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The Social Construction of Facts and Artifacts

Trevor J. Pinch and Wiebe E. Bijker

One of the most striking features of the growth of "science studies" in recent years has been the separation of science from technology. Sociological studies of new knowledge in science abound, as do studies of technological innovation, but thus far there has been little attempt to bring such bodies of work together. It may well be the case that science and technology are essentially different and that different approaches to their study are warranted. However, until the attempt to treat them within the same analytical endeavor has been undertaken, we cannot be sure of this.

It is the contention of this chapter that the study of science and the study of technology should, and indeed can, benefit from each other. In particular we argue that the social constructivist view that is prevalent within the sociology of science and also emerging within the sociology of technology provides a useful starting point. We set out the constitutive questions that such a unified social constructivist approach must address analytically and empirically.

This chapter falls into three main sections. In the first part we outline various strands of argumentation and review bodies of literature that we consider to be relevant to our goals. We then discuss the two specific approaches from which our integrated viewpoint has developed: the "Empirical Programme of Relativism" (Collins 1981c) and a social constructivist approach to the study of technology (Bijker et al. 1984). In the third part we bring these two approaches together and give some empirical examples. We conclude by summarizing our provisional findings and by indicating the directions in which we believe the program can most usefully be pursued.

Some Relevant Literature

In this section we draw attention to three bodies of literature in science and technology studies. The three areas discussed are the sociology of science, the science-technology relationship, and technology studies. We take each in turn.

Sociology of Science

It is not our intention to review in any depth developments in this field as a whole. We are concerned here with only the recent emergence of the sociology of scientific knowledge. Studies in this area take the actual content of scientific ideas, theories, and experiments as the subject of analysis. This contrasts with earlier work in the sociology of science, which was concerned with science as an institution and the study of scientists' norms, career patterns, and reward structures. One major – if not the major – development in the field in the last decade has been the extension of the sociology of
knowledge into the arena of the “hard sciences.” The need for such a “strong programme” has been outlined by Bloor: Its central tenets are that, in investigating the causes of beliefs, sociologists should be impartial to the truth or falsity of the beliefs, and that such beliefs should be explained symmetrically (Bloor 1973). In other words, differing explanations should not be sought for what is taken to be a scientific “truth” (for example, the existence of x-rays) and a scientific “falsehood” (for example, the existence of n-rays). Within such a program all knowledge and all knowledge claims are to be treated as being socially constructed; that is, explanations for the genesis, acceptance, and rejection of knowledge claims are sought in the domain of the social world rather than in the natural world. 3

This approach has generated a vigorous program of empirical research, and it is now possible to understand the processes of the construction of scientific knowledge in a variety of locations and contexts. For instance, one group of researchers has concentrated their attention on the study of the laboratory bench. 4 Another has chosen the scientific controversy as the location for their research and have thereby focused on the social construction of scientific knowledge among a wider community of scientists. 5 As well as in hard sciences, such as physics and biology, the approach has been shown to be fruitful in the study of fringe science 6 and in the study of public-science debates, such as lead pollution. 7

Although there are the usual differences of opinion among researchers as to the best place to locate such research (for instance, the laboratory, the controversy, or the scientific paper) and although there are differences as to the most appropriate methodological strategy to pursue, 8 there is widespread agreement that scientific knowledge can be, and indeed has been, shown to be thoroughly socially constituted. Those approaches, which we refer to as “social constructivist,” mark an important new development in the sociology of science. The treatment of scientific knowledge as a social construction implies that there is nothing epistemologically special about the nature of scientific knowledge: It is merely one in a whole series of knowledge cultures (including, for instance, the knowledge systems pertaining to “primitive” tribes) (Barnes 1974; Collins and Pinch 1982). Of course, the successes and failures of certain knowledge cultures still need to be explained, but this is to be seen as a sociological task, not an epistemological one.

The sociology of scientific knowledge promises much for other areas of “science studies.” For example, it has been argued that the new work has relevance for the history of science (Shapin 1982), philosophy of science (Nickles 1982), and science policy (Hale 1982; Collins 1983b). The social constructivist view not only seems to be gaining ground as an important body of work in its own right but also shows every potential of wider application. It is this body of work that forms one of the pillars of our own approach to the study of science and technology.

Science-Technology Relationship

The literature on the relationship between science and technology, unlike that already referred to, is rather heterogeneous and includes contributions from a variety of disciplinary perspectives. We do not claim to present anything other than a partial review, reflecting our own particular interests.

One theme that has been pursued by philosophers is the attempt to separate technology from science on analytical grounds. In doing so, philosophers tend to posit idealized distinctions, such as that science is about the application of truth whereas technology is about the application of facts. Indeed, the literature on the philosophy of technology is rather disappointing (Johnston 1984). We prefer to suspend judgment on it until philosophers propose more realistic models of both science and technology.

Another line of investigation into the nature of the science-technology relationship has been carried out by innovation researchers. They have attempted to investigate empirically the degree to which technological innovation incorporates, or originates from, basic science. A corollary of this approach has been the work of some scholars who have looked for relationships in the other direction; that is, they have argued that pure science is indebted to developments in technology. 10 The results of the empirical investigations of the dependence of technology on science have been rather frustrating. It has been difficult to specify the interdependence. For example, Project Hind-sight, funded by the US Defense Department, found that most technological growth came from mission-oriented projects and engineering R&D, rather than from pure science (Sherwin and Isen-son 1966, 1967). These results were to some extent supported by a later British study (Langrish et al. 1972). On the other hand, Project P. found that most technology stemmed from basic research (Ill Technology, 1968). All these studies criticized for lack of methodology, one must be cautious in drawing conclusions from such work (Kreilkamp and Rosenberg 1979). Most researchers willing to agree that technology is in place in a wide range of circum-stanical epochs and that the import of science to basic science therefore probably. 12 Certainly the view prevalent days” (Barnes 1982a) that science technology applies will no longer hold. Models and generalizations are done. As Layton remarked in 5

Science and technology have a mixed. Modern technology who “do” technology and function as scientists. . T basic sciences generate a which technologists then apply help in understanding cont... (Layton 1977, p. 210)

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Technology Relationship

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Science and technology have become intermixed. Modern technology involves scientists who "do" technology and technologists who function as scientists.... The old view that basic sciences generate all the knowledge which technologists then apply will simply not help in understanding contemporary technology. (Layton 1977, p. 210)

Researchers concerned with measuring the exact interdependence of science and technology seem to have asked the wrong question because they have assumed that science and technology are well-definite monolithic structures. In short, they have not grasped that science and technology are themselves socially produced in a variety of social circumstances (Mayr 1976). It does seem, however, that there is now a move toward a more sociological conception of the science-technology relationship. For instance, Layton writes:

The divisions between science and technology are not between the abstract functions of knowing and doing. Rather they are social. (Layton 1977, p. 209)

Barnes has recently described this change of thinking:

I start with the major reorientation in our thinking about the science-technology relationship which has occurred in recent years.... We recognize science and technology to be on a par with each other. Both sets of practitioners cre-}

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Although Barnes may be overly optimistic in claiming that a "major reorientation" has occurred, it can be seen that a social constructivist view of science and technology fits well with his conception of the science-technology relationship. Scientists and technologists can be regarded as constructing their respective bodies of knowledge and techniques with each drawing on the resources of the other when and where such resources can profitably be exploited. In other words, both science and technology may be socially constructed cultures and bring to bear whatever cultural resources are appropriate for the purposes at hand. In his view the boundary between science and technology is, in particular instances, a matter for social negotiation and represents no underlying distinction. It then makes little sense to treat the science-technology relationship in a general unidirectional way. Although we do not pursue this issue further in this chapter, the social construction of the science-technology relationship is clearly a matter deserving further empirical investigation.

Technology Studies

Our discussion of technology studies work is even more schematic. There is a large amount of writing that falls under the rubric of "technology studies." It is convenient to divide the literature into three parts: innovation studies, history of technology, and sociology of technology. We discuss each in turn.

Most innovation studies have been carried out by economists looking for the conditions for success in innovation. Factors researched include various aspects of the innovating firm (for example, size of R&D effort, management strength, and marketing capability) along with macroeconomic factors pertaining to the economy as a whole.13 This literature is in some ways reminiscent of the early days in the sociology of science, when scientific knowledge was treated like a "black box" (Whitley 1972) and, for the purpose of such studies, scientists might as well have produced meat pies. Similarly, in the economic analysis of technological innovation everything is included that
might be expected to influence innovation, except any discussion of the technology itself. As Layton notes:

What is needed is an understanding of technology from inside, both as a body of knowledge and as a social system. Instead, technology is often treated as a “black box” whose contents and behaviour may be assumed to be common knowledge. (Layton 1977, p. 196)

Only recently have economists started to look into this black box.14 The failure to take into account the content of technological innovations results in the widespread use of simple linear models to describe the process of innovation. The number of developmental steps assumed in these models seems to be rather arbitrary. 15 Although such studies have undoubtedly contributed much to our understanding of the conditions for economic success in technological innovation, because they ignore the technological content they cannot be used as the basis for a social constructivist view of technology.16

This criticism cannot be leveled at the history of technology, where there are many finely crafted studies of the development of particular technologies. However, for the purposes of a sociology of technology, this work presents two kinds of problem. The first is that descriptive historiography is endemic in this field. Few scholars (but there are some notable exceptions) seem concerned with generalizing beyond historical instances, and it is difficult to discern any overall patterns on which to build a theory of technology (Staudenmaier 1983, 1985). This is not to say that such studies might not be useful building blocks for a social constructivist view of technology — merely that these historians have not yet demonstrated that they are doing sociology of knowledge in a different guise.17

The second problem concerns the asymmetric focus of the analysis. For example, it has been claimed that in twenty-five volumes of Technology and Culture only nine articles were devoted to the study of failed technological innovations (Staudenmaier 1985). This contributes to the implicit adoption of a linear structure of technological development, which suggests that

the whole history of technological development had followed an orderly or rational path, as though today’s world was the precise goal toward which all decisions, made since the beginnging of history, were consciously directed. (Ferguson 1974, p. 19)

This preference for successful innovations seems to lead scholars to assume that the success of an artifact is an explanation of its subsequent development. Historians of technology often seem content to rely on the manifest success of the artifact as evidence that there is no further explanatory work to be done. For example, many histories of synthetic plastics start by describing the “technically sweet” characteristics of Bakelite; these features are then used implicitly to position Bakelite at the starting point of the glorious development of the field:

God said: “let Bakeland be” and all was plastic! (Kaufman 1963, p. 61)

However, a more detailed study of the developments of plastic and varnish chemistry, following the publication of the Bakelite process in 1909 (Bakeland 1909a, b), shows that Bakelite was at first hardly recognized as the marvelous synthetic resin that it later proved to be.18 And this situation did not change much for some ten years. During the First World War the market prospects for synthetic plastics actually grew worse. However, the dumping of war supplies of phenol (used in the manufacture of Bakelite) in 1918 changed all this (Haynes 1954, pp. 137-138) and made it possible to keep the price sufficiently low to compete with (semi-) natural resins, such as celluloid.19 One can speculate over whether Bakelite would have acquired its prominence if it had not profited from that phenol dumping. In any case it is clear that a historical account founded on the retrospective success of the artifact leaves much untold.

Given our intention of building a sociology of technology that treats technological knowledge in the same symmetric, impartial manner that scientific facts are treated within the sociology of scientific knowledge, it would seem that much of the historical material does not go far enough. The success of an artifact is precisely what needs to be explained. For a sociological theory of technology it should be the explanandum, not the explanans.

Our account would not be complete, however, without mentioning some recent developments, especially in the American history of technology. These show the emergence of a growing number of theoretical themes on which research is focused (Staudenmaier 1985; Hughes 1979). For example, the systems approach to technological development of the effect of labor relations on the technological environment,21 and despite some not-so-successful inventions or departures from the “old” histories,22 such work promises to be valuable in the analysis of technology, and we return to it later.

The final body of work we need to discuss in what might be described as “sociology,”23 There have been some recent years to launch such a sociological study of the technology and sociological studies by, for example, Johnston (1982), who advocate the description of technology in terms of change.24 Such approaches certainly offer more promise than standard sociological study, but it is still not clear what authors share our understanding of technology as social constructs. For example, Johnston considers ex nihilo a symmetric sociological explanation of successful and failed artifacts in the way. Indeed, by locating their level of technological paradigm, how the artifacts themselves are seen as neither author has yet produced a sociological study of science, where it is possible to give Kuhn’s terms a reference.

The possibilities of a more structivist view of technology on by Mulkay (1979a). He argues that the many and efficacy of technology could be a problem for the social constructivist. The argument counter that the practical explanation somehow demonstrates the sociology of science and the sociological explanation. Mulkay rightly in our opinion, by point of the “science discovers, in and a notion that implicit in such a claim against this position, Mul-

Mario Bunge (1966) that it is partly false theory to be used: it is essential practical application, technology would not then he about the “truth” of the scien
successful innovations seems same that the success of action of its subsequent development technology often seem connotative of the artifact as no further explanatory work ample, many histories of synteny referring to describing the "technically satisfactory" life of Bakelite; these features tly to position Bakelite at the glorious development of the

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tailed study of the development- docking chemistry, following the Bakelite process in 1909, shows that Bakelite was at the same time as the marvelously successful...ed to be. And this situation continues for some ten years. During this time, the market prospects for Bakelite initially grew worse. However, the pioneers in the field of chemistry in 1918 changed all this (fig. 1-14) and made it possible to compete with...such as celluloid. One can see Bakelite would have acted if it had not profited from it. In any case, it is clear that a...und of building a sociology of technological knowledge in the sense that the sociology of science is situated comprises a growing number of research projects. For example,

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which it was based. We find this second point not entirely satisfactory. We would rather stress that the truth or falsity of scientific knowledge is irrelevant to sociological analysis of belief. To retreat to the argument that science may be wrong but good technology can still be based on it is missing this point. Furthermore, the success of technology is still left unexplained within such an argument. The only effective way to deal with these difficulties is to adopt a perspective that attempts to show that technology, as well as science, can be understood as a social construct.

Mulkay seems to be reluctant to take this step because, as he points out, "there are very few studies...which consider how the technical meaning of hard technology is socially constructed" (Mulkay 1979a, p. 77). This situation however, is starting to change: A number of such studies have recently emerged. For example, Michel Callon, in a pioneering study, has shown the effectiveness of focusing on technological controversies. He draws on an extensive case study of the electric vehicle in France (1960-75) to demonstrate that almost everything is negotiable: what is certain and what is not; who is a scientist and who is a technologist; what is technological and what is social; and who can participate in the controversy (Callon 1980a, b, 1981, and Bijker et al. 1985). David Noble's study of the introduction of numerically controlled machine tools can also be regarded as an important contribution to a social constructivist view of technology (Noble 1984). Noble's explanatory goals come from a rather different (Marxist) tradition, and his study has much to recommend it. He considers the development of both a successful and a failed technology and gives a symmetrical account of both developments. Another intriguing study in this tradition is Lazonick's account (1979) of the introduction of the self-acting loom: He shows that aspects of this technical development can be understood in terms of the relations of production rather than any inner logic of technological development. The work undertaken by Bijker, Böök, and Van Oost is another attempt to show how the socially constructed character of the content of some technological artifacts might be approached empirically: Six case studies were carried out, using historical sources.

In summary, then, we can say that the predominant readings are innovation studies and the history of technology -- do not yet provide much encouragement for our program. There are exceptions, however, and some recent
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studies in the sociology of technology present promising starts on which a unified approach could be built. We now give a more extensive account of how these ideas may be synthesized.

EPOR and SCOT

In this part we outline in more detail the concepts and methods that we wish to employ. We start by describing the “Empirical Programme of Relativism” as it was developed in the sociology of scientific knowledge. We then go on to discuss in more detail the approach taken by Bijker and his collaborators in the sociology of technology.

The Empirical Programme of Relativism (EPOR)

The EPOR is an approach that has produced several studies demonstrating the social construction of scientific knowledge in the “hard” sciences. This tradition of research has emerged from recent sociology of scientific knowledge. Its main characteristics, which distinguish it from other approaches in the same area, are the focus on the empirical study of contemporary scientific developments and the study, in particular, of scientific controversies.28

Three stages in the explanatory aims of the EPOR can be identified. In the first stage the interpretative flexibility of scientific findings is displayed; in other words, it is shown that scientific findings are open to more than one interpretation. This shifts the focus for the explanation of scientific developments from the natural world to the social world. Although this interpretative flexibility can be recovered in certain circumstances, it remains the case that such flexibility soon disappears in science; that is, a scientific consensus as to what the “truth” is in any particular instance usually emerges. Social mechanisms that limit interpretative flexibility and thus allow scientific controversies to be terminated are described in the second stage. A third stage, which has not yet been carried through in any study of contemporary science, is to relate such “closure mechanisms” to the wider social-cultural milieu. If all three stages were to be addressed in a single study, as Collins writes, “the impact of society on knowledge produced at the laboratory bench would then have been followed through in the hardest possible case” (Collins 1981c, p. 7).

The EPOR represents a continuing effort by sociologists to understand the content of the natural sciences in terms of social construction. Various parts of the program are better researched than others. The third stage of the program has not yet even been addressed, but there are many excellent studies exploring the first stage. Most current research is aimed at elucidating the closure mechanisms whereby consensus emerges (the second stage). Many studies within the EPOR have been most fruitfully located in the area of scientific controversy. Controversies offer a methodological advantage in the comparative case with which they reveal the interpretative flexibility of scientific results. Interviews conducted with scientists engaged in a controversy usually reveal strong and differing opinions over scientific findings. As such flexibility soon vanishes from science, it is difficult to recover from the textual sources with which historians usually work. Collins has highlighted the importance of the “controversy group” in science by his use of the term “core set” (Collins 1981b). These are the scientists most intimately involved in a controversial research topic. Because the core set is defined in relation to knowledge production in science (the core set constructs scientific knowledge), some of the empirical problems encountered in the identification of groups in science by purely sociometric means can be overcome. And studying the core set has another methodological advantage, in that the resulting consensus can be monitored. In other words, the group of scientists who experiment and theorize at the research frontiers and who become embroiled in scientific controversy will also reflect the growing consensus as to the outcome of that controversy. The same group of core set scientists can then be studied in both the first and second stages of the EPOR. For the purposes of the third stage, the notion of a core set may be too limited.

The Social Construction of Technology (SCOT)

Before outlining some of the concepts found to be fruitful by Bijker and his collaborators in their studies in the sociology of technology, we should point out an imbalance between the two approaches (EPOR and SCOT) we are considering. The EPOR is part of a flourishing tradition in the sociology of scientific knowledge: It is a well-established program supported by much empirical research. In contrast, the sociology of technology is an embryonic field with no well-established programs of research, and the approach specifically (SCOT) is only in its early stages, although clearly gaining momentum.

In SCOT the development of technological artifact is described as variation and selection.”30 This “multidirectional” model, in contrast to previous models used explicitly in many cases and implicitly in much history, is a multidirectional model of technological development. This model offers an account of technical development which is not limited to the “successful” stages but also includes the less well-perceived ones. This multidirectional model offers an account of technical development which is not limited to the “successful” stages but also includes the less well-perceived ones.

The wider context

Finally, we come to the third program. The task here is to understand how the process of developing the artifact is related to the social and cultural milieu in which it is embedded. The sociological approach here is to see the development of technology as part of a larger social and cultural context. This approach is based on the idea that the development of technology is not an isolated process but is inseparable from the social and cultural context in which it takes place.

Conclusion

In this chapter we have been outlining an integrated social theory to the empirical study of science. We reviewed several relevant theories and streams of argument about social constructivist approaches within the sociology shows every promise of
resists a continuing effort to understand the content of the nature of social construction. Various programs are better researched than others, but there are many excellent first stages. Most recent re-creating the closure mechanisms that the second within the EPOR have been used in the area of scientific versus offer a methodological partitive ease with which they provide flexibility of scientific conducted with scientists who usually reveal strong and former scientific findings. As such, science is difficult: textual sources with which work. Collins has highlighted the "consensus group" in the term "core set" (Collins). The sociologist has most intimately and research topic. Because viewpoint in relation to knowledge (the core set constructs science of the empirical problem) differentiation of groups in scientific means can be overlooked in this set has another stage, in that the resulting situation will. In other words, the experiment and theorize at: and who become embroiled in the outcome of that core set of core set scientists can th in the first and second stages purposes of the third stage, may be too limited.

The wider context

Finally, we come to the third stage of our research program. The task here in the area of technology would seem to be the same as for science – to relate the content of a technological artifact to the wider sociopolitical milieu. This aspect has not yet been demonstrated for the science case, at least not in contemporaneous sociological studies. However, the SCOT method of describing technological artifacts by focusing on the meanings given to them by relevant social groups seems to suggest a way forward. Obviously, the sociocultural and political situation of a social group shapes its norms and values, which in turn influence the meaning given to an artifact. Because we have shown how different meanings can constitute different lines of development, SCOT's descriptive model seems to offer an operationalization of the relationship between the wider milieu and the actual content of technology. To follow this line of analysis, see Bijker 1985.

Conclusion

In this chapter we have been concerned with outlining an integrated social constructivist approach to the empirical study of science and technology. We reviewed several relevant bodies of literature and strands of argument. We indicated that the social constructivist approach is a flourishing tradition within the sociology of science and that it shows every promise of wider application. We reviewed the literature on the science-technology relationship and showed that here, too, the social constructivist approach is starting to bear fruit. And we reviewed some of the main traditions in technology studies. We argued that innovation studies and much of the history of technology are unsuitable for our sociological purposes. We discussed some recent work in the sociology of technology and noted encouraging signs that a new wave of social constructivist case studies is beginning to emerge.

We then outlined in more detail the two approaches – one in the sociology of science knowledge (EPOR) and one in the field of sociology of technology (SCOT) – on which we base our integrated perspective. Finally, we indicated the similarity of the explanatory goals of the two approaches and illustrated these goals with some examples drawn from technology. In particular, we have seen that the concepts of interpretative flexibility and closure mechanism and the notion of social group can be given empirical reference in the social study of technology.

As we have noted throughout this chapter, the sociology of technology is still underdeveloped, in comparison with the sociology of scientific knowledge. It would be a shame if the advances made in the latter field could not be used to throw light on the study of technology. On the other hand, in our studies of technology it appeared to be fruitful to include several social groups in the analysis, and there are some indications that this method may also bear fruit in studies of science. Thus our integrated approach to the social study of science and technology indicates how the sociology of science and the sociology of technology might benefit each other.

But there is another reason, and perhaps an even more important one, to argue for such an integrated approach. And this brings us to a question that some readers might have expected to be dealt with in the first paragraphs of this chapter, namely, the question of how to distinguish science from technology. We think that it is rather unfruitful to make such an a priori distinction. Instead, it seems worthwhile to start with commonsense notions of science and technology and to study them in an integrated way, as we have proposed. Whatever interesting differences may exist will gain contrast within such a program. This would constitute another concrete result of the integrated study of the social construction of facts and artifacts.
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Notes

This chapter is a shortened and updated version of Pinch and Bijker (1984).

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1 The science technology divorce seems to have resulted not so much from the lack of overall analytical goals within "science studies" but more from the contingent demands of carrying out empirical work in these areas. To give an example, the new sociology of scientific knowledge, which attempts to take into account the actual content of scientific knowledge, can best be carried out by researchers who have some training in the science they study, or at least by those who are familiar with an extensive body of technical literature (indeed, many researchers are ex-external scientists). Having gained such expertise, the researchers tend to stay within the domain where their expertise can best be deployed. Similarly, R&D studies and innovation studies, in which the analysis centers on the firm and the marketplace, have tended to demand the specialized competence of economists. Such disparate bodies of work do not easily lead to a more integrated conception of science and technology. One notable exception is Ravetz (1971). This is one of the few works of recent science studies in which both science and technology and their differences are explored within a common framework.

2 A comprehensive review can be found in Mulkay and Mitié (1980).

3 For a recent review of the sociology of scientific knowledge, see Collins (1983c).

4 For a discussion of the earlier work (largely associated with Robert Merton and his students), see Whitley (1972).

5 For more discussion, see Barnes (1974), Mulkay (1979c), Collins (1983c), and Barnes and Edge (1982). The origins of this approach can be found in Fleck (1935).

6 See, for example, Latour and Woolgar (1979), Knorr-Cetina (1981), Lynch (1985), and Woolgar (1982).

7 See, for example, Collins (1975), Wynne (1976), Pinch (1977, 1986), Pickerling (1984), and the studies by Pickinger, Harvey, Collins, Travis, and Pinch in Collins (1981a).

8 Collins and Pinch (1979, 1982).

9 Robbins and Johnston (1976). For a similar analysis of public science controversies, see Gillespie et al. (1979) and McCrea and Markle (1984).

10 Some of the most recent debates can be found in Knorr-Cetina and Mulkay (1983).

11 The locus classicus is the study by Hessen (1931).

12 See, for example, de Solla Price (1965), Jevons (1976), and Mayr (1976).

13 See, for example, Schumpeter (1928, 1942), Schoneder (1966, 1972), Freeman (1974, 1977), and Schole (1977).

14 See, for example, Rosenberg (1982), Nelson and Winter (1977, 1982), and Dosi (1982, 1984). A study that preceded these is Rosenberg and Vincenti (1978).

15 Adapted from Uhlanh (1978). p. 45.

16 For another critique of these linear models, see Kline (1985).

17 Shapin writes that "a proper perspective of the uses of science might reveal that sociology of knowledge and history of technology have more in common than is usually thought" (1980, p. 120). Although we are sympathetic to Shapin's argument, we think the time is now ripe for asking more searching questions of historical studies.

18 Manuals describing resinous materials do mention Bakelite but not with the amount of attention that, retrospectively, we would think to be justified. Professor Max Bottler, for example, devotes only one page to Bakelite in his 228-page book on resins and the resin industry (Bottler 1924). Even when Bottler concentrates in another book on the synthetic resinous materials, Bakelite does not receive an indisputable "first place." Only half of the book is devoted to phenol/formaldehyde condensation products, and roughly half of that part is devoted to Bakelite (Bottler 1919). See also Mathis (1920).

19 For an account of other aspects of Bakelite's success, see Bijker et al. (1985).

20 See, for example, Constant (1980), Hughes (1983), and Hanthes (1973).

21 See, for example, Noble (1979), Smith (1977), and Lazonick (1979).

22 See, for example, Vincenzi (1986).

23 There is an American tradition in the sociology of technology. See, for example, Gillian (1935), Ogburn (1945), Ogturn and Meyers Niémoff (1955), and Westrum (1983). A fairly comprehensive view of the present state of the art in German sociology of technology can be obtained from Jochik (1982). Several studies in the sociology of technology that attempt to break with the traditional approach can be found in Krohn et al. (1978).

24 Dosi uses the concept of technological trajectory, developed by Nelson and Winter (1977); see also Van den Belt and Rip (Bijker et al. 1985). Other approaches to technology based on Kuhn's idea of the community structure by Bijker et al. (1985). Shapin and Schaffer (1985) and the collection.

25 One is reminded of the finiteness of the sociology of science's "paradigm" concept. Kuhn's "paradigm" concept is employed by sociologists of science. Indeed there were some who thought that society was a science, such as preparedacticism, it soon became apparent that Kuhn's terms were too broad to warrant such an implication. One conclusion is that the idea of a paradigmatic approach to science is an important one - not only is it useful for understanding the nature of science, but it is also a useful tool for understanding the nature of society. It is important to note that the idea of a paradigmatic approach to science is not new. Many sociologists of science have used the concept in various ways, and it is important to be aware of the different approaches to the concept.

For a valuable review of the literature on paradigms and the sociology of science, see MacKenzie (1984).

For a provisional report of (1984). The five artifacts that were identified are: fluorescent lighting, the loom, and the transistor. S

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the community structure of science are mentioned by Bijker et al. (1985). See also Constant (Bijker et al. 1985) and the collection edited by Laudan (1984).

One is reminded of the first flush of Kuhnian studies in the sociology of science. It was hoped that Kuhn’s “paradigm” concept might be straightforwardly employed by sociologists in their studies of science. Indeed there were a number of studies in which attempts were made to identify phases in science, such as paradigmatic, normal, and revolutionary. It soon became apparent, however, that Kuhn’s terms were loosely formulated, could be subject to a variety of interpretations, and did not lend themselves to operationalization in any straightforward manner. See, for example, the inconclusive discussion over whether a Kuhnian analysis applies to psychology in Palermo (1973). A notable exception is Barnes’s contribution to the discussion of Kuhn’s work (Barnes 1982b).

26 For a valuable review of Marxist work in this area, see MacKenzie (1984).

27 For a provisional report of this study, see Bijker et al. (1984). The five artifacts that are studied are Bakelite, fluorescent lighting, the safety bicycle, the Sulzer loom, and the transistor. See also Bijker et al. (1985).

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