Perspectives

Cognitive empathy in inter-disciplinary research: the contrasting attitudes of plant breeders and molecular biologists towards rice†

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I draw attention to the perceptions of and interactions between molecular biologists and scientists engaged in plant breeding in India, who have been attempting to employ molecular biology tools to understand and intervene to improve the rice crop. The present essay suggests that the concept of cognitive empathy is crucial for enabling basic scientists and applied scientists to begin to understand phenomena from the point of view of the other and from the point of view of society at large, and in arriving at solutions that are scientifically feasible and socially acceptable. Socialization into disciplinary cultures, organizational factors and individual anxieties seem to inhibit inter-disciplinary collaboration. The majority of rice breeders and a small group of molecular biologists emphasize the relative merits of marker-assisted selection (MAS) in the near term vis-à-vis the currently controversial transgenic approach for rice crop improvement in India.

1. Introduction

Recent developments in applied molecular biology have opened up new ways of looking at life processes and led to the appearance of new technologies. The potential of the new knowledge inevitably raises questions related to the social process of production and application of knowledge in wide-ranging areas. Further, the resulting reactions at the level of policy-making and implementation are important in the sociology of science and technology. Applied researchers in India have been attempting to employ molecular biology tools in order to understand the biology of the rice plant. Their ultimate aim is to improve the rice crop through biotechnology-based interventions. In this context ‘improvement’ refers to yield and other desirable traits necessary to meet the needs of a burgeoning population in India and other countries. I have made an attempt to understand the perceptions of and interactions between, on the one hand, basic researchers such as molecular biologists, and on the other, applied researchers such as plant breeders, entomologists and pathologists. Rice is an important crop for Asia. At present rice is the staple food for nearly 3 billion people in the world, more than 90% of whom are Asians. By 2025 rice consumers will increase to 4·6 billion. According to an estimate by the International Rice Research Institute (IRRI), in 1999 the rice yield in India, 2·9 tonnes/hectare (t/ha), was far lower than that in China (6·3 t/ha) or Japan (6·4 t/ha). Given that production based on ‘green revolution’ technologies has reached a plateau, there is an urgent need to explore the potential of biotechnology for further increasing rice production. One can thereby address the problem of food scarcity in developing countries. From a personal angle, this study of rice biotechnology research in India afforded me an opportunity to understand the fascinating process of interaction (and the outcome of such interaction) among scientists who approach the same problem from different points of view.

In terms of Kuhn’s famous use of ‘paradigm’ in the sense of “. . . accepted examples of actual scientific practice . . . [which] provide models from which spring particular coherent traditions of scientific research” (Kuhn 1970), the discovery of the double helical structure of DNA by Watson and Crick in 1953 led to the establishment

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of a paradigm that still holds good. That discovery fueled a cognitive revolution in biology. Cross-fertilization of ideas from physics, chemistry and biology enabled scientists both to understand life processes and intervene in them at the molecular level. The Watson and Crick paradigm gave a new direction to the molecular analysis of life forms and life processes. Techniques for transferring discrete amounts of genetic material from one organism to another, developed in the 1970s, paved the way for genetic engineering. A variety of techniques, including genetic engineering, that use living organisms and their components in agriculture, food and other industrial processes have acquired the generic name biotechnology (Smith 1996).

2. Rice biotechnology research in India

The literature is replete with claims that biotechnology can play a significant role in India's economic development and technological self-reliance (Padmanaban 1991; Bhargava and Chakrabarti 1991). Swaminathan (1987) argues: "While new technologies based on high-yielding varieties are scale-neutral with regard to their suitability for being grown by farmers irrespective of the size of their holdings, they are not resource-neutral. Therefore, we need to add a dimension of resource-neutrality to scale-neutrality in technology development". However, these claims lack empirical support related to the social process involved in the production and utilization of knowledge in molecular biology and biotechnology. The relevant studies have only recently begun in India.

Within the country research in plant molecular biology and biotechnology is carried out in publicly funded institutions, private research foundations, and by international organizations. The institutions that are publicly funded include the Indian Council of Agricultural Research (ICAR) and its mission-oriented research organizations devoted to research and development related to various crops – cereals, pulses, and horticulture; some laboratories of the Council of Scientific and Industrial Research (CSIR); agricultural universities; and regular universities. Private research foundations such as the MAHYCO (Maharashtra Hybrid Seed Company) Research Foundation and SPIC (Southern Petrochemical Industries Corporation) Science Foundation, and several companies involved in plant tissue culture are funded by national sources. Research institutions funded by international sources include the International Center for Genetic Engineering and Biotechnology (ICGEB) and the International Crop Research Institute for Semi-Arid Tropics (ICRISAT). Further, the Department of Biotechnology (DBT) of the Government of India, in addition to providing research grants, has been involved in human resource development in the area of biotechnology. Since the late 1980s scientists have been attempting to use molecular biology tools to better understand the rice plant with the goal of developing rice varieties that are resistant against biotic stresses caused by pests and insects and abiotic stresses caused by drought, salinity and so on. A related goal is to overcome yield barriers. One fallout of Rockefeller Foundation funding since 1989–90 has been that Indian scientists engaged in rice biotechnology research have formed a voluntary network – the National Rice Biotechnology Network (NRBN) – to facilitate communication and collaboration among rice researchers. Collaboration among members of a network results in greater value-addition to research; increasingly, networks are emerging as foci of innovations (Powell *et al* 1996).

As mentioned above, the present essay is based on the results of a case study of rice biotechnology research in India. I wanted to understand the social processes of production of knowledge and its application in relation to the improvement of the rice crop. This was a phenomenon in which scientists trained in sub-disciplines of biology – such as molecular biology, plant breeding and pathology – were engaged in 'reconstructing' the rice plant in terms of a relatively new paradigm and were trying to evolve associated breeding practices. Object reconstruction imparts a new orientation to one's cognitive endeavors (Miettinen 1998). In the case of rice, the processes that I refer to involved a collective reconstruction of the problem-domain to generate knowledge and propose solutions that were both scientifically feasible and socially acceptable. The main questions that I explored are: How do various disciplinary cultures influence perceptions about the object (that is, rice)? How do they affect the process of construction of the object and suggest possible interventions within the terms of the new paradigm? How do organizational cultures and motivations and anxieties of individual scientists impinge on the inter-disciplinary collaborative efforts of the scientists involved?

3. How the study was conducted

The study included 33 research groups, 30 of which were located in public institutions such as universities, agricultural universities and mission-oriented research organizations supported by the government. Two research groups were drawn from private research foundations: one functioned in the MAHYCO Research Foundation and the other in the SPIC Science Foundation. One research group located in ICGEB (New Delhi) was also included. Out of the 33 groups, 14 were led by molecular biologists and the remaining 19 by applied scientists of whom a majority were plant breeders. Primary data from scientists were collected between 1998 and 1999.

Among the means used for data collection was a questionnaire to elicit information related to employment, organizational affiliation, research experience and research output. Also, I conducted in-depth interviews with individual scientists at their laboratories and participated in seminars, workshops and meetings of NRBN during the study period. In addition, I took part in two meetings of the International Rice Biotechnology Program supported by the Rockefeller Foundation.

Quite often, purely qualitative responses given in the interviews provided rich insights into the perceptions of scientists and the dynamics of the interactions. To repeat, the social process of production of knowledge in rice biotechnology involves collaboration among scientists drawn from molecular biology (basic science) on the one hand and applied sciences like plant breeding and genetics, pathology and entomology on the other. The rice biotechnology research community is in other words a community of specialist communities or, as it were, a hybrid community. Accordingly, the nature and extent of collaboration was influenced by several factors.

4. Basic versus applied research

Before discussing my findings it might be useful to look at the changing conceptions of relations between basic (pure or academic) research and applied (industrial) research and the resulting implications for biological research generally. Given the aim of my study, this becomes especially relevant in the context of the provisions of the World Trade Organization (WTO) on Intellectual Property Rights (IPRs). Traditionally, the relationship between basic science and applied science has been conceptualized in terms of hierarchical relations. Basic research was considered as the act of knowing (*episteme*) and hence superior. Applied research was considered as an act of manipulation (*techne*) and hence inferior. Recent literature suggests that the distinction between basic and applied science is historically constructed in the sense that 'today's basic science will be tomorrow's applied science'. Price (1982) argues that science and technology are parallel structures and the relationship between the two is symbiotic. Ziman (1996) states: "Academic (basic) science has been undergoing a cultural revolution. It is giving way to 'post-academic' science, which may be so different sociologically and philosophically that it will produce a new type of knowledge (p. 752). 'Public knowledge' is being transformed into 'intellectual property'. Basic research networks include many research groups with direct industrial interests. Researchers will not be protected from commercial influences by academic tenure. Their work will often deal with matters where social values – safety, profitability, efficiency – must have highest priority. In general, then, post-academic research is bound to be shot through with social interests" (p. 754).

As a part of the transformation referred to by Ziman, basic research too is getting linked to industrial interests (Buttel 1986, Coffman and Smith 1991) and the hitherto distinct cultures of basic and applied sciences have begun to merge. Indeed, the distinction between science and technology seems to be getting obliterated or at best blurred. The term 'techno-science' (Haraway 1998) captures the interpenetration of science and technology. The Watson and Crick (1953) model is an example of a theory that transcends and cuts across traditional disciplinary boundaries, and molecular biology as a whole is an example of the interpenetration. This interpenetration, or merger, ushered in partly by the corporate sector and more recently by the provisions of the WTO on Trade Related Aspects of Intellectual Property Rights (TRIPs), has begun significantly to influence both basic and applied research (Spillane 2000). Strategic research acquires especial importance in this context.

5. Molecular biology and strategic research

The position of molecular biology in biological research has been elevated as a result of many factors. They include deliberate changes in the reward structure of science which have led to increased private investment, increased pressures for regulation, alteration of the choice of problems and a propensity to patent the product or the process. In short, utilitarian considerations have begun to influence basic research in molecular biology (Markle and Stanley 1985).

By strategic research I mean research aimed at generating knowledge about, and solutions to, current problems of crucial importance. Such research necessarily questions the boundaries between basic science and applied science. Strategic research may be organized in two different ways. The intention can be to achieve either a 'supply-push' model or a 'demand-pull' model of technology. Biotechnology, as it has developed in the recent past under the auspices of private corporate enterprises most of which are multinational or transnational corporations, may be characterized as supply-push technology. What is needed on the other hand is a demand-pull model of technology development, one that basically involves client-driven research and development (Ashby and Sperling 1994). Demand-pull models have in their foreground a diversity of cognitive orientations, material interests and meaning systems of relevant social groups (as conceived by Pinch and Bijker 1984) including end-users. They also include complex interrelationships among the groups involved in designing technologies. Suchman (1998) argues that technology design and use must be seen as a web of social relations in a non-linear mode that facilitates interaction between technology developers and end-users during the course of technology development. This is in contrast to traditional linear models that tend to assume that interests and world-views are shared in common by technology developers and end-users.

The production of knowledge, not so much for its own sake as with the goal of providing utilitarian solutions, calls for a process of learning that involves efforts of researchers from more than one discipline who are willing to learn from each other and from diverse social and cultural groups in society. Knowledge acquired on the basis of interdisciplinary exchange would help in understanding the interconnections between complex problems and evolving solutions (Haberli 1995). The interdisciplinary exchange between molecular biologists and plant breeders can involve sharing of cultural resources – theories and methods – and physical resources like genetic material. One may conceive of a ‘pipe-line’ model of interaction for technology development in which molecular biologists do ‘up-stream’ research and plant breeders and other applied scientists carry out ‘down-stream’ research. The endeavour on the part of researchers with different disciplinary orientations to view phenomena from each other’s perspective as also the perspectives of relevant social groups involves cognitive empathy.

6. Cognitive empathy

Max Weber (1964) advocated empathy or imaginative identification as a methodological tool that would help in understanding meanings attached to social action. The method of imaginative identification, according to Weber, helps in achieving *Verstehen,* a distinctive type of knowledge. The peculiar feature of this understanding of the meanings underlying social action is the way in which actions can be related to one another and to their overall context in terms of logical or conceptual connections (Benton 1977). Science is a paradigm-based social action, the meanings of which are shared by the practitioners of the paradigm.

Cognitive empathy essentially means understanding phenomena from the point of view of the other by one’s imaginative identification with the other or simply by putting oneself in the shoes of the other (Haribabu 1997). This is the first step in transcending one’s disciplinary boundaries. Cognitive empathy can pave the way for viewing phenomena from a mutually shared perspective, construction of the object of research, development of concepts and arriving at a consensus regarding the meanings of concepts, and shared norms of communication and collaboration. These create conditions for the formulation of interrelated research problems and division of labour to execute them in order to generate knowledge and solutions that transcend disciplinary boundaries. Cognitive empathy can facilitate interaction in situations where the individuals involved in the interaction have shared interests but have different disciplinary orientations and approaches.

To what extent do breeders see the rice plant in the same way as molecular biologists do and vice-versa? My findings suggest that perceptions regarding the rice plant as an object and preferred strategies of intervention are strongly influenced by patterns of disciplinary orientation. Further, the culture and mandates of organizations, in addition to individual motivations and anxieties, affect the extent of collaboration between molecular biologists and scientists engaged in rice breeding.

7. Paradigms and perceptions

Webster (1990), in his study of interactions between molecular biologists and plant breeders in Britain, observes that the differences between the two can be expressed in terms of three aspects relating to the boundaries between them: one, the problem of translating the language of molecular biologists into the language of plant breeders; two, conceptions of craft skill; and three, different assessments of their professional roles.

Acquisition of a new paradigm creates conditions for the formation of a scientific community with shared cognitive beliefs and values, shared standards of research and related social and moral norms (Kuhn 1970). The new paradigm also shapes methods, instruments and instrumentation, standards of evaluation of scientific claims, patterns of communication among the practitioners of the paradigm and a meta-theoretical commitment to the paradigm. The scientific community that is committed to the paradigm tries to fit the world into the box-like structure of the paradigm. Thus, molecular biologists tend to prefer a molecular approach to understand life processes. The maintenance and continued development of specialist communities around model organisms such as *Escherichia coli*, *Drosophila melanogaster* and *Arabidopsis thaliana* has reinforced the commitment on the part of those who adhere to the molecular paradigm to look at life processes and their evolution at a molecular level.

The problem of translatability of language is a by-product of what night be termed a process of socialization. The paradigms that guide research in different disciplines or in different sub-disciplines of a given discipline give rise to different scientific cultures, and communication between the cultures demands, but does not necessarily result in, a set of mutually understood symbols. Specifically, in the Indian context, my study shows that differences exist between molecular biologists and plant breeders in their perceptions, world-views and preferred strategies of intervention for rice improvement, in part because of the absence of a shared language.

Molecular biologists see the object of research, that is rice, as a generic plant that can be understood at the molecular level and manipulated genetically, if necessary for utilitarian purposes, in a laboratory setting. Breeders see rice as a crop to be improved via selection in the field; obviously, they are aware of field-specific problems more intimately. The scale of operation and impact of plant breeders is in a certain sense much larger than that of molecular biologists. As one of the plant breeders that I spoke to mentioned: 'Plant breeders have a holistic view of the rice plant as a crop whereas molecular biologists have a narrow view of the rice plant.' Plant breeding is considered both a science and an art. As science it has a theoretical component, artifacts, and the social organization of breeding is a professional activity. As an art it involves the deployment of skills and aesthetic considerations that are gained over time as part of the practice of breeding. Plant breeders also attempt to incorporate environment-specific factors (e.g. climate and ecology) in their research.

As I have said, part of the culture of a paradigm is that social values are attached to professional practices. The value system of molecular biologists assigns a high value to the production of knowledge and its publication in peer-reviewed journals. On the contrary, in the rice breeders' value system the development of a product (i.e. plant variety) rates far higher. The yardstick of excellence in the case of molecular biologists is publications and consequent peer recognition whereas in the case of plant breeders the yardstick is the development of products, i.e. successful plant varieties. The culture of molecular biology tends to be *papyrocentric*, while that of plant breeding, *papyrophobic*, to borrow the terms coined by Price (1982).

It is the utilitarian dimension of plant breeding that is a critical source of the different value-orientation of breeders. In consequence, rice breeders are guided by operating principles that are more inclusive than those that guide rice molecular biologists. What I mean is that while carrying out their work breeders take into account the material interests and systems of meanings of end-users. To some extent plant breeders adopt the role of spokespersons for the relevant end-user groups in different contexts. This is clearly not the case with molecular biologists. Also, my impression is that the interaction between plant breeders and molecular biologists started with an initial perceptual gap regarding what each community could gain from the other, a gap which remains to be bridged fully. One of the scientists engaged in plant breeding told me: 'Plant breeders know the problems but they do not know the techniques. Molecular biologists know the techniques but they do not know the problems'. Another scientist characterized the state of awareness at the initial stages of interaction thus: 'Plant breeders have never seen DNA and molecular biologists have never seen a rice field'. The field view of rice as a crop, held by the breeders, and the laboratory view of rice as a plant, held by molecular biologists, needs to be integrated. One strategy that can be pursued in order to achieve integration is for rice breeders to get familiar with the techniques of molecular biology. (Out of the 19 applied scientists in my study, 15 had acquired some experience with using molecular biology tools in advanced laboratories in the USA and Europe thanks to the support of the Rockefeller Foundation.)

8. Strategies of intervention: Marker-assisted selection versus transgenic approaches

A representation of the rice plant at the molecular level also suggests novel intervention strategies at the molecular level. Breeders, who have traditionally relied on selection based on phenotypes, are now beginning to explore the possibilities of selection based on genotypes. Even so, at present rice breeders and molecular biologists in India appear to have different perceptions regarding the most appropriate strategy for the improvement of rice. The majority of rice breeders advocate marker-assisted selection (MAS) as the appropriate strategy. MAS is based on the intra-species transfer of genetic material and has the possibility of 'gene pyramiding' by accumulating genetic markers for desired multiple traits – higher yield, resistance against diseases, drought resistance, etc. Intra-species transfer of genetic material, as used in MAS-based technology, may not be all that precise, at least not at the level of defining what exactly is being transferred. On the other hand going by the arguments of the rice breeders, MAS may be more acceptable socially, at least in the short-term. I do not wish to imply that molecular biologists do not approve of MAS. But in addition, they strongly advocate genetic engineering methods that might also involve the inter-species transfer of genetic material. According to molecular biologists, a transgenic approach is inherently more precise and more efficient than conventional crossing and selection, and hence superior. One molecular biologist put it thus: 'MAS and transgenic approaches will go in different directions. I think MAS is a useful tool for breeders. You can go wrong with that. MAS is useful in the current scenario. But with transgenics you are dealing with the gene of your interest. In many ways transgenic technology is a superior technology.' However, molecular biologists also seem to have apprehensions regarding transgenic approaches for crop improvement; the inter-species transfer of genetic material is a controversial topic. A small number of molecular biologists saw the problem from a broader perspective and supported MAS. Consider this statement made by one of them: 'Transgenic technology will take a long time. We are not certain whether it works or not. It requires a lot of money and regulatory issues are involved. Further, it is single gene-based. Many traits do not depend on single genes. For improving a crop, transgenic technology has limitations. MAS will improve the input traits of plants. MAS is a better way of improving crops as it is highly complimentary to breeding programs. MAS is a benign technology.'

Though molecular biologists and plant breeders are parts of social groups that belong to different cultures of science, some of them are beginning to see problems from the perspective of the other. Interactions based on cognitive empathy are beginning to occur. A process of negotiation will set in as the result of such interactions and result in the construction of a problem domain, that is, in the formulation of concepts and systems of classification that are intelligible and meaningful to both groups. A prerequisite for further interactions between molecular biologists and rice breeders is that they evolve a consensus on the nomenclature and classification of genes. Mienke and Koorneef (1997), in their study of the Arabidopsis research community, point out that just such a process of negotiation (albeit between rather different groups) can be observed as a consensus is starting to form on the meanings of the relevant concepts, and nomenclature of genes, in the case of *Arabidopsis thaliana*.

9. Transforming esoteric technology into routine technology

An essential component of success in technological innovation is that the technology becomes a routine one. According to rice breeders, molecular biologists think that they have the techniques. The rice breeders have to take them off the shelf, so to speak, and implement them. Molecular biology tools and techniques are sophisticated, involving as they do the use of products, many of which are patented, not to mention state-of-the-art equipment for DNA analysis. They are fairly easy to use in a laboratory setting. But the use of most molecular biology tools and techniques for commercial purposes (e.g. production of a transgenic rice variety) is subject to significant patenting restrictions and/or licensing requirements. What rice breeders want is a set of routine techniques and tools that can be handled with relative ease in different field conditions and at affordable cost. The transition of biotechnology to such a routine phase requires active collaboration between molecular biologists, plant breeders, entomologists, pathologists, and agronomists. Rice breeders believe that MAS is more appropriate at this juncture from the point of view of the feasibility of integrating it with breeding practices, bio-safety restrictions and current social acceptability. While this indicates that further research in this direction has to be promoted, a social cost-benefit analysis needs to be undertaken to establish the relative advantages of MAS vis-à-vis transgenic methods. The differing types of incentives regarding Intellectual Property Rights (IPRs) that plant breeders and molecular biologists are subjected to, point to the likely generation of new tensions and conflicts. Molecular biologists tend to think of the patent system as an unmixed incentive whereas plant breeders are prone to accept the utility of Plant Breeders' Rights (PBR) or Plant Varietal Protection (PVP) rights (Spillane 2000). Breeders' Rights or Varietal Protection Rights, are a set of rights that provide patent-like protection to breeders over plant varieties. One can argue, as perceptive social scientists working within agricultural research systems have argued, that right at the stage of prioritizing research and choosing intervention strategies, farmers should be involved so that their direct experience would provide relevant inputs into rice breeding programs based on molecular biology tools (Farrington 1997; Thro and Spillane 2000).

10. Individual anxieties

In the Indian context, my impression is that the individual scientists that I spoke to experienced a certain degree of anxiety regarding collaborative endeavours. Perhaps the anxieties stem from what one might term the different world-views of molecular biologists and plant breeders, the laboratory view held by molecular biologists contrasting with the field view held by rice breeders. Internalization and endorsement of the conventionally held hierarchical model of relations between science and technology, in terms of 'superiority' and 'subordination', places molecular biology on a higher pedestal relative to rice breeding. 'There is a lot of glamour attached to molecular biology,' as one molecular biologist said. That is, molecular biologists are considered to be stars and rice breeders are their 'fans' and 'followers'. Power relations between molecular biologists and plant breeders are reflected in this imagery. The attitudes that are formed on the basis of the perceptions of power relations (in terms of who is placed on a higher pedestal) affect interactions and collaborations (Lukes 1974). In this kind of a situation cognitive empathy could result in compromise rather than the desired consensus. Further, in the case of a collaboration between two scientists drawn from institutions with different levels of resource endowments and reputations, the scientist from the less well-endowed and less reknowned institution develops an apprehension that his or her collaborator may gain disproportionately out of the collaborative research. Again, these values and the related attitudes have to be altered through a process of negotiation to arrive at a consensus over division of labour and credit sharing. A molecular biologist expressed it thus while speaking about collaboration: ‘We never developed a culture of collaboration. We pursued research in an individualistic manner. But at present if you look at biotechnology and molecular biology publications in the main international journals, papers with at least five authors have become common. Papers with a greater number of authors seem to have greater credibility. Either you work in teams or perish. Slowly a network project culture is emerging.’

All the same, as I see it, the notion that collaborative research will yield greater value-addition and richer dividends in the form of recognition and rewards to individual scientists than the conventional mode of ‘single-unit’ research, has yet to be internalized.

11. Organizational mandates and cultures

Members of the nascent rice biotechnology community in India are located in a variety of organizational settings – public institutions such as universities and mission-oriented organizations, research foundations and companies in the private sector. Organizational mandates and norms affect the inter-disciplinary exchange needed for transcending disciplinary boundaries. In regular universities the general tendency is to emphasize basic research and publications in addition to training, while mission-oriented organizations are mandated to carry out applied research and the development of products. The difference in relative emphases creates anxieties among molecular biologists and breeders. In the absence of a set of mutually accepted norms, the problem can be especially serious in the case of a collaboration between a scientist in a publicly funded institution and one in a privately funded company. The interests of private companies are directed towards the development of patentable products, with delays in research disclosure and accessibility being accepted. This means that problems can arise regarding the publication of scientific results and credit sharing. In my study, thirty-one scientists (a majority) emphasized the importance of public institutions in biotechnology research, as the products developed by public institutions would be economically affordable to many end-users. My feeling is that public institutions are only beginning to gear up to the challenges ahead.

12. Legitimization of knowledge

At the present juncture solutions based on the knowledge generated by molecular biology and biotechnology have become controversial; one senses the existence of a crisis concerning legitimization. The process of legitimization requires a discourse between the private corporate sector, public institutions and civil society consisting of the relevant social groups. These should include the end-users of biotechnology, the farmers, as well as consumers, who are going to experience the impacts of the technology either directly or indirectly (Thro and Spillane 20000). Values related to the concept of context-specific sustainable development should form the overarching framework of the discourse. Understanding the interests of socially relevant groups can facilitate the development of a qualitatively new perspective, construction of new concepts and meanings. That can lead to the production of knowledge that transcends disciplinary boundaries. The demand-pull model implies technology development via the democratic participation of all stakeholders (Ashby and Sperling 1994; Spillane 2000). It is in this context that the perspective of the scientific and technological community has to negotiate with a multiplicity of other perspectives and associated meaning systems of diverse socially relevant groups that have stakes at different levels. At present in India the farming community – to take an important and relevant social group – is highly differentiated in terms of resource-endowment levels. This refers to farm size, (small and marginal farmers with 1 to 5 hectares of land holdings constitute the majority), risk-bearing capacity, and ability to access information and institutional credit facilities. In this context, biotechnology solutions and products should not only be scale-neutral but also resource-neutral. There is a need to develop strategic organizational principles and networks in order to make for rapid development (Alagh 1993). An innovative institutional matrix – a new set of interrelated norms to guide research and development – that involves ‘actor networks’ (Callon 1989) makes this endeavour possible. Flexible networks of actors – the private sector, scientists, farmers, both men and women, civil society organizations and agencies of the state – have to evolve. A detailed discussion on these issues is beyond the scope of this essay.

13. Conclusion

Molecular biologists and rice breeders and other applied scientists in India are engaged in a discourse to evolve a program of strategic inter-disciplinary research designed to produce knowledge and solutions that transcend disciplinary boundaries. Cognitive empathy can facilitate their discourse and subsequent collaborative endeavors. An important finding of my study is that research related to MAS and its application seems to be the most appropriate at the present juncture from the point of view of its integration with breeding practices and current social acceptability. However, it is essential that a social cost-benefit analysis of MAS be undertaken to quantify its advantages. A demand-pull model of the development of biotechnology that incorporates principles of equity and justice, as well as networks of end-user groups in different social and cultural contexts, will have a great degree of legitimization and social acceptability.

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