Chapter 13
Creativity—Comments to the Scientific Process

Knowledge Production Referring to Traditional Knowledge

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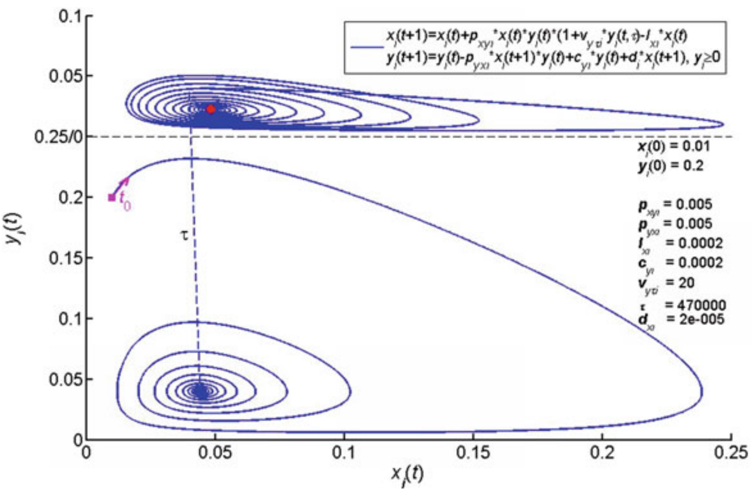

Fig. 13.1 Restricted creativity with a long-term discourse to previous knowledge—resulting toroidal boosts. Iterated function system based on an extended Lotka model where $x_i(t)$ means the actual knowledge and $y_i(t)$ are the problems which are aware of the i-th group at time t

P. J. Plath et al., *Imagery Synergetics*, Understanding Complex Systems,
https://doi.org/10.1007/978-3-030-95607-3_13

13.1 Introduction

13.1.1 Creativity in the Scientific Process

In the general understanding, the word *creativity* primarily means the property of an individual creating something that is new or original and useful [1–3]. This reference to the individual—especially the "genius"—leads to many problems in understanding the phenomenon of creativity. In particular, the attempt to understand creativity as a quality of an introverted, quiet and secluded working person, who is excellent and full of unusual ideas, seems to us to be very misleading [4].

But also the opposite thesis of brainstorming by Alex F. Osborn [5] does not work:

> People inspire each other to come up with new ideas and with the number of suggestions also their quality increases. You only have to put together a group and encourage them to express their ideas freely and without prohibiting thoughts.

Translated from German:

> Menschen inspirieren sich gegenseitig zu neuen Ideen und mit der Menge der Vorschläge steige auch deren Qualität. Man müsse bloß eine Gruppe zusammensetzen und sie ermutigen, ihre Ideen frei und ohne Denkverbote zu äußern. (Bund & Rohwetter, DIE ZEIT, 2019, p. 23)

Tomas Chamorro-Premuzic [6] found that

> Brainstorming in large groups was a 'waste of time'. … Responsible was the group's intrinsic urge to mediocrity, the so-called regression towards the middle. As a result, the most imaginative minds soon expressed only average thoughts. They adapted to the mediocre level of their colleagues.

Translated from German:

> Brainstorming in großen Gruppen sei, Zeitverschwendung'. … Verantwortlich sei der gruppenimmanente Drang zur Mittelmäßigkeit, die sogenannte Regression zur Mitte. Die führe dazu, dass die einfallsreichsten Köpfe bald nur noch durchschnittliche Gedanken äußerten. Sie passten sich dem mediokren Niveau der Kollegen an. (Bund & Rohwetter, DIE ZEIT, 2019, p. 23)

To be able to express and implement deviating and thus new ideas only works if committed confidants in the immediate vicinity of the idea provider take up this idea and work it out together [7, 8].

As a consequence, a protective and inspiring atmosphere is needed to develop new ideas and let them mature. In this sense, creativity is neither the property of a genius nor that of a brainstorming group, but a necessary nucleation phenomenon as with every phase transition [9]. In order for a new idea to spread into society, the society must also be excitable by the stimulation of this nucleus; i.e. the phase transition must be possible too, otherwise the nucleus of creativity vanishes.

Nuclei in this sense can be scientific institutes (e.g. the Center of Synergetics of H. Haken at the University of Stuttgart) or regular conferences (e.g. the Elmau conferences on Synergetics between 1972 and 1990 organized by H. Haken or the

Zeinisjoch seminars in Galtür/Austria between 1979 and 2008 organized by P. Plath); and the excitability of society can be achieved, for example, by appropriate research funding.

In their recent publication "Modellierungskonzepte der Synergetik und Theorie der Selbstorganisation", Ebeling and Scharnhorst [9] emphasize that the occurrence of innovations on the level of an overall system is always connected with destabilizing the current state and re-stabilizing the new one, i.e. the instability of the present system is a necessary pre-condition for the *New*. Then, an (external) impetus of a new invention into the pool of behavioral possibilities of the system may lead to a phase transition, and an innovation can prevail—or even not.

With respect to model various creativity approaches, we suggest to slightly modify the concept of Ebeling and Scharnhorst in a way that we consider a self-excitable system capable of an arbitrary number of impulses for new knowledge and new problems. In this context, we assume that knowledge and problems are arising again and again according to a Lotka-Volterra system, i.e. we consider a chain of (system-inherent) excitations which lead always to something new.

As already mentioned, such a system seems to be feasible only in a group of committed confidants, in which everyone can spontaneously bring in their ideas, without suppressing or deriding dissenting opinions in any way, e.g. in a relaxed tea or coffee round.

13.1.2 Modelling Creativity by a Lotka-Volterra Approach

This chapter is based on our presentation "Innovation und Interdisziplinarität", held in March, 2010, as part of the seminar "Interdisziplinarität und Institutionalisierung der Wissenschaft" at the Humboldt-Universität zu Berlin. In this lecture we presented an extended function system originating from the Lotka-Volterra [10–12] model in order to investigate the production of knowledge taking in account interdisciplinary cooperation. A remarkable result of this study was the occurrence of "bursts" in connection with innovations due to interdisciplinary cooperation (Fig. 13.1). The idea to use a generalized Lotka-Volterra system goes back to the work of Müller [13] in Greifswald who described the dynamics of the mutual dependence between problems and knowledge in the scientific process for the first time.

The suggestions from the discussion which followed our presentation lead us to the problem of "creativity". It seemed obvious to us that the approach taken by F. Müller, that the "*current problems*" and the "*current knowledge*" of a scientist or a group of scientists, or even of a whole scientific discipline, were the decisive variables of the dynamics of creation of new knowledge, that is knowledge capable of publication. Thus, they are very closely related to the problem of creativity.

To be clearly distinguished from current knowledge is the "*previously known knowledge*", which already exists in publications and is therefore no longer available for publishing.

In this way, we have created a rather operational approach to the idea of creativity, since the current, publishable knowledge is the new, just emerging knowledge, which has to be distinguished from the already known knowledge.

Analogously, the patent law is based on a very similar concept, i.e. a procedure is only patentable if the underlying idea is new, in other words it may not be considered as already known in lectures or publications including other patents.

In contrast to Amabile [14], however, we are not distinguishing between an operational definition and a conceptual one. For us, the process of generating new knowledge coincides with the newly identified product—the new knowledge. In other words, the process of creating new knowledge and new problems, as well as solving them, is itself a part of the problem and thus the object of our investigation.

For us it is crucial that the periodic process of the Lotka-Volterra system is limited by the "lifetime" of the researcher or research group, which can be achieved by an accordingly strong damping of the periodic function. In summary, it can be formulated:

In a first approximation, we consider **creativity as a periodic process** of creating new knowledge by solving problems.

For a group of scientists or a scientific institute headed by a scientific institute leader (usually a professor), creativity should be described by the classical equation system (13.1) of Lotka and Volterra, in which the problem function $y_i(t+1)$ is extended by the term $(+d_{xi}(t+1))$ corresponding to the damping caused by the current knowledge.

$$\begin{aligned} x_i(t+1) &= x_i(t) + p_{xyi}x_i(t)y_i(t) - l_{xi}x_i(t) \\ y_i(t+1) &= y_i(t) - p_{yxi}x_i(t+1)y_i(t) + c_{yi}y_i(t) + d_{xi}x_i(t+1); \\ & y_i(t) \geq 0, d_{xi} < 0\,. \end{aligned} \tag{13.1}$$

Here, $x_i(t)$ is the current knowledge and $y_i(t)$ are the current problems of i-th scientist or i-th group of scientists.

The concept of creativity also contains inherently the moment of surprise, i.e. the unexpected *New*. This goes beyond the conventional idea of the *New*, in which the *New* is indeed new, but somehow to be expected, since the problems from which it arises are certainly known.

But referring back to quite different problem areas, the *New* should no longer be associated with the omen of the already *known*. This can be accomplished by not only limiting to problems of the own discipline or of the own research group [15] as we have shown in the case of interdisciplinary and the innovations resulting from it [16], but by trying to tackle also problems of other disciplines or groups and treating them with the own methods. Then, one may obtain completely unexpected, eruptive events in the production of the *New*.

But one can also refer again to quite old problems which are almost forgotten. Then the resulting *New* is no longer the expected, foreseeable future, but the unexpected *New*, which no one seriously would have counted; and in this sense it is also emergent.

The technique of handling this recourse to previous problem areas is based on the use of the delay time τ. Instead of the current problem $x(t)$ at the actual moment—i.e., at time t—the problems $x(t-\tau)$ at time $(t-\tau)$ are now also taken into account, where τ should be sufficiently large.

13.2 Knowledge Reduces Problems

13.2.1 Natural Creativity

If one reduces the problem curve by a—negative—damping factor $d_{xi} = 1.4 * 10^{-6}$ (or even smaller), one obtains only a single maximum for $x_i(t)$ or $y_i(t)$, respectively, as the result of Eq. (13.1) (see Fig. 13.2). We will call this kind of creativity **natural** (or ordinary, normal) **creativity**. Then, the amount of the generated knowledge (integral) or the height of the maximum or the maximum slope of the knowledge function could serve as a quantitative measure of this type of creativity.

A crucial issue is how much the problem development of this leader or of his closest collaborators in their youth or during their studies has been—including their precocious, childhood or adolescent generation of problems. In this sense we speak here—without further differentiation, which would be quite possible—of natural creativity, since it is based on this natural creation of problems.

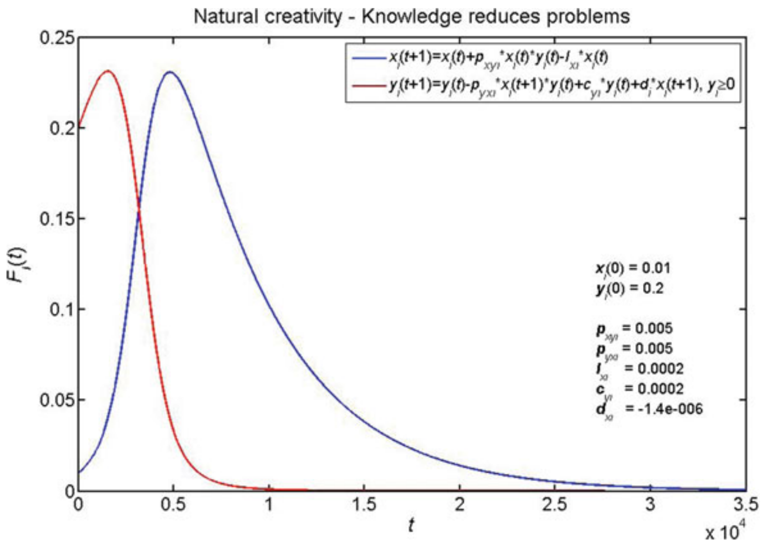

Fig. 13.2 Natural (ordinary, normal) creativity. Knowledge reduces the emergence of new problems. Time series of the problem and knowledge functions according to Eq. (13.1). The damping by the actual knowledge is so large in this case that only one problem/knowledge cycle is traversed

In the publications by Dobrov [17] and by Müller [13] an empirical investigation can be found of important scientists from the USSR and the USA regarding their “productivity”, which comes fairly close to our conception of “natural creativity”.

13.2.2 Autonomous Creativity

If the damping—i.e. the negative influence onto the problems due to the just created knowledge—decreases, several maxima (damped oscillations) can arise as well—even in the case of only one scientist/scientific leader. These multiple maxima of knowledge production correspond to the same number of maxima of problem generation. They cannot only be ascribed to the creativity or problem generation in the youth of the scientist, but correspond to further creative shifts due to the scientific process in which the scientist is involved. For this type of creativity we use the term **autonomous creativity**. An appropriate experimental evidence of such a behavior can be found in an article by Plath and Haß [16], where the “productivity” of selected scientists from the University of Bremen—which was just founded at that time—was studied.

An excellent example therefore is the group *aka* (angewandte Katalye = applied catalysis) which was part of the Physical Chemistry Department of the University of Bremen.

The principle course of knowledge production via autonomous creativity is exemplarily represented in Fig. 13.3 for a damping factor $d_{xi} = 5 * 10^{-7}$.

At first, the actual knowledge stimulates the process of knowledge production before its damping character comes into effect. We consider the damping term inevitable for knowledge generation of a single scientific group or a single scientist, because the corresponding problem function reflects the life cycle of the group/individual.

13.3 Classical Lotka-Volterra Model

13.3.1 Forced Creativity—Pulsating Creativity

If one considers a scientific institute such as the one of the Max-Planck-Society, creativity is artificially enforced by the “forced” change of the institution leader (**forced creativity**), due to the principle that the research area of that institute is personally connected to its associated leader (i.e. until the retirement of the former leader, who leaves due to age, and is replaced by a new leader). This practice is intended to ensure a constant—even though pulsating—creativity of the respective institute. It seems therefore obvious to describe this approach approximately by the classical Lotka-Volterra system.

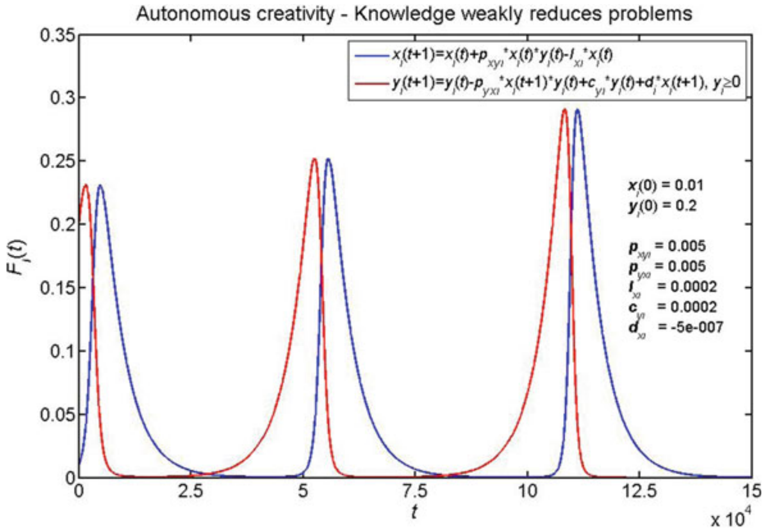

Fig. 13.3 Autonomous creativity. Knowledge reduces the emergence of new problems. Time series of the problem and knowledge functions according to Eq. (13.1). The damping by the actual knowledge is small in this case, such that several cycles of the problem and knowledge functions are passed through before the time series breaks down. The curves of maxima of the time series increase exponentially in the beginning before finally the damping prevails

In the ideal case of no damping ($d_{xi} = 0$), our equation system takes the form of the classical Loka-Volterra model and leads to a periodic solution for arbitrarily long times (Fig. 13.4). Let us denote in the following the distance between two knowledge maxima as a period of problem/knowledge interaction (about 30,000 time steps in the example shown in Fig. 13.4).

It is quite clear that there exists no damping in the principle of the Max-Planck-Society, since upon a change of the institution leader no accumulation of knowledge by means of knowledge transfer to the new leader occurs. The accumulated knowledge of the institute and the formerly existing problems are almost completely negated if the leadership of the institute is altered. At the best, old contracts continue until they end.

13.3.2 Large, Free Systems—Fully Developed Creativity

It looks totally different if we consider a society with a sufficiently large, diverse, and highly developed science landscape (e.g. the old Federal Public of Germany), in which parallel research—at different institutions—is possible. This would also lead to a periodic solution of the Lotka-Volterra system (no damping, see Fig. 13.4) and would thus correspond to a highly creative knowledge production.

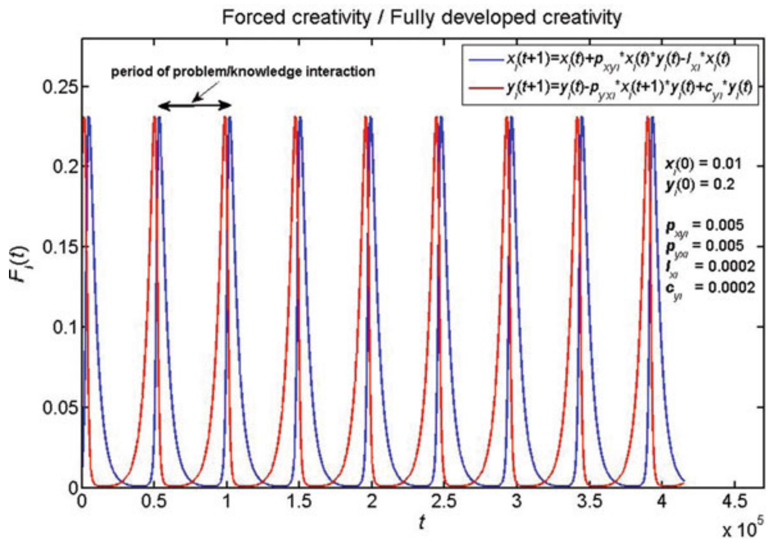

Fig. 13.4 Forced creativity/fully developed creativity. Classical periodic solution of the Lotka-Volterra model. As an example, the second period of problem/knowledge interaction is marked

13.4 Knowledge Enhances Problems

13.4.1 Restricted Creativity

A different situation exists, if—based on the argument of "comparability"—a canon of knowledge is in introduced with general obligation, as—for example—in the case of the unification of the education system by the Bologna and Pisa reforms in the new FRG or as practiced in the former GDR.

Then, a certain accumulation of knowledge and problems may happen, which leads to a positive damping of the system by the damping term ($+d_{xi}(t+1)$; $d_{xi} > 0$) (see Eq. (13.2)).

$$
\begin{aligned}
x_i(t+1) &= x_i(t) + p_{xyi}x_i(t)y_i(t) - l_{xi}x_i(t) \\
y_i(t+1) &= y_i(t) - p_{yxi}x_i(t+1)y_i(t) + c_{yi}y_i(t) + d_{xi}x_i(t+1), \\
& \qquad y_i(t) \geq 0, d_{xi} > 0\,.
\end{aligned}
\tag{13.2}
$$

In such a case, the system oscillates to a fix point (first quadrant in the *x*/*y* space) which is different from the zero point. This takes place the faster the stronger the damping factor d_{xi} is, i.e. the more the system is forced to constrain itself (see Figs. 13.5 and 13.6).

It would not produce anything new with respect to creativity or it could be even counterproductive, if one would modify the above-mentioned MPG principle, so

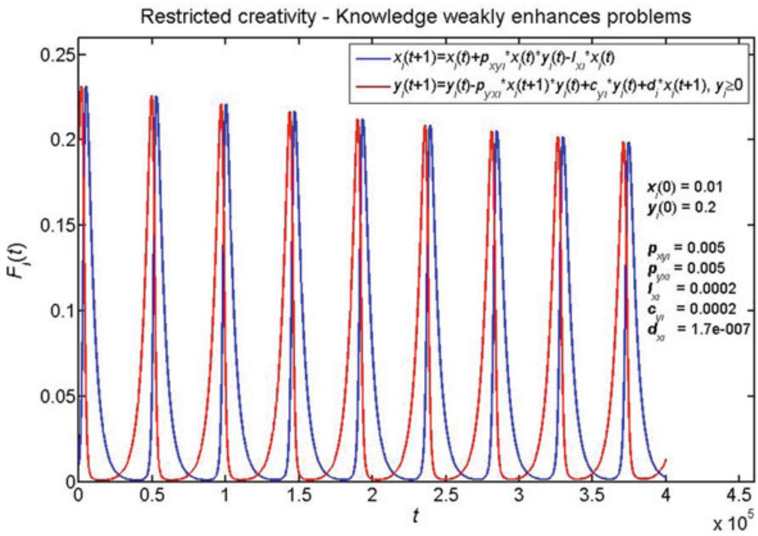

Fig. 13.5 Restricted creativity—weak damping: $d = 1, 7{*}10^{-7}$. Knowledge reinforces the emergence of new problems. Time series of the problem and knowledge functions according to Eq. (13.2). The strengthening by the actual knowledge is quite small in this case, such that the maxima of the problem and knowledge curves diminish only slowly

that the previous research is continued during an age-related change of the institution leader (e.g. by electing a suitable new successor) and thus the accumulated knowledge and the—thereby resulting—established problems are passed on the new leader. The damping cannot be avoided by this approach (see Fig. 13.6).

This is also true if one extends the function $x_i(t+1)$ of the knowledge production by an additional term $p_{xyi}x_i(t)y_i(t)\boldsymbol{v_{yi}\,y_i(t)}$ which is quadratic with respect to the problems (see Fig. 13.7).

$$\begin{aligned} x_i(t+1) &= x_i(t) + p_{xyi}x_i(t)y_i(t)\big(1 + v_{yi}y_i(t)\big) - l_{xi}x_i(t) \\ .\; y_i(t+1) &= y_i(t) - p_{yxi}x_i(t+1)y_i(t) + c_{yi}y_i(t) + d_{xi}x_i(t+1); \\ & y_i(t) \geq 0, d_{xi} > 0. \end{aligned} \tag{13.3}$$

Such an additional term could be justified by the assumption that the knowledge production (generation of new knowledge) does not only result by the simple product of knowledge and problems $x(t)y(t)$, but is also affected to a certain degree by higher powers of $y(t)$, e.g. in form of the product $x(t)y^2(t)$. This would mean that an intensified pressure of problems is created which contributes to a higher solution capability, i.e. creativity.

However, it results—as expected—that thereby the activity of knowledge production in the first period is increased (and also the frequency of the decaying creativity is slightly larger), but—on the other hand—the damping is strengthened and thus

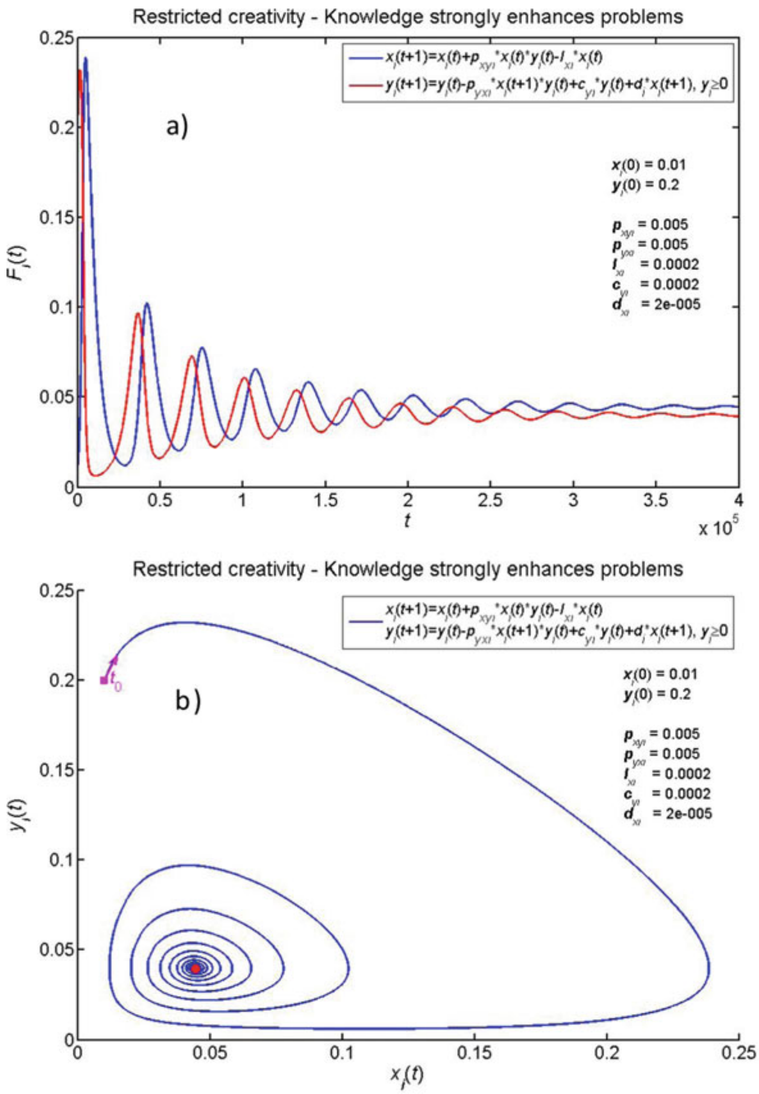

Fig. 13.6 Restricted creativity—strong damping: $d = 2{*}10^{-5}$. Knowledge reinforces the emergence of new problems. **a** Time series of the problem and knowledge functions according to Eq. (13.2). The enhancement by the actual knowledge is fairly large in this case, such that the maxima of the problem and knowledge curves diminish fast, **b** Phase diagram of the time series above. The trajectory clearly shows the oscillation to a fix point (red). It is also possible to exponentially approximate the decay curves of the maxima; for $\boldsymbol{t} \to \infty$ these approximation functions approach values greater than zero of knowledge and problems, the value for the knowledge being greater than that for the problems

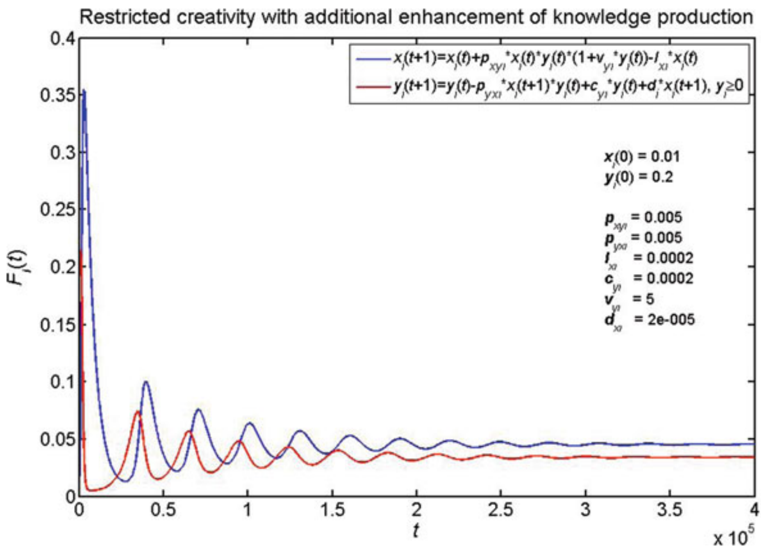

Fig. 13.7 Restricted creativity with enhancement of knowledge production by an additional term which is quadratic with respect to the problems. Knowledge reinforces the emergence of new problems. Time series of the problem and knowledge functions according to Eq. (13.3). The enhancement by the actual knowledge is quite large in this case, such that the maxima of the problem and knowledge curves diminish very fast

the fix points of the knowledge and problem functions are reached in less time t (compare Figs. 13.6 and 13.7).

13.4.2 Restricted Creativity with Recourse to Previous Knowledge

13.4.2.1 General

Let us now consider the question, how the system behavior is changed if the quadratic term

$$x(t)y^2(t)$$

is replaced by the expression

$$x(t)y(t)y(t-\tau)$$

according to Eq. (13.4):

$$
\begin{aligned}
x_i(t+1) &= x_i(t) + p_{xyi}x_i(t)y_i(t)\left(1 + v_{y\tau i}\left\{\begin{array}{c} 0, t \le \tau \\ y_i(t-\tau), t > \tau \end{array}\right\}\right) \\
. \qquad & \qquad -l_{xi}x_i(t)y_i(t+1) \\
y_i(t+1) &= y_i(t) - p_{yxi}x_i(t+1)y_i(t) + c_{yi}y_i(t) + d_{xi}x_i(t+1); \\
& \qquad y_i(t) \ge 0, d_{xi} > 0.
\end{aligned}
\tag{13.4}
$$

This corresponds to a partial recourse to previous problems by the time difference (t − τ). If the delay time τ is quite small, one cannot observe a noteworthy change as compared to a situation without time delay, i.e. τ = 0.

But if one increases the delay time τ sufficiently, then situations can be found in which the time behavior of the problem and knowledge curves are significantly changed. This corresponds to a recourse to earlier questions which are now taken up again, for example to document previous results in an overview article or in an appropriate textbook.

Of course, this requires that such recourse to former problems is possible at all. Problems of this type must therefore be published as open questions, which—in contrast to very old publications from the 19th and in the early twentieth century—is rather unlikely in the modern scientific publishing process.

Another possibility to recourse to former problems is to talk with scientists who are retired from the actual academic activities or to read their books or memoirs. In this way, senior scientists could play an important role—not so much as consultants, but rather as preserver of problems—a fascinating perspective. This could certainly be an interesting aspect of gerontology—virtually a cultural gerontology.

13.4.2.2 Short-Term Recourse to Previous Knowledge

If a delay time τ is chosen such that the recourse occurs between the two maxima of the knowledge and problem curves, one obtains a (transient) oscillation behavior to a limit cycle. This is shown exemplarily in Fig. 13.8 for the first occurrence of this situation after one period of problem/knowledge interaction (after about 39,000 time steps using the parameters chosen in the previous examples). We propose to describe this kind of knowledge production as (restricted) **creativity with short-term recourse to previous knowledge**.

As an exception, an oscillation behavior to a limit cycle is also obtained if the recourse takes place shortly after the first maximum of the knowledge curve when the problem curve already falls to a minimum (see Fig. 13.9 as an example for τ = 8000 time steps). In contrast to the previous case, the second maximum of the knowledge curve is significantly smaller and the convergence to the limit cycle occurs faster.

Such a recourse shortly after the first knowledge maximum may correspond to the fact that other researchers or research groups immediately take up a new idea and expand it with additional results.

On the other hand, if the number of iteration steps is selected in a way that the recourse takes place close to the minima of the problem and knowledge curves, the

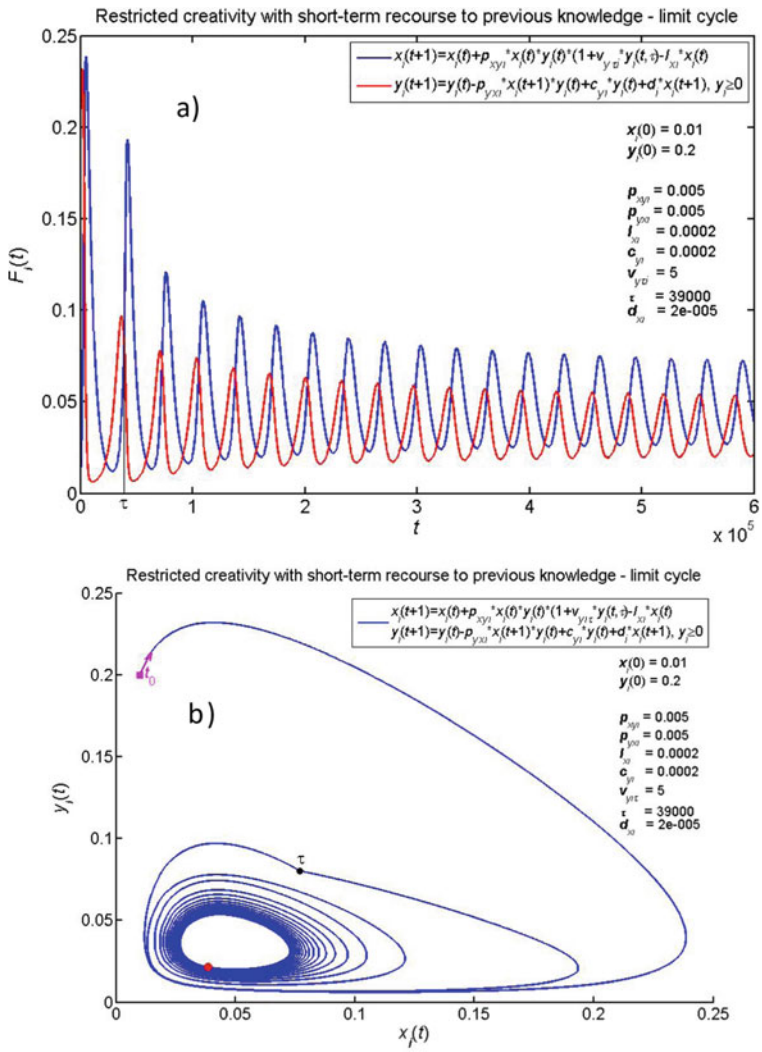

Fig. 13.8 Restricted creativity with enhancement of knowledge production by a quadratic problem term referring to problems which go back to about one period of problem/knowledge interaction. **a** Time series of the problem and knowledge functions according to Eq. (13.4) with $\tau = 9000$ time steps. A transient oscillation behavior of the knowledge production into a limit cycle can be observed. **b** Phase diagram of the time series above. The trajectory clearly shows the oscillation to a limit cycle (where the red point is located). Note that the trajectory exhibits a kink at delay time t when the recourse takes place

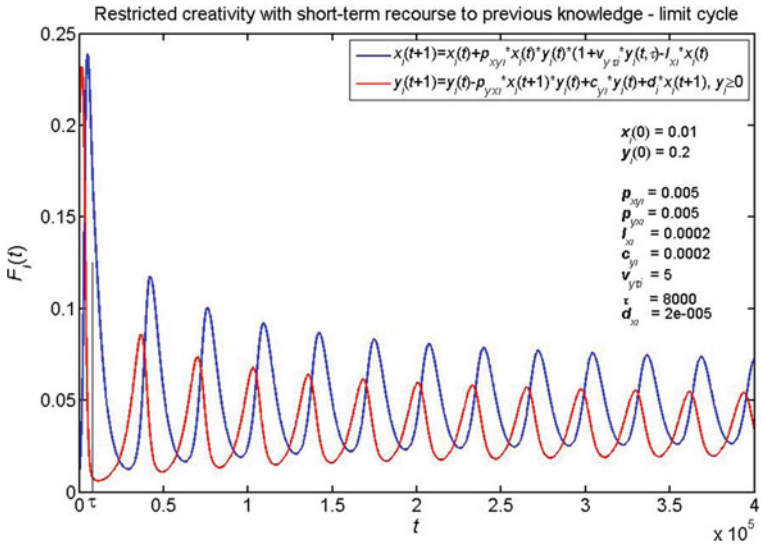

Fig. 13.9 Restricted creativity with enhancement of knowledge production by a quadratic problem term if the recourse occurs shortly after the first maximum of the knowledge curve, i.e. just after the invention of a new idea. Time series of the problem and knowledge functions according to Eq. (13.4) with $\tau = 8000$ time steps. A transient oscillation behavior of the knowledge production into a limit cycle can be observed with fast convergence to a limit cycle

system oscillates fast to a fix point as exemplarily shown in Fig. 13.10 for $\tau = 23{,}000$. This oscillation occurs much faster (only three periods of problem/knowledge interaction) than in the case of strong damping without recourse to previous knowledge or problems (see Fig. 13.6).

One may interpret this case as a (fast) loss of memory. This may occur if a new idea is strongly opposed by other scientists or by science policy reasons. It is not unusual that a new idea then ends in a drawer.

13.4.2.3 Long-Term Recourse to Previous Knowledge

A new situation results if τ is an n-fold ($n > 1$) of iteration steps between two maxima (or minima) of the knowledge or problem curve, respectively. Figure 13.11 shows exemplarily the corresponding time series for $n = 3$ and $\tau = 104.000$. After an initial decrease of the maximum values of both curves, a renewed amplification of the maxima is obtained after the time τ—in particular of the maximum value of the knowledge curve—followed by a rapid transient oscillation to a limit cycle.

This could be interpreted in such a way that, at the end of the creation process of a scientist, once again a creativity push takes place whereby the problem situation has changed only slightly.

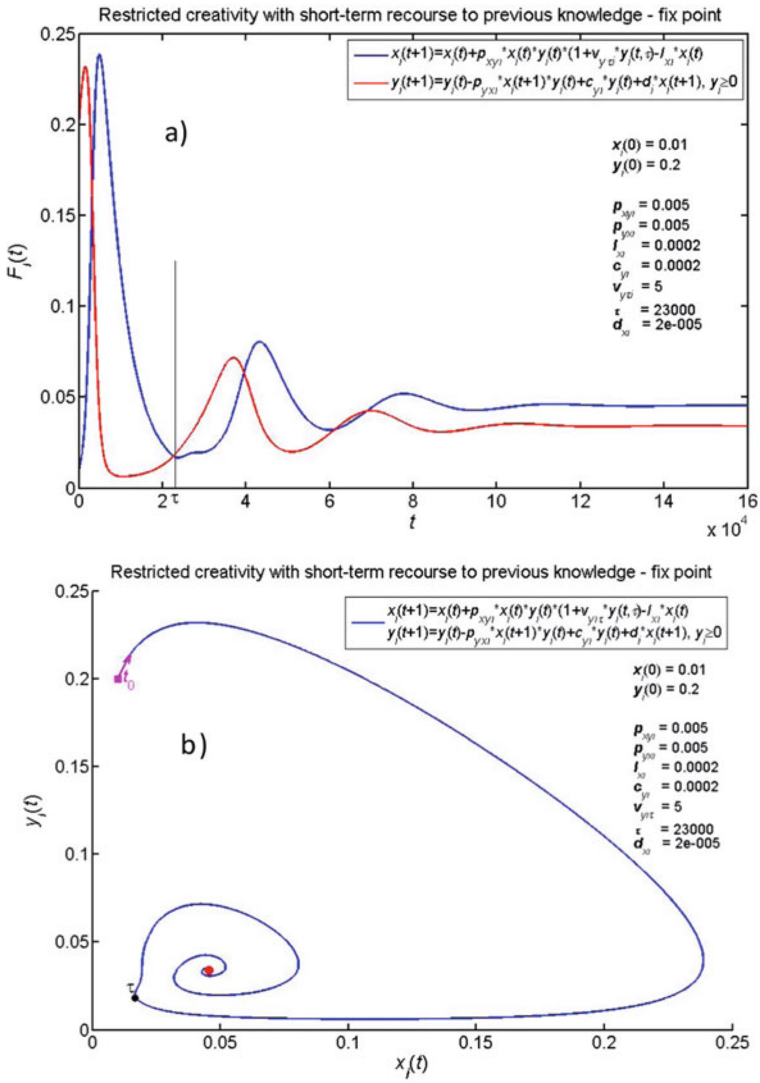

Fig. 13.10 Restricted creativity with enhancement of knowledge production by a quadratic problem term if the recourse occurs close to the first minima of the problem and knowledge curves. **a** Time series of the problem and knowledge functions according to Eq. (13.4) with $\tau = 23{,}000$ time steps. A very fast decay behavior of the knowledge production into a fix point can be observed. **b** Phase diagram of the time series above. The trajectory shows that the fix point (red) is reached after only three periods of problem/knowledge interaction

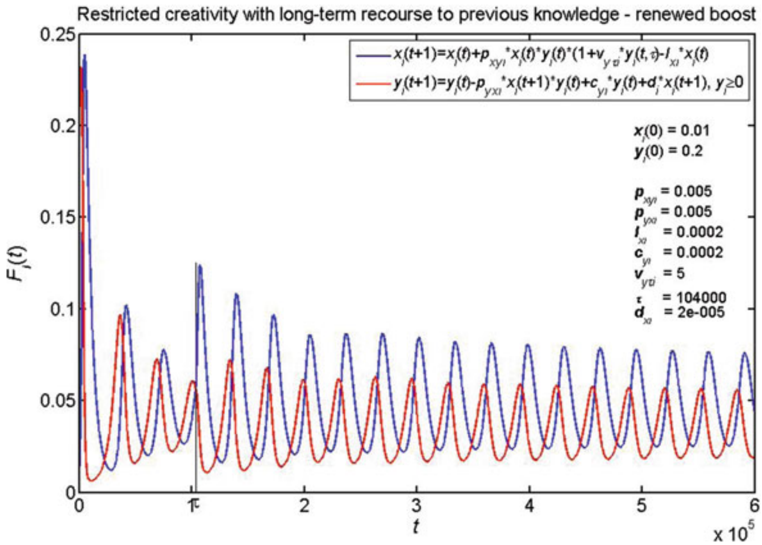

Fig. 13.11 Restricted creativity with enhancement of knowledge production by a quadratic problem term referring to problems which go back to about three periods of problem/knowledge interaction. Time series of the problem and knowledge functions according to Eq. (13.4) with $\tau = 104.000$ time steps. After an initial decrease of the maxima of both curves, a significant enhancement of the knowledge function takes place accompanied with a weaker increase of the problem function. Subsequently, a fast oscillation into a limit cycle occurs

The effect of a renewed amplification of the knowledge and problem curves becomes even more pronounced if far back reaching problems and questions—that were raised long time ago—are taken up again, but now under modified conditions.

The Renaissance, the revival of the ancient Greek atomic hypothesis in the reformulation of the atomic concept by Dalton, the questioning of the idea of "simultaneously" by Albert Einstein—these all are well-known examples of such "recourses" to very old problems in modern times, all of them combined with high creativity.

In our iterative model approach, this leads to a toroidal transient behavior at very large values of τ (for example: $\tau = 470.000$), where after a decrease of the problem and knowledge curves to almost fix point behavior, a new boost of knowledge production takes place according to a second, small circular frequency on a long-term scale (Fig. 13.12). In the (toroidal) transient range of this long-term oscillation, the maxima of the problem and knowledge curves oscillate similarly to a superimposed beat rhythm with a larger frequency due to the periods of problem/knowledge interaction. This may be interpreted as a toroidal creativity process.

The long-term behavior of the toroidal transient processes becomes particularly clear when the time series are extended over a considerably longer time interval, e.g. ten periods of long-term oscillations (see Fig. 13.13).

This long-term behavior which results from our model approach is indeed mathematically of interest, but it has probably no meaning for the modeling of creativity

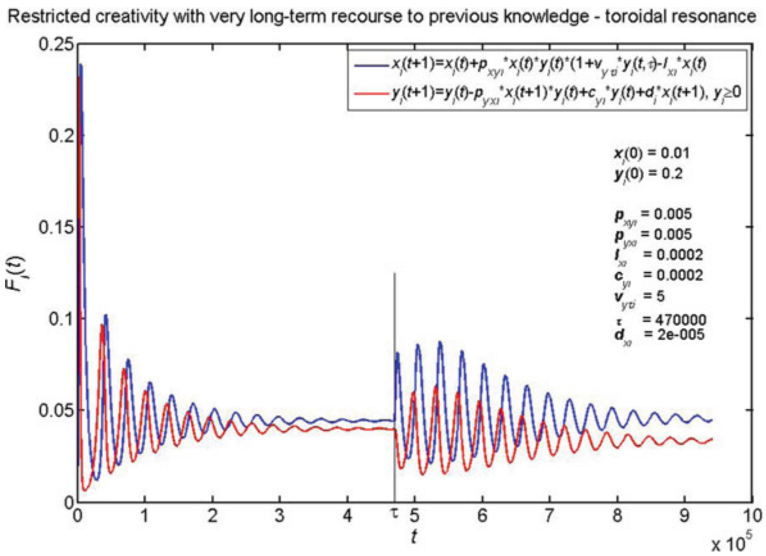

Fig. 13.12 Restricted creativity with enhancement of knowledge production by a quadratic problem term referring to far back reaching problems. Time series of the problem and knowledge functions according to Eq. (13.4) with $\tau = 470.000$ time steps over two periods of long-term oscillation. A toroidal transient behavior of the creativity can be observed, where—similarly to a superimposed beat rhythm—the problem and knowledge curves oscillate with a larger frequency within the small frequency of the long-term oscillation

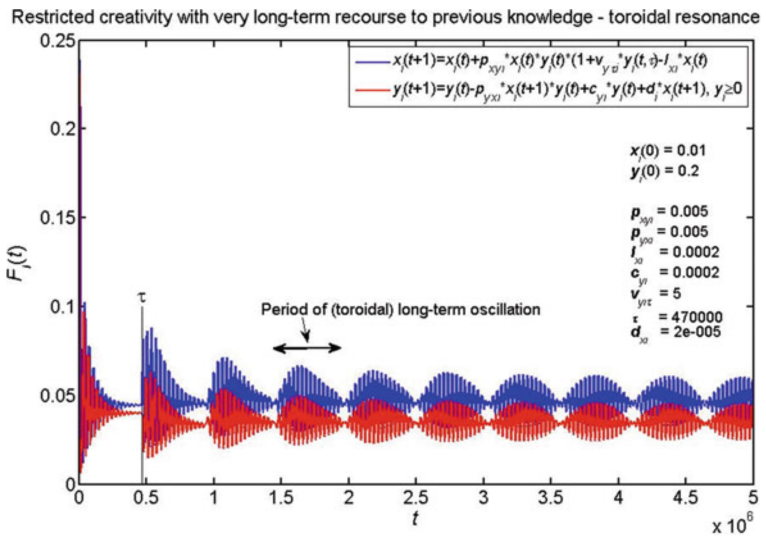

Fig. 13.13 Restricted creativity with enhancement of knowledge production by a quadratic problem term referring to far back reaching problems. Time series of the problem and knowledge functions according to Eq. (13.4) with $\tau = 470.000$ time steps over a very long time (about ten periods of long-term oscillation). As an example, the fourth period of (toroidal) log-term oscillation is marked

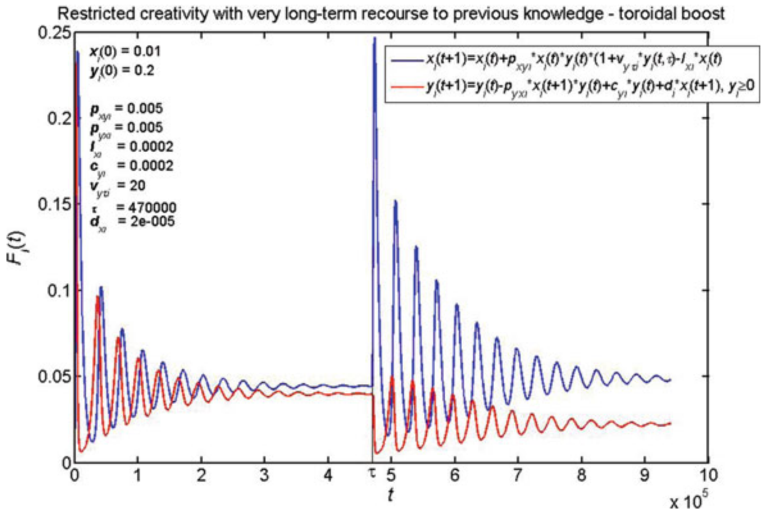

Fig. 13.14 Restricted creativity with enhancement of knowledge production by a quadratic problem term referring to far back reaching problems. Time series of the problem and knowledge functions according to Eq. (13.4) with $\tau = 470.000$ time steps over two periods of long-term oscillation. As can be seen in comparison with Fig. 13.12, an increase of parameter $\upsilon_{y\tau i}$ from 5 to 20 leads to an enhancement of the first amplitude by a factor three after recourse at time τ

in the real, present science process, since the conditions in our social system are nowadays no longer at least approximately constant over such long time periods.

Rather, the toroidal transient processes are here of essential meaning. In this context, the variation of weight $\upsilon_{y\tau i}$ in the quasi-quadratic problem term $p_{xyi}\upsilon_{y\tau i}x(t)y(t)y(t-\tau)$ which modifies the knowledge function is of particular influence. To the same extent as the parameter $\upsilon_{y\tau i}$ grows, the amplitudes of the knowledge curve of **the transient (oscillatory) creativity process** increase significantly after recourse at time τ, whereas the corresponding amplitudes of the problem function are slightly diminishing. This is impressively demonstrated in Fig. 13.14 where in particular the first of these knowledge amplitudes is about three times larger if $\upsilon_{y\tau i}$ increases from 5 to 20 (compare Fig. 13.12).

This all corresponds to a higher creativity and is thus of central importance for the understanding of the social process which is described with our model approach.

13.5 Summary and Outlook

As a consequence of our previous discussion, we propose the following classification of the concept of creativity:

- Natural creativity: negative damping by knowledge
  $\rightarrow$ Fix point (0|0) in the origin

- Social creativity: positive damping by knowledge
  $\rightarrow$ Fix point $(x_\infty|y_\infty) with x_\infty, y_\infty > 0$
- Cultural creativity: positive damping with recourse to previous knowledge after time τ
  $\rightarrow$ Fix point, limit cycle, toroidal oscillations

With a suitable choice of time delay $\tau \gg 0$, it is possible to transfer a system which is running to a fix point into a new state in which it can – oscillatory self-exciting – take the form of a limit cycle or a toroidal oscillation.

Finally, let us conclude with some general remarks about the concept of creativity.

Usually, creativity is conceived as a property of an individual person, whose respective thinking and action is targeted at producing originary, mostly unexpected, changes or solutions in the scientific process. Csikszentmihalyi [18] goes beyond this in so far as he considers domains which have to be changed, but which themselves—or the therefore responsible authorities—have to agree too. In this sense, he introduces a social component—the socially responsible environment—into the concept of creativity.

Steiner [19, 20] goes even one step further by granting creativity also to a group or to a network—more general to a cooperative system. This is similar to our approach which we are pursuing in our paper, although we distinguish between natural, social and cultural creativity, respectively. For us, Steiner's approach is particularly interesting in that it also attributes creativity to a network. The inclusion of networks opens up the possibility—analogous to our perception—to describe global processes in the field of sciences or arts in terms of creativity.

As an example for such processes, we consider highly networked and globally distributed groups of scientists who, on the one hand, are in close, almost direct exchange with each other—e.g. associated by public funding programs—and who, on the other hand, communicate and cooperate with groups far-away in other countries or cultural regions, but with a certain, noticeable temporal delay. First thoughts in this direction, based upon cellular automata, we have presented 2006 at a winter seminar in Galtür/Austria. These results were also published online in a short form [21].

Due to the abstract nature of our approach, however, it is also possible to treat any highly cross-linked network, where, apart from the direct neighborhood, there exist also areas, which are "temporally far-away" and which thus communicate only with a considerable delay. Such systems are of central importance in brain research, where appropriate networks have been discovered by Deco et al. [22] only a few years ago.

References

1. Runco, M., Jaeger, G.: The standard definition of creativity. Creat. Res. J. **24**,1.1, 92–96 (2012)
2. Mumford, M.: Where have we been, where are we going? Taking stock in creativity research. Creat. Res. J. **15**, 107–120 (2003)

3. Kreativität. (16. 04. 2020). Information retrieved on May 11th 2020, from https://de.wikipedia.org/w/index.php?title=Kreativit%C3%A4t&oldid=198954807.
4. Bund, K., Rohwetter, M.: Die Macht der Stillen. DIE ZEIT **49**, 23–24 (2019)
5. Osborn, A.: Your Creative Power: How to Use Imagination. Charles Scribner's Sons, New York (1948)
6. Chamorro-Premuzic, T.: Personality and individual differences (Vol. 4 of BPS Textbooks in Psychology). Wiley and 3rd edition ISBN: 978-1-118-77303-1 December 2016 (2007)
7. Swart, E., Plath, P.: Simulation of individual behaviour. In: Encarnação, J., Peitgen, H.-O., Sakas, G., Englert, G. (eds) Fractal Geometry and Computer Graphics, pp. 144–161. Springer-Verlag, Berlin, Heidelberg, New York, London, Paris, Tokyo, Hongkong, Barcelona, Budapest (1992)
8. Plath, P., Haß, E.-C., Swart, E.: Kooperatives Verhalten von Individuen bei destruktivem Wachstum in einer globalen Welt. Leibniz Online-Archiv, Jahrgang 2020, Nr. 39, 07 (2020), Plath.pdf. Information retrieved on May 11th 2020, from https://leibnizsozietaet.de/wp-content/uploads/2020/02/Portfolio-LO-39-2020.pdf
9. Ebeling, W., Scharnhorst, A.: Modellierungskonzepte der Synergetik und der Theorie der Selbstorganisation. In: Braun, N., Saam, N. (eds) Handbuch Modellbildung und Simulation in den Sozialwissenschaften. Springer, Wiesbaden VS (2015)
10. Lotka, A.: Contribution to the theory of periodic reactions. J. Phys. Chem. **14**(3), 271–274 (1910)
11. Lotka, A.: Zur Theorie der periodischen Reaktionen. Z. Phys. Chem. **72**, 508–511 (1910)
12. Volterra, V.: Variations and fluctuations of the number of individuals in animal species living together. ICES J. Mar. Sci. **3**(1), 3–51 (1928)
13. Müller, F.: Fortschritt der Wissenschaft - mathematisch modelliert. Wissenschaft und Fortschritt **22**(4), 162–165 (1972)
14. Amabile, T.M.: Creativity and Innovation in Organizations. Harvard Business School Background Note, 396–239 (1996)
15. Plath, P.J.: A Study on Knowledge/Problem Dynamics in Science. In: Ebeling, W., Peschel, M., Weidlich, W. (eds) Mathematical Research, Vol. 64, , pp. 60–76. MOSES. Akademie-Verlag, Berlin (1991)
16. Plath, P., Haß, E. Interdisziplinarität oder vernetzte Wissenschaften. In: Plath, P., Haß, E. (eds) Vernetzte Wissenschaften - Crosslinks in Natural and Social Sciences, pp. 153–179. Logos Verlag, Berlin (2008)
17. Dobrov, G.: Wissenschaftswissenschaft, p. 104. Akademie-Verlag, Berlin (1969)
18. Csikszentmihalyi, M.: Creativity; Flow and the Psychology of Discovery and Invention. Harper Collins Publishers, New York (1996)
19. Steiner, G.: The concept of open creativity; Collaborative creative problem solving for innovation generation—A systems approach. J. Bus. Manag. 5–33 (2009)
20. Steiner, G.: Das Planetenmodell der kollaborativen Kreativität - Systemisch-kreatives Problemlösen für komplexe Herausforderungen. Gabler Verlag | Springer Fachmedien, Wiesbaden (2011)
21. Haß, E., Plath, P.: Ein Modell der globalen Ausbreitung von Wissen. Leibniz-Online, Jahrgang 3/2007. Information retrieved on May 11 2020, from https://leibnizsozietaet.de/wp-content/uploads/2012/11/05-Hass_Plath_Ausbreitung.pdf
22. Deco, G., Jirsă, V., McIntosh, A., Sporns, O., Kötter, R.: Key role of coupling, delay, and noise in resting brain fluctuations. Proc. Natl. Acad. Sci. **106**(25), 10302–10307 (2009)