mindful not to develop unique contractual arrangements for each company in lieu of a membership-defined program of industrial collaboration. However, member companies may augment their support to the center through directed project support or contractual arrangements. Firms that are not members but provide directed project support often are classified as "affiliates" and firms and others that provide equipment and other donations are classified as "contributing donors." Guidelines for ERC industrial membership agreements, including example agreements, are available to registered users of the ERC Association. Standard membership agreements should address such issues as:

- Membership definition (e.g., members have nonexclusive equal access to any intellectual property developed under ERC funding; access to all meetings and workshops, interns, technical information, research collaborations, and placement of industry people in ERC labs; input into the research planning and review process; and a seat on the center's industrial advisory board)
- Fee clarification (appropriate membership categories and associated fee structure)
- Intellectual property (IP) rights (discussed in Section 5.4)
- Publication issues (usually governed by university policy)
- Membership termination (some centers require a two- to three-year membership commitment, or an extended – e.g., nine months – notice of termination to prevent under impact of the funding shift on students' support).

One ERC reported that an improvement on the initial contract would be a provision for modifications that would not require full legal approval. For example, fees could be changed by approval of Industrial Advisory Board (IAB) with 12 months' notification of members.

Intellectual property rights arrangements specified in the membership agreement are influenced by the type of industry, by the university's experience, and (it is to be hoped) by common sense. The type of membership structure also should influence IP decisions.

If the entire center's research activity is precompetitive and supported in common, shared rights for all members are appropriate. If the center has, in addition to generally supported research, special project support by a company, the arrangements should reflect that company's unique contribution and rights. In a typical center, the university owns IP and licenses are available to members. Access to licenses is based upon membership category, varying from royalty-free license to all center-developed IP to no access for any members. Other IP issues that may be included in the agreement or dealt with on a case-by-case basis include restrictions on a license, which pays for and maintains patents, and royalty amounts.

Member Responsibilities – Boards and Committees

A center's organizational chart reflects the formal role that industry plays in advising the center. All centers have industrial advisory boards or committees that serve functions such as the following:

- Provide advice on developing the strategic plan
- Review overall progress against strategic goals
- Suggest changes to the strategic plan, research and education efforts
- Identify areas for cooperation with industry or, in some cases, other institutions
- Discuss the strategic plan and suggest modifications based on research results
- Review invention disclosures and suggest patent action
- Critique the progress and direction of each research project
- Provide resources the research program may need
- Appoint industry speakers for workshops and seminars
- Carry out an annual SWOT (Strengths, Weaknesses, Opportunities, and Threats analysis of the ERC.

Because these activities are both technical and managerial, many centers have corporate advisors who come from both those groups within companies and who form two different types or levels of center advisory bodies (see case study). In most centers, the technical advisors meet formally at least twice a year; upper-level management advisors usually meet annually. A company's membership category determines how many advisories it may have and at what levels. Advisory committees may be chaired or co-chaired by industrial members, usually vote on key issues, and often have minutes and action items distributed.

The two main customers of an ERC are its students and industrial partners. It is essential, therefore, to make sure that the ERC's initiatives match the voice of its customers. One way to ensure full endorsement is to engage them in the formulation and implementation of the ERC's initiatives. The Students Leadership Council and the IAB, along with its subcommittees, are the center's best resources for support and collaboration.

Role of the Industrial Liaison Officer: Even though no standard model exists, NSF requires every ERC to have someone on staff, often called an Industrial Liaison Officer (ILO), who is responsible for establishing and maintaining a liaison between the ERC and its industrial sponsors. Each center needs to decide during the start-up and development phase how they are going to carry out this function. This section draws on the experience of several individuals who have functioned in this capacity at ERCs during various stages of center maturity.

Structure of the Position: The first consideration is what role the Industrial Liaison Officer will play in the center.If the senior faculty and Center Director are too busy or not prepared to market the center, then the ILO's role in marketing is primary. The ILO must then be someone who has the recognition and respect of both the faculty and industry, who can articulate what the center has to offer and can generate enthusiasm for it. If the center's reputation is already well-established and/or there are effective salespeople in the form of the Director and key faculty, then what may be needed is a capable, people-oriented, detail person whose primary is to provide customer service. He or she can make meeting and other arrangements, coordinate industrial visits, disseminate information, and deal with routine issues that may arise. In most centers, the ILO is somewhere between these two poles.

The Industrial Liaison Officer is not always a single individual. Centers staff the function of industrial liaison/technology transfer in different ways. Several have one or more professionals engaged solely in the industrial liaison effort; others use one staff person for multiple functions within the center, including industrial liaison; and a few uses only faculty and students in the liaison function – although the latter approach is not recommended. Industry input suggests that having a dedicated person in this role may be the most successful model, with the greatest likelihood for maintaining consistency and improving the ERC-industry interaction. In a multi-institutional ERC with no preexisting industry participation, it is wise to establish a single industrial liaison position. This person will be responsible for recruitment and retention of members and will serve as the single point of contact within the center for industry-related matters. Many ILOs have experience working in industry and find this industrial perspective helpful.

Most report to the Center Director and work directly with faculty, industrial researchers, and often with students. If the Director has high industry exposure, then the Industrial awareness of the ERC is heightened. Visibility of the ERC is further enhanced when the Director travels extensively and gives presentations at technology meetings attended by academic and industrial scientists and engineers. The visibility and reputation of the center rise to an even higher level if the key faculty also plays a role in marketing the ERC when they are on the road giving presentations. It is the nature and quality of the research that attracts customers the most.

Most Satisfying Aspects of the Role: Just as they define their job responsibilities differently, various Industrial Liaison Officer also define job satisfaction in different ways, to some degree as a function of their specific job structures within particular centers. The following quotes from Industrial Liaison Officers regarding some of their most positive experiences may provide a better appreciation of their role and the types of activities in which they are typically involved:"Many aspects of my position are exciting, but one that provided a great deal of satisfaction was my role in persuading one of the key members of the center to continue as an industrial sponsor. This company had been a member of the center for several years at the highest level of membership and provided substantial financial support. Due to personnel changes and changes in corporate strategy, the company was reviewing the advisability of their continued participation in the center. Our center was in real danger of losing one of its most important members, and as a result of the on-going discussions, the company had become two years behind in their membership fees. This presented two distinct challenges, one being to convince them of the benefits of continuing their membership and the other to recover compensation for the previous two years. Through meetings with key personnel, we were able to document the benefits of past and continued membership, the value of a compromise plan (including benefits for paying overdue fees), and the advantages of reorganizing the company's interaction with the center. Today this sponsor is one of the leaders of the center and the industry."

Most Difficult Aspects of the Role: Two difficulties plague many Industrial Liaison Officer: (a) insufficient time for multiple activities and (b) the challenge of motivating faculty members to take timely action on opportunities to interact with industry. Time management skills are an absolute requirement for success as an Industrial Liaison Officer. Lack of support staff is a serious drawback for many. Most Industrial Liaison Officer are realistic about budgetary constraints, but still would value technical support staff. Some expressed concern about having insufficient input into center budgetary decisions.

Other challenges faced by the ILOs have included:

- Mediating between industry and faculty researchers when projects don't go as planned
- Additional coordination among industry champions and faculty researchers on the respective campuses in the various subthrust areas, especially for multi-institutional ERCs.
- Having to "fire" a visiting industrial researcher while still maintaining his company's involvement and support;
- Protecting the intellectual property of individual companies while developing opportunities to expand industrial involvement.
- Learning to work with both company and university personnel in parallel move an idea forward; and the loss of member companies from the center;

- Providing mechanisms for researchers and industry representatives to meet and exchange ideas that may lead to sponsored research projects in the center;
- Creation of a team environment where center and industry researchers can effectively collaborate and communicate on their projects.

In the case of multi-institutional ERC, the Industrial Liaison Officer may assume the delicate role of coordinating inputs from industry champions and their respective faculty researchers on various campuses. Competing for the attention of these various individuals, with varying priorities, personalities and working styles, is a real challenge.

3. Building And Industrial Constituency

Attracting Corporate Members: The need to attract new members continues long beyond the start-up phase, as all centers experience turnover in membership due to shifts in corporate strategies and fiscal constraints. Many centers have formal criteria, often developed with the Industrial Advisory Board, for identifying those companies that may belong to the center. These criteria deal with issues such as foreign firms and multinationals, whether consulting firms may belong, and whether company size or location limits membership. (It is noteworthy that, while some centers have a geographically concentrated membership, no center limits membership based on location, and many have all of their members at long distance.) This section addresses successful strategies for recruiting appropriate members.

Strategic Plan for Recruitment: The Industrial Liaison Officer manages this activity. Centers vary significantly in the formality of their strategic plan for recruiting member companies. A few centers function only in response to inquiry, without active recruiting (not a wise approach). Most of the centers focus on identified industry groups (sometimes with IAB input) and establish membership goals, do market research to further identify appropriate company prospects, and tailor recruitment strategies for each prospect. This approach is recommended.

Marketing the Center: Every center uses its Director, staff, faculty members, and sometimes students in its marketing efforts, actively or responsively. At least one center uses a part-time consultant to contact potential sponsors to identify and explore areas of mutual interest.It is the high quality of research (and graduates) that is always most valuable to companies. Carefully identifying the companies that might benefit from the research in the center – that is, finding the right partners – is important in successful marketing. Presenting information about the center's respected faculty members must be accompanied by clearly defining the value of center participation from the company's perspective. This is particularly difficult in industries with poor track record for R & D funding. Marketing techniques include literature, newsletters, and brochures; visit to industry by directors and faculty; visits to the center by industry representatives; booths and exhibits at trade association meetings; participation at technical society conferences; publication of technical papers; participation in industry research consortia; a center website; informational videotapes; letters to potential industrial sponsors identified through contacts; and topical workshops.

4. Conclusion:

Previous research shows that collaborative learning provides an environment to enrich the learning process by introducing interactive partners into an educational system and creating more realistic social contexts. However, there are no recipes that guarantee successful use of technology to support collaborative learning due to the complexity of analyzing collaborative interaction. There have been a large number of studies proposing and developing collaborative learning tools and different approaches to analyzing the collaborative interaction, as discussed in Chapter 2 learning systems is still in its infancy.

Constraint-Based Modeling has previously been used to effectively represent domain knowledge in several ITSs supporting individual learning. The main contribution of this research is the use of CBM to model collaborative skills, not only domain knowledge. CBM technique is used in this project to model student/group knowledge and represent the ideal model of interaction as a set of met constraints. COLLECT-UML (the system implemented during the course of this research) provides task-based feedback on students' and group solutions as well as collaboration-based feedback intended to make the collaboration process more effective. The collaborative feedback is provided by analyzing students' activity and comparing them to an ideal model of collaboration. UML is selected as an appropriate task for this research due mainly to its collaborative nature, its appropriateness for discussion and its complexity for novice software engineering designers.

The work evaluates the possibility of giving advice when comparing student work with an expert solution as well as group solution, in contrast to the approach usually taken by other previous studie3s that have either support tutoring (teaching the domain concepts) or coaching the social interaction (encouraging the students to discuss and participate). Therefore, the proposed system can be considered as a learning environment that supports both individual and collaborative learning. The evaluations are an essential part of research, which include testing the correctness of the system, the pedagogical agent, the usability of the interface and feedback generation. The studies have been carried out at the University Canterbury, in a second-year Software Engineering course.

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