Challenging incommensurability – What we can learn from Ludwik Fleck for the analysis of complex technical systems

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ISU Working Paper #08.21
Abstract:
This paper explores the work of Ludwik Fleck and its applicability for the analysis of innovation in complex technical systems. The objectives of the paper are twofold. First, it strives to bring Ludwik Fleck back on the map of technology analysis. For this purpose, it develops a Fleckian perspective on technological change and innovation that augments the well-known concept of technological paradigms with insights about thought styles and collectives. Secondly, the paper shows that this perspective provides important cues to understand the interactions of different industrial sectors in innovation – a common yet under-researched occurrence in innovation of complex technical systems.

[Presented at the 4S/EASST Joint Conference “Acting with Science and Technology”, Rotterdam August 2008]
1. Introduction

The rising importance of Information and Communication Technologies (ICTs) has been a topic for years, and it has led to profound changes in the organization of innovation (Freeman and Louça, 2001). In particular, complex technical systems have been identified as a peculiar new form of technology, where a component and an architectural level of knowledge can be distinguished (Henderson and Clark, 1990; Prencipe et al., 2003). As yet, however, innovation of complex technical systems is not sufficiently understood, especially in terms of related changes in the organization and dynamics of industrial structures (Mummann and Frenken, 2006; Prencipe, 2003). In this context, technological fields such as Augmented or Virtual Reality Technologies, Telecare and Smart Homes are striking examples, where long standing high expectations have not yet been converted into stabilized patterns of exploitation.

This paper builds on these insights and takes a closer look at the consequences of (the pervasiveness) of ICTs for the organization and dynamics of industrial sectors. In particular, innovation processes have become common place that span distinct industries and R&D trajectories. As a consequence, new forms of coordination and collaboration of distributed innovation are becoming necessary, where the incommensurability of technological paradigms, in a strictly Kuhnian sense, marks a salient challenge for innovation (Peine, 2008a). The present paper elaborates upon the idea of inter-industry collaboration in innovation processes of complex technical systems. It demonstrates that incommensurability indeed poses a challenge rather than a definite obstacle to innovation. This phenomenon, however, is hitherto not sufficiently understood. The paper then explores the work of Ludwik Fleck on thought styles and collectives (Fleck, 1979) and its applicability to the analysis of technological change.

The objectives of this paper are thus twofold. First, it strives to bring Ludwik Fleck back on the map of technology analysis. While the work of Thomas Kuhn on scientific paradigms has had a remarkable influence in the literature on innovation and technological change (see Peine, 2006 for a review), the work of Fleck, which has anticipated many ideas of Kuhn, has widely been neglected in the innovation literature. The first and primary aim of this paper is thus conceptual in nature – a controlled attempt to analyze the value of Fleckian ideas for the analysis of technological change against the background of what we have learned from Kuhn.

Secondly, the paper links the benefits of a Fleckian perspective to innovation of complex technical systems, where different technological paradigms jointly shape innovation. I shall demonstrate that Fleck’s perspective offers a number of cues for a sound sociological analysis of the interaction between different industrial sectors, something that is hitherto only insufficiently addressed in the literature on industrial change and innovation. In this

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1 Of course, Fleck’s work has received wide attention in the sociology and philosophy of science, but with regard to technological change and innovation Fleckian ideas have not received detailed attention. Remarkable exceptions are Bijker, whose ideas of technological frames and inclusion borrow from Fleck in passing (Bijker, 1987: 186n4) and Tuomi (2002), who has provided an analysis of thought collectives as a socio-cognitive space of innovation.
sense, Fleck’s classic ideas seem to link up much better with recent phenomena in technological change and innovation than the notion of technological paradigms.

This paper is organized as follows. In Section 2, a brief introduction is provided to complex technical systems. An important question is identified – that of inter-industry collaboration in technological fields. Section 3 starts with a brief summary of Kuhnian ideas of scientific progress 3.1). It then explores the Fleckian prototype in terms of analogies and differences with the Kuhnian conception (3.2). It then identifies a number of advantages of a Fleckian perspective on innovation (3.3) Section 4, finally, argues that these advantages are particularly important for the analysis of complex technical systems because it provides a number of cues that are especially well-suited to capture simultaneous changes in the knowledge bases of distinct industries.

2. Complex technical systems – A brief overview

In a seminal paper, Henderson and Clark (1990) introduced the notion of architectural innovation. Concerned with the competitive consequences of technological change, they analyzed products as sets of components and distinguished between two levels of analysis: the components themselves and the links between them. They found that only small changes in the way components are integrated in a product architecture can have major consequences on industry competition. Accordingly, the distinction between incremental and radical innovation was incomplete and had to be extended by a dimension of architectural innovation. An architectural innovation leaves the core design concepts of the components unchanged but alters the way in which the components are linked.

Henderson and Clark’s work has pointed to an increasingly important phenomenon – the rising relevance of complex technical systems, where different components operate together to constitute an end-product. Such complex technical systems have been described as hierarchies of subsystems and components that are typically embedded in nested hierarchies of design spaces that correspond to simple industries (Baldwin and Clark, 2006; Murmann and Frenken, 2006). In this connection, a key conceptual distinction has been established between the component level of a system and the architectural level, which are respectively represented by interrelated yet distinct bodies of knowledge. A prolific body of studies has explored the modular nature of technical system (for overviews see Ernst, 2005; Peine, 2008b), where a fixed architectural structure enables flexibility at the component level. Moreover, the coordination of the integration of technical systems has been identified as a key challenge for the management and organization of innovation, which is a particularly sophisticated matter when technical system’s span distinct knowledge bases and industries. In such latter cases, diachronic systems integration, i.e. the coordination of simultaneous changes in different knowledge bases over time, still is a poorly understood issue (Prencipe, 2003).

Two important insights from the technical system’s literature are relevant for this paper. First, complex technical systems are technologies sufficiently compound to distinguish between two kinds of knowledge – component knowledge and architectural knowledge.
Understanding the dynamics of systems, therefore, makes it necessary to take into account two levels of dynamism: changes in component knowledge and changes in architectural knowledge. The majority of the literature has investigated modular innovation, i.e. innovation guided by relatively stable product architectures, while only a few studies have looked closer into the configurational nature of technical systems, where architectural knowledge is the level of change, i.e. knowledge accrues with regard to how to arrange a given set of components into a system (Fleck, 1993; 1994).

Secondly, the rising relevance of technical systems is a consequence of the increasing pervasiveness of Information and Communication Technologies (ICT) (Freeman and Louça, 2001). And this has led to an increased relevance of configurational systems, in particular, where ICT enable the interoperability of previously independent components in systems, such as Smart Home (Peine, 2008b) or Virtual Realities Technologies (Rolwagen, 2008). Innovation processes of such systems are typically distributed across different knowledge bases, design spaces, and R&D trajectories and thus frequently span different industries (Peine, 2008a). This phenomenon implies important consequences for the organization of innovation, and this paper explores conceptually one of these consequences – the coordination of changes in the knowledge bases and R&D trajectories of different industries that are linked through the emerging interoperability of “their” products. In the remainder of this paper, I discuss the writings of Ludwik Fleck in terms of their applicability to this issue.

3. Towards a Fleckian understanding of technological change

This section makes a conceptual attempt and explores the usefulness of an early analyst of knowledge production – Ludwik Fleck and his ideas of thought styles and thought collectives. It compares Fleck’s work with the work of Thomas Kuhn, who frequently cited Fleck as an influence of his own ideas and whose idea of scientific paradigms has been an important prototype for modelling technological knowledge production. I start with a short overview of Kuhn’s main propositions (3.1), and shall demonstrate that Fleck’s original conception was more sophisticated on a number of aspects (3.2). Finally, I show that these aspects constitute the basis of a Fleckian understanding of innovation, that seems to be better suited to understand recent changes in the organization of contemporary innovation (3.3).

3.1. Thomas Kuhn on scientific paradigms

Thomas Kuhn’s seminal work The Structure of Scientific Revolutions (hereafter: SSR) was published in 1962. In this work, Kuhn has outlined an understanding of science that starkly differed from the logical positivism of the Vienna Circle and from the Critical Rationalism of Karl Popper. For Kuhn, science is not merely a matter of cumulativeness but rather proceeds in phases of cumulative progress (normal science) and radical shifts (scientific revolutions). The very nature of normal science – and thereby the very nature of most scientific activities –

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2 In what follows I am referring to the 2nd edition of the SSR that includes a postscript (Kuhn, 1970).
is articulation, not replication or falsification: Scientists attempt to further articulate the propositions accepted in their field of study to achieve a larger number of solved problems and a greater accuracy of prediction. Normal science is a process of puzzle-solving ("mopping-up") and elaborates expected solutions to accepted problems in a particular field of study. The accepted problems and the expected solutions to these problems are – by and large – fixed in what Kuhn calls a *paradigm* that is shared within a scientific community. Normal science as conceptualized by Kuhn does not produce much novelty. Only in rare instances can facts discovered not be brought into accordance with a predominant paradigm. Occasionally, such instances may lead to a paradigm shift, for which Kuhn has coined the term *scientific revolution*. After a revolution has occurred, a different paradigm is accepted within the community; the *gestalt* by which scientists of this community perceive their field of study has changed. Kuhn’s interpretation of scientific progress includes four central propositions:

(I) Knowledge production within scientific disciplines is *fundamentally distinct* from other forms of knowledge production due to the existence of a paradigm. Indeed, Kuhn distinguishes between pre-paradigmatic science and paradigmatic science (cf. Chapter 2 in SSR). Pre-paradigmatic science proceeds in a non-cumulative way, the directions of problem solving are generally random, and virtually everything that belongs to a field of study seems relevant. However, from this more or less chaotic process of random and unselective search, such achievements or theories may occasionally emerge that are, within a certain community of scholars, accepted as a common ground for further investigation. Once a paradigm has emerged, knowledge production is not the same anymore. Those that adhere to the paradigm do not, in every step they take, have to rebuild the foundations of their field of study.

(II) Paradigm bound progress is described by Kuhn as *normal progress* (cf. Chapter 3 in SSR). Normal scientific progress elaborates upon those phenomena and theories that are already known. In this connection, Kuhn describes the essence of normal progress as "mopping-up activities" – expected solutions are developed to those problems that are already accepted as such. In this sense, normal progress allows for a directed, selective and in-depth exploration of a scientific field that would not be possible without the guidance of a paradigm. Indeed, Kuhn has maintained that normal science does not aim at producing the unexpected, but rather thrives on a fascination for puzzle-solving (SSR: 36). And this exactly is the strength of normal science – the existence of a paradigm allows scientists to concentrate on a well selected set of problems and their respective solutions. In a previously chaotic stream of observations, a *gestalt* emerges that distinguishes between relevant and irrelevant aspects.

Kuhn’s original book was criticized for its plurivalent and fuzzy definition of the term paradigm itself. In the postscript to SSR’s 2nd Edition, Kuhn responds to this criticism by distinguishing between two general ways in which he uses the notion of paradigms: first, a paradigm marks a constellation of group commitments (rules and theories, norms and values). Secondly, however, a paradigm is an exemplary and concrete solution accepted
within a community of specialists that sketches out a pattern for problem solving. For Kuhn it was this second definition that constituted the true innovation of his work (SSR: 187). First of all, paradigms are exemplars; these exemplars, in turn, embody tacit norms and rules that give rise to a cognitive system. Therefore, concrete objects – artifacts, so to speak – outline the principles that guide “normal” science. This interplay of concrete problem solutions and group commitments is at the center of a scientific paradigm and thus also of normal science.

As a consequence, paradigms can neither be explicated in any set of rules, nor are they uniformly interpreted within a scientific discipline. Rather, paradigms exist prior to any set of rules or theories. Kuhn has referred to this as the priority of paradigms: “Paradigms may be prior to, more binding, and more complete than any set of rules for research that could be unequivocally abstracted from them.” (SSR: 46) A paradigm can thus only be acquired through experience with reproducing exemplary solutions, i.e. it cannot be acquired by the study of books, rules and theories alone. Education into a paradigm is a process in which mild force is exerted on the apprentice to ensure that he obtains the right kind of experience.

(III) Kuhn distinguishes between two forms of change – normal progress and paradigm shifts. In times of normal progress, the paradigm itself remains unaltered as a framework, while the knowledge produced according to that framework accumulates. Only after times of crises, when solutions discovered within a discipline do not fit with the expectations of a paradigm, existing paradigms may occasionally be overturned by new ones. A scientific revolution has occurred and the gestalt through which a scientific discipline orders its field of study has shifted.3 Kuhn’s conception of scientific progress thus implies a distinction between paradigms and knowledge accumulated according to a paradigm. In times of normal progress the gestalt prescribed by a paradigm remains (widely) unaltered; only in times of a crisis, the foundations of a paradigm are called into question and may occasionally change. For Kuhn, scientific progress is essentially punctuated in nature, where phases of cumulative, normal change are punctuated with radical shifts.

(IV) A fourth aspect concerns the nature of the community that shares a paradigm. Kuhn never worked out this important sociological implication of his work but rather confined himself to the following, generic heuristic remarks about the nature of scientific communities (SSR: 176-181). First, communities are identifiable prior to the analysis of the paradigm they share. This underlines Kuhn’s belief that communities can rather easily be identified with the methods of social science research. Secondly, scientific communities are groups of specialists in a certain field of scientific study that share identical professional initiation; members of a scientific community refer to the same body of standard literature that delineates a particular subject matter. Thirdly, members of scientific communities generate and verify scientific knowledge. They are knowledge creating communities that base knowledge creation on a particular paradigm. Kuhn presented these remarks to sketch out an agenda that would identify scientific communities. He did not, however, actually

3 As the title suggests, Kuhn dedicates more than half of his book to an exploration of scientific revolutions. And indeed, this idea has caused much of the popularity of Kuhnian ideas (cf. Fuller, 2003). However, scientific revolutions also rank among the most problematic aspects of his work as they impose a rigid scheme on the history of science and scientific disciplines as a whole. In this paper, I do not focus on scientific revolutions in greater detail. I have provided a more profound discussion of this issue elsewhere (Peine, 2006: 51-56).
develop such an agenda (SSR: 178), and indeed the social structure of scientific communities has remained a poorly developed aspect of his work.

3.2. **Ludwik Fleck on thought styles and collectives**

In the preface to SSR, Kuhn mentions an early influence that “anticipates many of my own ideas” (SSR: ix): Ludwik Fleck’s work on the *Genesis and Development of a Scientific Fact* (Fleck, 1979, German original from 1935, henceforth: GDSF) – by now a classic reading in the Study of Science and Technology, but at the time when Kuhn wrote his monograph an almost unknown piece of work. In this book, Fleck fleshes out the basis for a sociological understanding of scientific progress that is in many ways similar to that of Kuhn. For Fleck, the key idea is that cognition not only involves the individual and the objective reality, but also a body of knowledge shared between a particular group of individuals. This body of shared knowledge mediates every instance of cognition and thus makes knowledge production an essentially social process. Hence, it is the thought collective, a group of individuals exchanging ideas and thus developing and nurturing a particular thought style, that is a crucial element of cognition. It is not the individual that develops a scientific fact, but the exchange of propositions between individuals. Against this background, Fleck calls for a *comparative epistemology* (DCSF: 22) that would allow to compare different modes of knowledge production and different histories of ideas, on equal terms. For him, every thought style is the product of a contingent historical process, where “the interaction between what is already known, what remains to be learned, and those who are to apprehend it” (DCSF: 38) leads to a certain constrain on though (Denkwang). And only through this intricate historical process, of which members of a thought collective are normally not aware, occurrences in a chaotic stream of observations are constructed to appear as mere and simple facts, as “stylized signal[s] of resistance in thinking” (DCSF: 98). According to Fleck, every theory of scientific thought should focus on these hidden processes.

Since the late 1970s, Fleck’s monograph has received substantial scholarly attention due to the publication of an English translation in 1979, and the re-publication of the German original shortly after. In what follows, I trace Fleck’s influence in Kuhn’s conception of scientific progress along the lines of the four propositions discussed in 3.1.4 While Fleck has laid out a conception of scientific knowledge production that is similar to that proposed by Kuhn, and indeed many studies seem to treat both works as being in widely the same spirit, I show that a number of marked differences exist:

(I) According to Fleck, there is no *fundamental* difference between scientific and other forms of knowledge production. Conceptually, this was Fleck’s explicit deviation from the works of Durkheim, Levy-Bruhi and Jerusalem, which he credited as major influence for his conviction that thought collectives are social facts leading a life of their own, but which he also accused to unduly grant science a different quality as compared to other, more

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4 I do this for the sake of sharpening differences between the authors. I do not attempt to make any statement about how closely Kuhn really examined Fleck’s prototype. Kuhn was aware of Fleck’s work, but he insisted to have developed most of his own thoughts independently (Kuhn, 1979).
traditional forms of knowledge production. For Fleck, the particular strength of thought collective theory is revealed in its ability to compare very different forms of knowledge production (DGSF: 46-51). As such, scientific thinking distinct from other forms of thinking only in style – by a “postulate ‘to maximize experience’” (DGSF: 51) and a typical orientation towards “maximum thought constraint with minimum thought caprice [emphases omitted – A.P.]” (DGSF: 95). Hence, Fleck identifies a general pattern in the development of scientific facts, leading from a “vague initial visual perception” to the “developed direct visual perception of a form” (DGSF: 92), but this pattern is neither unique to scientific facts (although Fleck seems to suggest that it is more pronounced in such cases) nor does it distinguish between pre-science and science. This indicates an important difference with Kuhn’s conception: paradigms seem to emerge at relatively distinct points in time, and once they exist, the modus operandi within the respective community is paradigmatic. In this sense, Kuhn suggests that the emergence of a paradigm is a form of social closure, separating two qualitatively different modes of collective thinking. For Fleck, thought styles continuously change, and occasionally they may exert the degree of thought constraint that characterizes scientific thinking. However, this is a gradual process rather than a marked shift. While Kuhn suggests that there is a unifying form that distinguishes scientific thinking, i.e. paradigmatic thinking, from other forms of thinking, Fleck is more flexible in this respect – scientific thinking is peculiar in nature, but its specific forms may vary considerably and the boundaries with other forms of thinking are quite blurred.

(II) This implies a different conception of scientific progress in the works of Kuhn and Fleck. Indeed, in Fleck’s description there is no elaborate equivalent to scientific revolutions. But also the very nature of cumulative scientific progress, guided by paradigms or thought styles, differs in the writings of Kuhn and Fleck. In normal science (Kuhn), the premises of a paradigm itself remain widely unaltered, only the knowledge that is produced under its guidance changes. For Fleck, there is no such distinction. A thought style includes that what has been learned and what is learned, and thus changes with every instance of cognition. “[E]very discovery is actually a recreation of the whole world as construed by a thought collective.” (DGSF: 102) Thought styles thus continuously change as knowledge is created and, for Fleck, active and passive connections are the primary concepts to capture the nature of this continuous change: Active connections denote the collectively constructed preconditions of cognition, and passive connections refer to what is experienced as objective reality (DGSF: 40). Scientific thinking, according to Fleck, proceeds through increasing both active and passive connections (DGSF: 83, 94-95). This is similar to the Kuhnian notion – science is peculiar because the direction of scientific progress is detail and depth (i.e. not truth). However, this similarity should not mask an essential difference:

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5 See Douglas (1986) for a more detailed discussion of this point.

6 Note that “perception of form” is used as a translation of Gestaltsehen, a translation that masks Kuhn’s and Fleck’s joint emphasis of gestalt as an important element of paradigms and thought styles, respectively.

7 Fleck does suggest that the history of comprehensive theories proceeds through eras of elascility, “when only those facts are recognized that conform to it exactly”, and eras with complications, “when exceptions begin to come forward” that may occasionally outnumber normal instances (DGSF: 29). While this anticipates some ideas that Kuhn uses to describe scientific revolutions, it is only a sideline in the argumentation of Fleck. This difference is the most obvious between the works of Kuhn and Fleck and has been stressed before (Babich, 2003; Harwood, 1986).
Where Kuhn explains the tenacity of a paradigm through closure (what is accepted as a problem, and expected as a solution is established with the emergence of a paradigm), Fleck offers a more advanced explanation for the tenacity of thought styles – a continuous reproduction of the interlocking of active and passive linkages within thought collectives. Hence, constrain of thought (in a way, the equivalent to Kuhn’s puzzle solving) is a result of continuous collective efforts to maintain and increase such a constrain, and facts are not just puzzles solved but actively created in every instance of cognition. In other words, the “closedness” of thought styles is a matter of degree and change, rather than absolute once accomplished, only surmountable through a paradigm shift.

A second difference exists because Fleck does not grant exemplary solutions the same status as Kuhn within a scientific community. Fleck does develop the idea of *proto-ideas*, early traces of concepts of contemporary thought styles, but these pre-ideas do not figure as central elements at the surface of recent versions of a thought style. Indeed, according to Fleck, *proto-ideas* are valuable because of their heuristic significance in early phases of a thought collective, but as such they are hardly able to demonstrate the functioning of a whole thought style (DGSF: 25) – which is the role Kuhn ascribes to exemplary artifacts within paradigms (SSR: 187-189). Indeed, according to more advanced versions of a particular thought style, the *proto-ideas* are often questionable, representing the “vague initial visual perception” (DGSF: 92) and carried along only because their heuristic value is so deeply connected to the foundations of a thought style. This difference underpins that the priority Kuhn assigns to exemplars as core constituents of paradigms is indeed a true innovation (SSR: 187).

Fleck is, however, very explicit that the initiation into a thought collective is based on experience. Here, he is in fact quite similar to Kuhn in that a thought style can in principle not be explicated in rules and procedures. To the contrary, scientific thinking becomes possible to the degree that active connections are implicit, and passive connections strike members of a thought collective as mere facts. For both authors, therefore, one can become member of a thought collective or paradigm only through hands-on experiences with a particular set of practices. While Fleck provides a rather broad description in this respect, Kuhn has emphasized exemplars as the main carrier for such sets of practices.

(III) The most important differences between Fleck’s and Kuhn’s conception of scientific progress exist with regard to the specification of the social structure of thought collectives or paradigms. While Kuhn widely neglects this issue (see 3.1), Fleck dedicates wide sections of his monograph (in particular, the complete Chapter 4) to it. The following aspects of thought collective theory provide a rich description of the social structure of scientific thinking:

Thought collectives can have different degrees of stability. For Fleck, a “though collective exists whenever two or more persons are actually exchanging thought” (DGSF: 102). Of course, such rudimentary versions of a thought collective, while illustrating well the essence of the concept itself, are volatile, “forming and dissolving at any moment” (DGSF: 13) and can thus not account for the kind of intricate thinking characteristic of science. However, such initial groups may grow and persist over time and then the respective thought style
“becomes fixed and formal in structure” (DGSt: 103). According to Fleck, modern science proceeds in such stable or comparatively stable thought collectives. With some simplification, therefore, it can be said that Kuhn, in his description of paradigms, resembles what Fleck has described as stable thought collectives, where “[p]ractical performance [...] dominates over creative mood, which is reduced to a certain fixed level that is disciplined, uniform, and discreet” (DGSt: 103). However, not all collectives are equally stable, and for Fleck the stability of thought styles is subject to continuous social production and change. In this sense, Kuhn’s paradigms seem to be a more constricted version of thought styles because he argues that in principle normal science proceeds in stable thought collectives, i.e. scientific paradigms.

Indeed, Fleck puts further flesh to this general notion and describes two different kinds of communication that account for the social production of a certain balance of stability and change in thought collectives – the communication of thought within a collective (intrakollektiver Denkverkehr), and the communication of thought between collectives (interkollektiver Denkverkehr). According to Fleck, the structure of thought collectives consists of many intersecting circles, “a small esoteric circle and a larger esoteric circle” (DGSt: 105), and initiates reveal different grades of adhering to a thought style. While only the members of the esoteric circle are directly related to the creation of thought, it is the communication within the structure of overlapping circles that produces a specific balance between stability and change. Hence, Fleck identifies the esoteric circle as a primary source of novelty, because here, the coercive force of a thought style is reduced (DGSt: 108). For him, it is only the communication of thought, often over great distances in time and space, that produces the tenacity of a thought style, because coercion of a thought style increases with distance from the actual creation of thought. This is a marked difference with Kuhnian paradigms, which are an esoteric circle by definition highly bound by the premises of a paradigm, and which become overturned only in response to the propositions of outsiders. In this sense, Fleck’s conception provides an opposite perspective, with change, if created at all, being triggered in the center of a thought collective, and tenacity being produced in communication between the center and the margins.

However, Fleck describes a second, even more important source of novelty – the communication of thought between collectives. He explicitly confines himself to some general remarks in this respect (DGSt: 109), but these provide a number of cues for a more comprehensive understanding of change that arises at the intersection of thought collectives. First, communication between collectives can be assumed to be the more difficult the greater the difference between these collectives is. “Collectives, if real communication exists between them, will exhibit shared traits independent of the uniqueness of any particular collective.” (DGSt: 109) Secondly, words are an important carrier of the

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8 Note that “practical performance” is a translation of “realisierende Ausführung”. This phrase from the German original, which was the version available to Kuhn, readily connects with Kuhnian ideas of puzzle solving and mapping up activities.

9 Fleck illustrates this point with the example of fashion. Here, the “most dedicated followers of fashion” can be found in customers with no direct contact to “the powerful dictators forming the esoteric circle” (DGSt: 108). Only these dictators, however, can permit themselves to challenge and rethink the foundations of fashion.
communication of thought between collectives, as words may have concrete but different meanings in different thought styles, and thus provide the flexibility to induce change when circulated intercollectively (DGSF: 109). Words are, in this sense, a vessel that can permeate the closedness of thought collectives. Thirdly, therefore, every intercollective communication results in a shift or change of a thought style:

“Just as the shared mood within a thought collective leads to an enhancement of thought currency, so does the change in mood during the intercollective passage of ideas produce an adjustment in this cash value across the entire range of possibilities, from a minor change in coloration, through an almost complete change of meaning, to the destruction of all sense.” (DGSF: 109-110)

In summary, Fleck’s remarks, while not fleshing out all details of intercollective communication, indicate that such communication is a frequent occurrence and leads to the change of thought styles. The nature of such change may cover a whole continuum ranging from minor adoptions to complete shifts of the foundations of a thought style. It is remarkable that Kuhn has proposed one extreme of this continuum, the shift of the very premises of a paradigm, to be of such great relevance to scientific progress. More important in the context of this paper, however, is the fact that Kuhnian paradigm shifts are based on endogenously created crises, whereas for Fleck, intercollective communication, while not without difficulties, seems to be a constant and standard occurrence in scientific thinking.
3.3. **Back on the map of technology analysis**

The influence of Kuhn's ideas of paradigms and revolutions in the innovation literature can roughly be grouped into two approaches. A first approach was built on the assumption that technology, just as science, can be conceived of as a knowledge system. Therefore, technological change is a process of knowledge production describable in strictly Kuhnian terms (Granberg and Stankiewicz, 1981; Johnston, 1972; Vincenti, 1990). While this perspective has been criticized for putting to much emphasis on an internal structure of technology (see Fleck et al., 1990), it has most consequently explored the usefulness of Kuhnian ideas to understand cognitive aspects of technological change (see Nightingale, 1998). A second, more influential strand stems from the evolutionary economics literature, where scholars have used Kuhnian ideas to reconcile demand pull and technology push models of innovation (Dosi, 1982; Nelson and Winter, 1977; Saviotti, 1988). In this perspective, technological paradigms emphasis that search heuristics and routines of technologists are patterned (i.e. the basis of non-random search activities) and respond to information from the demand side. Technological paradigms then emerge where technical knowledge meets knowledge about demand (Tunzelmann et al., 2008). Both of these strands have used Kuhnian ideas to explore the punctuated nature of technological change, where incremental progress leads to a saturated maturity where further incremental progress becomes too expensive and thus alternative paradigms seem more promising (most pronouncedly in Sahal, 1985).

Recently, Peine (2008a) has proposed to focus more closely on the nature of normal technological process using Kuhn's focus on exemplars as a starting point. In this perspective, it is not so much the Kuhnian notion of revolutions and shifts that is emphasized, but the interplay between exemplars and shared group commitments as an important driver of change in mature industries. Therefore, the Kuhnian idea of normal scientific progress becomes relevant where the closure upon a dominant design is relatively strong, because, in a strictly Kuhnian sense, it would then be accompanied by a closure upon a particular styles of producing technical knowledge. However, for complex technical systems, this work has also shown that the Kuhnian conception has severe limitations in explaining cumulative and stable learning processes where different industries are involved.

It is precisely in this context that Fleckian ideas constitute more fine-grained lenses on technological change, because they combine the particular strength of the Kuhnian stance with a better understanding of the social structure that accounts for the emergence and persistence, but also for the openness and evolution of paradigms. To begin with, Fleckian and Kuhnian ideas are both strong in explaining the influence of design decisions on further technological change. It is in this context that Kuhnian ideas of closure are particularly valuable. Because in technology analysis exemplary solutions have been traced well empirically in the form of dominant designs, paradigms as exemplary solutions have a concrete equivalent in innovation. As a consequence, dominant designs give rise to particular forms of knowledge production that can be explained in Kuhnian terms. A
Fleckian understanding of innovation departs from this notion, and poses that stable thought collectives correspond with this description of technological paradigms. In mature and well-evolved industries, therefore, a Fleckian understanding of innovation explains the same aspects of technological change in the same way as the Kuhnian reading. This is the first element of a Fleckian understanding of innovation.

The Fleckian prototype, however, does explain more. Above all, it does not assume closure to be complete at any point in time, and it is richer in specifying the social structure that establishes and sustains closure. Thus, when dominant design research has underpinned that dominance is a matter of degree (Afuah and Utterback, 1997; Murmann and Frenken, 2006), this is not well covered in the Kuhnian notion of technological paradigms that suggests that a dominant design either exists or not. Fleck’s description of the evolution of thought collectives is richer in this sense, connecting better with the idea that designs can be more or less dominant in industries. In particular, his notion of active and passive connections seems to be of great value in this context, where active connections resemble the elements of a dominant design that are fixed in design rules (Baldwin and Clark, 2000; Brusoni and Prencipe, 2006). Thus instead of assuming the existence of a technological paradigm, a Fleckian understanding of innovation would underpin the importance to measure the “amount” of rules and practices that account for the dominance of a particular design (Murmann and Frenken, 2006), and then explore the passive connections to which they give rise. This resolves much of the flavor of technological determinism, for which the idea of technological paradigms has frequently been criticized (Russell and Williams, 2002), by substantiating the basic idea with the social mechanisms that account for the dominance of designs and respective corridors of further change. The dominance of a design then resembles what Fleck has described as the tenacity of thought styles, and the effect of a dominant design becomes describable in terms of the constraints it puts on further knowledge production. Thus, a second element of a Fleckian understanding of innovation is to conceive of dominant designs as a set of socially (re-)produced active connections. It is, therefore, a first task of this perspective to identify a likewise equivalent of passive connections. A Fleckian perspective on technological change not only emphasizes design changes, but also changes in the degree of dominance of particular designs within industries.

Another aspect is closely related. Kuhnian ideas of technological change assume that normal progress is characterized by cognitive coherence within industries – at least to a certain degree. However, as Kuhn has widely neglected the continuous collective efforts through which the coherence of a scientific paradigm is sustained, a likewise neglect of the social structure that produces and sustains the cognitive coherence of industries characterizes large parts of the innovation literature. Again, a Fleckian understanding of innovation provides important elements to remedy this neglect, and back up a cognitive stance on innovation processes with an important stylized fact: New knowledge is indeed produced in esoteric circles of specialists – so far: in accordance with the Kuhnian reading –

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10 In a different context, Kaplan and Tripsas (2008) have recently raised the same concern.
but the degree to which the particular mindset of this circle influences change depends on its relations with a number of other circles. Thus, a Fleckian perspective, just as the Kuhnian perspective, grants technologists and their style of producing knowledge a peculiar position in innovation processes, yet it emphasizes that technologists are connected with other circles of a thought collective through communication. A *third element* of a Fleckian understanding of innovation is thus the distinction between technologists as esoteric and other actors in the innovation process as exoteric, together with a proposition how these circles are interconnected in technological change. This provides advantages both above the Kuhnian perspective (that grant dominance to the technologists) and the organizational perspective (that often neglects the influence of technologists altogether).

Finally, it is the communication between collectives that most clearly distinguishes Kuhnian and Fleckian ideas of change. This relates to Fleck's weaker notion of incommensurability, and underpins that different thought collectives can meaningfully exchange ideas and thus jointly create new knowledge. For the analysis of technological change, this implies a possibility that actors of different industries can jointly shape innovation processes. While this has not explicitly been denied in earlier concept of technological change, Kuhn's strong notion of incommensurability has suggested to focus on technological change of stand-alone rather than compound technologies (Dosi, 1997). As a consequence, technological paradigms are strongly related to the analysis of change in single industries, and their analytical scope virtually excludes knowledge production that spans different industries and R&D trajectories.

This leads to a *fourth element* in a Fleckian understanding of technological change and innovation – the overlap of distinct thought collectives characterized by different degrees of stability. For Fleck, it is the communication between collectives that constitutes a major driver of change. Conceptually, this corresponds to innovation processes that span different industries and R&D trajectories, and the Fleckian prototype, with its graded notion of incommensurability, readily embraces the possibility of such innovation processes. Moreover, it provides a number of conceptual suggestions to come to grips with their peculiarities.

New structures do not have to substitute for old structures. That is, continued communication between the thought collective of different industries may lead to new structures that do not have to overturn the existing industries. Hence, the Fleckian conception allows for a differentiated notion of "technology fusion" (Kodama, 1991; Tidd, 1995), where joint R&D activities of industries may generate knowledge additionally to that generated within these industries. In this connection, a Fleckian perspective on innovation squarely puts learning processes into the center that are fed by different thought collectives, and provides the equipment to explore how the emerging structure evolves as a result of actions and interactions of actors from these different collectives. In addition to technological paradigms, a Fleckian understanding of innovation emphasizes that incommensurability is socially produced, and thus indeed constitutes an obstacle, but an obstacle that can be overcome. In this sense, Fleck's conception highlights, just like a
Kuhnian perspective would do, that the different cognitive orientations of technologists within industries constitute a challenge for inter-industry collaborations. But at the same time, his work provides a framework through which solutions to this challenge can be analyzed.

4. Challenging incommensurability: Ludwik Fleck and the analysis of complex technical systems

This paper is based on insights from the complex technical system’s literature and has concerned itself with recent changes in technological change and innovation that are due to the increasing pervasiveness of ICTs. In particular such systems have gained relevance for which the architectural level emerges on the top of an existing set of components. The technical nature of such systems has consequence for the organization of technological knowledge production, and inter-industry linkages are a crucial feature of the respective innovation processes. Here, learning must be facilitated that spans the R&D trajectories of distinct and often mature industries, and it is hitherto not sufficiently understood how inter-industry linkages are coordinated, how they evolve over time in relation to the underlying trajectories, and what kind of structure eventually emerge from sustained inter-industry linkages.

In this connection, the paper is an attempt to bring Ludwik Fleck back on the map of technology analysis and industrial dynamics. For this purpose, I have compared Fleck’s early ideas with the Kuhnian notions of scientific paradigms and revolutions. Most importantly, Kuhn’s ideas imply a strong notion of incommensurability, which renders the interaction of members of different paradigms virtually impossible. In a strictly Kuhnian sense, therefore, innovation of complex technical systems would be severely constrained because it is not guided by a single paradigm but by multiple paradigms. Indeed, for complex technical systems it is the emergence of an overarching structure from the interaction of different paradigms that constitutes a key challenge (Peine, 2008a). Ludwik Fleck’s work provides a number of more sophisticated notions that seems to be more suitable in this respect.

First, it includes a conception of mature industries that is similar to that of Kuhn. In a Fleckian reading, knowledge production in mature industries proceeds in stable thought collectives, and here the interplay between a (more or less) dominant design and the search routines it has crystallized accounts for the tenacity of the respective R&D trajectory. However, Fleck’s work has provided more details about the continuous social production of tenacity, and in particular it has made a distinction between the inner and outer circles of a thought collective, where the communication among these circles produces a certain balance between stability and change. In this sense, a Fleckian understanding of innovation resembles a particular strength of Kuhnian notions, i.e. it grants to technologists a peculiar role in producing change within industries, yet it emphasizes that stability is dependent on the organizational structure of the complete industry. With regard to the analysis of complex technical systems, this implies that the closure of industries upon certain design
and search heuristics can have different and changing degrees that are a matter of continuous collective efforts.

Secondly, Fleck's conception implies a weak and graded notion of incommensurability, i.e. communication between thought collectives is possible to different and changing degrees. Indeed, Fleck assumes that this is a prime driver of change. Hence, where communication between thought collectives is possible, this may both give rise to a new thought collective and trigger changes within the original collectives. While Fleck has not elaborated upon these aspects in great detail, his writings suggest that once communication between thought collectives is initiated the closedness of thought collectives becomes permeable, and the production of stability and change proceeds on different terms henceforth. When different paradigms battle for dominance (Dew, 2006; Suarez, 2004), therefore, this battle, in a strictly Fleckian perspective, does not have to be resolved in favour of one paradigm, but may lead to links between and changes in these original paradigms. For innovation of complex technical systems this means that distinct industries can compete for dominance in a particular field, but that such competition may develop forms of knowledge production that transcend the boundaries of each of these industries alone.

Thirdly, for Fleck overlap and interrelatedness, both within and between thought collectives, is a primary feature of the organization of thought collectives. In this sense, his theory is particularly suitable to capture the different levels of knowledge production relevant in innovation of complex technical systems, and to come to grips with new structures that emerge in addition to existing structures. Inter-industry linkages, in a strictly Fleckian sense, comprise the communication between stable thought collectives, and develop an initially volatile but potentially stabilizing new collective. Fleck has provided a vocabulary to analyze the social processes that lead (or do not lead) to the stabilization and institutionalization of this new structure, and the changes it triggers (or does not trigger) in the original structures. In this sense, a Fleckian understanding of innovation seems to be particular relevant to explore in greater detail diachronic system's integration, where the accumulation of architectural knowledge has to be stabilized from initially uncertain and volatile attempts to coordinate changes in the knowledge bases of the components.

References


