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Idea Generation

► Brainstorming and Invention
► Product Development, Business Concept, and Entrepreneurship

Idea Leadership

► Creative Leadership

Ideal Leadership

► Creative Leadership

Idea-Marathon System (IMS)

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Synonyms

Brain-writing; Continuity; Self-Brainstorming

What is Idea-Marathon System?

Idea-Marathon System, so-called IMS, is a philosophical approach of creativity, to build up a habit of daily thinking and immediate writing in one's notebook along with a consecutive number to each idea. IMS was created by Takeo Higuchi in 1984. Higuchi has been writing these days 50 ideas everyday, often with drawings in his 408 notebooks as of Oct, 2012, accumulating more than 360,000 ideas in his notebooks.

Principles of Idea-Marathon

1. Keep using notebooks of the same kind.
2. Generate new ideas everyday to write in the notebook chronologically with idea numbers.
3. Draw pictures for your ideas as often as possible.
4. Talk to your neighbors.
5. Review your ideas.
6. Implement the best ideas out of stock.

Unique points of Idea-Marathon (IMS) are that it is done DAILY so that IMS will become a habit for at least 3 months.

What to Record Idea in IMS

In Idea-Marathon, there are no limits for idea creation. We often can get interesting ideas for

E.G. Carayannis (ed.), *Encyclopedia of Creativity, Invention, Innovation, and Entrepreneurship*,
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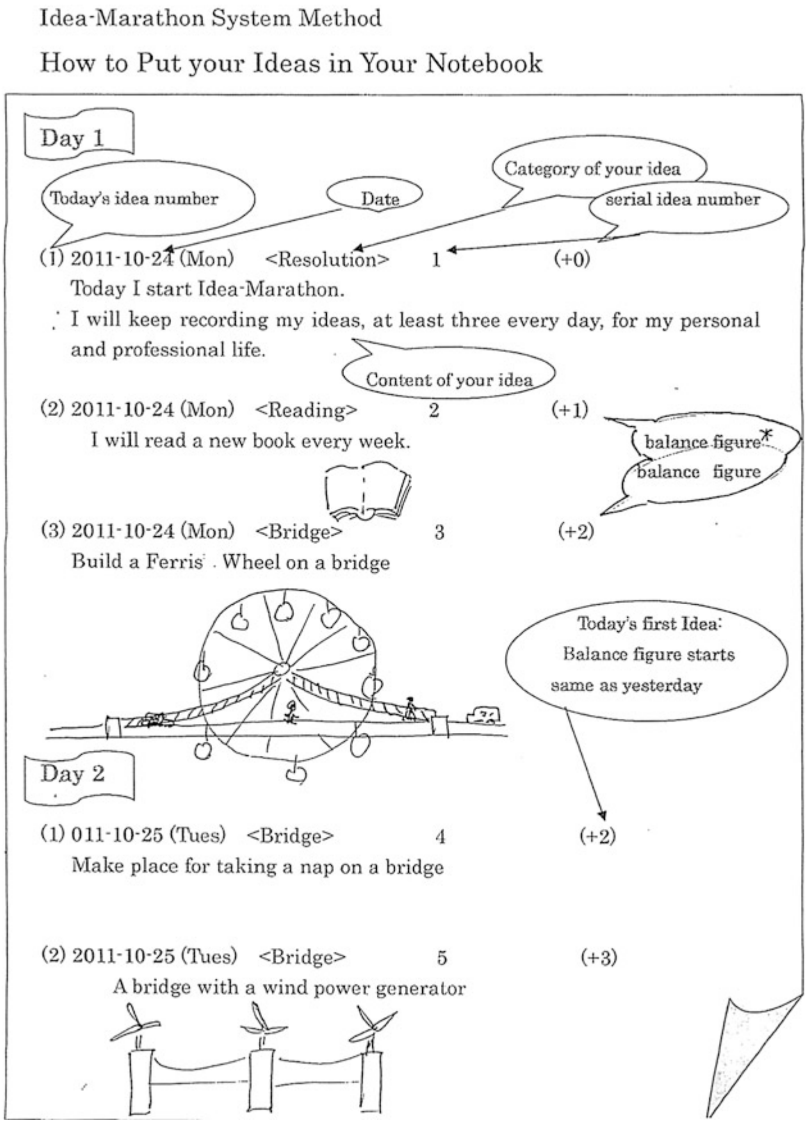

Idea-Marathon System (IMS), Fig. 1 Balance Figure

our work and specialty when we are thinking about something other than our work and specialty.

We can write ideas of hardware and software, better solution, improvement, concepts, project ideas, long range plan, dreams, doubt, checking points, good own jokes, sketches, poems, essay's title, novel's scenario, etc., almost everything out of our brain. Each idea will be written in the notebook like the following example (Fig. 1):

Your balance figure remains even (+0) when you keep writing one idea every day. And if you put forward more than one idea in a day your balance figure will be +1 or more.

IMS Effectiveness for University Students

Empirical quantitative analysis of Idea-Marathon was done by T. Kawaji, M. Higa, and Y. Nakaji of Otsuki City College in 2011. As the result, IMS practice for 3 months showed significant effect in Fluency of Ideas and

Originality of ideas while not effect in Flexibility (Kawaji et al. 2011).

Accumulation Effect or Progressive Stock of Ideas in Notebooks

If one keeps Idea-Marathon with the average of two ideas per day, after only 1 year, one has a stock of 730 ideas in notebooks, 2 years – 1,460 ideas, 10 years – 6,300 ideas. In case any ideas written in notebooks, our brain keeps vague but widely scattered image-like memory of ideas inside brain. Therefore, if we keep a large quantity of our ideas in our notebooks, it starts to resonate with our brain. Our brain is getting faster and stronger in creative power and reaction with the back-ground stock of ideas written in notebooks. One's creative confidence will also be increased accordingly.

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Ideas and Ideation

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Synonyms

Brainstorming; Divergent thinking; Flexibility; Fluency; Originality

Introduction

Ideas are meaningful units of thought. In fact, they represent the most useful unit of thought. There is no way to pinpoint some of the dimensions of ideas since they vary so much (e.g., your idea of "a good time" is probably more complex than your idea of "your favorite color"), but this is in fact part of their utility. They can be defined such that the variation and flexibility are retained. Ideas are smaller than concepts, which are also varied but cover entire categories of thought (e.g., "funny movies"). Ideas can be quite precise. They are the smallest meaningful unit of thought.

Ideas often make themselves known to the individual (in consciousness) in a verbal form, but it would be a huge mistake to see them as always verbal. Ideas occur in all modalities and perhaps in all domains (e.g., music, mathematics). It is typical to think about ideas in some verbal form, but that is just because it is most common to represent thinking with words. The same tendency is apparent in the research on ideas: it is easiest to study words when they are represented in words. Yet ideas need not be verbal. And an important part of the ideational process is in fact preverbal. This is when thoughts (and perhaps emotions) coalesce into meaning.

Ideas play an important role in creativity and innovation. Simply put, most creative breakthroughs, inventions, innovations, and original contributions of any sort begin with an idea. The more significant the creative or innovative product, the more likely it is that other things (revision, communication, judgment, evaluation) are required after the initial idea, but still, the process begins with an idea. That is why there are programs to stimulate ideation (e.g., brainstorming) and several tests of ideation (divergent thinking tests, such as the *Torrance Tests of Creative Thinking* or the *Runco Creativity Assessment Battery*) and why there is a long history of interest in ideas and ideation (Runco 1991, 2008, 2012).

The History and Philosophy of Ideas

The interest in ideas and ideation goes back millennia. PLATO discussed ideas in his *Republic*. There he used the allegory of a cave, with shadows seen by the cave dwellers merely representations of deeper forms. These forms, then, cast shadows which in turn conjure ideas.

John Locke, seventeenth-century author of *An Essay Concerning Human Understanding*, was also explicit about ideation and the concern for ideas. He discussed them as part of his epistemology, the key idea being that we are not born with ideas preformed. Each of us is a tabula rasa, or blank slate, and knowledge and ideas are acquired from experience. Locke suggested that simple ideas are reactions to sensory information and interaction with the environment. These can grow into complex ideas when they are combined and sometimes when divided.

Other philosophical treatises have developed theories of ideas (e.g., David Hume, William James, Alexander Bain), but it has not been only the philosophers who, throughout history, have pondered the origin of ideas. There is, for instance, a long-standing interest in, and debates about, ideas and ideation in the field of jurisprudence. Much of this focused on criteria and methods for recognizing original ideas as part of intellectual property and protection.

Several aspects of ideas seem to have remained constant through history. Ideas are usually associated with knowledge, for example, or are involved with the ontology of knowledge. PLATO suggested that knowing ideas is impossible, yet the observable world (the allegorical shadow) is a mimesis, a parallel of the form (the object which casts the shadow). The association of knowledge and ideas is currently a matter of debate. Many in the cognitive sciences see knowledge as static and dependent on experience. (Personal or reflective experience may be all that is involved; it is not necessarily experience with the objective world.) Ideas may be independent of experience or, more likely, personal constructions that may or may not be the result of thinking about experience. In the terminology of the cognitive sciences, some intellectual processes are top-down and being with thinking, while others are bottom-up and reactions to experience and sensory information. Often these work together; our thoughts draw from interactions with the natural environment but also draw from our imagination and inferences. Ideas, in this light, may result from an interplay of top-down and bottom-up processes. They are not, however, solely dependent on knowledge. Again drawing from the cognitive sciences, the information we hold in long-term memory is often factual and just information, sans personal input and interpretation. This kind of information is not ideational. Admittedly, the process leading up to the formation of an idea (or construction of an interpretation, for that matter) is not well understood. Headway has been made since new brain imaging technologies have been brought to bear. fMRI research, for example, shows that insights may occur as the individual works with factual knowledge, but eventually switches (due to "decisions" of the prefrontal lobes) to a broader activation of knowledge (in the right hemisphere) such that new options can be found.

Another interesting example from the history of ideas and ideation involved Alfred Binet, author of the first test of mental ability. (The procedure for standardizing that led to the IQ was after Binet's work. Binet recognized that ideas are related to fantasy while perception contributes to the experience of reality. Since perception is closely tied with the physiological contributions of our sensory systems, ideas allow transcendence of physical and temporal laws held by common perceptions. Furthermore, when ideas and perception align, they aid in adaptation to our physical surroundings. The external validity provided by our environment allows substitution of ideas for sensation and provides a coupling that appears as perception. Both ideas and perceptions occupy space in our personal realities.

As an aside, Binet's work exemplifies early empirical research on the topic of ideas. He is famous for his work on the psychometrics of IQ, but when he was working, there were fewer distinctions among modes of thought than there are today. Just as Binet did not have the concept of an IQ at his disposal, so too did he lack (as did all of the behavioral sciences) the distinction between *convergent* and *divergent thinking*. Yet Binet's first test of mental abilities actually contained tasks that required the examinee to draw from long-term knowledge as well as tasks that allowed the examinee to product multiple ideas. You might even consider this a kind of historical preverbal process, at least in that Binet was testing both convergent and divergent thinking even though he did not have the labels for them. Those labels were not suggested for another 50 years. Applying this analogy of preverbal processes a bit further to the history of ideas and to Alfred Binet, it is interesting to see how the lack of the distinction (and labels) for convergent and divergent thinking constrained Binet's thinking about possible modes of thought. This is certainly how it works on a personal level (and perhaps on a historical level as well): once you have the labels and concepts about a subject, you can delve into it, but without the labels and concepts, you can't think much about it at all.

Original Ideas and Divergent Thinking

There is a large literature on divergent thinking that has direct implications for our understanding of ideas and ideation. Indeed, this area of research has no doubt contributed more than any other to such understanding. It is a fairly rigorous area of research, spanning just over 50 years, with innovations in both the tasks designed to elicit ideation and the analytic approaches applied to the resulting ideation. J. P. Guilford is usually credited with initiating this line of research in the late 1940s. He developed a structure of intellect model which ostensibly covered all modes of thought. Just before his death, Guilford (1988) claimed that he had identified 180 distinct modes! Many of them reflected what he called convergent thinking. This is usually used when an individual encounters a task or problem for which there is one correct or conventional answer. If asked to name the largest ocean on Earth, for example, there is one correct answer. Divergent thinking, on the other hand, is used when the task at hand is ill-defined and open-ended. The individual can product many ideas. He or she can in fact think in different directions and, as a result, find original ideas (rather than just the correct ones elicited by convergent thinking tasks).

The technology of divergent thinking defines several kinds of ideation. There is, for example, *ideational fluency*. This is simply the productivity of an individual and operationalized as the number of ideas generated to any one task. Ideational originality is operationalized as the number of unique or novel ideas (usually statistically determined). Ideational flexibility is operationalized in terms of the number of conceptual categories in an individual's output. If asked to name bodies of water on Earth and the person responds with "Atlantic Ocean, Pacific Ocean, Lake Erie, the Mississippi River, and my bird bath," he or she will probably receive a flexibility score of four (one for oceans, one for lakes, one for rivers, and one for baths). Ideational flexibility is very important in that it is indicative of a kind of adaptability. Flexible individuals can cope with changes or surprises much better than an inflexible, or rigid, person. Originality, on the other hand, is indicative of creative potential. Indeed, originality is necessary (but not sufficient) for creative thinking. Fluency is actually predictive of both originality and flexibility. It does not replace them, but it is likely that a fluent individual will be original and flexible – likely, but not absolutely certain. Of course someone can have one idea, but it is an incredibly original one!

In 1962 Mednick published the very influential paper, "The Associative Basis of Creative Thought." This described how new ideas are found and had implications for a theory of how fluency is related to originality. Mednick's (1962; Mednick and Mednick 1967) theory received partial support. His idea of remote associates, for example, usually holds up. In particular, when faced with an opportunity to produce various ideas, the first things most people think of are conventional and obvious. Only after they are depleted do most people turn to more original ideas. Note the implication that time may be needed to find original (and therefore creative) ideas. Mednick's own Remote Associates Test has not fared as well. It presents three concepts to an individual (e.g., Meadow: Mowing: Hay::), and the respondent must think of a third concept that is connected to them (Grass). The problem with the RAT is that it tends to be verbally biased: people with good verbal skills usually do well and people with poor verbal skills do not. Still, Mednick was able to infer that ideas are often associated by acoustics (they sound alike), by functionality, or experientially.

Various technologies are now available to mimic associative tendencies (e.g., the Semantic Web). One kind of software uses an algorithm in assignment semantic proximity to a pair of words. These powerful computations of semantic similarity power a bulk of our Internet search engines and often allow the individual at the keyboard to find what he or she is looking for, despite inaccurate queues. Given the ubiquity of these technologies and their apparent context validity, the psychometric potential of semantic analysis will increase in relevance as associative theories of ideation evolve.

Other assessments have been developed, in addition to tests of divergent thinking and the *Remote Associates Test*. The *Runco Ideational Behavior Scale*, for example, is a self-report that asks the respondent how often they have produced certain kinds of ideas and in what settings. Some measures examine ideational skill, but instead of looking to the productivity or originality of ideas, they look at evaluative tendencies. The rationale for these tasks is that the production of ideas is only one of several important skills involved in creativity and innovation. Not only is it important to produce good ideas, it is also important to be able to judge ideas, to evaluate them, and to know when you have in fact found ideas with potential. Such evaluative skills are moderately, but not overwhelmingly, correlated with divergent thinking and the production of ideas. It is as if producing ideas gives individuals experience at judging ideas (the more you produce, the more experience you will have examining them), but there are people who are good at one or the other (divergent thinking or idea evaluation).

Conclusions and Future Directions

Ideas are a part of intellectual property, innovation, everyday creativity, and world-changing insights. They are a part of every day. They are not easy to define in any way that implies universality, but to do so would probably mean that the result is artificial and not indicative of spontaneous ideation. Still, ideas are as operational as, say, "bits" of information (not a binary digit "bit" used in computer code, but a "bit" used in the cognitive sciences to describe units of information processed in short-term working memory). Bits also vary from person to person and must be defined on a level that allows such variation. The technology of divergent thinking indicates that ideas are defined in a fashion that allows scientific study. There is a huge literature on divergent thinking, and much of it is experimental or quasi-experimental and moderate in internal validity.

Numerous innovations have taken place in the research on ideas and ideation. The literature summarized herein has identified the best tasks and assessments for particular populations, for example, and research has demonstrated that familiar tasks elicit a large number of fairly unoriginal ideas (probably because the person can draw from experience), while unfamiliar tasks are better for eliciting original ideas. Several new indices of divergent thinking (e.g., transformational power, appropriateness) are being used in ongoing research, and associations between ideation and intrinsic motivation, attitude, and values are being examined, often with cutting-edge statistical methods. Future directions include a study of the interstices of thought – what happens between ideas? – and their neurological basis. Given the value of ideas for various kinds of thinking, including creativity and innovation, no doubt these areas will soon receive the attention they deserve. Ideas about them are already being offered in various theoretical discussions.

Cross-References

▶ Brainstorming
▶ Divergent Thinking
▶ Idea-Marathon System (IMS)

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Ideation

▶ Divergent Thinking

Identifying and Assessing Creativity

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This chapter discusses the methods for identifying and assessing children's creativity and outlines the various behaviors found in the classroom as well as reported findings from existing creativity research on the most and least valued student traits by teachers. This is followed by a section on assessing creativity and includes the need for creativity assessment, as outlined in the educational policy documents of various countries as well as general literature, and the various assessment instruments which are in use. Following this are the findings from a large-scale mixed-methods study, conducted in Pakistan, which looks at the teachers' views on ways to assess primary school children's creativity as well as policy provisions for this and primary school children's performance on the Torrance Tests of Creative Thinking (TTCT).

Identifying Creativity

Some of the behaviors which are said to be found in the classroom when children are being creative include those outlined by the UK government, as part of the initiative to promote creativity in schools. These include:

Questioning and challenging: ask "why?" "how?" and "what if?"; ask unusual questions; respond to ideas, questions, tasks, or problems in a surprising way; challenge conventions and their own and others' assumptions; and think independently.

Making connections and seeing relationships: recognize the significance of their knowledge and previous experience; use analogies and metaphors; generalize from information and experience, searching for trends and patterns; reinterpret and apply their learning in new contexts; and communicate their ideas in novel or unexpected ways.

Identifying and Assessing Creativity, Table 1 Most valued pupil characteristics from the ideal pupil checklist

Fryer and Collings (1991), $N = 1{,}028$	Sen and Sharma (2004)	Torrance's experts in Sen and Sharma (2004)	Stoycheva (1996)
Considerate (45)	Doing work on time, healthy, sincere	Courageous in conviction	Sincere
Socially well adjusted (29)	Courteous, competitive	Curious	Curious
Self-confident (26)	Self-confident, neat, and orderly	Independent in thinking	Thorough
Independent in thinking (23)	Courageous in conviction, desirous of excelling		Healthy
			Persistent
		Independent in judgment	Sense of beauty
Curious (20)	Affectionate, industrious	Willing to take risks	Sense of humor
		Intuitiveness	
		Becomes preoccupied with tasks	Independent thinking
	Curious, independent in thinking, refined, free of coarseness	Persistent	
	Physically strong, socially well adjusted	Unwilling to accept things on mere say	
	Remembering well, versatile	Visionary	
	Altruistic, energetic, determined, persistent		
	Popular, well liked		

Source: Fryer and Collings (1991), Sen and Sharma (2004), and Stoycheva (1996)

***Envisaging what might be*:** imagine, seeing things in the mind's eye; see possibilities, problems, and challenges; ask "what if?"; visualize alternatives; and look at and think about things differently and from different points of view.

***Exploring ideas, keeping options open*:** play with ideas; experiment, try alternatives and fresh approaches; respond intuitively and trust their intuition; anticipate and overcome difficulties, following an idea through; and keep an open mind, adapting and modifying their ideas to achieve creative results.

***Reflecting critically on ideas, actions, and outcomes*:** review progress; ask, "is this a good…?" and "is this what is needed?"; invite feedback and incorporate this as needed; put forward constructive comments, ideas, explanations, and ways of doing things; and make perceptive observations about originality and value (QCDA 2009, p. 1).

Studies into teacher views about creativity have shown that certain student characteristics are more valued than others. Some of these studies used the Torrance's Ideal Pupil Checklist which contains over 60 characteristics (also refer to ► Creative Behaviors and ► Creativity Across Cultures). The most valued characteristics across studies are shown in Table 1.

There is a difference in the most valued traits of students in that independence of thinking is among the top in the Torrance's experts rating and Fryer, but it is not in Sen and Sharma (India) or Stoycheva (Bulgaria). Many of the most valued traits in the Sen and Sharma's study are different to the other studies.

The top-rated least valued trait by Torrance's experts is "conformity"; however, although this is also in the Sen and Sharma's list, it is not among the highest rated (refer to Table 2). Obedience is another trait which is among the least valued in studies other than Sen and Sharma's, which shows that there are differences in teacher views across countries. Other creative behaviors outlined using different instruments include:

- Has interesting, uncommon ideas
- Shows great curiosity and interest in things others are not interested in

Identifying and Assessing Creativity, Table 2 Least valued pupil characteristics from the Ideal Pupil Checklist

Fryer and Collings (1991), $N = 1{,}028$	Sen and Sharma (2004)	Torrance's experts given in Sen and Sharma (2004)	Stoycheva (1996)
Negativistic (62)	Fearful, apprehensive	Conformity	Bashful
Haughty and self-satisfied (48)	Disturbs procedures and organization of group	Willing to accept judgments of authority	Haughty Self-satisfied
Stubborn and obstinate (48)	Haughty and self-satisfied	Fearfulness	Timid
Disturbing group organization and procedures (44)	Timid, shy, bashful	Timidity	Sophisticated
Domineering (43)	Stubborn, negativistic	Obedience	Quite
	Talkative	Courteousness	Obedient
	Faultfinding, objecting	Promptness in doing work	Faultfinding
	Critical of others	Socially well adjusted	
	Unsophisticated	Haughty and self-satisfied	
	Conforming	Neatness and orderliness	

Source: Fryer and Collings (1991), Sen and Sharma (2004), and Stoycheva (1996)

- Quickly understands real-life problem situation and suggests nontrivial but effective solutions

However, in research studies in which teachers were asked to describe their students so that a new teacher could become familiar with them, it was found that creativity and related behaviors was not among the most important characteristics and outlined by very few teachers. The ranking of creativity-related behaviors from a list of 61 items was low, perhaps indicating that the findings depend upon the instruments used, as the following shows:

- Searching for novelty, interested in the unknown, showing creative preference (49th)
- To do very well in uncommon situations (61st)
- To have original ideas (25th)
- A climate for creative work (37th) (Stoycheva 1996, p. 1)

Assessing Creativity

The Need for and Problems of Assessing Creativity

The Assessment and Learning Research Synthesis Group (ALRSG) in their review protocol for systematic review of research on "The impact of the use of ICT for assessment of creative and critical thinking skills" state that

> . . .if valued goals of education are to be effectively taught, they need to be effectively assessed. (ALRSG 2003, p. 8)

The NACCCE (1999) report defined assessment as the process of "judging pupils' progress and attainment" and made recommendations that "all schools should review their provision for creative and cultural education." It went on to highlight that

> reliable and systematic assessment is essential in all areas of the curriculum, to improve quality of teaching and learning and to raise standards of achievement. This is as true of children's creative and cultural education as for all other areas of education. (p. 124)

McCann (undated) also emphasizes that ". . .creative processes and products be part of the overall assessment plan in the curriculum," arguing that

> . . .in schools, work that is not linked to standards and assessed in some systematic way is treated as less important and less vital to educational purposes. When work is not assessed, it is treated as if it does not "count." (p. 9)

There are a number of reasons outlined for the need to assess creativity. It can lead teachers to prepare and plan for it (Rogers and Fasciato 2005) as well as to create the required environment (Foster 1971) and encourage it (Compton and Nahmad-Williams 2009).

Assessment of creativity is said to be a neglected area despite its importance. This is regarded as a reason for concern keeping in view the high profile that creativity currently has and its linking with education for preparing children for the future (ALRSG 2003). The cause for this neglect may be that assessment for creativity is regarded as "problematic" (Scoffham 2003, p. 5), "difficult" (Thorne 2007, p. 24), and "challenging" (Feldman and Benjamin 2006, p. 332).

There are various reasons given why assessment of creativity is seen to be difficult despite being investigated for over a century. These include having no definite standards or standard methods (Afolabi et al. undated). There are also said to be definitional problems in that creativity is no longer defined as production of something novel; rather, it also includes the outcome being useful. This makes it difficult to assess particularly since what is of value may differ from culture to culture (Scoffham 2003). In fact, some are of the view that the question of whether or not creativity can be assessed depends upon the definition of creativity adopted (Cartier 2001) and in order to assess it a definition is needed (Rogers and Fasciato 2005). Other problems include the different opinions over what is deemed as creative across different subjects and using instruments based on Western ideas in other cultures (Rudowicz 2003). In summary, McCann (undated) states that assessment is challenging because creative work is

> . . .multi-faceted, multi-layered, and do not yield a single, correct, and easy-to-score response. (p. 9)

Instruments for Assessing Creativity

Nevertheless, despite the attributed problems of creativity assessment, many efforts have been made resulting in the development and use of various methods and instruments. Fishkin and Johnson (1998) outlined 60 instruments for use with school-age children. These were grouped into process, personality, products, press, combination measures, and systems or procedures approach. Hennessey and Amabile (1993) grouped assessment methods into three categories: personality inventories, biographical inventories, and behavioral assessments (p. 7). Afolabi et al. (undated) divided these into ten categories: divergent test, attitude and interest inventories, biographical inventories, personal inventories, teacher nomination, peer nomination, supervisor ratings, judgments of products, eminence, and self-reported creative activities and achievement (p. 2). These are not without criticism either. One of these is that they are not adequate for the task (Loveless 2002). There are also problems of reliability and validity (Diakidoy and Kanari 1999) as well as "subjectivity and bias" (Afolabi et al. undated, p. 4). In the case of tests, there are also scoring problems (McCann, undated).

Children's creativity, it is claimed, can be assessed informally or formally using "tests or expert judgments" (Sharp 2001, p. 6). Tests which have been used in education and regarded as the most popular are the divergent thinking type which includes the Torrance Tests of Creative Thinking (TTCT) (1974) and the Wallach and Kogan (1965) tests (Plucker 2001). Such tests are also said to be effective when used to evaluate the effect of programs introduced to develop creativity (Fishkin and Johnson 1998). The TTCT (also called the Minnesota Tests of Creative Thinking) has been used across the world from Brazil (Wechsler 2006) to India (Misra et al. 2006) and "remain the most widely used assessments" (Sternberg 2006, p. 87). It is regarded as appropriate for identifying and educating gifted children but more so for "discovering and encouraging everyday life creativity" (Kim 2006, p. 11) being useful for researchers and teachers for assessing children's creative abilities.

However, despite much praise for the TTCT, it is not considered as useful if teachers are interested in day-to-day changes in children's creativity. For this, the Consensual Assessment Technique is suggested to be more appropriate. This uses judges who "are familiar with the domain to independently evaluate products and then reach consensus" (Fishkin and Johnson 1998, p. 43). In this, the respondent is asked to complete a task, and then experts in that particular "domain" such as poetry are required to rate the creativity of the product (Hennessey and Amabile 1993).

Other tests which have been used in classroom setting include the Remote Associations Test (RAT), which requires respondents to find connections between items. However, it has been criticized for being more of a measure of intelligence than creativity (Taylor 1975). There is also the Guilford's Unusual Uses Test which requires the respondent to come up with as many names for common objects as possible (Hennessey and Amabile 1993). Instruments which collect data about the personality and attitude aspects based on details of past achievements are not regarded as good for primary school children. The approaches in which information about the creative environment is collected are said to lack "well-researched" instruments; however, one of the instruments given in this category and the only one related to classroom observation for creativity is the "Classroom Creativity Observation Schedule (CCOS)." Other more recent measures are combining the standard measures with some alternative approaches such as "performance assessment techniques" which include "direct writing assessments, open-ended written questions, hands-on experiments, performances or exhibits, and portfolios." But evaluating children's work requires "clear standards and knowledgeable judges" (Fishkin and Johnson 1998, pp. 42–43).

All measures, however, are said to have their strengths and weaknesses. It is therefore suggested that in order to assess children's creativity, multiple measures should be used (Plucker 2001). The measures used will depend upon the assessment purpose and the definition of creativity adopted (Fishkin and Johnson 1998) as well as the aspect of creativity that is of interest such as the "product, process, person, and environment" (Auh 2009, p. 1). Taylor (1975) suggested that thought be given to how the creative process occurs over long periods of time using a variety of techniques. The methods for assessment, whichever used, will have some implication for the way teachers "think about creativity" (Hennessey and Amabile 1993, p. 9).

Identifying and Assessing Creativity, Table 3 Teachers' preferred criteria for assessing creativity in pupils' work

Assessment criteria	Percentage of teachers reporting the criteria
Imaginative	87
Original for pupil	85
Showing initiative	79
Pleasing to pupil	74
Expressing depth of feeling	70
Useful	13
Accurate	6
	$N = 1{,}028$

Source: Fryer and Collings (1991)

Teacher Views on Assessment of Creativity

Studies of teacher views on creativity assessment have shown mixed attitudes. Fryer and Collings (1991) reported that three quarter of the teachers said that test scores were not useful for assessing children's creativity. The preferred assessment criteria were as given in Table 3 which includes, as the top rated, imagination and originality in the pupils' work.

In another study of UK trainee teachers ($N = 315$), it was found that 12% of all respondents (Rogers and Fasciato 2005) said creativity could not be assessed. This study included teachers from two universities, and 43% from one said they were certain that it could be assessed and 12% from the other. The majority of the teachers said that assessment should be informal. It should be assessed "in order to share ideas and develop enthusiasm and creativity even more." Some suggested assessing children's implementation of their ideas, while others suggested assessing the process rather than the outcome, yet some said that children should not be assessed on their creative ideas. Some trainees suggested that pupils could assess their own creativity as well as being assessed by the teacher.

However, the teachers were of the view that assessment could pose certain problems as well. It could lead to discouragements, which raises the question, the author says, of whether creativity should be assessed. It was also considered as subjective, as it may mean different things to different people and may be different in different areas. Teachers felt that they lacked set criteria and guidance for assessing creativity and thus were unprepared. They wanted a creativity definition and criteria for assessment. Some said that "creativity is individual" and so there cannot be any criteria for assessment or that there is no one way of assessing it since pupils are creative "in different ways" (Rogers and Fasciato 2005).

Having discussed the existing literature and findings from previous research, the identification and assessment of creativity seemed to be the two weaker areas. In this, Foster (1971) was of the view that the chances of teachers being able to identify creativity can be increased if they have

> . . .sound knowledge of the psychological bases of creativity, an understanding of the creative process and personality, an awareness of the conditions which are likely to elicit creative response.

With this, teachers can also attempt to assess creativity. However, he was apprehensive about this as he stated:

> . . .this seems like an entire study of a subject in itself which teachers need to master, [it has] implications for teachers training and may be very difficult in countries where teachers barely manage to have mastery of the subjects they teach, however the positive side is that once mastered it can be applied to all subjects where only the contents will differ. (p. 53)

This completes the discussion on the various methods and problems related to identification and assessment of creativity. It has been found that research carried out in different countries shows that the teachers, to some extent, value different characteristics for creative students. The remaining chapter presents the findings from a large-scale study conducted in Pakistan related to the question of assessment of creativity. First, the findings from the review of the educational policy and primary curriculum documents are presented, followed by the primary school teacher survey, and lastly, the creativity scores obtained from administering the Torrance Tests of Creative Thinking (TTCT) to primary school children.

Assessment as Outlined in the Policy Documents and National Curriculum

The assessment system in Pakistan has been widely criticized in policy documents, as the White Paper states:

> . . .the examination system like most others is compartmentalized into a limited role of promoting or failing the student. Even within this limited role there are shortcomings that have serious consequences for the quality of the learner produced in the country . . .Since the "learning" is rote based, assessments simply test the memory (Aly 2007, p. 20).

In the Green Paper, it is stated that

> in Pakistan the assessment systems are usually designed to measure individual student ability to move further up the system and there are critical examinations at the matriculate and intermediate levels that determine the career options for students.. . .there is general criticism that these assessment systems encourage rote learning and selective study. (Aly 2006, p. 8)

The National Education Policy, 1998–2010, outlines the assessment mechanisms but not the contents with reference to assessment of creativity (Government of Pakistan 1998). The White Paper for review of this policy defines the five "pillars of quality" which also include assessment (Aly 2007, p. 17). In reviewing the National Curriculum for Science, Mathematics, and English, it was found that all three provide assessment guidelines. In the math curriculum, the assessment objectives include developing relationships, identifying patterns, making predictions, hypothesizing, deducing relationships, identifying problems, planning and conducting investigations to solve problems, and proposing solutions to problems, all related to creativity. The science curriculum advocates assessment which must be:

> Open-ended, allowing for discussion and revision of new understanding
>
> Tolerant of divergent thinking and promote the notion of no "one right answer" (Ministry of Education 2006b, p. 67)

In the science curriculum, it is also emphasized that such test items be used which measure students' achievement in problem-solving skills and analytical and creative thinking (Ministry of Education 2006).

The English curriculum outlines a range of assessment methods, including use of multiple-choice items. The different types described include "best answer type" and "incomplete statement" type, both of which are said to measure "higher order thinking," and also the multiple response type which is "used in dealing with questions to which more than one clearly correct answer exists" (Ministry of Education 2006, p. 154). However, following this is a contradiction in that

> it is recommended that only correct answer type and best answer type multiple choice items should be used. (Ministry of Education 2006, p. 154)

The English curriculum further states that assessment

> requires students to create or produce their own answer in response to a question or task. This allows teachers to gain insight into students' thinking and creative processes, and to assess higher order thinking.... (Ministry of Education 2006, p. 155)

It can be seen from the evidence above that the curriculum documents allow some role for creativity in assessment.

Methods Reported by Teachers for Assessing Children's Creativity

Teachers have reported using a number of methods for assessing children's creativity (Table 4). It has been seen from the classroom observation that children are only asked questions which require recitation of previously learned information, they are also only invited to talk for this purpose as well, there is no practical work in class, and group work is a rarity. It is therefore questionable if all these techniques are really used for assessment at all. Teachers do take exams, mark children's work, and listen to them recite learned text ("sabaq") verbally, which are the only methods of assessment observed in most schools. It is therefore interesting that more teachers have not reported using these as compared to other methods. The fact that 80% of the teachers reported that they use reciting previously learned text as a way of assessing children's creativity implies that creativity is rote learning and regurgitating information which shows a different understanding of creativity held by teachers. This would imply that creativity means learning and regurgitating learned facts. There was not very much variation in the teachers' views on methods to assess children's creativity, across the background variables; however, there were fewer teachers reporting using some of the methods from the other public sector and those with no professional qualification. This research did not involve any further work on assessment in the classroom; therefore, more cannot be said.

From the open comment section, the methods outlined for assessing children's creativity are given in Table 5. One of the interesting things is teachers outlining that they use methods in which children do things such as observation, designing questions, and asking questions rather than the teachers doing this and also giving children material beyond the curriculum. It is also interesting that teachers are reporting that they assess by getting children to obtain answers, whereas in the lessons, as the findings from the classroom observation show, it is the teachers who give children the answers. Perhaps these are methods not used but suggested for assessing creativity.

Identifying and Assessing Creativity, Table 4 Methods used by teachers to assess primary school children's creativity (closed response)

Reported methods of assessing creativity	Percentage of teachers reporting using each method
Asking children different questions	97
Giving children opportunity to speak	94
Observation	93
Practical work	92
Group work	87
Exams	85
Marking or grading children's work	82
Listening to children recite their "sabaq" (learned text)	80
Playing games	79
	$N = 1{,}008$

Source: Shaheen (2011)

Identifying and Assessing Creativity, Table 5 Methods of assessing children's creativity from open response section

Method of assessing creativity	Percentage of teachers reporting using each method
Children obtaining answers to questions (including from outside curriculum)	19
Problem-solving activities	16
Holding competition	12
Involving them in extracurricular activities	9
Drawing	9
Holding debates among children	7
Speeches	7
Through writing	5
Children designing questions (objective type)	3
Children asking questions (each other and the teacher)	3
Amount of interest shown in work	2
Children doing observations	2
Giving topics beyond the curriculum	2
Giving lesson-related assignments	2
Giving topics of interest	2
	$N = 58$

Source: Shaheen (2011)

Torrance Tests of Creative Thinking (TTCT)

The Torrance Tests of Creative Thinking (TTCT) were developed by Dr. E. Paul Torrance in 1966. There are two versions of the test, TTCT-Verbal and TTCT-Figural. Each of these has two forms, A and B. In this study, the TTCT-Figural Form A was used because it was deemed as the best possible instrument which can be implemented, translated, understood, and scored with given the time scale available. In each of these activities, a shape or a number of shapes are given as a stimulus. In activity one there is an egg shape, in activity two there are 10 incomplete figures, and in activity three there are 30 pairs of vertical parallel lines. The respondent is instructed in each activity to use the given shapes to draw something (picture, object). The essential thing is to make these shapes part of the drawing. The instructions urge the respondent to think of something which no one else will think of and to keep adding ideas so that the drawing tells an interesting and exciting story. Once the drawing is complete, they are required to add a title which is "clever" and "unusual," helping to tell the story already started in the drawing (Torrance et al. 2008 p. 2; for more details refer to Torrance 1979; Torrance and Safter 1999). The test requires 30 min of working time, 10 min for each activity. Additional time is required for initial interaction with the children. The TTCT tests for "creative thinking abilities" which are described as a "constellation of generalized mental abilities that are commonly presumed to be brought into play in creative achievement." Although there is a debate about the terming of these abilities, Torrance has however maintained that "high degrees of the abilities measured by tests such as TTCT increase the chances that the possessor will behave creatively" (Torrance et al. 2008, p. 2). These abilities are part of a model for studying and predicting creative behavior (Torrance and Safter 1999, p. 51). A description of the creative abilities scored for in this study is provided in the next section which describes the methods used to administer the TTCT.

Method Used to Administer the TTCT

The TTCT test booklet (originally in English) was translated into Urdu and recomposed, making it the 38th language into which the TTCT has been translated so far. The Urdu version of the test was then pretested in the UK with one child and 30 class five children in Pakistan. These children were of mixed academic abilities. The test was revised in the light of findings obtained from pretesting and then administered by the researcher to 154 children from 17 primary schools in Pakistan using the procedure described below. The schools were both from private and public sectors as well as urban and rural locations consisting of both single and mixed gender student intake.

In each school, an introductory meeting was held with the head teacher to discuss the nature of the test, the number of class five children required to participate, and their selection criteria. If there were more than 10 children in the class, then a group was selected consisting of academically high-, average-, and low-performing students. In mixed sex schools, an attempt was made to select an equal number of girls and boys for each of the three categories. All the children participated in schools where there were fewer than 10 children in the year group.

Once the children were selected, familiarization activities were conducted for rapport building to create a more relaxed, friendly, and nonevaluative atmosphere. The activities included introductions, telling jokes, discussing likes, favorite TV programs, celebrities, cricket, and a magic trick. The children could easily relate to and talk on these topics without hesitation or shyness. One of the things which helped to develop a closer rapport was the researcher also sharing information about herself and answering the questions asked by the children as well relating to them as their "baji" (elder sister) rather than a teacher or researcher.

As an introduction to the test-type activities, the children were asked to describe ways in which they could improve their schools. This was aimed at stimulating them to think in the manner required for the TTCT activities. Another step toward this was asking them if they do drawing as the test is drawing based, although the aim is not to test their ability to draw. The children were then given the test booklet and asked to fill in their identification information on the front page such as name, age, and gender. They were then asked to look at the picture on the cover page of the test booklet and generate as many ideas about what the picture could possibly represent. They could share ideas with each other and work in groups for discussion. It was emphasized that there were no wrong responses and everybody's answer could be different. The drawing could represent anything, and everybody must try to think of something different. For children who found this activity difficult, the researcher pointed to sections of the picture and asked what they thought it could be or generated the first idea. The children's responses were noted and used as a means to appreciate and encourage their ability to generate ideas. After this, the test activities were administered.

For each of the three activities, the children were asked to turn to the required page. The researcher also showed the page, indicating to the stimulus and the accompanying instructions. The instructions were read out loud from the Urdu instructions manual, and the children followed the written text from their own test booklets. They then read the instructions either silently or aloud, and some were asked to repeat these. Effort was made to ask those children who, it was felt, may not have understood. This was also a means of verification to check that the instructions had been understood, and if not, they were repeated again both in Urdu and the local language. Children were encouraged to ask if they did not understand instructions or the meaning of any words. For example, in one government girls school, one girl asked what the word "ajeeb-o-ghareeb," that is, "unusual and original," meant.

It was felt that conceptually some of the instructions did not convey the meaning and were not understood by the children such as "using the stimulus to make a picture," "adding ideas to ideas to tell a story," and "connecting ideas." In this regard, efforts were made to find examples to clarify the instructions. Some of these examples included finding a word to complete a sentence, arm being part of the body, and threading bead after bead to make a necklace. In a school where the building was without a roof, this was used as an example of the building being incomplete until the roof was added.

Children were encouraged to ask questions even during the activities, and in order to answer these, the researcher went to them to prevent others from being disturbed. Those who did not start immediately or at all were encouraged to draw anything. Continuous encouragement and motivation was given throughout the test, and instructions were reinforced, particularly if the children were making random drawings and not using the stimulus. Some children repeatedly erased their drawings so much so that erasers were taken from them so that they concentrated more on their drawing rather than erasing. This may have been due to the children being unsure of their drawings being "right" or appropriate such as heart, alcohol bottle, or simply that it was not a good drawing.

If children had writing problems, they were advised to complete the pictures first and then after the test were helped to write the suggested titles. Since writing seemed to be a problem for a number of children in different schools, the researcher included, as part of the instructions, to write without worrying about spelling. It was hoped that the fear of misspelling a word would not prevent the children from doing the activities.

In case children finished before time, they were encouraged to continue adding more detail as some had the habit of working quickly, usually the children regarded as bright by the teachers. In order to explain that there was a time fixed for each activity but at the same time trying not to create a test-like atmosphere, examples were given where timings are important, for example, one-day cricket match and school timings. Some children were very keen to work beyond the activity time and were worried that they had not finished. When two boys were asked to stop drawing and give titles, they said, "we haven't finished pictures yet, how can we write the titles."

Once the three activities were completed, the researcher checked each child's booklet. The purpose of this was to ensure that all titles had been added and writing was legible. If children had difficulty with writing, the researcher supported by writing down the titles suggested. If a title was not added but picture drawn, then the child was asked to add a title. Some of the children had written titles in the local language such as "Saraikee" and could not be understood. In this case, the children themselves were asked to elaborate or the translator was asked. The booklets of children who were shy or seemed to be easily intimidated were checked last and not in the presence of other class children.

The test booklets were scored using the guidelines provided. The scoring provides information about the "creative functioning of a child" (Torrance et al. 2008, p. 1) and results in five norm-referenced and thirteen criterion-referenced measures (also known as creative strengths). The norm-referenced measures are fluency, originality, elaboration, abstractness of titles, and resistance to premature closure. The criterion-referenced measures (the checklist of creative strengths) are emotional expressiveness, storytelling articulateness, movement or action, expressiveness of titles, synthesis of incomplete figures, synthesis of lines, unusual visualization, internal visualization, extending or breaking boundaries, humor, richness of imagery, colorfulness of imagery, and fantasy. The results discussed in this chapter are related to the norm-referenced measures only, and a description of these "creative abilities" is provided next:

- Fluency is the ability to produce alternatives, and it is claimed that those who produce many alternatives have a greater chance of generating more workable solutions and succeeding in problem solving (Torrance and Safter 1999, p. 58). Creativity itself is considered by Torrance as a "special kind of problem solving" (Torrance 1970, p. 2). The fluency score represents the ability to produce a large number of images.
- Originality involves "getting away from the obvious and common place or breaking away from habit bound thinking." It is stated that the measure of originality predicts creative behavior more accurately than other measures such as fluency (Torrance and Safter 1999, p. 87).
- Elaboration is the "ability to develop, embroider, embellish, carry out ideas" and it is claimed that in reality "the ability to elaborate, work out plans, implement, and sell solutions is important" (Torrance and Safter. 1999, p. 109).
- In order to successfully solve problems and produce something creative which is also valuable, it is important not to become entangled in the information available. This is the rationale behind "abstractness of title" where the ability "to produce good titles involves the thinking processes of synthesis and organization" (Torrance et al. 2008, p. 12). Producing something of value is considered by many as a definition of creativity.
- The "psychological openness" of a person is considered to be an important and accepted

characteristic of a creative person. This involves not jumping to premature conclusions but rather taking time to understand the problem, considering the important factors involved, thinking of alternative and better solutions (Torrance and Safter 1999, p. 117), and considering the available information (Torrance et al. 2008, p. 13).

With a description of the various scoring criteria (creative abilities), the next section discusses the scores obtained by Pakistani primary school children beginning with the fluency scores.

Pakistani Children's Performance on the TTCT

Fluency Scores

Most children exhibited some ability to generate ideas and alternatives which indicates that they are able to solve problems and provide solutions. This is shown by their attainment of raw fluency scores (total fluency score for three activities), with almost 60% of the children achieving scores in the range of 40–60%. In fact, 23% of the children obtained at least 70% and above (Table 6).

The fluency scores when examined independently for each activity showed that children performed better in activity two. There is a positive relationship between the percentage of children and the percentage of fluency scores obtained. In fact, majority of the children (70%) obtained scores from 70% to 100%. This may have been due to having more time to complete fewer shapes, that is, 10 pictures in 10 min, or that the stimulus shapes appeared more meaningful and easily triggered children's thinking to generate ideas. Therefore, the type of initial shape, the number of shapes, and the amount of time given to complete the activity may affect the child's performance on fluency. Almost one third of the children obtained 100% fluency scores for this activity. These children were from private, government, rural, urban, all boys, as well as mixed sex schools. This shows that having a high level of fluency ability does not perhaps depend upon the school sector, location, or gender of students. However, no girl from an "all girls" school achieved 100% score which may be attributed

Identifying and Assessing Creativity, Table 6 Percentage of raw fluency scores and percentage of children obtaining these scores

Percentage of children obtaining the raw fluency scores	Percentage of raw fluency scores obtained
1	0
4	10
5	20
8	30
14	40
25	50
19	60
10	70
8	80
3	90
3	100
$N = 154$	$N = 40$

Source: Shaheen (2011)

to the difference in the school environments. There were more boys achieving 100% fluency score than girls which indicates that boys are perhaps more fluent in their ideas and that there may be a relationship between the ability to be fluent and the child's sex and/or the type of school they attend (in terms of student gender).

For activity three, the scores obtained by children were not as high as activity two. Initially, as the scores increase, the number of children obtaining these also increases, but beyond 40% of the scores, this trend then reverses with fewer children obtaining higher scores. The highest percentage of scores (60%) is obtained by only 11% of the children. Only 2% of the children obtained full scores. These were from both government and private schools although belonging to the same district. The low scores for this activity are in contrast to activity two. One of the reasons for this may be that there were three times as many pictures to complete, 30, but the time given was the same (10 min) as in activity two. In this regard, it may be said that where time is limited, the children's ability to solve problems is perhaps also limited. Another explanation for the poorer performance in activity three is that the same stimulus, pair of lines, is repeated each time which may not give fresh food for thought, may reduce interest and motivation, and may cause boredom. It may also be that this activity required children to rely more on their imagination which was difficult because they are more used to recalling and regurgitating facts. Both children and teachers in Pakistani schools are very particular about getting things right, and it may be that more children spent more time on each picture in an attempt to get them right, while a few who may not be so right answer fixated, and do not usually get things right, worked faster and finished more drawings, hence obtained higher scores.

In summary, children overall performed well on the fluency criteria although the scores were better for activity two than three.

Originality Scores

While the children were able to demonstrate that they could generate ideas (fluent) and hence be on the path of creative behavior, they showed poor performance on the originality criteria. This is shown by the majority of the children achieving less than 40% originality score (Table 7). This means that they were unable to break away from the "obvious," "common," and everyday way of thinking. The performance on the measure of originality is regarded as a better predictor of creative behavior than other measures such as fluency (Torrance and Safter 1999, p. 87) which indicates that with the obtained scores, Pakistani children have demonstrated very little creative behavior.

Identifying and Assessing Creativity, Table 7 Percentage of raw originality scores and percentage of children obtaining these scores

Percentage of children obtaining the scores	Percentage of raw originality scores
1	0
15	10
24	20
32	30
16	40
9	50
2	60
0	70
1	80
0	90
0	100
$N = 154$	$N = 57$

Source: Shaheen (2011)

The achievement of low originality scores could perhaps be explained by the fact that children are not into the habit of generating original ideas and work and therefore have not been able to display the desired ability which would show indication of creative behavior. In fact, there is evidence, gathered as part of this study through teaching observation, which shows that teaching in the schools does not involve activities which encourage and develop their abilities to be original. The major and only focus is on knowledge acquisition through rote memorization and regurgitation of the learned material. However, having said this, it is important to mention that teaching in these schools also does not include activities to specifically develop children's fluency ability; nevertheless, children performed better in this as already discussed. This perhaps means that it is more difficult to be original than fluent and that the ability to be original perhaps comes with more guided practice. In this, the children's ability to understand the test instructions may have also influenced their performance particularly as the children are unlikely to have been exposed to the terminology used in the test as evidenced from the lack of its use in the textbooks which is the only teaching material used in schools by both teachers and students. Another important factor contributing to the low scores may have been the children's fear of getting things wrong as many asked during the test "what if I get it wrong?" and "can I draw anything?" despite being repeatedly reassured that nothing they draw is wrong and they are free to draw anything.

On a positive note, it is interesting to note that there were also a few children who obtained scores as high as 80% and 60%, and therefore this raises further questions of how, despite all children going through same school routine, they are able to perform better and whether teaching for abilities such as originality is solely down to school or there are other influencing factors such as just natural ability, family background, and environment.

The discussion regarding originality has so far focused on the total scores obtained by children; however, a closer examination of the scores for each of the three activities showed that children obtained relatively higher scores for activity two than three as described below.

Examination of the originality scores obtained on each of the three activities showed that for activity one, less than half (42%) of the children ($N = 154$) were able to produce something original. Some examples of these include pictures such as "bird-balloon," "butterfly-spider," and "chicken egg and a baby inside." Less children producing something original can perhaps be attributed to the difficulty of the shape, despite being given 10 min to work on this single drawing as compared to 10 in activity two and 30 in activity three. This highlights the need to give time to develop ideas to produce something original. It may also be attributed to the fact that since it was the first activity in the test, the children may have been nervous, unsure about what to do, and out of their comfort zone since they were not being asked to reproduce something previously learned which is what they are habitually required to do. The pictures drawn by the children for this activity were categorized, and it was found that many things drawn were common everyday objects from the children's surrounding environment, such as names of animals, plants, fruits, and body parts. However, the list used to determine the originality of these responses is not produced based on the Pakistani context which raises the question of the difference it may have made to the originality scores if such a list existed and was used. This is perhaps a limitation of the TTCT list itself for use in different contexts.

For activity 2, almost half (49%) of the children obtained scores within a range of 40–60%, while 20 were able to obtain 80%. There were also nine children who demonstrated (obtained zero scores) no originality. These were from all boys, mixed sex, rural, government, and private schools. Those who achieved full scores (3) (Table 8) were from rural, urban, government, private, all boys, and mixed sex schools. This is interesting since the mean originality score was higher for children from private schools, but the two boys obtaining 100% originality scores were from rural government schools and the girl from mixed sex school. This shows that the variation in originality ability is perhaps not due to school sector but something else, perhaps the individual child.

Identifying and Assessing Creativity, Table 8 Percentage of originality scores for activity 2 and percentage of children obtaining these scores

Percentage of children obtaining the scores	Percentage of originality scores for activity 2
6	0
3	10
8	20
5	30
12	40
18	50
19	60
8	70
13	80
6	90
2	100
$N = 154$	$N = 20$

Source: Shaheen (2011)

The originality scores for activity 3 showed that majority of the children scored lower on this with 125 children obtaining scores between 10% and 40%. Only 22 obtained scores between 50% and 80%, and no child obtained a score beyond 80% (Table 9). This pattern may be explained by the fact that children also performed lower on fluency for activity three which left less figures to be scored for originality and/or that the children drew pictures which were less original. There were also 8 children who obtained zero scores who were almost all from rural, government, and boys' schools which raises questions about the government schools and their current ability to develop children's originality.

Another criterion through which the children's originality was assessed included their ability to join one or more shapes given in the test to complete a picture. This is called the "bonus" scores for originality. Children performed very poorly in this as well. No child obtained any bonus scores for originality for activity 2 which is surprising since children produced combinations of things (the requirement for obtaining bonus scores for originality), using the stimulus in activity one where they were not required to do so.

Identifying and Assessing Creativity, Table 9 Percentage of originality scores for activity 3 and percentage of children obtaining these scores

Percentage of children obtaining the scores	Percentage of originality scores for activity 3
5	0
20	10
23	20
19	30
19	40
5	50
5	60
3	70
1	80
0	90
0	100
$N = 154$	$N = 30$

Source: Shaheen (2011)

One of the explanations for this is that they were not provided instructions to do this and following instructions is the core of their teaching. If the children had been told that they could join figures together to make something, it would have been interesting to see the results. For activity three, 92% (154) of the children achieved a zero score, four children obtained 30% ($N = 13$), and two obtained 100% who were from urban private mixed gender schools. This perhaps shows that a coeducation gives a freer environment which is more conducive for enhancing the ability to be original.

In summary, few children obtained bonus scores for originality, over one third of the children produced something original for activity one, whereas the originality scores obtained for activity two were higher than three. This may be because for activity two children had higher fluency scores. Since the shapes in activity 2 are more suggestive than those in activity 3, one would assume that this may restrict children and prevent them from thinking beyond the obvious and rather recall and reproduce things from their existing experiences than making something new. Whereas in activity three where the shapes are less suggestive, one would assume that they provided more freedom for children to let their imagination go wild and come up with weird and wonderful things. But the less suggestive shapes in activity three giving lower fluency and hence originality scores mean that children may have felt more comfortable with the clues in the shapes in activity two than thinking for themselves which is something they are not habitually required to do. This is because it has been observed in classroom teaching that all answers are provided by the teachers in the lessons so children do not have to think for themselves.

The ability to generate ideas and original ideas (fluency and originality) seems to go hand in hand as there is the highest correlation, which can be explained by the fact that the more objects/pictures are drawn, the greater the chance of generating some original ones. It also indicates that creativity in the sense of producing something original is not a short snappy process but one that involves repeated effort (producing many ideas); hence, it could be said that idea generating is a prerequisite to producing original ideas. An important aspect which has emerged from the above discussion is that there appears to be a high correlation between fluency and originality as found in the scores for activity two. This has also been found by other authors such as Torrance himself. Besides this, the children have shown better performance on fluency criteria than the originality criteria which leads onto the next aspect of assessment, the elaboration criteria which assessed the children's ability to elaborate their ideas and produce something which is creative but at the same time valuable without becoming entangled in the information available.

Elaboration Scores

The majority of the children obtained a raw elaboration score in the range of 30–50%, while only 13 obtained a higher score than this. This included one girl who scored 100% (Table 10). She was from a mixed sex urban private school which perhaps suggests that girls may be better at developing and implementing ideas. It is also important to mention that the four children who obtained zero scores were all from rural government schools.

A comparison of elaboration scores across the three activities showed that these were higher for

Identifying and Assessing Creativity, Table 10 Percentage of raw elaboration scores and percentage of children obtaining these scores

Percentage of children obtaining the score	Percentage of raw elaboration score
2	0
6	10
8	20
21	30
36	40
18	50
5	60
3	70
0	80
0	90
1	100
$N = 154$	$N = 18$

Source: Shaheen (2011)

Identifying and Assessing Creativity, Table 11 Percentage of raw abstractness of titles scores and percentage of children obtaining these scores

Percentage of children obtaining the score	Percentage of raw abstractness of titles score
60	0
28	10
9	20
3	30
	40
	50
	60
	70
	80
	90
	100
$N = 154$	$N = 33$

Source: Shaheen (2011)

activities which contained more figures to complete, for example, 48 children obtained 20% for activity one where there was only one stimulus, 52 children obtained 20% for activity 2 where there were 10 figures, but 58 children obtained 60% for activity 3 where there were 30 figures. This perhaps suggests that children perform better if there is more choice for elaboration and more opportunities to exhibit this ability.

In summary, the overall low score on elaboration may be attributed to the fact that children had to work within a limited time which left them less time to add detail to their drawings. However, more importantly, this poor performance shows the children's lack of ability to further develop ideas to produce something creative. Further to producing something creative is the ability to communicate what is produced. In the test, the children were provided an opportunity to exhibit this ability through thinking up abstract titles for their pictures. This required them to synthesize and organize the information they had from their pictures. The children's performance on this criterion (abstractness of title) is discussed next.

Abstractness of Title Scores

The children seemed least able on this measure of creativity as evidenced by 60% being unable to produce any abstract titles. However, the remaining were able to produce the required titles and obtain scores ranging from 10% to 30% (Table 11).

Although the aggregate score for abstractness of title was low, more children had higher score for activity 2 than activity one. This can perhaps be attributed to children having more chances to exhibit this ability in activity 2 because they had more drawings to do than in activity 1. For activity one, 81% of the children failed to score, and only 12 achieved a score of 3, which was the highest obtainable. Those who achieved the maximum score were more boys and from urban private schools. Although the scores for activity two were higher than for activity one, these were still low with the highest being 30% obtained by 3 of the children and 105 obtaining no score who were more from private sector schools than government. These low scores indicate the children's inability to synthesize and organize information and communicate it in a creative way through providing written titles.

Premature Closure Scores

The children's performance on premature closure is better than that on the abstractness of titles although still weak with majority of the children obtaining below 50% scores (Table 7). Only 14 children were able to achieve a score between

Identifying and Assessing Creativity, Table 12 Percentage of raw premature closure scores and percentage of children obtaining the score

Percent of children obtaining the score	Percentage of score for closure
8	0
15	10
18	20
17	30
14	40
19	50
5	60
3	70
1	80
	90
	100
$N = 154$	$N = 20$

Source: Shaheen (2011)

Identifying and Assessing Creativity, Table 13 Percentage of creativity index score and percentage of children achieving the score

Percentage of children obtaining the score	Percentage of creativity index scores
1	0
0	10
3	20
16	30
25	40
27	50
23	60
5	70
	80
	90
	100
$N = 154$	$N = 186$

Source: Shaheen (2011)

60% and 80%. The highest score of 80% was obtained by only two children (Table 12). The low scores can be explained by the fact that children are not required to do such activities, hence, not trained to think this way and cannot do what is being asked. It may also be due to the fact that children are more hesitant to give unusual titles, afraid that they may get them wrong or afraid of the response it may attract. One child wrote “alcohol” (forbidden in Muslim cultures), and when I asked him to tell me what he had written, he whispered this to me.

Resistance to premature closure is about being open enough to be able to make what Torrance called the “mental leap” (2008) which it is claimed makes possible original ideas. The children’s low scores on this criteria again have shown that they have not been able to open up their thinking which would have enabled them to produce something creative which can again be attributed to the rigid and repetitive routine they are expected to follow daily in schools, rote memorize material and regurgitate it.

This completes the primary school children’s performance on the five norm-referenced measures of creativity, and it has been seen from one criterion to the next that most children have not performed well. Nevertheless, it is admirable at the same time that children did demonstrate some performance, more on some criteria and less on others despite being totally new to the test and the test-type activities. In total, their overall performance can be seen through their creativity index score which is discussed next.

Creativity Index

Almost all children showed some creativity as evidenced by their attainment of scores on the creativity index. The majority, 140, achieved scores ranging from 30% to 60% with only seven achieving 70% of the CI score which was the highest obtained (Table 13). In this, there were more boys than girls. All these children were said by the teachers to have creativity, but only one was said to be high academic performing, while the remaining were rated as average in their studies. Children who achieved scores above 50% were children from private, urban, and mixed sex schools.

Intercorrelations Among the Separate Assessments of Creativity

There is a high correlation between the separate elements of creativity and the overall indicator of creativity (creativity index) (Table 14), which is what we may expect considering that each

Identifying and Assessing Creativity, Table 14 Intercorrelations among the separate assessments of creativity, along with correlation of each with the creativity index (Pakistan)

	Creativity criteria				
Ability	Originality	Elaboration	Abstractness of title	Resistance to premature closure	Creativity index
Fluency	0.7	0.5	0.2	0.5	0.7
Originality		0.5	0.2	0.5	0.7
Elaboration			0.4	0.5	0.8
Abstractness of title				0.3	0.6
Resistance to premature closure					0.7

Source: Shaheen (2011)

Identifying and Assessing Creativity, Table 15 Intercorrelations among the separate assessments of creativity, along with correlation of each with the creativity index (USA)

	Creativity criteria				
Ability	Originality	Elaboration	Abstractness of title	Resistance to premature closure	Creativity index
Fluency	0.8	0.25	0.23	0.61	0.73
Originality		0.26	0.28	0.57	0.75
Elaboration			0.48	0.28	0.68
Abstractness of title				0.39	0.67
Resistance to premature closure					0.74

Source: Torrance (2008)

element contributes toward the overall creativity. However, there is variation in the contribution of each element which may indicate that children are stronger on some aspects while weaker on others such as the ability to add abstract titles. However, it could also be that this is due to weakness in the children's writing ability, that is, the ability to express creative thoughts in words, and not the ability to think up abstract titles. Hence, it may be that the method being used to test this creative ability is inhibiting children from exhibiting it because of poor writing ability. It could also simply be that children are not required to do such activities, hence, not trained to think this way and cannot do what is being asked. It may also be due to the fact that children are more hesitant to give unusual titles, afraid that they may get them wrong or afraid of the response it may attract. One child wrote "alcohol" (forbidden in Muslim cultures), and when I asked him to tell me what he had written, he whispered this to me. Similarly, the correlation of this score with other elements is also low, with a common variance of 4–9% indicating its independence and the fact that it may be testing something different.

The ability to generate ideas and original ideas (fluency and originality) seems to go hand in hand as there is the highest correlation, which can be explained by the fact that the more objects/pictures are drawn, the greater the chance of generating some original ones. It also indicates that creativity in the sense of producing something original is not a short snappy process but one that involves repeated effort (producing many ideas); hence, it could be said that idea generating is a prerequisite to producing original ideas. What is interesting from the findings when compared to those of other countries such as the USA (Table 15) is that the correlations are highest for both, which seems to point to the fact that these elements of creativity are common in children across cultures.

The children in Pakistan may be required to be more particular and detailed in their routine school work partly because of the tradition of learning whole chunks of text and reciting it in lessons or regurgitating it in exams, which may explain the high correlation of elaboration with fluency, originality, and closure as compared to the American scores, with a common variation of 16–25%; for American children, this is 4%. This also shows that children with the ability to embellish their work may be more likely to be fluent in their ideas, original, and able to resist the temptation to quickly complete their work in the easiest possible way rather than deeply think about what they are doing. From this, it could be said that children who exhibit one type of creative ability are likely to exhibit a number of others. This therefore indicates that separate elements of creativity may vary in their strengths and weaknesses but are likely to be present to some degree with one affecting the other.

Conclusions and Future Directions

In this chapter, the findings have been presented from the policy documents and the teacher survey regarding assessment of creativity in primary school in Pakistan. Also presented are the primary children's creativity scores as obtained on various criteria of the TTCT.

It has been found that Pakistani obtained low scores on the TTCT measures of creativity. Although in this they may have perhaps been disadvantaged as the TTCT-type activities are not part of their teaching, it is very clear that children are unable to generate, develop, and communicate original ideas, all of which requires them to use their ability to synthesize, organize information, and remain open enough to move beyond the everyday, common way of thinking. These findings raise questions about the extent to which the primary education system in Pakistan is supporting children's creativity. In this, it could be argued that despite the policy provisions and directives for inclusion of creativity into the education system, there are gaps at the implementation level in schools. The children's poor performance on the TTCT has shown that just enabling children to acquire knowledge through rote memorization and regurgitation of these facts is doing little to develop their creativity. These findings call for immediate and radical interventions to develop children's creativity through education if creativity is to be used as a tool for the country's progress and development. Unless this is done and some outcomes emerge, it is very difficult to accept existing claims of creativity being a tool for achieving economic progress and development.

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Illness

▶ Technological Invention of Disease

Imagery

▶ Imagination

Imagery and Creativity

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Synonyms

Imagination; Mental image; Visualization

Key Concepts and Theoretical Background

Mental images – a kind of representation people often employ in everyday life (Antonietti and Colombo 1996–1997) – play a facilitating role in thinking processes as a means of *simulation* and as a means of *symbolization* (Kosslyn 1983).

As simulation cognitive tools, images allow people to anticipate mentally the actual operations and the physical changes and provide an internal representation that keeps an analogical correspondence with the outside world. As symbolization tools, mental images stand for objects or concrete events, which are replaced by conventional signs. In the first case, images are useful because they offer the opportunity to view the mental consequences of the situation that the representation in verbal or abstract terms does not make immediately obvious. In the second case, images help individuals to mentally manipulate the elements of a situation, because mental images require less memory load than other representations, thus prompting at smooth and rapid transformations of the elements.

With more specific reference to creativity, the search for similarities and differences and the identification of links between distant realities – operations which are assumed to be involved in creativity – are facilitated by mental images that are sensitive to structural symmetries and organizations (Shepard 1978). These mental images permit people to modify data so that the changes which are to be produced in reality may be more flexibly stimulated in the mind. Furthermore, mental images allow a person to reorganize the way in which he/she represents a situation, so that it can be reconsidered in a more productive manner. Finally, the mental representation of information in a visual form can help people by providing a pictorial counterpart of abstract concepts, thus allowing individuals to represent simultaneously various elements of a situation so that they can identify the relationships between those elements. Mental images can therefore help the creative process because they are a kind of representation which is particularly flexible, easily convertible and useful to combine multiple elements into a new concept (Antonietti 1991).

Biographical Reports and Experimental Findings

Several autobiographical reports suggest that mental images have significantly contributed to scientific discovery (Shepard 1978). For example, the French mathematician Jacques Hadamard used visual representations when he thought of algebraic problems. Hadamard relied on these mental images especially when problems become too complex, so much so that the visual encoding allowed him to have a simultaneous understanding of all elements of the problem. Another example is Albert Einstein's use of mental images while working on the theory of relativity. Einstein, at the age of 16, imagined himself traveling at the speed of light sitting on the end of a light beam with a mirror in front of him. In this mental image, the observer could not ever see the image of the traveler. The light and the mirror, in fact, were traveling in the same direction and at the same speed, so that the mirror was always a little ahead of the beam and that the traveler could not reach the mirror and could not see his reflection. From this mental image, Einstein concluded that there can be no observer (i.e., nobody) that can reach or exceed the speed of light. Thus, it passed the assumption, shared by physicists afterward, that an object could achieve any speed, given a sufficient enough acceleration, and hence, the way for the subsequent theory of relativity was opened. A final example is that of Nikola Tesla, who used mental images in the process of inventing neon lights and self-starting engines. He, in fact, used to develop images of mechanical models that ran in his mind for several weeks in order to determine which parts were subject to premature wear.

These autobiographical anecdotes are confirmed by research (Roskos-Ewoldsen et al. 1992). In adults, high correlations have been found between the use and control of mental images and divergent thinking, ideational fluency, and ability to rebuild squares from cuts (a task which is assumed to be associated to the creative manipulations of the given elements). Furthermore, it was found that originality in thinking is associated with the tendency to process complex mental images. Finally, the ability to compose mental images is related to creativity too: Finke (1990) showed that the synthesis of mental images is particularly effective in inspiring original objects that can be used in everyday life.

Not only transformation of mental images but also a static feature, that is, vividness, has some functional significance, especially in situations of intellectual impairment, as suggested by some studies on so-called idiot savants. Research by Selfe (1983) indicated that children with autism and mental retardation with strong artistic skills possess high visual abilities: they use photographically realistic proportions more than normal children for the representation of three-dimensional space as well as the size, distance, and occlusion of overlapping objects. For idiot savants, mental images are one of the forms of representation which they use to perform intellectual operations which majority of people cannot perform (Treffert 2000).

Positive correlations between imagery vividness and divergent thinking skills have been reported, whereas no correlation between vividness and flexibility of thought was found. However, the ability to form vivid mental images is a skill which is separate from the ability to transform images. Kosslyn (1983) supported the componential nature of imagery by showing that at 5 years it is possible to distinguish four distinct types of imagery skills: image generation, maintenance, inspection (scanning), and rotation. The distinctiveness of these skills is supported by research showing that the vividness of the mental image, the main feature in the generation and maintenance of mental images, is not correlated with visual-spatial ability measured by tests based on the rotation and the synthesis of figures.

Implications for Practice

Eckhoff and Urbach (2008) maintained that imagery is crucial for educators to promote creative thinking in informal and formal learning environments. Imagery promoted creative language skills linked to poetry writing. The spontaneous use of imagery in preschool playing behavior was predictive of creative skills in older children and adults. The link between imagery and creativity also appeared to be in the opposite direction: creativity induced a more frequent and complex use of mental imagery.

These findings support the attempts to enhance creativity by means of training activities based on imagery. This can be achieved both by devising structured educational programs aimed at improving mental visualization skills and at addressing such skills to the accomplishment of creative task (Mc Kim 1980) and by inducing people to develop the spontaneous tendency to rely on mental images when creativity is needed in everyday-life situations (Shone 1984).

Western culture has generally underestimated the power of visual thinking. In many theories, both philosophical and psychological, images are considered preparatory or auxiliary forms of thinking, which play the role of substitutes of more sophisticated forms, such as logical, verbal, or mathematical thinking. Imagery is viewed either as a set of cognitive representations and strategies that precedes the development of nonvisual ways of reasoning (a sort of "springboard" for abstract thinking) or as a sort of "crutch" which abstract thinking relies on when one is in trouble (e.g., when he/she needs to explain a concept to a person for whom it is difficult to follow logical arguments).

In other cultures, however, is not so. For example, in certain nomadic tribes, shepherds are aware of the lack of some sheep in the herd, not counting the animals one by one but through a simple "look" thrown to the flock: a function that Western schools have accustomed pupils to play through a mathematical procedure is here performed through an intuitive and fast visual process. This explains why in some cultures children's games also insist on the development of capacities of the latter type. For example, in some parts of Africa, a childhood favorite play is to build piles of stones and then determine their number simply by looking at them: the child who approached more to the exact number of stones piled up won the game. Imagery strategies are used also for solving complex problems. For example, for the inhabitants of the Polynesian islands, orientation in navigation is established by means of a spatial mental model, rather than through a complex system of calculations.

There are populations who pay very special attention to images, in particular to images that occur while dreaming. Reporting and processing dreams are an important part of youth education in some tribes of Central Malaysia. Every morning, children and adults talk about the dreams of the night. The aim is to help those who have made a dream in which negative elements (fear, death, and so forth) occurred to take advantage of these experiences to turn them, in reality, toward positive goals. In fact, who told the dream that was later the subject of the discussion within the tribe is invited to dream it again differently during the day. From this second dream, the individual has to come back with something creative that could be communicated to others so to accomplish an action, an inspiration for a piece of art (a poem, a song, a dance, a sculpture, a story), or the solution of a problem. For example, a child has dreamed of meeting a scorpion on the path and escaping from it. The child is then asked to revise the dream during the day. After several attempts, the child communicates to the elders of the tribe that he reached the desired outcome: In his mind, he saw the scorpion that blocked the passage; he went to call his older brother, who took the scorpion by the tail and let the path free.

Educational practices in various Eastern cultures make use of imagery as a technique to help one to overcome emotional or relational problems creatively. This is an example. There was a famous wrestler called O-nami (literally, Great Waves). He was the strongest, but when he had to compete in front of an audience, his shyness made him weak enough to be defeated by the worst of his colleagues. O-nami was entrusted to the wisdom of his Zen master, who thought to solve the problem in this way: "Your name is Great Waves – he said – So, next night you will stay in the temple and you will imagine to be those waves, those huge waves that destroy anything they meet in front of them. Do so and you will be the greatest wrestler in the country." O-nami meditated the next night: He was no longer the fighter, but he imagined to be a great wave. In the morning, O-nami participated in the wrestling contests and won.

From all the suggestions reported above, it is clear that visual mental images can be highly effective to inspire insights and original ideas to be applied in everyday life, and as a consequence, people should be trained to use visualization creatively.

Conclusions and Future Directions

Training procedures and operational guidelines are extremely useful to strengthen both imagery skills per se and to improve their use to foster creative thinking. Few experimental studies have been carried out to assess the capacity of the imagery training to increase creativity. However, existing research data indicate that it is possible to improve the flexibility with which people perform mental figural synthesis and originality of the products that are generated in this way. In fact, with regard to the imaginative strategies followed, the comparison between pre- and posttraining showed that experimental groups had test-retest differences which reflect and increased mobility and transformation of mental images in comparison to control groups. Overall, data suggested that imagery training induces a greater dynamism for imaginative synthesis. One may conclude that the repeated exercise of the combination of images, far from generating repetition and mechanical executions, can stimulate new and more creative solutions, supported by enhanced flexibility in the processing of figures.

Cross-References

▶ Imagination
▶ Metaphorical Reasoning and Design Creativity: Consequences for Practice and Education

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Imagination

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Synonyms

Chronesthesia; Daydreaming; Dreaming; Dynamic generation; Episodic future thought; False memory; Forecast; Hypothetical thinking; Imagery; Make-believe; Mental imagery; Mental modeling; Mental simulation; Picturing; Pretend play; Pretense; Procedural modeling; Prospection; Retrodiction; Retrospection; Supposition; Synthesis; Thought experimentation; Visualization

Imagination: A Cognitive Science Approach

The term "imagination" is used in two general senses. The first is synonymous with "creativity." The second sense, and the one that will be explored in this entry, refers to the ability to create and experience virtual situations in the mind that are independent of sensory input. For example, a person might picture what a new sofa would look like in her living room, dream of walking through a jungle, or entertain a hypothetical situation in which the Renaissance never happened.

Our imaginative abilities have given our species a great evolutionary advantage. In the Upper Paleolithic, humans were able to produce tools days before using them, created dwellings designed for lengthy occupation, and made stylized tools, cave paintings, and burial practices. All of these practices seem to require imagination, typically imagining possible futures. Harris (2000, pp. ix–xi) suggests that this might have been key to the success of our species, particularly in competition with the Neanderthals, who, lacking these behaviors, were likely to have lacked imaginative abilities.

Imagination can be roughly grouped into two kinds: sensory and suppositional (Goldman 2006). Sensory imagination refers to internally generated sensory-like imagery in the head, such as picturing a tree, hearing a voice or music in your head, or imagining the smell of cinnamon. Sensory imagination can be completely internal, as when dreaming, which is a kind of natural virtual reality. Imagination can also occur in the presence of normal perception, such as when, with one's eyes open, one imagines a new color on a wall. In these instances, imagination works as a kind of augmented reality. Though not related to the senses, motor and emotional imagery is often included in this category, such as imagining running or being happy (Markman et al. 2009, Chapter 18). Sensory imagination uses the same parts of the brain as perception (Kosslyn 1994), just as motor imagery uses the same brain areas as action (Markman et al. 2009, Chapter 2). As such, imagery can interfere with perception (Kosslyn 1994). For example, if you are trying to see something while you are vividly imagining something else, your perception will be compromised.

Sensory imagination also goes by the name of "mental imagery" and has received a great deal of scientific investigation, particularly for visual imagery.

There are two hypothesized formats that can represent visual information. The first, descriptive representations (Kosslyn 1994), are sentence-like statements, such as "ocelot in tree." The second format, depictive representations, represents visual things at the level of points of color at particular locations. In computer graphics, this is known as a "bitmap." In a bitmap, there is no explicitly represented content. To know that an ocelot (a South American wild cat) is in the picture, perceptual processes would need to be applied to the bitmap. In the descriptive representation, by contrast, the existence of the ocelot is explicit, as the symbol representing an ocelot would be present in the description.

The theory of visual mental imagery (which is somewhat controversial) holds that the human brain represents visual memories as descriptions but can transform those descriptions into depictions (called enactment-imagination, or e-imagination by Goldman 2006). Although the processes that do this are still poorly understood, the end result is theorized to be an activation pattern in the spatially organized neurons in the visual cortex (Kosslyn 1994).

It is generally assumed that perceptual reinterpretation is the function of visual mental imagery. For example, when asked how many chairs one has in one's house, one typically will need to visualize a walk-through and count the chairs imagined to eventually arrive at an answer. After doing this once, however, the number of chairs in the house is stored as a descriptive memory and might be retrieved in the future without needing to use mental imagery and counting. Studies supporting this theory show that the same areas of the brain used for visual perception are used when generating mental imagery. However, behavioral evidence for people's ability to use mental imagery for reperception has been inconsistent.

Although psychologists have studied how people can perceive and manipulate mental images and their effects on sport performance and depression, there has been relatively little work on how these images are generated and composed from descriptive long-term memories. Open questions include the following: What determines the relative amount of confabulation and memory retrieval in recollection? Does a mental image require refreshing from long-term memory? Is the answer different if the image is rotating? When imagining a new scene, such as a playground, how does the mind determine when to stop adding objects to the imagined scene? How do we keep from believing the things we imagine (e.g., if we imagine we can fly, how do our minds keep track of what is imagined and what is real)? How do causal mental models interact with visual memory for mental simulation and planning? When one imagines oneself doing something, when do they take a first-person point of view (in which it appears as it would if they were doing it), and when do they take a third-person point of view (as it might appear in a video)?

Suppositional imagination need not have any sensory element. It is pretense, or the hypothetical entertaining of counterfactuals (Markman et al. 2009, section III). For example, one might imagine the stock market crashing, how someone feels (also known as empathy, using theory of mind, or affective forecast), what the world would have been in like if President Kennedy had not been assassinated, or that one owned a pet ocelot.

Many real-world instances of imagination involve both sensorimotor and suppositional elements. This kind of imagination is studied with different subfield labels. "Mental modeling" studies the working internal representations people have and create to understand systems such as calculators and written descriptions. It has important implications for educational and interface design. "Chronesthesia" is mental time travel, that is, imagining the past (called recollection, retrodiction, or retrospection) or the future (called episodic future thought, forecast, or prospection). "Mental simulation" is a person's sensory imagery informed by nonsensory understanding of systems, such as physical restraints. One might use mental simulation to decide if a sofa could fit through a given door. Mental simulation in a scholarly context is often called "thought experimentation." "Pretend play" is treating objects as though they are something else, as when children use stones and sticks to represent teacups and people or when they have imaginary companions (Markman et al. 2009, Chapter 14; Harris 2000).

More familiar phenomena such as planning, dreaming, daydreaming, and fantasizing are subjects of study that also use both sensory and suppositional imagination.

Imagination is also studied with an eye toward how it can affect performance, memory, and mental outlook. Imagining doing something before you do it facilitates performance. Mental practice has been found to be helpful for over 20 sports, including pure muscle strengthening. Use of imagination can alter stereotypes (Markman et al. 2009, Chapter 3).

When we remember things that have happened to us, although it feels sometimes that we are recalling a veridical representation of what happened, it is actually an imaginative reconstruction based on a few accurately remembered elements. In fact, every time we remember an incident, we subtly change the memory itself. This benefit of imagination is also a drawback, as we sometimes remember our imaginings as real events. This happens not only upon recall of actual memories but when asked to imagine a completely new episode. There is a large literature describing this “false memory” effect (Garry et al. 1996).

Another drawback is that when planning for the future, one of the major uses of imagination, people tend to underestimate task-completion times (Buehler et al. 1997). This is, in part, because when imagining another situation, perhaps in another time (e.g., the future) or place (e.g., California), we imagine the only difference being the one under consideration or the most salient feature. For example, people will mistakenly believe they would be happier living in California when the good weather is the most salient difference with where they are currently living (Schkade and Kahneman 1998) and will fail to imagine unforeseen but inevitable difficulties that interfere with plans in the future (Lam et al. 2005).

Computer scientists have done work to automate imaginative abilities with computer programs (Ebert et al. 2002). Although most computer graphics are created by human designers, scientists in the graphics and artificial intelligence fields have made programs that imagine visual scenes. This work is referred to as synthesis, procedural synthesis, dynamic generation, procedural modeling, and visualization. Some programs create plants, others faces, mountains, planets, or cities. They have applications for the automatic creation of virtual environments and characters for art, entertainment (e.g., movies or computer games), and training.

Of the variety of methods that these computer systems use, I will describe grammars, fractals, and explicit knowledge.

A grammar is a set of rules that describe acceptable expressions. In language, a successful grammar will generate only grammatical sentences in a language. In procedural modeling of a city, the grammar would consist of rules describing, for example, what buildings can go next to others and what kinds of windows would appear on which buildings. In music, a grammar might describe what notes are allowed to follow other notes.

Fractals are shapes that are self-similar at different scales. For example, rivers often have a fractal structure, where the small branches upstream resemble the larger branching structures downstream. Fractals are particularly useful for describing natural scenes such as plants and mountains, as fractal geometry often appears in nature. In general, fractal geometry appears whenever a system needs to maximize the area of something in a finite space.

The benefit of grammatical and fractal descriptions is that they can generate many combinations of acceptable outputs with a relatively small description. The downside is that it is difficult for them to take larger context and common sense into effect.

Finally, procedural modeling can be done with explicitly encoded knowledge. For example, to describe a building, the knowledge base might have representations indicating that all rooms must have doors and that ceilings need to be higher than six feet tall. The system can then generate new buildings that satisfy the constraints in the knowledge base. The downside of this is that the knowledge takes a great deal of time and effort to put into the system. In particular, large knowledge bases are prone to contradicting themselves and become unwieldy.

Conclusion and Future Directions

We know little of how human minds decide what goes into an imagined scene (with the exception of the mental modeling literature) and how these things are transformed into mental imagery. Computer scientists have developed methods for automating the generation of scene descriptions as well as their visual rendering.

We know a fair bit about the nature of mental images in people, what we can and cannot do with them (e.g., rotation, reperception), and how they affect our mental states, creative processes, and performance.

However, as a scholarly discipline, imagination is fragmented by methodology (e.g., philosophical argumentation, psychological experimentation, and computer science program implementation) and phenomena of interest. In the future, interdisciplinary cross talk should shed light on the unexplored areas of this important topic.

Cross-References

▶ Cognition of Creativity
▶ Imagery and Creativity
▶ Nature of Creativity

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In Search of Cognitive Foundations of Creativity

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Synonyms

Abstract intelligence; AI; Brain science; Cognitive computing; Cognitive informatics; Cognitive model; Computational intelligence; Creation; Creativity; Denotational mathematics; Invention; Mathematical model

Introduction

Creativity is a gifted ability of humans in thinking, inference, problem solving, and product development (Beveridge 1957; Csikszentmihalyi 1996; Holland et al. 1986; Matlin 1998; Smith 1995; Sternberg and Lubart 1995; Wang et al. 2006; Wilson and Keil 1999). A creation is a new and unusual relation between two or more objects that generates a novel and meaningful concept, solution, method, explanation, or product. Creativity has been perceived diversely and, sometime, controversially in psychology, intelligence science, knowledge science, and cognitive science (Csikszentmihalyi 1996; Guiford 1967; Leahey 1997; Mednich and Mednich 1967; Matlin 1998; Sternberg and Lubart 1995; Wallas 1926; Wang et al. 2009a, b). Creativity may be treated as a form of art that generates unexpected results by unexpected paths and means. It may also be modeled as a scientific phenomenon that generates unexpected results by purposeful pursuits. Matlin in 1998 perceived that creativity is a special case of problem solving (Matlin 1998). From this perspective, he defined creativity as a process to find a solution that is both novel and useful. However, problem solving often deals with issues for a certain goal with unknown paths. Therefore, creation is much more divergent than problem solving, which deals with issues of both unknown goals and unknown paths for a problem under study.

Human creativity may be classified into three categories known as the abstract, concrete, and art creativities. A scientific (abstract) creation is usually characterized by a free and unlimited creative environment where the goals and paths for such a creation is totally free and unlimited, while an engineering (concrete) creation is characterized by a limited creative environment where a creative problem solving is constructed by a certain set of goals, paths, and available conditions. The third form of creation is the art (empirical) creation that generates a novel artifact in order to attract human sensorial attention and perceptual satisfactory.

This entry formally investigates into the cognitive mechanisms of creation and creativity as one of the most fantastic life functions. The cognitive foundations of creativity are explored in order to explain the space of creativity, the approaches to creativity, the relationship between creation and problem solving, and the common attributes of inventors. A set of mathematical models of creation and creativity is established based on the cognitive properties of human knowledge.

Cognitive Foundations of Creativity

Human creativity as a gifted ability is an intelligent driving force that brings something into existence.

Definition 1. *Creativity* is the intellectual ability to make creations, inventions, and discoveries that brings novel relations, entities, and/or unexpected solutions into existence.

Definition 2. A *creation* is a cognitive process of the brain at the higher cognitive layer that discovers a new relation between objects, attributes, concepts, phenomena, and events, which is original, proven true, and useful.

Taxonomy of Creations

Various creativities and creation processes may be identified such as free/constrained creativity, analytic/synthetic creativity, inference-based creativity, problem-solving-based creativity, and scientific/technological/art creativity. The entire set of creativities can be classified into three categories according to their creation spaces, approaches, and problem domains as summarized in Table 1.

It is conventionally perceived that creations and discoveries are usually concrete and tangible. However, more creations and discoveries are abstract or intangible, such as new languages, theories, methods, and doctrines. Therefore, it is noteworthy that a much larger portion of human cognition information is abstract knowledge and wisdom beyond the base-level concrete knowledge about the physical world in the knowledge hierarchy (Wang 2009d). The abstract creations

In Search of Cognitive Foundations of Creativity, Table 1 Taxonomy of creativity and creation

No.	Category	Type of creation	Description	Reference
1	Creation space	Free	A creation process with an unlimited creation space S_c, which is determined by unconstrained sets of alternatives N_a, paths N_p, and goals N_g	Def. 4
2	Creation space	Constrained	A creation process with a limited creation space S'_c where one or more conditions such as the goals N'_g, paths N'_p, or alternatives N'_a, are limited	Def. 5
3	Approach	Analytic	A top-down creation process that discovers a novel solution to a given problem by deducing it to the subproblem level where new or existing solutions may be found	Def. 7
4	Approach	Synthetic	A bottom-up creation process that discovers a novel solution to a given problem by inducting it to a superproblem where new or existing solutions may be found	Def. 8
5	Approach	Inference-based	An abstract creativity based on the deductive, inductive, abductive, and analogy inference methodologies	Def. 9
6	Approach	Problem-solving-based	A novel solution for a given problem by creative goals and/or creative paths	Fig. 1
7	Domain	Scientific (abstract)	A free and unlimited creative environment where the goals and paths for such a creation is totally free and unlimited	Section "Introduction"
8	Domain	Technological (concrete)	A limited creative environment where a creative problem solving is constructed by a certain set of goals, paths, and available conditions	Section "Introduction"
9	Domain	Art (empirical)	A free and unlimited creative environment where a novel artifact is generated that attracts human sensorial attention and perceptual satisfactory	Section "Introduction"

and discoveries are formed as a result of human intelligence by creatively mathematical, logical, and causal reasoning.

The Space of Creativity

Definition 3. A *creation space* Θ is a Cartesian product of a nonempty set of baseline *alternatives* A, a nonempty set of *paths* P, and a nonempty set of *goals* G, i.e.,

$$\Theta \triangleq A \times P \times G \tag{1}$$

where $\times$ represents a Cartesian product.

On the basis of the creation space, the nature of free and constrained creativities can be explained.

Definition 4. A *free creativity* is a creation process with an unlimited creation space S_c, $S_c \subseteq \Theta$, which is determined by unconstrained sets of alternatives N_a, paths N_p, and goals N_g, i.e.,

$$\begin{aligned} S_c &\triangleq N_a \bullet N_p \bullet N_g \\ &= |A| \bullet |P| \bullet |G| \end{aligned} \tag{2}$$

Equation 2 indicates that the creative space of a free creation may very easily turn to be infinitive, because N_a, N_p, and N_g can be extremely large. Therefore, the cost or difficulty of creation is often extremely high. That is, only mechanical and exhaustive search is insufficient for potential creations and discoveries in most cases, if it is not directed by heuristic and intelligent vision. In other words, creations and discoveries are usually achieved only by chance of purposeful endeavors of prepared minds, where an appreciation of highly unexpected result is always prepared. This is also in line with the empirical finding of Pasteur as stated that "Creation always favorites prepared minds (Beveridge 1957)."

Definition 5. A *constrained creativity* is a creation process with a limited creation space S'_c, $S'_c \subseteq S_c \subseteq \Theta$, where one or more conditions such as the goals N'_g, paths N'_p, or alternatives N'_a, are limited, i.e.,

$$S'_c \hat{=} N'_a \bullet N'_p \bullet N'_g = |A'| \bullet |P'| \bullet |G'|, \; A' \subset A \wedge P' \subset P \wedge G' \subset G \quad (3)$$

Usually, a scientific and art creation is characterized as a free creation process, while an engineering creation is featured as a constrained creation process.

Approaches to Creativity

A variety of typical approaches to creation have been identified in literature, such as divergent production (Guiford 1967), remote association test (Mednich and Mednich 1967), analysis/synthesis (Wang et al. 2006), and inferences (Wang 2007c). Wallas identified five stages in a creative process (Wallas 1926) as follows: (1) *preparation*, (2) *incubation*, (3) *insight*, (4) *evaluation*, and (5) *elaboration*. Csikszentmihalyi pointed out that creativity can best be understood as a confluence of three factors: a *domain* that consists of a set of rules and practices; an *individual* who makes a novel variation in the contents of the domain; and a *field* that consists of experts who act as gatekeepers to the domain, and decide which novel variation is worth adding to it (Csikszentmihalyi 1996).

The approaches to creativity can be categorized into three categories known as the analytic, synthetic, and inference approaches.

Definition 6. The *analytic creativity* is a top-down creation process that discovers a novel solution to a given problem by deducing it to the subproblem level where new or existing solutions may be found.

Definition 7. The *synthetic creativity* is a bottom-up creation process that discovers a novel solution to a given problem by inducting it to a superproblem where common or general solutions may be found.

Definition 8. The *inference creativity* is an abstract creation process based on the deductive, inductive, abductive, and analogy inference methodologies.

Wallas (1926), Beveridge (1957), and Smith (1995) pointed out an important phenomenon in human creativity known as *incubation*.

Definition 9. *Incubation* is a mental phenomenon that a breakthrough in creation and problem solving may not be achieved in continuous and intensive thinking and inference until an interrupt or interleave action is conducting in a relax atmosphere.

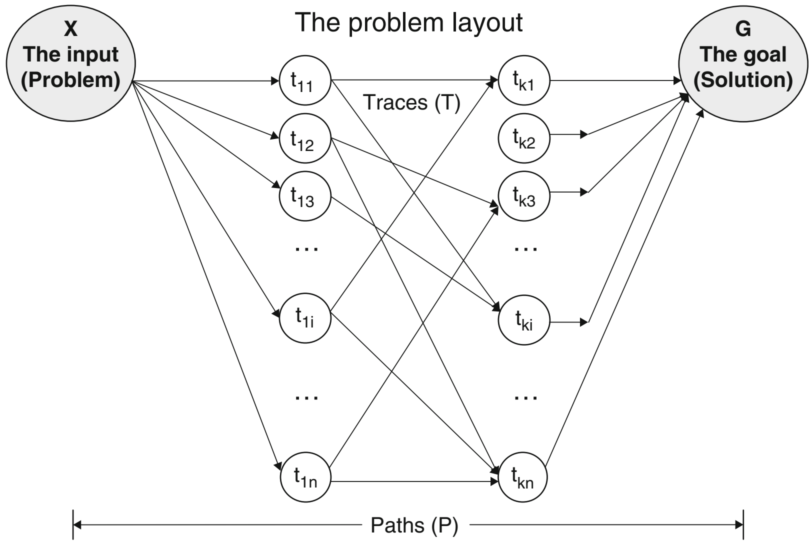
Incubation is often a necessary process in the middle of creation and discovery. The cognitive mechanism of incubation can be explained by the subconscious processes of the brain (Wang2012d) related to thinking and inference, such as perception, imagination, and unintentional search, which are involved in complex thinking and long chains of inferences. Whenever there is an impasse, incubation may often lead to a creation under the effect of active subconscious processes. Incubation has been observed playing an active role in the creation process by researchers.

As creativity is a novel or unexpected solution to a given problem, a creation may be perceived as a special novel solution in problem solving where the problem, goal, or path is usually unknown. Therefore, the study on creativity can analogue to the theory of problem solving (Wang and Chiew 2010). The solutions S and paths P in problem solving can be illustrated in Fig. 1.

In the layout of Fig. 1, a creation is a search for the unknown goals, unknown paths, or both under a given problem or a set of coherent problems. Therefore, creations can be classified into the categories of goal-driven, method-driven, and problem-driven. Among them, the problem-driven creation is a full open process because both goals and paths are unknown for the given problem.

Formal Models of Creation and Creativity

On the basis of the discussions on the cognitive foundations of creativity, a more rigorous



In Search of Cognitive Foundations of Creativity, Fig. 1 The layout of the solution space in problem solving

treatment of it can be developed in this section on the mathematical models of creation and creativity.

The Tree Structure of Human Knowledge

It has been empirically observed that the tree-like architecture is a universal hierarchical prototype of systems across disciplines of not only science and engineering but also sociology and living systems. The underlying reasons that force systems to take hierarchical tree structures are as follows: (a) the complexity of an unstructured system can easily grow out of control, (b) the efficiency of an unstructured system can be very low, and (c) the gain of system by coordination may diminish when the overhead for doing so is too high in unstructured systems.

An ideal structural form for modeling a knowledge system and the creation space of humans is known as the complete tree (Wang 2007a).

Definition 10. A *complete n-nary tree* $T_c(n, N)$ is a normalized tree with N nodes in which each node of T_c can have at most n children, each level k of T_c from top-down can have at most n^k nodes, and all levels have allocated the maximum number of possible nodes, except only those on the rightmost subtrees and leaves.

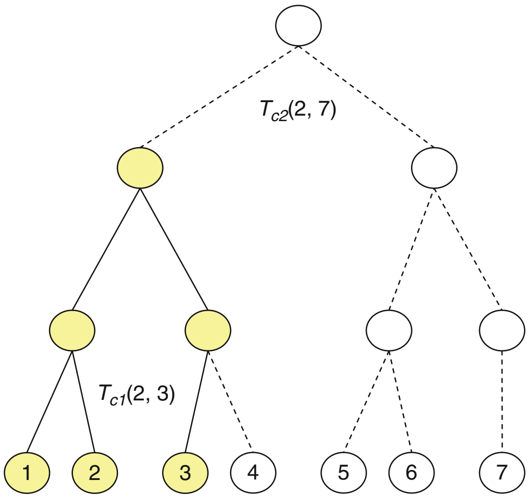
It is noteworthy in Definition 10, a tree said to be *complete* means that all levels of the tree have been allocated the maximum number of possible nodes except those at the leave level and the rightmost subtress. The advantage of complete trees is that the configuration of any complete n-nary tree $T_c(n, N)$ is uniquely determined by only two attributes: the unified *fan-out* n and the number of leave nodes N at the bottom level. For instance, the growth of a system from complete tree $T_{c1}(n_1, N_1) = T_{c1}(2, 3)$ to $T_{c2}(n_2, N_2) = T_{c1}(2, 7)$ is illustrated in Fig. 2.

Theorem 1. The *generic topology of normalized systems* states that systems tend to be normalized into a hierarchical structure in the form of a complete n-nary tree.

Systems are forced to be with tree-like structures in order to maintain equilibrium, evolvability, and optimal predictability. The advantages of the hierarchical tree structure can be formally described in the following corollary.

Corollary 1. *Advantages of the normalized tree* architecture of systems are as follows:

(a) *Equilibrium*: Looking down from any node at a level of the system tree, except at the leave level, the structural property of fan-out or the



In Search of Cognitive Foundations of Creativity, Fig. 2 The growth of a complete tree of hierarchical systems

number of coordinated components are the same and evenly distributed.

(b) *Evolvablility*: A normalized system does not need to change the existing structure for future growth.

(c) *Optimal predictability*: There is an optimal approach to create a unique system structure $T_c(n, N)$ only determined by the attributes of the unified fan-out n and the number of leave nodes N at the bottom level.

Based on the model of the complete tree, the topology of the knowledge space for creation can be denoted as a concept tree with each node of the n-nary complete tree as a concept.

Definition 11. A *concept tree*, $CT(n, N)$, is an n-nary complete tree in which all leave nodes N represent a *meta-concept*, and other nodes beyond the leave level represent *superconcepts*.

For instance, a ternary CT, $CT(n, N) = CT(3, 24)$, is shown in Fig. 3. Since the CT is a complete tree, when the leaves (components) do not reach the maximum possible numbers, the right most leaves and subtrees of the CT will remain open.

A set of useful topological properties of CT is identified as summarized in (Wang 2007a). CT can be used to model and analyze the knowledge space of creativity. It also shows that a well-organized knowledge tree in the brain is helpful for creation, because it can greatly reduce the cost and complexity for search.

Measurement of Creativity

On the basis of CT, the extent of creativity can be quantitatively analyzed by the relational distances between two or more concepts in the concept tree as shown in Fig. 3.

Definition 12. The *relational distance* of a creation, δ, is a sum of the distances δ_1 and δ_2 of a pair of concepts or objects c_1 and c_2 to their closest parent node c_p in a given concept tree CT, i.e.,

$$\begin{aligned}\delta(c_1, c_2) &\triangleq \delta_1 + \delta_2 \\ &= |c_1 \leftrightarrow c_p| + |c_2 \leftrightarrow c_p|\end{aligned} \tag{4}$$

where $\delta_i = |c_i \leftrightarrow c_p|$ denotes the distance between a concept c_i and its most closed parent concept c_p shared with the other given concept.

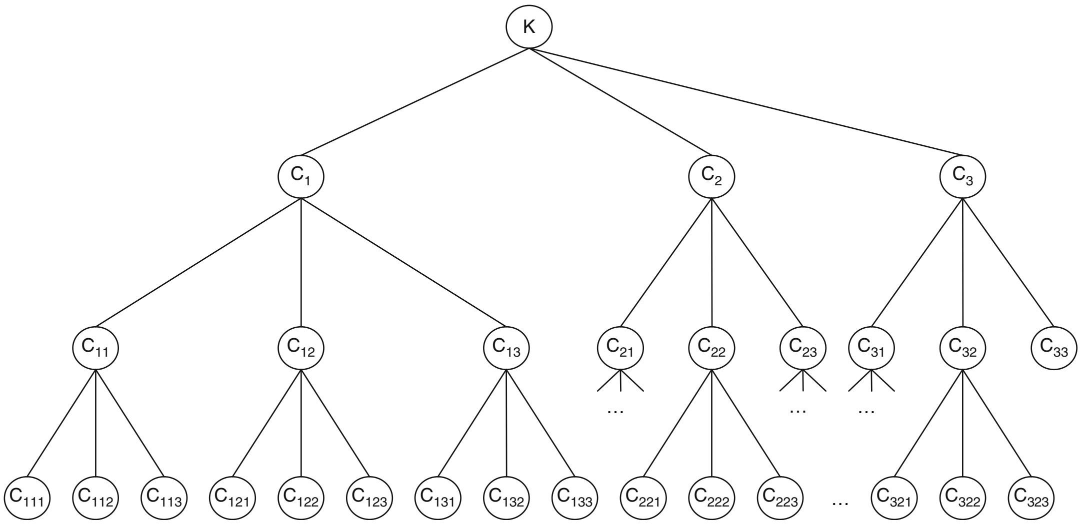
According to Definition 12, the minimum creation distance $\delta_{\min}(c_1, c_2) = 2$ when any pair of concepts at the same level of the CT under the same parent node.

Definition 12 can be extended to a more general case where multiple concepts are involved in a creation based on a given CT as follows.

Definition 13. The *general relational distance* of a creation, δ, is a sum of $n, n > 1$, subdistances δ_i, $1 \le i \le n$, between all individual concepts c_i and the closest parent node c_p in the given knowledge space modeled by a CT, i.e.,

$$\begin{aligned}\delta &\triangleq \sum_{i=1}^{n} \delta_i \\ &= \sum_{i=1}^{n} |c_i \leftrightarrow c_p|\end{aligned} \tag{5}$$

Example 1. Given a knowledge space modeled by a CT as shown in Fig. 3, any potential pairwise



In Search of Cognitive Foundations of Creativity, Fig. 3 A ternary concept tree $CT(3, 24)$

or multiple creation distances can be determined according to Definition 13 as follows:

$$\begin{aligned} \delta(c_{111}, c_{113}) &= |c_{111} \leftrightarrow c_{11}| + |c_{113} \leftrightarrow c_{11}| \\ &= 1 + 1 = 2 \\ \delta(c_{121}, c_{323}) &= 3 + 3 = 6 \\ \delta(c_{111}, c_{113}, c_{121}, c_{323}) &= 3 + (3 - 2) + (3 - 1) \\ &\quad + 3 = 9 \end{aligned} \tag{6}$$

It is noteworthy that the creativity of a creation is proportional not only to its relational distance but also to its originality and usefulness.

Definition 14. Assume $O = \{0, 1\}$ is a Boolean evaluation for the false or true originality of a creation, M the total number of nodes at level k out of the d level creation space for a given CT. Then, the extent of *creativity* C is a product of the creation distance δ, the size of the creation space M, and its originality O, i.e.,

$$\begin{aligned} C &\triangleq (\delta \bullet M) \bullet O \\ &= \delta O \bullet \sum_{i=0}^{d-k} n^i \end{aligned} \tag{7}$$

where n is the fan-out of the given CT.

Example 2. Based on the three solutions as given in Example 1, assume their originalities $O_1 = O_2 = O_3 = 1$, then the creativities of the three solutions can be quantitatively evaluated as follows:

$$\begin{aligned} C_1 &= \delta_1 O_1 \bullet \sum_{i=0}^{d-k_1} n^i = 2 \bullet 1 \bullet \sum_{i=0}^{3-2} n^i = 2 \bullet (1+3) = 8 \\ C_2 &= \delta_2 O_2 \bullet \sum_{i=0}^{3-1} n^i = 6 \bullet (1+3+9) = 78 \\ C_3 &= \delta_3 O_3 \bullet \sum_{i=0}^{3-0} n^i = 9 \bullet (1+3+9+27) = 360 \end{aligned} \tag{8}$$

Obviously, Case 3 represents the greatest creativity among the three cases.

Corollary 2. The creativity of a creation is proportional to the product of the creative distance and the size of the creation space, subject to a satisfactory originality.

Corollary 3. The larger the size of the creation space, the greater the chance for the generation of a creation.

Further elaborations of Corollary 3 will be discussed on the relationship between the creation space and knowledge properties in the following section.

Knowledge Science Foundations of Creativity

On the basis of Corollary 3, it is recognized that the knowledge spaces and capacities of individuals may significantly influence the chance of one's creativity. According to the object-attribute-relation (OAR) model (Wang 2007d) of the internal knowledge representation in the brain, knowledge of an individual can be modeled as a concept network, which is configured by a set of concepts and their semantic relations (Wang 2007d, 2008b).

Definition 15. The *knowledge space K* of an individual is proportional to both the number of concepts, n, and the number of their pairwise relations in one's long-term memory (LTM), i.e.,

$$K = C_n^2 = \frac{n!}{2!(n-2)!} \qquad (9)$$

where higher-order relations among concepts can be reduced into multiple pairwise relations.

A fundamental question in knowledge science is to what extent the differences of knowledge spaces could be among individuals. This question can be modeled by contrasting an expert with coherently m disciplinary knowledge K_Σ and those of m experts with separated single disciplinary knowledge K_m. A quantitative analysis of this problem, i.e., K_Σ vs. K_m, is formally described in the following principle.

Theorem 2. *The power of multidisciplinary knowledge* states that the *ratio of knowledge space* r_Σ between the knowledge of an expert with coherently m disciplinary knowledge K_Σ and that of a group of m experts with separated single disciplinary knowledge K_m is:

$$r_\Sigma(m,n) = \frac{K_\Sigma}{K_m} = \frac{C_{m\bullet n}^2}{\sum_{i=1}^{m} C_n^2} = \frac{\frac{(mn)!}{2!(mn-2)!}}{\frac{m(n)!}{2!(n-2)!}} \approx \frac{(mn)^2}{mn^2} = m \qquad (10)$$

where n is the number of *average knowledge objects* (or concepts) in the discourses of multiple disciplines.

Theorem 2 indicates that the difference of knowledge spaces in term of the ratio, K_Σ vs. K_m, is m. In other words, an expert with coherently m disciplinary knowledge has a knowledge space that is m times greater than the sum of the group of m experts with separated single disciplinary knowledge. Based on Theorem 2, a new question may be raised as follows: What is the difference between the knowledge spaces of the m disciplinary expert, K_Σ, and that of an individual, K_1, from the group K_m? This problem can be reduced to one that seeks K_Σ vs. K_1 as stated in the following corollary.

Corollary 4. The *first property of knowledge* is that the *ratio of knowledge space* r_1 between the knowledge of an expert with coherently m disciplinary knowledge K_Σ and that of an expert with single disciplinary knowledge K_1 is:

$$r_1(m,n) = \frac{K_\Sigma}{K_1} = \frac{C_{m\bullet n}^2}{C_n^2} \approx \frac{(mn)^2}{n^2} = m^2 \qquad (11)$$

Corollary 5. *The second property of knowledge* is that the more the interdisciplinary knowledge one acquires, the larger the knowledge space, and hence the higher the possibility for creation and invention.

Corollary 5 provides a rational explanation for another fundamental question in knowledge science: Which is more important in knowledge acquisition if there is a need to choose the preference from broadness and depth for an individual's knowledge structure? According to Definition 15, Theorem 2, and Corollaries 4 and 5, a rigorous answer to this question can be formally expressed in the following corollary.

Corollary 6. *The third property of knowledge* is that, in knowledge acquisition toward creativity and naval problem solving, broadness is more important than depth in one's knowledge structure.

The above corollary can be proven by Eqs. 10 and 11 as provided in Theorem 2 and Corollary 4, which is perfectly in line with the philosophy of holism. Corollary 6 also explains why most interesting problems in research are often at the edges of conventional disciplines. Therefore, the maintenance of a global and holistic view is one of the fundamental insights of scientific creation and knowledge development.

Analyzing the complexities and speeds of knowledge creation and acquisition, it is noteworthy that, on one hand, the creation of new knowledge requires tremendous time, effort, and ingenuity. However, on the other hand, learning and acquisition of such knowledge are relatively easy, fast, and only need normal intellectual ability. For example, the development of mathematics from arithmetic to calculus had to go through several centuries. However, all undergraduate students can learn and use all of them in the first year of university studies. In another instance, the digital computers have been created and developed as a result of over 60-year effort. However, digital computer architectures and principles can be understood and learnt by students and practitioners with a few months training. These phenomena in knowledge science can be described more formally as follows.

Corollary 7. The *fourth property of knowledge* is that the *effort* of knowledge creation, E_c, is far more greater than that of its acquisition, E_a. Therefore, the *speed* of knowledge creation, V_c, is far more slower than that of its acquisition, V_a, i.e.,

$$\begin{cases} E_c \gg E_a \\ V_c \ll V_a \end{cases} \tag{12}$$

Corollary 7 reveals another significant property of knowledge. That is, although human brains are capable to pragmatically and systematically learn existing knowledge, there is no systematical and predictable approach to create and discover new knowledge. This is because creativities that result in new knowledge are driven by curiosity and random processes, often by chances of well-prepared minds within an extremely large state space and capacity of synergized knowledge. It is noteworthy that the creation of knowledge is a conservative process, which establishes a novel relation between two or more objects or concepts by searching and evaluating a vast space of possibilities in order to explain a set of natural phenomena or abstract problems (Wang 2009d). Since the memory capacity of human can be as high as $10^{8,432}$ bits as quantitatively estimated in (Wang and Wang 2006), the complexity in search for new knowledge is necessarily infinitive if not a short cut shall be discovered by chance during extensive and persistent thoughts. However, the acquisition of knowledge is simply a process of adding a new relation into LTM of an existing knowledge structure. Therefore, the effort for acquiring a piece of existing knowledge is much lower than that of knowledge creation.

Attributes of Inventors and Researchers

A number of typical attributes sharing by inventors have been studied by Beveridge (1957). In his book on *The Art of Scientific Investigation* (Beveridge 1957), Beveridge perceived that the research scientists are fortunate in that in their work they can find something to give meaning and satisfaction to life. Beveridge identified a set of attributes required for researchers and inventors, such as enterprise, curiosity, initiative, readiness to overcome difficulties, perseverance, a spirit of adventure, a dissatisfaction with well-known territory and prevailing ideas, and an eagerness to try his own judgment, intelligence, imagination, internal drive, willingness to work hard, perseverance, and tenacity of purpose (Beveridge 1957).

In studies of inventive behaviors of creation in cognitive psychology, Sternberg and Lubart's (1995) elicited the following set of attributes of inventors known as intelligence, knowledge, motivation, appreciation, thinking style, and personality. Contrasting the two sets of attributes identifies by Beveridge and Sternberg/Lubart, it is interesting to note that the former would have understood scientific creation and invention deeper than the latter, because the former has much firsthand insight in research and discoveries than that of psychological observations on inventions.

Beveridge believed that an insatiable curiosity and love of science are the two most essential attributes of scientists. He pointed out that a good maxim for researchers is look out for the unexpected. He described that creators are those whose imaginations are fired by the prospect of finding out something never before found by man, and only for those will succeed who have a genuine interest and enthusiasm for discovery (Beveridge 1957). Another crucial attribute is perseverance or persistence as Pasteur wrote: “Let me tell you the secret that has led me to my goal. My only strength lies in my tenacity (Dubos 1950).” Pasteur has also revealed that “In the field of observation, chance favors only the prepared mind.”

It is noteworthy that the above investigations into research itself and researchers have overlooked a more significant attribute for creativity and discovery ability, i.e., *mathematical skills* or the *abstract inference capability*, because mathematics plays the ultimate role of meta-methodology in science and engineering creativities. Actually, mathematical skills and abstraction capability are the most important foundation for efficient scientific creation and invention, which enables a scientist to inductively generalize a hypothesis into the maximum scope, usually the infinitive or the universal domain based on limited empirical studies and/or mathematical/logical inferences. It is noteworthy that mathematics is the generic foundation of all science and engineering disciplines, as well as all scientific methodologies. To a certain extent, the maturity of a discipline is characterized by the maturity of its mathematical means (Bender 2000; Zadeh 1965, 1973; Wang 2007a, 2008a, 2008b, 2012a). One of the major purposes of cognitive informatics is to develop and introduce suitable mathematical means into the enquiry of natural intelligence, computational intelligence, cognitive science, and knowledge science. The studies on denotational mathematics (Wang 2008a, 2008b, 2012a), such as system algebra (Wang 2008c), concept algebra (Wang 2008b), RTPA (Wang 2002b, 2008d), inference algebra (Wang 2011a, 2012b), and visual semantic algebra (VSA) (Wang 2009b) are fundamental endeavors toward the formalization of the entities that are conventionally hard-to-be-formalized.

According to cognitive informatics (Wang 2002a, 2003, 2007b, 2009a, 2009c, 2010, 2011b, 2012c; Wang and Wang 2006; Wang et al. 2006, 2009a, b), significant cognitive attributes related to creativity are those of knowledge organizational efficiency, searching efficiency, abstract ability, appreciation of new relations, curiosity, induction, and categorization, because those identified in the list are fundamental cognitive mechanisms and processes of the brain at the layers of metacognition and meta-inference according to the layered reference model of the brain (LRMB) (Wang et al. 2006), which are frequently used in supporting higher-layer cognitive processes.

Conclusions and Future Directions

This entry has presented the cognitive process of creation and creativity as a gifted life function according to the layered reference model of the brain (LRMB) (Wang et al. 2006). The cognitive foundations of creativity, such as the space of creativity, the approaches to creativity, the relationships of creation with problem solving, and the attributes of inventors, have been explored. A set of mathematical models of creation and creativity has been developed based on the hierarchical structures and properties of human knowledge known as concept trees. The measurement of creativity has been quantitatively analyzed. The knowledge science foundations for creativity have been systematically explored.

In this entry, a creation has been defined as a novel and unexpected solution, which is a subset of the entire set of the creation space that meet the criteria of *novelty, originality*, and *utility*. The extent of creativity has been modeled as proportional to the product of the creative distance and the size of the creation space, subject to a satisfactory originality. Various creativities and creation approaches have been identified such as free/constrained creativity, analytic/synthetic creativity, inference-based creativity, problem-solving-based creativity, and scientific/technological/art creativity. The entire set of creativities has been classified into these three categories according to their creation spaces, approaches, and problem domains.

According to Corollary 7, as well as observing the history of science development and human civilization, it is noteworthy that a modern society must encourage creativity and inventions of their elites. Because they are the locomotive for knowledge advancement who form an indispensable engine for the society, based on it the entire society will be enhanced and benefited.

Corollary 8. The *fifth property of knowledge* is that whatever the champions can achieve in knowledge development will then become the norm of the entire society.

That is, according to Corollary 8, no matter how fast the champions may run in creation and knowledge development, everybody in the societies can follow. However, in sports, hardly few may catch up the world record of a champion. Therefore, it will never be underestimated that how much a society may gain from the leading intellectual forces in creation and knowledge generation.

Cross-References

- ▶ Cognition of Creativity
- ▶ Creative Brain
- ▶ Invention Versus Discovery
- ▶ Science of Creativity

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Incentive-Diffusion Dilemma

▶ Intellectual Property, Creative Industries, and Entrepreneurial Strategies

Incubators

▶ Microfirms

Independent Entrepreneurship

▶ Corporate Entrepreneurship

Individual Determinants of Entrepreneurship

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Synonyms

Internal factors; Personality/traits explanations; Psychological determinants

Introduction

Everyone agrees on the importance of entrepreneurship in the development of regions and its contribution to generate innovation and economic growth. To better understand this phenomenon, the determinants of entrepreneurship have attracted the interest of several researchers. Some are interested in the individual factors; others looked at the determinants related to the environment in which individuals are situated.

Moreover, many researchers have shown that entrepreneurship is a function of the interaction between the individual determinants and other environmental determinants.

The main goal of this entry is to provide a road map for researchers interested in the individual determinants of entrepreneurship. It tries to review the major individual factors that prior researchers have suggested should influence the entrepreneurial activities.

The origin of individual determinants of entrepreneurship as a research topic has its roots in the 1960s in the classic entrepreneurship literature. This literature attempted to explain the creation of new venture with a focus on personality traits and characteristics of entrepreneurs. The board conclusion of this literature is that determinants related to the individual are composed of special qualities and motivations that endowed entrepreneurs with unique abilities or driving forces encouraging them to create new ventures.

A growing literature examines the impact of individual determinants on entrepreneurship. Researches emphasize the importance of personality traits and characteristics in the decision between self-employment and salary work. Authors identified two categories of explanations. The first class emphasizes entrepreneurial motivations. Previous researches have explored several motivations and their effects on entrepreneurship.

Entrepreneurial Motivations

The Need for Independence

The most studied motivation in this context is the need for independence. Individuals having a preference for autonomy desire freedom from organizational constraints and control from supervisors (Schein 1990). They want to work independently and be "their own boss." They prefer to be maximally free in their work so that they can define their own objectives and achieve them as they would like. They want to take the responsibility to fix their own decision instead of following the orders of others. To achieve all these ambitions, individuals having a need of independence turn away from salary work and prefer to move towards an entrepreneurial career.

The Need for Achievement

Within the research domain of personality traits and entrepreneurship, the concept of need for achievement (nAch) or the need for personal development has received much attention. Mc Clelland (1961) identified it as a key influencing personal characteristic on the creation of new ventures. This motivation is related to the need for the individual to learn every day, to exercise his creativity, and to innovate. Individuals with a high need for achievement have a strong desire to set their own goals and carry them out. They want to take responsibility for actions and do well in competitive situations. They dislike routine activities, and they have a tendency to choose difficult tasks. While those with a low need for achievement choose very easy tasks in order to reduce the risk of failure. Thus, they consider the creation of business as a challenge to meet which encourages them to create their own businesses.

The Locus of Control

The locus of control is another motivation of interest, which emerged from Rotter's (1966) original research on entrepreneurs. Rotter (1966) argued that individuals having a high internal locus of control believe that they will realize their success by their own actions. They have the perception that all events are under their control so that they do not attribute outcomes to the chance or external environment. However, individuals with an external locus of control believe that the result of an event is out of their control. Individuals having an internal locus of control prefer to pursue an entrepreneurial career because they desire situations in which their personal actions have a direct impact on outcomes.

Thus, the study of the most considered entrepreneur's motivations like the need for independence, the need for achievement, and the locus of control is relevant because they have been interpreted in the entrepreneurship literature as potential internal driving forces among entrepreneurs.

Entrepreneur's Qualities

The second class of explanation of self-employment emphasizes entrepreneur's qualities that are necessary to become an entrepreneur. The decision to create a new business has been considered in many researches as a function of the qualities associated to the individual. Entrepreneur's qualities are defined as the skills and abilities of an individual encouraging him to create a new venture.

Entrepreneurial Self-Efficacy

One of the key factors that have received attention is entrepreneurial self-efficacy which is developed by Bandura (1977) and has been demonstrated to play a crucial role in the development of entrepreneurial intentions and actions. The concept of self-efficacy or self-confidence is based on individuals' self-perceptions of their skills and abilities to succeed in creating new businesses. These perceptions are able to increase the level of interest in pursuing an entrepreneurial career. Individuals with high entrepreneurial self-efficacy are also more likely to believe that they possess a viable idea for a new venture. They exert more effort for a greater length of time and persist to achieve this idea and to improve their performance.

Risk Tolerance

The classic work of Knight (1921) stresses the importance of risk tolerance in the entrepreneurial decision. Risk tolerance consists of a general tendency to pursue and take calculated risks. Entrepreneurs often accept uncertainty; however, other individuals desire to avoid risk because they are afraid of failure. As a result, they prefer easy and safety situations because there is a high chance of success. In a recent study, Fairlie and Holleran (2011) note that creating a new business is inherently risky, and individuals who are more risk tolerant have higher levels of entrepreneurial intentions and opportunity-identification efficacy.

Creativity

In addition to these individual determinants, many other significant factors have been identified by an important number of researchers. Schein (1978) found that individuals with a strong creativity and innovative anchor are motivated to create "something new" for the chance to use their skills to innovate and develop new ideas. They are characterized by the ability to produce an original and useful work in the same time.

Some Empirical Studies About Individual Determinants of Entrepreneurship

A large number of empirical studies examine whether these motivations and qualities in addition to other identified characteristics are important determinants of entrepreneurship.

In his study, Hornaday (1982) lists 42 attributes of entrepreneurs. These attributes include need for achievement, risk-taking propensity, and internal locus of control. Additionally, he notes the importance of other special qualities such as dynamism, adaptability, taking initiative, and the ability to resolve problems in the creation of new ventures.

In a study based on 40 success stories of entrepreneurs, Hernandez (2006) explored the reasons why individuals start enterprises and make career choices. The results of his research indicated that the main reasons individual's start enterprises are passion, self-realization, autonomy, authority, financial success, and difficulty to find a salary work.

A recent empirical study of Fairlie and Holleran (2011) tried to examine the influence of several personality characteristics on the creation of new ventures in Germany. On the basis of a large representative household panel survey, they found that tolerance to risk, entrepreneurial ability, and locus of control are important in determining who creates a new venture. Moreover, they identified extraversion and openness to experience as key influencing factors on entrepreneurship. Extraverted individuals are defined as self-confident, ambitious, energetic, sociable, and dominant persons. With regard to openness to experience, it consists of the individual's ability in looking for new experiences and exploring novel ideas.

Conclusion and Future Directions

Thus, this entry contributes to review the major individual determinants (and does not provide an exhaustive list of these determinants) that prior researchers have suggested should influence entrepreneurial activities. The literature analyzing this question has examined the impact of personality traits on the creation of a new venture. Authors identified two categories of explanations. The first class emphasizes entrepreneurial motivations such as the need for achievement, the locus of control, the need for independence, the need for approval, and the need for personal development. The second class of explanation emphasizes entrepreneur's skills and qualities such as self-efficacy, risk preference, creativity, and dynamism.

Studying the individual determinants of new firm creation is relevant. However, the entrepreneurial phenomenon is multidimensional and cannot be fully understood by only individual factors. There might be important and interesting interaction effects between the qualities and motivations of the entrepreneurs and factors related to the environment in which he is situated.

This may explain why the focus of entrepreneurship research changed in the late 1980s with authors proposing a more holistic approach taking into account both individual and environmental determinants at different stages of the entrepreneurial process. Then, the inclusion of both individual and environmental factors in understanding entrepreneurial behaviors is crucial in theoretical as well as empirical studies.

Cross-References

▶ Creative Personality
▶ Creativity and Innovation: What Is the Difference?
▶ Psychological Aspects of Entrepreneurial Dynamics
▶ Psychology of Creativity

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Individual Enterprise

▶ Small Business

Individual Initiative

▶ Entrepreneur and Economists
▶ Heroic Entrepreneur, Theories

Individual Musical Creativity

▶ Creativity in Music Teaching and Learning

Individual-Opportunity Nexus

▶ Entrepreneurial Opportunity

Industrial Activity

▶ Heroic Entrepreneur, Theories

Industrial Atmosphere

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Synonyms

Innovative milieu; Localized knowledge

Introduction: Key Concepts and Definitions

Industrial Atmosphere and Industrial Districts

The term "industrial atmosphere" is used in economic literature in relation with the issue of localized business activities and more specifically with the notion of "industrial district." The latter notion describes geographical concentrations of firms characterized by specific relationships among participants. Industrial districts are localized clusters of firms, generally small or medium firms, where special modes of business cooperation among firms can be found, be they rivals or based on customer-supplier relationships, with some degree of loyalty and cooperative attitude creating a peculiar business-friendly "atmosphere" in the local industry.

Italian Industrial Districts

The modern economic literature on districts is based on the observation of specific forms of localized industrial activities that emerged in Italy during the 1960s and 1970s, called "Italian industrial districts." These localized clusters of firms defined the new industrial model of the "Third Italy," the structure, mechanisms, and rationale of which differed from both the classical industrial development of the Italian northwestern region, in the Milan-Turin-Genova triangle, and the underdeveloped "*Mezzogiorno*" of Southern Italy. Economic studies on Italian industrial districts such as the Prato textile industry, for instance, describe clusters of small firms mostly specialized in a single production phase and linked together in a complex process of cooperation and competition giving birth to an "industrial atmosphere," meaning close business relationships among participants. These relationships are based on technological information sharing, loyalty, social and family ties, interpersonal friendship, and cooperative connections (Becattini 1989, 1991).

Overview

From a historical viewpoint, localized clusters of firms have been initially observed and analyzed by Alfred Marshall in the British industry of the nineteenth century. Modern analyses owe much to Marshall's founding intuitions. In the first section, the works of the famous Cambridge master will be evoked to show how a peculiar "industrial atmosphere," as he called it, emerges from the historical, geographical, and organizational characteristics of localized industrial activities. The second section focuses on the specific role of entrepreneurial activities in the crystallization of industrial atmosphere.

Marshallian Industrial District and Industrial Atmosphere

The notion of industrial atmosphere was first coined by Alfred Marshall. In Marshall's *Principles* (Marshall 1920), the concentration of specialized industries in particular localities is considered as one of the main forms of industrial organization leading to economic development. Industrial localization and the division of labor and its influence on machinery, production on

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a large scale, and business management are the main causes of a long-term tendency to increasing returns. Alfred Marshall first pointed to the industrial atmosphere of some clusters of firms such as Sheffield's cutlery industry, a prototypical example of this form of industrial organization in the nineteenth century. For Marshall, interestingly, an industrial district is not simply a localized industry. Inside the district, interactions among firms matter because they give birth to external economies leading to aggregate outcome equivalent to scale economies that can be observed in big firms.

According to Marshall, people following the same skilled trade take great advantages from near neighborhood to one another. These advantages come from knowledge sharing leading to the diffusion and enhancement of knowledge, the seizing of new ideas that are simply "in the air" among participants, and the speeding up of the innovative pace. In Marshall's words:

> The mysteries of the trade become no mysteries; but are as it were in the air (. . .) Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed; if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas. (Marshall 1920), p. 225

The reasons for a geographical concentration of firms may be various, depending on local resources, physical conditions, demand conditions, etc., whereas Marshallian industrial districts are more significantly characterized by a particular combination of competition and cooperation through which entrepreneurial talent must be allowed to express itself. In districts, some relationships prevail among firms; firms specialize in particular phases of the productive process from where on they interact through many forms of cooperation, subcontracting, and exchange processes. Thus, because of this dense network of relations, subsidiary industries devoted to small phases of the productive process but working for a large number of neighbors are able to use and maintain machinery of a very specialized character. Another advantage of industrial districts is the existence of a local market for special skills where employers are likely to find a good choice of workers of many different skills. However, according to Marshall, whereas small districts specialized only in one kind of work can rapidly lose their advantages, the most efficient forms of cooperation are seen in large industrial districts and large manufacturing towns where many specialized branches of industry are put together into an "organic whole."

In *Industry and Trade*, the author explicitly uses the term "industrial atmosphere" to express the environment into which the firms are immersed and obtain "more vitality than might have seemed probable in view of the incessant change of techniques" (Marshall 1919, p. 287). Marshall explains in detail how the problem of the scale of production can be overcome if small and medium firms closely collaborate. The most common system used by English firms was interfirm cooperation or, as Marshall calls it, "associated action" among firms in the same district (see Belussi and Caldari 2009, pp. 338–339).

According to Giacomo Becattini, the main revivalist of the Marshallian approach, "the term localization stands for something other than an accidental concentration in one place of production processes which have been attracted there by pre-existing localizing factors. Rather, the firms become rooted in the territory, and this result cannot be conceptualized independently of its historical development" (Becattini 1990, p. 40).

Thus, the origin and development of an industrial district is not simply the local result of the matching of some sociocultural characteristics of a community, of historical and natural conditions of a geographical area, and of technical aspects of the production process. It is "also the result of a process of dynamic interaction (a virtuous circle) between division-integration of labor in the district, a broadening of the market for its products, and the formation of a permanent linking network between the districts and the external markets" (Becattini 1990, p. 44).

Marshall's approach to interfirm relations cannot be separated from his conception of the dynamics of industry developed in the *Principles*. His vision of firm and industry shows a great homogeneity because it inextricably links the principle of organization resulting from the division of labor, and the principle of substitution which is mainly based on the evolutionary notion of natural selection in which entrepreneurship plays an important part.

Entrepreneurship and Industrial Atmosphere

Industrial districts are a special form of industrial organization which needs a cognitive interpretation of industrial atmosphere. The latter is mainly based on the emergence and intervention of entrepreneurs whose abilities and competence are, for the most part, to organize the division of labor and specific forms of cooperation among competitors. Take, for instance, the "*impanatore*" of Italian textile industries of the twentieth century; this entrepreneur is instrumental in the linking up of customers located outside the district and the different suppliers working inside of it at various levels of the supply chain. The *impanatore* mainly plays an architectural role for the district, giving instructions or advice to the suppliers for organizing, or reorganizing, their production processes according to his knowledge of the changes of customers' taste and needs.

Entrepreneur, Undertaker, and Promoter

The analysis of geographical concentration of firms is inseparable from a vision of the economic actor embedded in complex social relationships and business relations assuming honesty and good faith. The importance of neighborhood is central to this idea: "the desire to earn the approval, to avoid the contempt of those around one is a stimulus to action which often works with some sort of uniformity in any class of persons at a given time and place" (Marshall 1920, p. 19). In this neighborhood, entrepreneurs are those who take the risks and the management of business and participate to the organized industry.

The central figure of the "undertaker" is the main spring of economic development. The undertaker must deploy "ability" which corresponds to knowledge, a quality which can be acquired and improved by education and learning. On the other hand, the undertaker must also exhibit "energy," synonymous with creativity and innovativeness. Business management is considered as part of industrial organization and necessitates the following abilities, listed by Marshall: an entrepreneur must be endowed with "a thorough knowledge of things in his own trade," "power of forecasting the broad movements of production and consumption," and the capacity of "seeing where there is an opportunity for supplying a new commodity that will meet a real want or improving the plan of producing an old economy"; finally, the business manager must be "able to judge cautiously and undertake boldly," and he must be "a natural leader of men" (Marshall 1920, quoted by Pesciarelli 1991). The entrepreneur's role is improved particularly through the advantages of large-scale production. The emergence of joint-stock companies studied in *Industry and Trade* (Marshall 1919) gives rise to another entrepreneurial figure, the "promoter," who organizes industrial cooperation on purely business lines and forecasts future businesses based on new inventions leading to new opportunities and new profitable alliances between industries.

Localized Knowledge and Innovation

The emergence of different kinds of territorial development and industrial districts in the twentieth century called for a general analytical background that could be used to explain, not only the districts of Northeast and Central Italy but also other forms of industrial localization experienced in different countries and regions, such as Orange County and the Silicon Valley in California, or some attempts of industrial development areas in the Third World, such as the shoe industry in Rio Grande do Sul. In these territories, small and medium firms substituted for mass production and large firms using heavily structured production processes based on machinery and unqualified workers. Industrial districts were characterized by flexible regimes of production using more specialized workforce and decentralized forms of coordination in which market relations and reciprocity replaced the managerial hierarchies of multidivisional corporations (Piore and Sabel 1984).

However, during the last two decades, localization phenomena turned back to more traditional modes of organization because of globalization and the emergence of new technologies (especially ICT) and when leading innovative firms were taken over and merged into bigger corporations. This is the reason why, for instance, the success stories of some famous Italian districts of the 1970s came to an end (Prato district, Benetton system).

The modern approach to localized industries proceeds from a reflection on technological progress which is structured around two main themes: (a) specific human resources obtained through localized learning processes and (b) organizational framework characterized by cooperative links among participants. In this modern context, the innovative process takes the form of a collective learning activity sequentially organized along the different phases of the production process. Thus, innovation becomes endogenous to the dynamics of industrial development (Lecoq 1993; Antonelli et al. 2008).

Entrepreneurial alertness is still at work in this framework. Industrial dynamics is mainly dependent of actors who organize complex processes, but the classical notion of district cannot cover the entire logic of the phenomenon. Industrial territories such as those of the nineteenth century described by Marshall were specialized in a single industry like the cotton industry in Lancashire or Sheffield cutlery trade. Likewise, their modern Italian equivalents specialize, for instance, in the textile industry as in Prato, or pottery in Sassuolo. More generally, industrial districts greatly differ according to the way complementary activities are organized; the main activity develops a large range of secondary activities, be they horizontal or vertical, along the different phases of the production process. These activities can also differ because of more or less formal social relationships and differently structured social networks. Finally, they also diverge because of the disparity among training institutions and the divergence in cooperative relationships.

Conclusion and Future Directions

The common central aspect of the various forms of localized activities that can be observed in modern industry lies in the fact that they incorporate a dense network of local communities and neighborhood interactions. The background created by close and tangled up relationships between the organization of productive activity and the functioning of social structure is at the basis of contextual connection and business cooperation which explain the very meaning of "industrial atmosphere." The coherence of this complex "organic whole" is not attained by chance or any natural process or market mechanism; the viability of the system must be organized by specific actors who take care of the durability and continuity of the industrial atmosphere. Different sorts of atmospheres can be found depending on the nature of the localized network: in a science park driven by start-ups, business angels, and academic entrepreneurs; in an industrial district dominated by buyer–supplier relations; in a knowledge-based metropolis; or in a localized system of innovation organized by innovative institutions. The mix of localized knowledge, competitive spirit, emulation, and cooperation that exist in these different industrial milieus is the basic material of the kind of entrepreneurship that is exerted in them.

Future developments of the concept lie in the possibility of maintaining a creative industrial atmosphere in large multidivisional and multiproduct firms. This can be obtained by encouraging the emergence of islands of corporate entrepreneurship in the administrative ocean of giant companies.

Cross-References

▶ Business Climate and Entrepreneurialism
▶ Innovative Milieu
▶ Network and Entrepreneurship
▶ Territory and Entrepreneurship

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Industrial Mathematics

► Innovation by Applied Mathematics

Industrialization

► Heroic Entrepreneur, Theories

Informal Venture Capital

► Angel Investors

Information and Knowledge Stock

► Knowledge-Capital and Innovation

Information Asymmetry and Business Creation

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Synonyms

Adverse selection; Market failures; Moral hazard

Definition

Information asymmetry is considered by economists as a major source of market failures. When an information asymmetry affects the quality of a good, a service, or a project, it is likely to generate a failure in the process of allocating resources. Akerlof (1970) first demonstrated that "when there exist information asymmetries between buyers and sellers, high- and low-quality goods and services can coexist in the marketplace" (Nayyar 1990, p. 514). This situation induces search costs for buyers who have "to determine the quality of goods and services they buy" (Nayyar 1990, p. 517). Because of information asymmetry, "prices do not accurately convey all information necessary to coordinate economic decisions" (Eckhardt and Shane 2003, p. 337). More precisely, scholars discriminate between two types of information asymmetry: moral hazard and adverse selection. The latter are central features of principal-agent relationships which characterize standard agency theory. As Picard (1987, p. 305) observed, "moral hazard results from the inability of the principal to monitor an agent's actions while adverse selection corresponds to the inability of observing an agent's private information." Guesnerie et al. (1988, p. 807) referred to the notions of "hidden knowledge" and "hidden actions" to identify these two sources of inefficiency in resource allocation. Hence, moral hazard and adverse selection, respectively, emerge when buyers are (1) incapable of evaluating the quality of goods and services or (2) unable to observe "either the seller's characteristics or the contingencies under which the seller operate" (Nayyar 1990, p. 517). If a market exhibits these two types of information asymmetry, "bad-quality providers can enter the market and drive out the good-quality providers by so lowering price that the latter cannot obtain returns on their investments for competence enhancement" (Nayyar 1990, p. 517).

Research Questions

The literature investigating the relationships between information asymmetries and business innovation focuses on three subthemes: (1) the financing of innovation, (2) the relationships between information asymmetries and business opportunities, and (3) the impact of information asymmetries on collaborative approaches to innovation.

Information Asymmetries and the Financing of Innovation

Within the context of capital markets for R&D, information asymmetries between entrepreneurs (agents) and investors (principals) about what the entrepreneur knows and does are likely to create what Akerlof (1970) called a market for lemons. Therein, a funding gap might emerge because entrepreneurs hold information that potential financiers do not possess and/or cannot observe. The risk is that only undesirable transactions will be accessible to investors "by raising entrepreneurs' sunk costs" (Shane and Cable 2002, p. 365), provoking a market failure when high-quality entrepreneurs leave the market (Emons 1988). As Aboody and Lev (2000, p. 2750) argued, "the uniqueness of R&D investments makes it difficult for outsiders to learn about the productivity and value of a given firm's R&D from the performance and products of other firms, thereby contributing to information asymmetry." In addition, it has been demonstrated that "market players in closer touch with a firm and its business (. . .) are those who possess better information about that firm" (Bharath et al. 2009, p. 3215). It follows that when entrepreneurs seek financing, financiers must address two problems: information disclosure and opportunism. As Shane and Cable (2002, p. 364) argued, "entrepreneurs are reluctant to fully disclose this information to potential investors because such disclosure will make easier for other people to pursue the opportunity" (e.g., through imitation). In addition, since entrepreneurs hold information that investors lack, they "may act opportunistically towards them (. . .) because entrepreneurs vary in their ability to identify and exploit opportunities" (Shane and Cable 2002, p. 364). In this context, scholars investigated how seed-stage venture capitalists manage to mitigate the effects of information asymmetries. In particular, scholars addressed the following question: how do potential investors find ways to confront the difficult challenges of identifying and selecting promising ventures to fund?

As Shane and Cable (2002, p. 364) explained, "three mechanisms –the allocation of contractual rights, the staging of capital, and risk shifting- led entrepreneurs to self-select and disclose information in ways that overcome this information asymmetry." The explanations provided by economists – namely, the allocation of contractual rights, the staging of capital, and risk shifting – are considered by the authors as incomplete for at least two reasons. "First, the over optimism of entrepreneurs (. . .) undermines the effectiveness of the contractual mechanisms described by economists" (Shane and Cable 2002, p. 366), making self-selection ineffective. The argument brought by the authors is that early-stage investors cannot shift all the risk of investing in a new venture to entrepreneurs and "must make investments that risk the total loss of their capital" (Shane and Cable 2002, p. 366). In addition, information disclosure through patenting for example (Antelo 2003), cannot lead outsiders (i.e., venture capitalists) to gain all the private information they need. As Kyle (1985, p. 1326) argued, although insiders' information get progressively incorporated into market signals through information disclosure, "not all information is incorporated into prices."

Contrasting economists' explanations, organizational theorists have generally proposed that potential investors rely on social relationships to select which ventures to fund. Scholars have argued that two different mechanisms – information transfer through social ties and social obligation – influence investors' decision. Adopting a socio-organizational lens, Shane and Cable (2002, p. 366) contended that "social obligations between connected parties, and information transfer through social relationships, influence venture finance decisions." On the one hand, social ties enable investors to obtain private information about the ventures to fund and their potential opportunities. The foregoing argument is consistent with a self-interested approach to investors' behavior, the latter exploiting their social capital to identify and select better projects. On the other hand, direct and indirect ties "create social obligations between the parties, which cause them to behave generously towards each other" (Shane and Cable 2002, p. 370). By referring to these two complementary mechanisms, the authors underlined the role played by entrepreneurs' reputation in providing investors with additional information about his or her capacity of implementing, managing, and developing the venture which, in turn, "help disentangle the effects of social obligation and information access" (Shane and Cable 2002, p. 371).

It should be noted that the creation of a spin-off company is likely to hamper the effects of information asymmetries on venture finance decisions. Basically, a good reason for founding spin-offs is the reduction of information asymmetry. Following Woo et al. (1992, p. 435), "the proposed benefits of spin-offs have often been articulated under the guise of an improved agency relationship between shareholders (principal) and managers (agents)." Within this framework, the benefits in a spin-off lie in the reduction of information asymmetries characterizing the evaluation of firm's activities. As Krishnaswami and Subramaniam (1999, p. 78) argued, spin-offs enable the bidder "to value the separate entities better and thus the standard adverse selection problem that arises under information asymmetry is mitigated." Spin-off decisions, therefore, are likely to protect the firm from misevaluating its profitability and operational efficiency, in particular when "the spin-off is motivated by a need to raise external capital" (Krishnaswami and Subramaniam (1999, p. 79).

Information Asymmetries as Sources of Opportunities

Information asymmetries arising from investments in R&D and innovation projects are also viewed by scholars (notably those belonging to the Austrian tradition in economics) as sources of opportunities. Elaborating on the works of Hayek (1945) and Kirzner (1973), Ardichvili et al. (2003, p. 108) defined an opportunity as "a chance to meet a market need (...) through a creative combination of resources to deliver superior value." In its most elemental form, it describes "a phenomena that begin unformed and become more developed through time" (Ardichvili et al. 2003, p. 108). As a result, opportunities are likely to be limited in time. Shane (2000, p. 451) further suggested that "opportunities exist because different people possess different information." It follows that "everyone in society must not be equally likely to recognize all opportunities" (Shane 2000, p. 451) merely because people differ according to their prior knowledge, the latter being determinative for their ability to *discover* entrepreneurial opportunities.

As Eckhardt and Shane (2003, p. 339) explained, discovering an opportunity "is far from the trivial exercise of optimizing within existing means-ends frameworks because it requires forming expectations about the prices at which goods and services that do not exist yet will sell." However, the discovery and exploitation of (valuable) opportunities is likely to generate entrepreneurial profits which, in turn, might provide financiers with positive returns on investment (Eckhardt and Shane 2003). Since entrepreneurs hold information about what they know and do outsiders do not possess, scholars indicated that they can earn rents by exploiting information asymmetries, the latter being considered as a source of monopoly power. In particular, as Davis (2001, p. 327) argued, rents can be obtained by combining four information-oriented strategies: "(1) publish the details of the innovation in return for legal protection (patents, copyrights, and the like), (2) keep the information inside the firm (secrecy, tacit, and firm-specific knowledge), (3) make the information selectively available to others on an informal basis, and (4) widely disseminate the information making it freely accessible to all comers." In doing so, firms seek to control how information about the characteristics of their innovations get revealed to the market in order to confront potential competition (through imitation for example) and ensure sustainable profitability.

Within this framework, information asymmetries "can be a potent source of competitive advantage" (Nayyar 1990, p. 517), in particular, for firms that are capable of diversifying their offers through the implementation of an effective communication strategy. Miller (2003) introduced a three-step model that exemplifies how firms convert asymmetries into resources enabling them to benefit from competitive advantage. The author demonstrated that building capabilities out of asymmetries involves that the firm is capable of doing "three things well:

1. Discover the asymmetries (. . .) and discern the potential between them
2. Turn asymmetries into capabilities by strategically embedding them within an organizational design configuration that exploits them and sustains their development
3. Match asymmetry-derived capabilities to market opportunities" (Miller 2003, P. 965)

Therein, the identification and selection of valuable asymmetries require both internally and externally oriented processes, including experimentation, incremental learning, organizational introspection, reflective inquiry and search for weaknesses, and bootstrapping on emerging capabilities (Miller 2003, pp. 965–968).

Information Asymmetries and Collaborative Innovation

In the recent years, scholars reported many examples of successful companies that invented and commercialized new products and services by participating in collaborative networks (Nieto and Santamaria 2007). Collaboration enables the firm to access to a variety of external and internal sources of innovation that can be used in combination to generate new ideas, incorporate them into new products and services, and capture value from their commercialization (Chesbrough and Appleyard 2007). As Abramo et al. (2011, p. 885) suggested, "private enterprises use collaboration to solve specific technical or design problems, develop new products and processes, conduct research leading to new patents, recruit university graduates and access cutting-edge research." Within this framework, the firm must confront the challenge of selecting the "right" research partner based on their private information about the quality of the scientific knowledge available on the market and its cost. Here again, information asymmetries make it difficult for private companies to discriminate between the variety of offers. When market fails to provide agents with complete information, the selection of partners is guided by socio-organizational factors. In particular, "geographic and social proximity (. . .) should play a determining role in the choice of research partner" (Abramo et al. 2011, p. 85). Therein, social capital, direct and indirect ties, and reputation effects are likely to guide the firm in identifying promising research partners if information about their quality is lacking. Tödling, Lehner, and Kaufmann (2009) supported this assertion indicating that collaborative innovation "draw on new scientific knowledge generated in universities and research organizations" and that "the exchange of this type of knowledge requires personal interactions" (Tödling et al. 2009, p. 59). The adoption of collaborative business model therefore is likely to enable partners in innovation projects to mitigate the effects of information asymmetry but necessitate interaction and communication through formal (e.g., licensing, spin-offs) and informal (e.g., sociocultural proximity) relationships.

Conclusions and Future Directions

The relationship between information asymmetries and business creation is a key issue for both scholars and managers. Future research efforts could be directed towards deepening our understanding of how various stakeholders involved in business creation and funding (entrepreneurs, investors, public agencies, etc.) manage to balance (1) information asymmetries as sources of opportunities and (2) the sharing of information (and knowledge) as it enables collaboration and reduces financial and technological risks. This might lead to depart from market-driven models of information asymmetries to promote an entrepreneurial approach to business creation. The latter would insist on critical resources enabling agents to deal with information asymmetries and exploit opportunities such as relational networks, communication strategies, fiscal incentives, and public/private partnerships. This, in turn, would enlarge our understandings of the role played by information asymmetries on the nature and logics of business creation.

Cross-References

▶ Entrepreneurial Opportunities
▶ Financing Entrepreneurship
▶ Technological Entrepreneurship and Asymmetries

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Information Monitoring and Business Creation

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Synonyms

Business intelligence; Competitive intelligence; Environmental scanning

Theoretical Foundation

Studies about business creation and business monitoring have multiplied and branched out over the last 30 years. For the sake of clarity, concepts are based on a classification adopted by business specialists Gilbert, MacDouglas and Audrestch (2006), i.e., approaches based on the theory of growth – with a focus on the individuals, business life cycles, strategies, population ecology, resources and coherence. In each of these, determinants are analyzed that either complete or respond to one another. Among others, analyzing the environment of business creation processes is key for approaches based on strategies, resources, and population ecology (Hrisman et al. 1999).

In these three approaches, analyzing the environment allows the entrepreneur to spot opportunities and make choices. As established for corporate governance practices (OECD 1999), information is at the heart of environmental analysis. Depending on the norms, this can either have an implied or implicit dimension, or an explicit dimension. In the latter case, it materializes as an information monitoring system that can be defined as an informational process through which an organization scans its environment to decide and act to pursue its objectives.

Research about business creation – which, depending on the author, is presented either as a result or as a process – is always centered on three notions: the entrepreneur, the new company, and the environment in which the process occurs (Marchenay and Messeghem, 2001). This environment is all about understanding and apprehending favorable and unfavorable factors. Studies of the couple "new company/its environment" deal with the forms it can take, the various possible locations (science parks, nurseries, etc.), and the business segment's characteristics (maturity, turbulence, etc.), as well as performances and the problems that are occurring (Porter 1985). It is then important for the creator to be given notions of environmental scanning in order for him/her to use it as a tool to orient his/her activity.

The very first paper about business intelligence dates back to 1974 and explains how environmental analysis must be conducted – not omitting to mention that the method and the tools it proposes are those used by US intelligence agencies.

Terminological confusion must be highlighted here, that arises from using an expression which simultaneously embodies two concepts: the monitoring process in itself, and the result of this monitoring process. Hence, "environmental scanning" or "business monitoring" now describes the process in itself, while "business intelligence" or "competitive intelligence" correspond to the end product of this process.

Business Monitoring Process

The scanning/monitoring process is described as a system by Dutton, Frayer, and Narayanan (1983), based on several subsystems, and relying on information provided both by external players and the organization itself. The macro-environment has a political, an economical, a sociological, a technological, an ecological, and a legal dimension. The identified players are the clients, the suppliers, the employees, the unions, the partners, the competitors, the governments, the networks, the media, and the press conglomerates. The inner environment of the company consists of its resources, its culture, its strategies, its governing body, and its structure (Davenport and Prusak 1998; Kahaner 1996).

The main system of the business monitoring process comprises three elements, namely, the inputs, outputs, and cycle. Inputs refer to the many needs of the company's players. Listed by several authors (Beal 2001; Bryant and Richardson 1999; Fuld 1995), these needs pertain to identifying clients, markets, competitors, suppliers, and partners. Outputs refer to information products aimed at making decisions and taking action. Depending on the phase of the cycle, these can either be data, or information, or knowledge. There are several steps in the business monitoring cycle:

- Defining the need
- Collecting information, using a list of formal and informal sources of information
- Assessing the truth of, and validating, information relatively to the needs, through a workgroup
- Analyzing and interpreting the groups of documents to outline the emerging trends, spot weak signals, and make recommendations
- Disseminating information

Although spying is illegal and not part of the business monitoring process, protecting information should be added to that list, as violating it is more and more common practice in spite of rigorous ethics.

Conclusion and Further Reading

Information technologies play an important role in implementing business monitoring within companies, irrespective of their size and the phase of their life cycle. The ever-growing number of data mining software is now pushing science parks and nurseries to get their smaller companies acquainted with them, thereby giving them access to a better knowledge of their external environment – which for them is an asset both to predict potential external threats and to take advantage of every opportunity.

Cross-References

▶ Business Emergence
▶ Entrepreneurial Opportunities
▶ Small Business

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Information Processing

▶ Cognition of Creativity

Information Technology (IT)

▶ Digital Economy and Business Creation

Initiative

▶ Innovations of Direct Democracy

Innovate

▶ Invention Versus Discovery

Innovation

▶ Applied Design Thinking Lab and Creative Empowering of Interdisciplinary Teams
▶ Creative Personality
▶ Creative Destruction
▶ Creativity and Church
▶ Creativity and Systems Thinking
▶ Creativity in Invention, Theories
▶ Effects of Intuition, Positive Affect, and Training on Creative Problem Solving
▶ Entrepreneur and Economists
▶ Entrepreneurship Policies
▶ Game Theory and Innovation Analysis
▶ Innovation Systems and Entrepreneurship
▶ Knowledge Creation and Entrepreneurship
▶ Knowledge Society, Knowledge-Based Economy, and Innovation
▶ Model for Managing Intangibility of Organizational Creativity: Management Innovation Index
▶ Nature of Creativity
▶ Promoting Student Creativity and Inventiveness in Science and Engineering
▶ Social Innovation
▶ Technological Invention of Disease

Innovation – Deviation, Alteration, Implemented Novelty

▶ Institutional Entrepreneurship, Innovation Systems, and Innovation Policy

Innovation and Democracy

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Synonyms

Democratic reforms; Democratization; Political change

The connections between innovation and democracy are numerous and complex. Many recent contributions to the field center on "innovating democracy" (Goodin 2008) in terms of designing, implementing, and using new or "unconventional" forms of decision making in democratic systems. But while this perspective covers a huge and quickly expanding field, and may capture some of the most intriguing aspects, it certainly marks not the only way of looking at innovation and democracy. The structural capacity of democratic systems to generate innovation in politics as well as in other areas, such as technology and science, constitutes another key component of the larger subject. The brief overview that follows considers both of these different, but related, topics.

Before we turn to this, a working definition of both key terms is in order. *Democracy* is here referred to as "a political system in which different groups are legally entitled to compete for power and in which institutional power holders are elected by the people and are responsible to the people" (Vanhanen 1997, p. 31). It is difficult to find a similarly clear-cut and substantive definition of innovation in the political science literature. Recent attempts to describe innovations as "special subsets of change" (Newton 2010, p. 4) are not fully convincing. *Innovations* are about change, but are nevertheless closer to reform than to change because change is neither an equivalent to nor necessarily the result of conscious and deliberate action. The latter, however, characterizes innovation as well as modernization and reform. What separates both innovation and reform from mere modernization is in particular the degree of projected change. But it remains difficult to establish what exactly distinguishes the former two from each other. As Ken Newton suggests, a meaningful general conceptualization of innovation may center on introducing "new ways of doing things" (Newton 2010, p. 4). By contrast, reforms tend to focus specifically on altering established rules or procedures. Reforms are also usually launched (if by no means always demanded in the first place) by actors who possess a special authority to formally initiate reform processes, which cannot be considered a necessary requirement of introducing innovations.

Democracy's Capacities for Innovation

From a normative perspective, democracies would appear to provide excellent conditions for innovations in such different areas as arts, science, and technology. Of the two main ideas, or principal norms, defining liberal democracy – freedom and equality –, especially the former is essential for making democratic political systems innovation-friendly environments. The free flow of ideas is strongly conducive to innovation (if not necessarily to invention and creativity which can be found even in contexts characterized by strong structural barriers against innovation). The possible effects of equality on the innovation capacity of different societies are more ambiguous. On the one hand, a strong commitment to equality may result in a wide distribution of resources within a given society which is likely to benefit the cause of innovation in different areas. On the other hand, a strong emphasis on equality in organizing a given society may make it harder for innovative actors to acquire an exposed position and prevail in the competition between innovation and established norms and practices.

Democracies also, and in particular, share a strong normative commitment to *political* innovation. As John Keane has pointed out, "When democracy takes hold of people's lives, it gives them a glimpse of contingency of things. They are injected with the feeling that the world can be other than it is – that situations can be countered, outcomes altered, people's lives changed through individual and collective action" (Keane 2009, p. 853). Even more to the point, Michael Saward has observed that "the story of democracy is nothing if not a story of innovation. One of the defining features of democracy may well be its restlessness, dynamism and comparative openness to new ideas" (Saward 2000a, p. 3). The latter properties are not just general defining characteristics of liberal democracies, however, but play a crucial role in the maintenance and persistence of democratic regimes. Indeed, the prospect of future change and political innovation is central for legitimizing democratic politics and democratic systems, and it is of special relevance to those citizens who are not supporting the government of the day (Anderson et al. 2005).

Further, democracies are not only characterized by a general appreciation of innovation and change in different areas, they also incorporate a special mechanism designed to bring about innovation in politics: elections and alternations in government. In fact, the single most important function of democratic elections is to be seen in empowering the citizens to "turn the rascals out," to clear the way for a fresh start. Other things being equal, major policy innovations in democracies are most likely to occur in the aftermath, and as a result, of alternations in government. This key assumption, which is explicitly spelled out particularly in some concepts of party government (Katz 1987), is obviously based on several other assumptions, including in particular that the different parties competing with each other for governmental office have reasonably different policy agendas.

But the structural capacity of democratic systems to bring about innovation is not exclusively concentrated in the hands of the governing elites. The opposition has long been acknowledged as "the other mover of politics," and the opposition actors performing innovation-related functions (at the level of public agenda setting and beyond) include both fully institutionalized actors, such as the parliamentary opposition in parliamentary democracies, and much less institutionalized actors, such as social movements (Helms 2010).

From an empirical perspective on the West European parliamentary democracies, one of the first things to mention about democracy's capacity for innovation is the fact that wholesale changes in the party composition of governments mark a comparatively rare occurrence. Often, elections tend to produce governing coalitions that include at least one party that has been a member of the outgoing coalition which, other things being equal, reduces the innovative potential of newly formed governments (Ieraci 2012). The innovative potential of (be it wholesale or partial) alternations in government is further reduced if there is a strong policy convergence of the parties competing for office, as Peter Mair suggests to be the case in much of Western Europe (Mair 2008).

Apart from the suggested trend toward policy convergence of the parties, that can be observed in some but by no means all established liberal democracies (Budge et al. 2012, pp.66–70), the innovation capacity of newly incoming governments, including majority single-party governments, has arguably always been overestimated. There is a strong element of inheritance in public policy even under the most favorable institutional and political circumstances, as Richard Rose and Phillip L. Davies have shown for the British Westminster democracy (Rose and Davies 1994). Even radical governments rarely repeal much of the legislation of the previous administration. This notwithstanding, all other things being equal, the overall capacity for innovation of newly incoming single-party governments in majoritarian types of democratic systems is larger than that of coalition governments operating in politically and institutionally complex systemic environments.

In presidential democracies, such as the United States, the closest equivalent to majority single-party governments in parliamentary democracies are administrations facing a legislative branch that is being controlled by the president's party ("unified government"). *Ceteris paribus*, their legislative leverage and capacity for innovation are larger than that of administrations operating under the conditions of "divided government" which can, to some extent, be compared with minority governments in parliamentary democracies. The political history in the United States since 1945 has been marked by a high share of "divided government" (in fact, more than two-thirds of all post-war administrations fall into this category) and, more recently, a strong trend toward party polarization (Baumer and Gold 2010) – a combination that has made the implementation of innovative policy agendas more difficult to achieve than ever.

In all those politically and institutionally different contexts, individuals can make a difference (Greenstein 1987), and innovative leadership is possible (Moon 1993). However, even if governmental decision makers are able and willing to initiate innovative policies, democratic governance requires the substantial support from social actors and society at large as well (Bevir 2010). What has been said about political reforms – that the process of institutional reform only begins after its passing and implementation (Scharpf 1987, p. 144) – would appear to hold just as true for political innovations.

Much research on the social aspects of innovation focuses on learning. If learning is conceptualized as "socialization in routines of proven value" (Ober 2008, p. 19), there is indeed "an inherent tension between learning . . . and the redeployment of knowledge for innovation," and "too much learning can compromise competitive advantage" (Ober 2008, p. 19, 274). If, by contrast, the emphasis is on learning something new, innovation – or more specifically the successful dissemination of innovations throughout society – has convincingly been conceptualized as a learning exercise (Rogers 2003). However, as Richard Freeman has argued, ultimately the successful diffusion of an innovation is at least as much about teaching as about learning (Freeman 2006, p. 370). And indeed, teaching – in terms of public leadership advocating innovative solutions to collective problems – is at the very heart of innovative or, more precisely, innovating democratic leadership.

Innovating Democracy

The overarching aim of democratic innovations in different areas and at different levels of democratic political systems can be seen in "improving the quality of democracy" (Geissel 2010, p. 164). There is an understanding in the recent comparative literature that there is no compelling reason to count only those innovations as genuine innovations that have not been tried and observed anywhere else. A "relative newness," that is, the novelty of a given idea within the boundaries of a given system, tends to be considered a sufficient defining feature of democratic innovations. This seems reasonable; otherwise, there would be little to study. In particular, comparative research in democratic innovations would bereave itself the valuable and important opportunity to study the differing effects of similar democratic innovations in different contextual settings.

Kenneth Newton has usefully distinguished between "top-down innovations" and "bottom-up innovations" (Newton 2010): Top-down innovations tend to focus on political structures and processes, in particular on the institutions of democratic government that regulate the performance of politicians and make them more accountable and responsive to the general public. By contrast, bottom-up innovations tend to focus more on the input of citizens into the political system; they are primarily concerned with improving the capacities, knowledge and participation of citizens in order to empower them to play a more active part in public affairs.

Both of these two main categories comprise a host of different ideas and measures. Arguably the single most important distinction within the category of top-down innovations relates to innovations that center on *horizontal* accountability, that is, on the relationship and the accountability between the branches of government, and those centering on aspects of *vertical* accountability, that is, accountability of government to its citizens. Most ideas and measures relating to horizontal accountability are concerned with expanding the control capacities of parliaments and courts toward the executive branch. Ideas and measures seeking to improve the state of vertical accountability in democratic regimes are usually not confined to aspects of democratic responsibility but extend to the related area of democratic responsiveness. Term limits for elected representatives and the possibility of recalling them before the end of the regular term are examples for democratic innovations in this area (Newton 2010, pp. 7–8).

Democratic bottom-up innovations comprise a vast number of rather different measures and ideas. Some agendas seek to transform and expand voting rights regimes, for example, through reducing the voting age (with ideas ranging from slightly below the legal age of majority to voting rights from birth) or through providing noncitizen residents or even noncitizen nonresidents with affected interests with the right to vote. Such innovations in the realm of representative politics (many of which have not been put into practice anywhere) have been accompanied by expansive agendas that seek to break the monopoly of representative democracy through the introduction of new forms of citizen participation. Within this category, it is ideas for introducing and/or expanding direct democracy that possess by far the most impressive historical track record reaching back to the early days of the progressive era (Cain et al. 2003 pp. 5–6), and political scientists have to work hard in order to capture the latest developments and the growing pluralism in real-world democracies (Altman 2011). However, it is "co-governance," direct citizen involvement in the activities of the state, and other forms of consultation and deliberation that have found most attention among contemporary scholars of innovative democratic procedures (Goodin 2008; Smith 2009).

The ubiquity of projected democratic innovations in different countries makes it all but impossible to identify any clear-cut cross-national trend. However, as Michael Saward has observed, to the extent there is a common denominator, most democratic theorists and democratic activists share a special commitment to, and appreciation of, new ways of constraining conventional democratic majorities and ways of building new majorities of a special sort (Saward 2000b). There is also a broad consensus that even the most radically innovative ideas at the level of direct democracy and/or deliberative democracy would not, and should not, abolish representative democracy as the bedrock of contemporary liberal democracy. The future of representative democracy may be difficult and demanding, but there would appear to be no credible alternative to an institutional formation that has proven for more than 200 years to possess a resilience being unmatched by any other form of organizing individual and collective action (Alonso et al. 2011).

Some of the most serious challenges of the decades ahead relate to safeguarding the accomplishments of democratic development into what could be described as an age of unprecedented global interdependence. While democratic innovators in nation-states, or in subnational entities, can draw on the experience of neighboring states or communities, there is little, if any, lesson-drawing when it comes to designing and implementing innovative solutions to global democracy. All the more so, genuine and ingenious innovations in democratic institutional engineering will be needed to master the towering challenges of an increasingly interdependent world, and to use the power of innovation for the sake of democracy's futures.

Conclusion and Future Directions

Innovation and democracy are likely to remain important subjects of political and social research whose complexity seems bound to increase further. A considerable proportion of future efforts will have to be spent on linking different strains of political and social research on "innovation" that share little more with one another than the use of the same key term. There is a fast-growing body of research focusing on innovation policy (see, for example, Llerena and Matt 2010; World Bank 2010; Bauer et al. 2012) that has been consciously omitted from the brief overview above, mainly because it has evinced conspicuously little interest for democratic issues. Some authors of course have sought to reach beyond treating democracy as a mere background condition of innovation processes. For example, Eric von Hippel has looked more specifically into the possibilities of democratizing innovation processes. However, in his work "democratization" is understood to mean no more than "that users of both products and services – both firms and individual consumers – are increasingly able to innovate for themselves" (von Hippel 2005, p. 1), which according to this author applies to information products such as software as well as to physical products. There is ample room for introducing considerably more demanding conceptualizations of democracy and democratization to the study of innovation policies.

Another link to be established and developed is that between political research on innovation and democracy, and the quality of democracy. While the innovative capacity of different political regimes (for example, as described above, in terms of government alternation) has been acknowledged as a crucial component of a given polity's overall democratic performance in many classic contributions to political theory, innovation has failed to be specifically included in the numerous more recently construed indices of democratic quality. Some of the foremost challenges in this area relate to specifying what exactly a reasonable amount of innovation, or the absence of it, may actually mean for the democratic quality of different political regimes. As with, for example, transparency whose true relevance for the concept of democratic governance is brought to bear only in combination with accountability, innovation (as conceptualized above) would appear to represent not so much a goal in itself but rather a crucial means for achieving other meta goals of democratic governance.

Cross-References

▶ Innovation Policy Learning
▶ Social Innovation

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Innovation and Entrepreneurship

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Synonyms

Breakthrough technology; Economic development; New venture creation; Paradigm shift

Introduction

Entrepreneurship is an ambiguous concept unless it is contextualized. The focus in this entry is the role of the entrepreneur within the context of innovation. Thus, if a business activity is conducted under what Schumpeter (1939) calls "competitive capitalism," then there is no innovative activity and the market is operating as a pure neoclassical mechanism in which the "nirvana" of market efficiency in the allocation of goods and services is achieved. This is a static equilibrium position in which there is no change, no economic development, and no entrepreneurs to drive innovation. All that is needed are efficient business managers. As a result, in neoclassical economics, entrepreneurship is merely seen as agency in any form of business activity, including routine managers. This, in one fell swoop, conflates the original work of Schumpeter and his entrepreneur with the mainstream market conception of an entrepreneur who simply operates a business.

Baumol (1968, p. 1) rejects the conflation of managing a business and the higher responsibility of driving free enterprise:

> The entrepreneur is at the same time one of the most intriguing and one of the most elusive characters in the cast that constitutes the subject of economic analysis. He has long been recognized as the apex of the hierarchy that determines the behavior of the firm and thereby bears a heavy responsibility for the vitality of the free enterprise society. In the writings of the classical economist his appearance was frequent, though he remained a shadowy entity without clearly defined form and function.

The role of the entrepreneur has proved difficult to formalize within the innovation process. Well expressed by classical economics writers, notably Adam Smith and Karl Marx, Schumpeter (1912) reintroduced endogeneity of innovation in the capitalist process after the 1870s marginalist absorption of classical economics into the neoclassical mainstream placed innovation firmly into the "black box," making the entrepreneur invisible. Despite Baumol's oft-cited 1968 quotation above, due to the nature of the neoclassical model itself, economists have not been able to find a way to formally endogenize the entrepreneurial function. A very large increase in the number of innovation studies and the bringing of technology into the endogenous growth function still cannot fill in the gap. To his credit, Baumol has made attempts to incorporate entrepreneurial behavior into the economics mainstream. The task is not easy when a major intellectual in neoclassical economics needs three books to do this (Baumol 1994, 2002, 2010). While this effort is commendable, and in particular Baumol (2010) serves a useful purpose in further conceptualizing (along the lines of Schumpeter) the role of the entrepreneur in the economy from a rich vein of historical studies, the actual integration of the dynamic role of the entrepreneur in the static neoclassical model remains problematic.

Baumol models the decisions of entrepreneurs by an optimality algorithm where new and innovative entrepreneurial activities are subject to known constraints. If the economy is at an equilibrium measured in a static state, then the algorithm has a clear resolution, and the role of the entrepreneur is insubstantial. Leave it to the routine manager. At this equilibrium, a potential exit exists where the dynamic entrepreneur is in her/his element. It is an "escape hatch" from the static state. Where is Baumol's optimizing entrepreneur at this point? It is at this very point that optimality breaks down because there is no way any optimal algorithm can provide an answer to this exit point. There is no theoretically logical and consistent way of escaping static optimality unless a stochastic shock is devised, which removes the endogeneity of the entrepreneurial spirit. Baumol (2010, p. 70) himself admits this optimality problem by stating: "…nor does it provide any rigorous standards by which the issue can be judged."

The contradictions within the neoclassical economics model in addressing innovation and the role of the entrepreneur responsible for such activity lead to a lack of a rigorous research model for future study. In the next section, imperfection in the market is seen as the way out of equilibrium, but is in effect "no way out" from a theoretical perspective. Having rejected this standard approach, it is necessary to reconceptualize the entrepreneur within a realist complex systems framework. This is the task of the following section "Risk and Uncertainty" provide the appropriate concepts from which to further develop this realist systems model of creative entrepreneurship, as set out after the entrepreneur is clearly delineated. The impact of this systems model on business creation and the path of economic development complete the realist account. The conclusion then sets up a more fruitful research path for entrepreneurship studies within a more coherent economic framework than the bland characteristics-based studies that have multiplied in the literature and encouraged by the individualist-based neoclassical model.

Market Imperfections

Baumol (2010, p. 100) states: "In order to achieve optimality, one must eliminate the externalities and then correct any new, undesired redistribution effects that result." This is the neoclassical market imperfections argument justifying public policy actions to "correct" for externalities and "address" inequality of distribution issues. Such actions brings one back to the static model and its inability to handle dynamic variables. What is the "correct" action if there is no rigorous standard to evaluate public policy actions? Thus, lack of an optimal endogenous entrepreneurial escape from the static state, although termed "market imperfections," can be more accurately described as a systemic failure of markets (Smith, 1998). This failure leads to total inability of the neoclassical abstract market mechanism to provide theoretical understanding or empirical guidance for action.

Without the rigor of a static model to provide algorithmic precision, economists revert to metaphysical analogies (Robinson 1962) to provide what Taleb (2008, pp. 62–84) calls a "narrative fallacy" in order to provide some meaning and causality to an event that is not able to be given a rigorous analysis. The problem arises when a metaphysical narrative is presented to rationalize an axiomatically rigorous model. This occurred in a powerful way at a symposium on entrepreneurship in the Carnegie-Mellon University, Pittsburgh in November 1997, when two Nobel Laureates in Economics were on a panel and asked to depict how entrepreneurs operate in the context of equilibrium in the market mechanism. Each presented a starkly different scenario.

Architect of the general equilibrium model, Kenneth Arrow, describes entrepreneurs as "dragging" markets out of equilibrium by innovative activity that is inconsistent with providing the same type of goods and services. In effect, successful innovation disrupts equilibrium. Arrow continues by explaining that the process of moving back into equilibrium can be discerned when other entrepreneurs follow the "first-mover advantage" entrepreneur and diffusion of innovation occurs. This process of "follow the (innovation) leader" continues until the market becomes again one in which there is a homogenous product with many sellers meeting the demand of many buyers. The proliferation of such homogenous markets delivers a general equilibrium.

The inspiration behind the concept of bounded rationality, Herbert Simon, describes the same process in very different terms. Simon depicts the entrepreneur searching in a world of discontinuities for opportunities to innovate. The successful entrepreneur finds a new good or service that creates a fresh market into which other entrepreneurs quickly follow, but the rush to market by followers leads to only a temporary equilibrium in which supply meets demand. Followers will continue to produce leading to overproduction and disequilibrium. Such disequilibrating markets provide the basis for new discontinuities and, thus, new opportunities arise.

The two metaphysical analogies described above clearly show that the neoclassical market equilibrium approach with its imperfections arising from the innovative activities of entrepreneurs is an inappropriate framework of analysis. The rest of this entry addresses entrepreneurship and the role of innovation as a dynamic concept within a complex adaptive system (CAS). Holling (1973) identifies the strength of relationships within a particular CAS, such that the more stable a relationship within a complex system, the less resilience the system possesses. In this context, the maintenance of equilibrium within a system endows a system with greater stability, but with less capacity to absorb variations with significant fluctuations. The essential aspect of innovation is change, so a framework that can adapt to change from first principles is a much more appropriate vehicle to understand the entrepreneurial process and the entrepreneur how instigates this change. More recently, Archer (1995) has extended the CAS model by arguing that the behavior of such a system is not a simple and direct consequence from an external stimulus. As a system becomes more complex, it develops endogenous autonomous processes that determine its behavior, such as adjusting the system to better deal with external influences. This is a better approach to systematizing the endogeneity of the entrepreneurial spirit that so troubled Baumol across three books.

Entrepreneur

Schumpeter (1912) brings the endogenous entrepreneur onto the center stage economic analysis unlike any writer previously. The entrepreneur for Schumpeter must be seen as the human agency, via innovation, to economic development. It is this agency role that makes the development process non-deterministic and instead, adapting to complex changes: "The economy does not grow into higher forms by itself" he says. "The history of every industry leads us back to men and to energetic will and activity. This is the strongest and most prominent reality of economic life." (Schumpeter 1912, p.75) In other words, human agency via the entrepreneur is involved in effecting the innovations required for economic development.

In trying to understand the totality of the economy, Schumpeter divides economic processes into three categories or classes: "…into those processes of the circular flow; into those of development; and into those which impede the latter's undisturbed course." (1934, p. 218). Throughout his body of work, he refers to the processes of the circular flows in the market process as "statics," and those of economic development in which innovation resides as "dynamics." As Schumpeter states in his first published book:

> This distinction is crucial. Statics and dynamics are two totally different areas. Not only do they deal with different problems, but they use different methods and they work with different materials. They are not two chapters in the same theoretical construction – they are two totally different buildings. Only statics has been worked on sufficiently, and this book mainly addresses this kind of problem. The analysis of dynamics is still in its beginnings; it is a 'land of the future'. (Schumpeter 1908, p. 626, translation cited in Swedberg 2007, p. 30).

Schumpeter's thinking on that "land of the future" would emerge 4 years later in *The Theory of Economic* Development (Schumpeter 1912). By "circular flow" or statics, Schumpeter means that part of the overall economy that can be conceptualized as operating as a general equilibrium system under stationary conditions as proposed by the neoclassical economists. Within this system, commodity and product prices settle at levels that cause supply and demand in each market to be matched and *homo economicus* is rational and narrowly self-interested as he seeks to maximize his economic gain. Incremental quantitative growth is achieved through stimuli such as changing consumer tastes in conditions of gradually increasing population, saving, and capital accumulation. Importantly, there is no endogenous development that results in qualitatively new phenomena.

Schumpeter, by this distinction between statics and dynamics, places the entrepreneur clearly into the dynamic process and questions the role of the entrepreneur in the neoclassical model. Either neoclassical theory accepts that its statics is only a partial analysis of a more complex real system, and cannot, therefore, make valid knowledge claims about the entire system, or it is claiming that the entire real economic system behaves as a self-reinforcing system in static equilibrium that maintains itself. The former interpretation can be seen as a realist view on the static approach that qualifies any knowledge claims deriving from it. The latter interpretation is fundamentalist and susceptible to knowledge claims derived from static analysis techniques and, thus, questions the role of the entrepreneur within the neoclassical system.

In Chap. 2 of the second edition of *Theory*, Schumpeter describes the individuals who carry out new combinations as entrepreneurs.

He immediately qualifies this, saying the concept is broader than a single individual:

> . . .we call entrepreneurs not only those 'independent' businessmen in an exchange economy who are usually so designated, but all those who actually fulfil the function by which we define the concept, even if they are, as is becoming the rule, 'dependent' employees of a company, like managers, members of boards of directors, and so forth. . .(Schumpeter 1934, pp. 74–5).

The reason for this formulation is explained in a note to the second edition (1934) he challenges ". . .one of the most annoying misunderstandings that arose out of the first edition." This was the suggestion that, in a variation of the "great man theory," he had identified the individual entrepreneur as the prime cause of innovation and hence economic change. "If my representation were intended to be as this objection assumes, it would obviously be nonsense" he says and points out that his concern is not with ". . .the concrete factors of change, but the method by which these work. . ." An individual is ". . .merely the bearer of the *mechanism of change*" (Schumpeter 1934, p. 61n, emphasis in the original), or simply, the agency for introducing novelty into the organization. Such novelty is regarded by Schumpeter as disruptive to the current *status quo* in the production system, whether that is the firm, industry, or the economy. Schumpeter categorizes this novelty into five types of discontinuous development: introduction of new products and new production processes, opening of new markets, acquisition of news sources of inputs, and reorganization of firms or industry sectors (Schumpeter 1934, p. 66). All five types can be new to the organization, to the industry or even to the system widely. Entrepreneurs who introduce novelty into their organization are effectively conducting diffusion of innovation (Rogers 1995).

Schumpeter has an example of railways and mail coaches which provides great insight to this dynamic mechanism of change and the role of innovation. His concern is not with the nature of any underlying technology *per se*, but with changes in its economic use. Mail coaches and railways in the nineteenth century were the temporal stages of development in two distinct means of transporting goods and people. The former were wheeled and freely steerable on any surface hard enough for the wheels to turn without a resistance greater than the power of their locomotive force, typically a team of two, four, or six horses. Mail coaches were an incremental technological development of a transport tradition that can be traced back through Roman chariots to the earliest and simplest of flatbed wagons that must have quickly followed the invention of the wheel.

The steam-driven locomotives with which the Liverpool to Manchester passenger and freight services began in 1830 were also an incremental technological development, this time of wheeled vehicles running on a prepared track that bears their weight and guides the vehicles and acts as a limit to their range and direction. The origins of this form of railed transportation can be traced back to at least the Greeks and Romans (Lewis 2001). Even the steam engine was not new technology in 1830. The earliest engines were novelties invented by Hero of Alexandria in the first century AD and practical stationary engines had been undergoing incremental development since Thomas Savery's invention for pumping water in 1698. However, none of these incrementally developing technologies had resulted in the type of discontinuous economic change with which Schumpeter is concerned until the performance of George Stephenson's Rocket at the Rainhill Trials in 1829 demonstrated that a mobile version of a steam engine on rails could be used to transport large numbers of people safely over long distances at speed (Encyclopedia Britannica 1984).

Success of the steam locomotive resulted in an economic discontinuity caused by change in the way in which people and goods moved around Britain. Before 1830, the primary means of land transportation was by horse-drawn mail coach, and steam locomotives progressively displaced the coaches after that date. It was not new technology *per se* that had produced the change, but a new combination of existing technologies brought forward by the entrepreneur. Thus, what is "new" for the entrepreneur is not technical knowledge, nor ability to finance innovation; instead, it is the skills and characteristics the entrepreneur brings to development in the sense of a transition from one norm to another which is not reachable through a series of incremental steps, i.e., when the change is discontinuous and disruptive. Conversely, he considers that "mere managers" have the ability to implement incremental change, i.e., that which *can* be decomposed into a series of infinitesimal steps. Since this, by definition, includes all incremental innovation intended to optimize processes or offer slightly improved versions of existing products and services, conclusion can be drawn that there is no role for the entrepreneur in such continuous innovation.

This interpretation is supported by concrete examples of how businesses organize for the two different types of change. For example, to bring a new product to market teams are typically formed outside the normal hierarchical management structure and only exist temporarily while engaged in this activity. Introduction of new products is one of Schumpeter's five types of discontinuous development. Once introduced as a new product, the tasks of launch, support, and maintenance (including release of new versions) is typically the responsibility of a permanent unit within the normal hierarchy of the firm. A similar situation prevails in software development, where a specially formed project team will carry out the development of new application software, while a separate support department will handle the subsequent maintenance and new releases. More generally, organizations implementing small process improvements to production or administration systems will normally entrust these to existing line management. It is only when attempting more complex and revolutionary process re-engineering that the task will be allocated to a specialist project team outside the day-to-day management structure.

The distinction in an organization is between the "dynamic" entrepreneur as a mechanism of change vis-à-vis the "static" manager as a mechanism of consolidation. Across organizations, Baumol (2010) makes clear there are two different types within the category of "dynamic entrepreneur." Crucially, and most importantly, there is the "true" productive entrepreneur as a person (or team) which is productive in a welfare-enhancing development process that adds to productive wealth. This is the type that Schumpeter envisages in his works. In contrast, Baumol recognizes also the "disruptive" entrepreneur who is unproductive since the activity being engaged is only rent-seeking, like identifying previously unused speculative or illegal opportunities. The term "disruptive" is used by Baumol in a subjective manner to indicate economic activity that is antisocial and unethical, while the same term is used by Schumpeter in an objective manner to indicate the outcome of discontinuous development. When used in the context of Baumol's subjective definition, the term needs to have quotation marks around it, i.e., "disruptive."

The "disruptive" unproductive entrepreneurs look initially to be adding value through employment or stockholder value, as did the entrepreneurs who innovated the sub-prime mortgages and collateralized debt obligations during the early 2000s (see Kregel 2008). Further down the track, such activity unravels into major costs to society and to the business community in general that far outweighs any initial positive value, as exhibited by the Global Financial Crisis that resulted in a banking collapse in September 2008, followed by the long-running "Great Recession" (see Arestis and Karakitsos 2010).

A question arises for the dynamic entrepreneur, be it productive or "disruptive." Is the change arising from innovation something the entrepreneur can calculate the risk of within the probabilities of failure and success? Or, instead is the change so novel and fundamental that no risk assessment can be made, leaving incalculable uncertainty in its wake that needs to be "managed" in the best way possible.

Risk and Uncertainty

There is much confusion in the entrepreneurship literature over the risk/uncertainty dichotomy, despite the clear distinction made in economics by both Keynes (1907) and Knight (1921). All the entrepreneurship textbooks identify entrepreneurs as being *risk-oriented*, but then emphasize that risk assessment is required in order reduce *uncertainty* on “wild chances” through business planning and preparation (Frederick et al. 2006, p. 31). This merging of the risk/uncertainty dichotomy distorts the entrepreneurs role, since “. . .[p]rofit arises out of the inherent, absolute unpredictability of things. . .that cannot be anticipated. . .” (Knight 1921, p. 281). The issue is that risk assessment is possible and recommended under continuous incremental innovation, where “things” are not unpredictable. Whereas, discontinuous innovation has such high level of uncertainty that risk assessment is impossible, with only some general scenario planning for different contingencies within a CAS is the only feasible approach. The risk/uncertainty dichotomy thus reflects the continuous/discontinuous distinction adopted in this entry based on the Schumpeterian perspective.

From this risk/uncertainty dichotomy, it transpires that the entrepreneur is not the same as the capitalist. Only the capitalist bears the risk of an investment failing. As Schumpeter (1934, p. 75n) makes clear: “Risk obviously always falls on the owner of the means of production or of the money capital which was paid for them, hence never on the entrepreneur as such.” Some entrepreneurs are owners and thus take on risk and the role of capitalist, just like some entrepreneurs, as described in the previous section, can be technologists who take on the technical implementation. In this context, risk is an activity undertaken by the capitalist and not the entrepreneur.

What an entrepreneur takes on, Schumpeter argues, is the significant uncertainty involved in the introduction of new disruptive combinations due to the indeterminate nature of novelty. The depth of analysis typically required for the risk-oriented decision-making within the static state “circular flow” of incremental innovation is not available for discontinuous innovation due to the lack of relevant data for the latter decisions. The entrepreneur must, therefore, be comfortable operating with uncertainty and making decisions by “instinct” or “gut feel.” This is related to another neoclassical axiom that is challenged in this continuous/discontinuous distinction. The axiom states all economic agents are rational and self-interested, which is essential for a robust equilibrium algorithm to exist. However, when there is discontinuous innovation, such a decision cannot be analyzed or rationalized in any coherent approach, since there can be no concept of rational choice in an environment of indeterminate uncertainty.

When it comes to entrepreneurial motivation, Schumpeter rejects narrowly defined hedonistic motives. Hedonism requires one to ignore uncertainty in the search for rewarding financial risks (e.g., trading on the stock market), whereas the entrepreneur needs to engage with uncertainty that requires much intellectual activity. In this context, entrepreneurs tend to be workaholics and “. . .activity of the entrepreneurial type is obviously an obstacle to hedonist enjoyment. . .usually acquired by incomes beyond a certain size, because their ‘consumption’ presupposes leisure” (Schumpeter 1934, p. 92).

At several points, Schumpeter draws comparisons between the characteristics of entrepreneurs and “mere managers” in the circular flow. Managers, in trying to keep their jobs and making an impact with the owners or directors, must consider that decision-making is based on the market and by the previous state of the business. Managers learn to read the signs, such as changes in demand from customers, from training and experience, and then adjust productive resources accordingly. Neither directing nor directed labor therefore exercises any real leadership over the business: The managers respond to consumers and workers respond to their managers. Day-to-day management of the business, in so far as it consists of adapting to normal fluctuations in supply of goods and services and the demands of customers, involves no creative input whatsoever and does not require handling uncertainty (Schumpeter 1934, pp. 20–2). In striving for the optimal methods of operation, managers tend to seek the best method of those that are familiar and have been tried and tested in practice.

The innovation decision-making of endogenous entrepreneurs under uncertainty occupies a different plane of activity. This is different because entrepreneurs in this world of uncertainty are one in which they elect the most appropriate method possible, which, by definition, may be untried, untested, and unfamiliar (Schumpeter 1934, p. 83). This means that optimizing rationality under *homo economicus* conditions is not an option. Such optimizing decision-making behavior is not an option due to the lack of data and inability to even identify where the data can be obtained (Courvisanos 2009). In this world of uncertainty, entrepreneurs conduct satisficing behavior under procedural (or bounded) rationality as explained by Herbert Simon (1976). This type of satisficing decision-making opens the door for new venture business creations that are truly innovative.

Business Creation and Innovation

Of course nothing in the Schumpeterian interpretation of an entrepreneur suggests that people who possess the ability to fulfill an entrepreneurial role may not be engaged on continuous innovation activities within the firm or organization. However, they are not acting as an entrepreneur when they do so and their entrepreneurial skills and capabilities are therefore latent and dormant. Neither does it mean that innovative entrepreneurial activity cannot take place within a firm; simply that business creation that is truly innovative has to consist of disruptive discontinuous change.

Throughout his career, the economic phenomenon that most fascinated Schumpeter was that of economic development, and it could only be seen in the context of history. As Michaelides and Milos (2009, p. 496) explain, "Schumpeter's notion of development is viewed. . .[as a]. . .theoretical approach of integrating theoretical and historical concerns." Schumpeter did not reject the usefulness of the popular equilibrium model as an analytical tool to analyze the stationary state of "ordinary routine work" (Schumpeter 1939, vol I, p. 40). However, he realized that the "circular flow" equilibrium of stationary capitalism with static markets could not explain the dynamics of economic growth.

In *The Theory of Economic Development* (Schumpeter 1912), three characteristics of economic development are specified. These three characteristics are the essence of disruptive business creation that Schumpeter calls "creative destruction." First characteristic of such development is the need to be endogenous to the economic system and not a reaction to external events or other stimuli. Second characteristic is based on business creation as discontinuous which does not occur in smoothly changing processes. In fact, Schumpeter explains it is at the trough of business cycles that such creative destruction is bound to be more successful, as there are around many failed previous continuous incremental innovations. Third characteristic is that such business creation is disruptive to the *status quo*, with old equilibrium conditions – and old competitors – all being radically changed. As a result, "creative destruction is the essential fact about capitalism" (Schumpeter 1942, p. 83) and the entrepreneur is the prime agent of this economic change. The endogenous stimulus is, Schumpeter argues, innovation which he sees as the creation of "new combinations" based around the five types of discontinuous development.

As his thinking developed, by 1942, Schumpeter was suggesting the disruption caused by innovation is traumatic, especially as new firms produce new products by innovative processes that puts old firms out of business. Such trauma led Schumpeter to predict that once these new businesses become powerful large capitalist firms, they will cease to be innovative, and this could threaten the viability of capitalism. Hamdouch et al. (2008) identify the integration of the two Schumpeterian models of small innovative entrepreneur and large firm "intrapreneur" into a new broader "networked" model based on strong collaboration and clustering activities using modern information technology. This network model has allayed the lack of innovation in emerging new industries like biotechnology (Hamdouch and He 2009) and software industry

(Salavisa et al. 2009), while established older industries like automotive and electrical appliances suffer from lack of disruptive innovation in order to merely fortify their market position (Buxey 2000).

From this economic development perspective, Schumpeter contends that expansion of credit is an important, but only secondary, part of the growth mechanism. Thus, the management of general levels of interest rates by central banks is ineffectual in stimulating recovery from a recession. Thus, with "quantitative easing" or lowering interest rates, firms reason that it better (as Schumpeter says) to cease:

> . . .to wonder why. In fact, it can be argued that the outcome is likely to be worse due to a two-fold dampening effect on the discontinuous innovation required to generate the growth required for the economy to emerge from recession. (Schumpeter 1935, p. 8).

Schumpeter (1935, p. 8) goes on to note that: '. . .any satisfactory analysis of the causes [of the cycle] must start with what induces that credit expansion. . .' and unless that credit demand is coming from entrepreneurs for the purpose of initiating discontinuous innovation, the expected economic development will not occur. Increasing the availability of cheaper credit to firms within the circular flow – as the US monetary authorities are doing to stimulate the economy out of a post-GFC stagnant malaise – will have the effect of, in the worst case, reducing costs, the benefit of which is returned directly to shareholders as companies seek to maintain their levels of dividend payouts to shareholders. In the best case, the reinvestment of profits stimulates investment in adaptive improvement which, by supporting the longevity of established businesses, reduces the likelihood of creative destruction occurring. In fact, the risk-adversity of firms in the circular flow and their reluctance to undertake any investment in recessionary conditions may tend to make the former outcome more likely than the latter. This is what Schumpeter refers to as the "two-fold dampening effect"; one is the increased dividend payout, the other is the reinvestment in minor incremental innovation.

A more effective monetary policy in recessionary conditions may be to hold general levels of interest rates steady while implementing policies to improve the flow of lower cost credit to potential entrepreneurs. Analysis of such a proactive policy is beyond the scope of this entry, but the objective would be to increase the flow of credit to dynamic discontinuous entrepreneurs while restraining the availability of credit to existing businesses.

Conclusion and Future Directions

This entry has taken a discernibly strong Schumpeterian perspective to entrepreneurship, since this perspective is the *only* rigorous approach that unites entrepreneurs with innovation without conflating the innovation process with simply the operation of a business. In neoclassical economics, there is no such clear perspective since it lacks an economic development approach, leaving entrepreneurship to be merely the organizing agency of the available resources of land, labor, and capital within a static equilibrium model. Instead, what is required by economic thought for future analysis is a dynamic complex adaptive model implied by Schumpeter with his description of innovative movement into disequilibrium. A growing body of evolutionary and neo-Schumpeterian economics provide this dynamic Schumpeterian perspective that has much to offer future economic analysis, but only if this "supply-side" is combined the "effective demand-side" work of Post Keynesians and Kaleckians on investment, consumption, and income distribution which determine how economic development out of innovation materializes (Courvisanos 2012b).

There are some significant implications that arise from the discussion above that provide clear suggestions for future research directions. One is systematizing endogeneity of the entrepreneurial spirit within a complex adaptive system and rejecting the static market equilibrium approach. This would then provide basis for better economic development models of national economies and major regions. Another suggestion is the role of the dynamic entrepreneur in combining existing technologies into new areas of activity that eventually diffuses such innovation to become major industries. This would then provide basis for better analysis of the role of the entrepreneur in the path of creative destruction. Third suggestion is based on satisficing decision-making under uncertainty that evaluates new venture business creations that are truly innovative. This would then provide basis for better understanding of role of uncertainty in innovation decision-making in the context of intuition and sensitivity to change. Final suggestion is based on the role of innovation in cycles and crisis, such that passive monetary policy to stimulate economies is ineffective. This would provide basis for distinctly proactive public policies that create "room to move" for new trajectories that reject incumbent powerful monopolies, but also do not eulogize small business operators (for more on this, see Courvisanos 2012a).

Cross-References

- ▶ Business Climate and Entrepreneurialism
- ▶ Business Cycles
- ▶ Corporate Entrepreneurship
- ▶ Creativity and Innovation: What Is the Difference?
- ▶ Entrepreneurship Policies
- ▶ Joseph A. Schumpeter and Innovation
- ▶ Risk, Uncertainty, and Business Creation
- ▶ Schumpeterian Entrepreneur

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Innovation by Applied Mathematics

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Synonyms

Industrial mathematics; Mathematical modeling and numerical simulation

Introduction

Following the OECD Oslo Manual (2005), *an innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations. [. . .]*

A product innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness, or other functional characteristics. Product innovations can utilize new knowledge or technologies or can be based on new uses or combinations of existing knowledge or technologies. [. . .]

A process innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment, and/or software. Process innovations can be intended to decrease unit costs of production or delivery, to increase quality, or to produce or deliver new or significantly improved products.

Techniques from applied mathematics belong to the main drivers of product and process innovations. For a range of examples, see Levy et al. (2011) or RICAM Video (2007).

The typical steps in the mathematical treatment of an industrial problem are the following:

1. Ask the right questions.
2. Formulation of mathematical models for the relevant phenomena to be covered: Translate the industrial problem into a problem in mathematical language.
3. Calculate a solution of the problem, typically by numerical simulation on computers.
4. Interpret and verify the results.

In most cases, this is not a sequential procedure but requires several iterations. It may also happen that reasonable solutions for a specific problem cannot be obtained within reasonable time, within a given budget, or due to a lack of data.

An Example from Heavy Industries

Blast furnaces have been in use for iron production at least for the last 2000 years (Fig. 1).

Innovation by Applied Mathematics, Fig. 1 Blast furnace of the Chinese Han dynasty (Source: Private photograph)

A modern blast furnace may be in continuous operation for 10 years and may produce 5 million tons of metallic iron per year. Questions of interest are as follows:

– How does the chemical analysis of the iron ore influence the properties of iron and slag?
– How much energy/coke/hydrogen is used per day?
– Can the operator influence the daily production?
– Can the melting point of iron or the viscosity of the slag be influenced by additional materials like limestone? How can this be done methodically?

A mathematical model of a blast furnace covers the following phenomena:

– The flow of solid iron ore, coke, additional materials from the top to the bottom.
– The flow of reduction gas (hydrogen, carbon monoxide) from the tuyeres at the bottom to the top.
– A range of chemical reactions. To obtain a detailed understanding of the process, up to 40 or 50 chemical reactions and their kinetics have to be taken into account.
– Energy balance: The melting point of iron is between 1,400 °C and 1,500 °C. During the residence time of the iron ore in the furnace, its temperature has to be increased from surrounding temperature to the melting point.

These phenomena are coupled: Chemical reactions may produce energy or consume it and may need a certain temperature level to start. Increased temperature influences the flow behavior of the solids; coke is finally burnt and thus changes from the downward solid flow to the upward flow of carbon monoxide and dioxide. The layerwise charging of iron bearing layers and coke is essential to avoid an obstruction of the gas flow.

The mathematical translation of these phenomena leads – by taking into account conservation of mass, momentum, and energy – to a system of nonlinear partial differential equations describing, e.g., the temperature or the concentration of iron oxide FeO of a point (x, y, z) at time t. These equations are coupled in the sense that, as an example, the temperature at a point is influenced by the history of particles reaching that point, and, on the other hand, the temperature is a main driver for the kinetics of chemical reactions.

The solution of the coupled blast furnace model cannot be derived by applying analytic formulae but has to be obtained by numerical techniques. For these, the calculation domain (the furnace) is meshed by a finite element grid (Fig. 2). It turns out that the simplification of

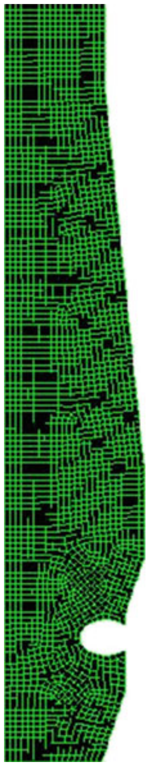

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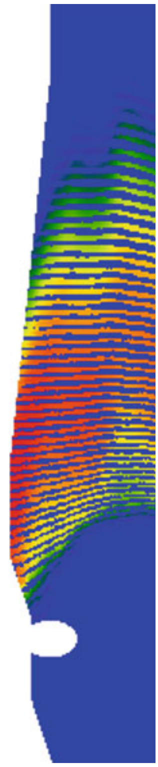
Fig. 2 Typical calculation meh in a 2D calculation (Source: MathConsult)



Innovation by Applied Mathematics,
Fig. 3 Concentration of FeO. The highest concentration is reached in the *red* layers. Coke layers between are *blue* (Source: MathConsult)

rotational symmetry is reasonable, which decreases the computational effort significantly. Nevertheless, as the thickness of the iron ore and the coke layers have to be resolved, a typical spatially two-dimensional blast furnace simulation needs 800.000 unknowns for which the equations are solved.

The numerical treatment of these coupled equations requires techniques from fluid dynamics and from chemical engineering in combination with sound programming skills. Additional difficulties arise from the different time scales (the gas flow is 1,000 times faster than the solid flow) and from discontinuities between the layers.

The interpretation of the results and their verification by measurements may, at least during the first modeling iterations, lead to the insight that additional chemical reactions have to be taken into account or that other phenomena may be neglected without a significant change in the results.

Depending on the number of chemical reactions to be considered and on the size of the numerical grid, a real world process day is computed within 2–5 h on a conventional personal computer. The results show a very good coincidence with experimental measurements. For details, see Fig. 3 (Engl et al. 2007).

There are several innovations related to this kinetic blast furnace simulation:

– New operational conditions of a blast furnace (e.g., different raw materials, a different burden distribution, or a more aggressive firing with additional fuel leading to an assumed higher productivity) may be analyzed in advance by computer simulation before an operational strategy is chosen. Such computer experiments are typically much cheaper and environmentally friendly.
– In the plant engineering and construction, different geometries of blast furnaces may be studied.
– The online control and monitoring of a furnace may lead to a safer operation, longer maintenance intervals, and therefore a higher productivity.

Sources of Innovation by Applied Mathematics

The mathematical modeling of industrial processes by applying conservation principles from physics has a long tradition since the development of modern calculus from the nineteenth century onward. However, an accurate quantitative analysis of industrial processes by means of manual calculations is often not possible due to the nonlinearity or the complexity of the process.

With the breakthrough of computer power and computer availability during the last decades, the numerical simulation of industrial processes has become feasible for a wide range of applications. On the hardware side, standard personal computers of today are certainly 1,000 times faster and have 1,000 times the memory of expensive workstations in the late 1980s. Even smartphones are equipped with more memory.

For the rapid development in mathematical simulation of complex processes, at least two more pillars have been essential.

The careful analysis of numerical algorithms for (here) differential equations has led to new methods of solution techniques, which often require much fewer iterations than conventional solvers. Parallelization, multigrid techniques, and preconditioning yield additional orders of magnitude in calculation speed.

Of equal importance is the development in software design and the availability of tools for rapid prototyping of small and medium-sized problems. Modern software architecture leads to a better usability and reusability of mathematical software for different application fields and to better maintenance properties of mathematical algorithms.

Automotive Industries

The technical specifications on modern cars are more and more demanding: Engines are either combustion or electrical engines or a combination of these. Although cars are significantly heavier than 20 years ago, fuel consumption should be reduced, the exhaust gas should satisfy tight environmental requirements, maintenance intervals are increased, and the safety of drivers and passengers is improved continuously.

Mathematical modeling and simulation in automotive industries are key factors to reduce development cycles, to optimize exhaust gas and its catalytic aftertreatment, and to adjust cars to the environment in which they are used.

Automotive simulation is also a good example to demonstrate multiscale modeling and different modeling depth (Fig. 4): For the detailed analysis of the combustion process, a three-dimensional fluid dynamics simulation will be necessary, which may take hours or even days to simulate a few combustion cycles; on the other hand, for the setup and optimization of the interaction between power train, gear box, wheels, brakes, and several more aggregates, a coarser modeling makes sense. So-called surrogate models, often realized as support vector machines or as neural networks, are used to obtain very fast input–output relations either from measurement data or by offline training cycles based on detailed simulation. In the past years, these surrogate models allowed to combine virtual engines and test beds of physical engines. Obviously, in such environments, the simulation software must be at least as fast as the physical motor and simulate each millisecond of physical time within a millisecond on the computer.

Mathematical Simulation in Medicine and Biology

Modern medical imaging would not be possible without mathematical computation. The basis of computerized tomography (by utilizing X rays in various directions) is the Radon transform, which was introduced by Johann Radon in 1917. Using other sources of waves leads to magnetic resonance tomography, electrical impedance tomography, or to medical ultrasound. When inverting raw data obtained from different imaging instruments, it is essential to take into account the noise characteristics of the specific instrument and to apply specific mathematical inversion algorithms.

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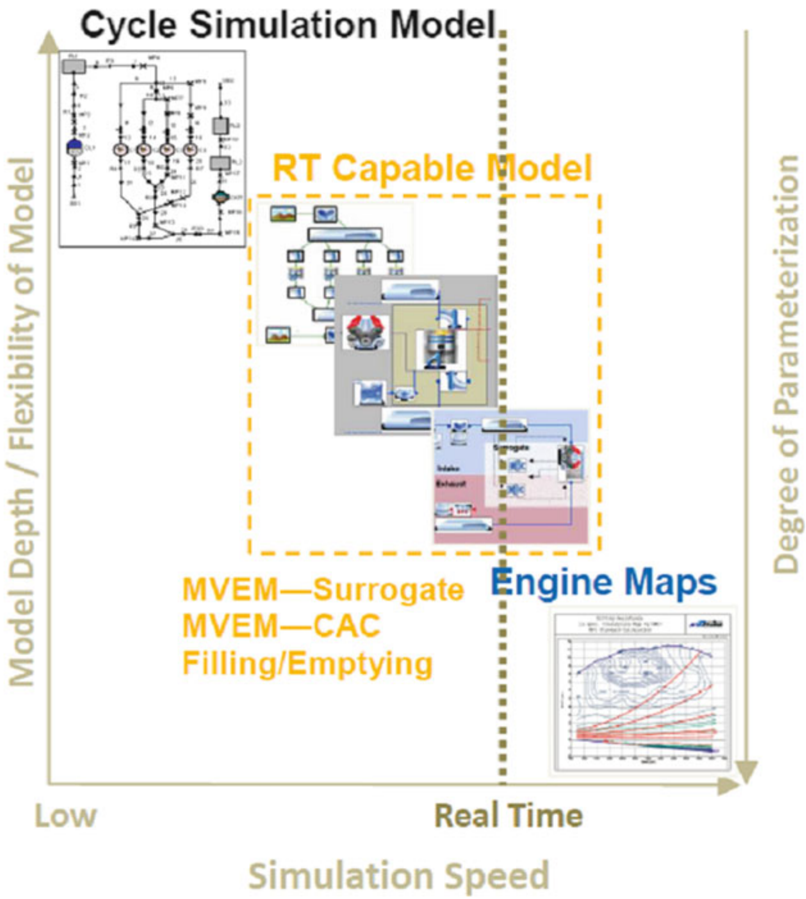
Fig. 4 A schematic view of the relation between simulation speed and model depth in automotive simulation (Source: MathConsult and AVL List)



Systems biology is a relatively young biological discipline that claims to consider cells and organisms as entities in a holistic way. At the same time, it focuses on the interplay of components from the molecular to the systemic level. Quantitative measurements and recordings of biological processes are merged with advanced mathematical methods to yield predictive theoretical, mostly computational, models of biological systems. High mathematical complexity arises from the fact that the metabolism of the cell is the set of several thousands of catalyzed biochemical reactions resulting in molecular concentrations of a large number of substrates, products and enzymes as functions of time (Engl et al. 2009).

A major goal of systems biology is to provide an understanding of properties and behavior of cells or organisms emerging as consequence of the interaction of large numbers of molecules, which organize themselves into highly intricate reaction networks that span various levels of cellular or organismal complexity. The number of nodes in metabolic networks amounts to several thousand molecules.

Computational Finance and Risk Management

Computational finance, as it is widely understood in the mathematical finance community, deals with the valuation, the risk analysis, and the risk management of financial instruments like bonds, swaps, futures, options, and arbitrarily complex derivative or structured instruments (Albrecher et al. 2012). The necessary steps for valuating such financial instruments are as follows:

– Choose one or more models for the stochastic behavior of the underlying. This underlying may be the quoted spot price of an equity share, a Libor rate, or a foreign exchange rate.

– Determine the parameters of the model in a stable and robust way by utilizing market data of liquid instruments. Note that there may be severe traps hidden in this model calibration, which may yield misleading results.
– Valuate the derivative or structured financial instrument by applying numerical techniques. These are typically Monte Carlo techniques, methods form partial differential equations, or Fourier-based methods.

The requirements on the response times in quantitative finance are quite strict, so that almost real time calculation is needed.

The developments on the financial markets since 2007 showed that risk controlling and risk management need mathematical tools even mightier than those used at the trading floors in order to analyze market, credit, and liquidity risk properly.

Applied Mathematics and Education

It is observed that in high schools around the world, there are typically no real world problems to be solved, but intersections of planes are calculated, tangents on ellipses or hyperbolas have to be determined, or integrals have to be calculated by hand. (These are tasks that a computer (or even a cell phone) can do better.) For the sake of calculations, the steps (1), (2), and (4) of the Introduction are underweighted, and doing the calculations (3) lies in the main focus. See also Ziegler (2011), Wolfram (2010).

Doing more experimental mathematics (like in http://www.myphysicslab.com/dbl_pendulum.html) might bring curiosity back to school.

Conclusion and Future Directions

The mathematical modeling and numerical simulation of complex systems allow product and process innovation in a wide range of application fields. A few of these, in which the author was personally involved, have been mentioned, but there are many more areas in which research, development, and innovation are not possible without the heavy use of mathematical simulation.

While mathematical simulation has been used in physics, astronomy, and mechanical and chemical engineering since the emersion of computers, during the last years, heavy progress was made, e.g., in systems biology, drug design, and nanoscience.

The progress in modeling capability by a deeper understanding of the relevant processes and in computer hardware and algorithm development will allow problems to be tackled which today are out of simulatory reach.

Cross-References

► Product Innovation, Process Innovation

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Innovation Diffusion

▶ Epidemiology of Innovation: Concepts and Constructs
▶ Nonlinear Innovations

Innovation Diplomacy

▶ Applied Design Thinking Lab and Creative Empowering of Interdisciplinary Teams

Innovation Ecosystem

▶ Mode 3 Knowledge Production in Quadruple Helix Innovation Systems: Quintuple Helix and Social Ecology
▶ Technology Push and Market Pull Entrepreneurship

Innovation in Business: Six Honest Questions

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Synonyms

Creative leadership; Design thinking; Innovation practices; Research and innovation

The Right Questions

> *Complex problems have simple, easy to understand, wrong answers.*
> Henry Louis Mencken (1880–1956)

> *I keep six honest serving-men*
> *(They taught me all I knew):*
> *Their names are What and Why and When*
> *And How and Where and Who.*
> By Rudyard Kipling, *Elephant's Child* (1902)

The fundamental idea behind creative activity and creative problem-solving – which is the cornerstone of innovation – is to question, that is, to ask the right question. Whatever the product, service, process, or solution, the crucial point is to answer the right question or rather questions. What, why, when, how, where, and who tell you everything essential that creative questioning includes. Deriving from the poem by Rudyard Kipling, these can be called *The Six Honest Questions*, with which one can achieve genuinely new answers and furthermore radical innovations that create something new. By answering deeply the questions of the six "serving men" about form, process, place, and time as well as competence and goals in addition to the user and the context, one can find the path leading to the future – the homeland of innovations.

Another way to examine this issue is to question the practices employed for seeking answers and to focus attention on those stages of the process and working methods which actually destroy creative thinking and prevent its development as well as, ultimately, the actual use of creativity and its realization. Ryan Jacoby, the head of IDEO, New York, has described *Seven Deadly Sins of Innovation* (Walter 2012) which in practice block the emergence of significant innovations. Most companies have processed the product development of innovation work, although the process as such does not guarantee the emergence of innovations – rather the opposite, in fact. According to Jacoby, the obstacles to innovation or innovation killers are the following seven business culture practices:

The Seven Sins of Innovation (as interpreted by the author)

1. *Thinking the answer is in here, rather than out there*. It is necessary to get out of the comfort zone in order to challenge the existing norm. One should look around and be open to external possibilities. In global competition, normal is not enough.
2. *Talking about it rather than building it*. Innovation should be an action, a verb, and an aspiration. There is a great slogan in the end of the famous IBM Innovation Man video: "Stop talking, start doing." Learning by

doing also speeds up innovation development since by doing so, one also has to apply tacit knowledge.
3. *Executing when one should be exploring*. Too often experts and managers rush forward when they should be taking a closer look instead, to study, to research, and finally to understand more profoundly the issue at hand. Making final decisions too early might lead to fatal decisions in long-term thinking.
4. *Being smart*. That will kill debate and block new ideas. Ideas are so fragile, as Jonathan Ive had said that you should protect them against intellectual attacks and indifference in order to keep them alive. Creative culture does not need "smarties."
5. *Being impatient for the wrong things*. Developing radical innovations takes definitely more time and resources than developing incremental ones. There should be a match between what is expected and what can be achieved.
6. *Confusing cross-functionality with diverse viewpoints*. Diversity is a key to innovation; different functionalities do not guarantee diverse approaches if the people do not have genuinely different backgrounds and competences.
7. *Believing process will save everything*. This is the most fatal single sin: trusting in the process to solve the problems and generate innovations. Many innovations happen by accident or they are done by taking another path rather than following mainstream thinking and processes.

True creative leadership, which is a prerequisite for innovation work, is by nature a visionary searching, guided by genuine, right, and honest questions. It does not follow predetermined processes and formulas but rather proceeds by questioning both methods and practices, finding its own genuine and unique path.

What: First Versus Fast Follower

Most national and regional innovation programs emphasize customer-oriented innovation and the importance of the customer-centered design that supports this. Different types of user experience tests and usability-simulation methods solidify the notion of the customer's omnipotence: people first! In the worst case, this situation leads to responsibility for developing products and the product needs actually being transferred to the end users, whose needs and wishes are then directly implemented in products and services – without ever questioning their true rationality, needfulness, and sustainability.

Two famous architects have decided on the opposite approach in their work, and both have attained a reputation as superb, visionary designers among the public and professionals alike. Architect Frank Gehry has wisely observed (Bell 2012):

> You can't just build a building based on what the clients say, because their vision is based on what's normal. How do you get out of the normal? You've got to question everything. Spend time with the user group. Glean all the information you can. And then throw it all away and begin to play.

Many gradually developed product improvements and small-scale innovations can emerge through the customer's wishes and insights – but real, radical, and creative innovations demand the ability to see further into the future while simultaneously still understanding the users' need continuum. Without "throwing ourselves into the creative play," it is impossible to detach oneself from the convention and step outside the comfort zone, which is where significant new insights and innovations emerge.

It is also a question about corporate culture and the role of the company: does it want to be first or a fast follower? The latter depends literally on the customer as, when asked, the user usually says he wants something like his "neighbor" – that is, a competitor – has. The first-mentioned builds his products and services on the foundation of a vision and turns it into a story which also extends into the future. Products of this kind, which look creatively into the future, change and revolutionize the world, creating new-generation products, services, and users.

The same creative freedom and the responsibility it entails were referred to by architect

Louis I. Kahn in the following quotation (Johnson 1975):

> I don't believe in need as force at all. Need is a current, everyday affair. But desire – that is something else again. Desire is the forerunner of a new need. It is the yet not stated, the yet not made which motivates.

Gehry's juxtaposition of the ordinary with the special gains support from Kahn's emphasis on the time dimensionality of innovation from the present into the future. A need-based product is already in existence – but a desire-based, aspirational product or service is the forerunner of a new need, thus pointing strongly into the future. It is something which has not yet taken on a concrete form; it is something which is still on the way. In innovation work, these "forerunners" Kahn refers to are signals of change, out of which significant new drivers in products, the economy, society, or culture may emerge. By understanding these drivers of change, it is possible to navigate to the future and create new, currently hidden future needs.

The desirability of Apple products and services is based on the fact that the company has succeeded, time after time, in surprising its users positively with new and unique products and services which have no predecessors in history. The crucial characteristic of innovation is that it surprises – usually even the person who made it – with the power it gains among users in the market as well as in the influence it ultimately has on the way of life and on society. Apple's products and services are a good example of how innovations can create new, emergent needs and transform familiar practices.

Why: Exploring Versus Executing

Questioning is part of the very core of innovation work: it forms the critical framework against which the assigned task, the problem itself, and any demarcation are tested. The most innovative team never accepts the problem as such as their starting point, preferring to ask each time: why this question in particular? Why-questions are among the toughest conundrums in science; by their nature, they are explanatory of a phenomenon and not descriptive of it. It is harder to ask the question why something is meaningful than to describe how it is meaningful. When profound questions have to be faced in innovation work, the answer cannot be only on the product level; the solution also takes a stance on its social influence and even its potential impact on human behavior. Social innovations are usually answers to why-questions and to great challenges: in addition to individual solutions, they also take a stance on the general social and philosophical-ethical discussion.

To creative people, why-questions are important: with them, creative curiosity is channeled toward new, unknown regions to discover what is essential in the answer. Core questions also generate far-reaching replies. These are so-called killer questions, which point beyond conventional solutions. In the future, more and more frequently, the race will go to boldly and profoundly phrased questions – not answers that lean on the normal and conventional.

Answering why-questions also creates new experiences for users. Power questions often lead to "killer applications," that is, products and services that change human behavior and the value chain paradigm. Sohrab Vossoughi, Ziba's founder, president, and chief creative director, has said (Vossoughi 2012):

> What Apple offers is an Apple experience. There is no equivalent Samsung experience. Crafting a consistent, compelling experience is extremely difficult. It takes nothing less than company-wide commitment to a purpose and a vision of what the world ought to be like: how it should look, feel, sound, and evolve over time.

> *I send them over land and sea,*
> *I send them east and west;*
> *But after they have worked for me,*
> *I give them all a rest.*
> By Rudyard Kipling, *Elephant's Child* (1902)

When: Flux Versus Flexi

Years ago, in the futurologists' conference, inventor Ray Kurzweil opened a talk by saying: "*Timing, timing – timing*." One of the most important elements of inventions and innovations is their timing: if a product or service is too futuristic, it will be left unexploited; on the other hand, if it is behind the times when it enters the market, it will no longer meet the criteria for innovation as it has no novelty value.

Today we talk about the flux environment of constant change in connection with business and innovation work. This means that long-term planning is almost impossible and that innovation has to be of a flexible, rapid, and agile nature, taking advantage of opportunities opened up by various situations. Reading the signs of the time correctly will rise in importance as a central part of the new creative activity. We will need more and more understanding of the future direction in support of creative product development and innovation work.

In his book *The Act of Creation* (1964), Arthur Koestler wrote about how a creative invention or innovation demands the right spirit of the times, "ripeness," for it to become possible and to win the acceptance of society (Popova 2012):

> The 'ripeness' of a culture for a new synthesis is reflected in the recurrent phenomenon of multiple discovery, and in the emergence of similar forms of art, handicrafts, and social institutions in diverse cultures. But when the situation is ripe for a given type or discovery, it still needs the intuitive power of an exceptional mind, and sometimes a favourable chance event, to bring it from potential into actual existence. On the other hand, some discoveries represent striking tours de force by individuals who seem to be so far ahead of their time that their contemporaries are unable to understand them.

The correct timing of an innovative product and service demands background work and above all vision, without which even the best idea cannot hit the "nerve of the times" and create new markets or reach new users through new needs.

The clock speed of corporate research and innovation work could as well be ahead as behind. Only the most visionary leaders can read and recognize the signs of the times correctly and respond to them in an anticipatory way time after time – mastering flux.

How: Navigating Versus Planning

Maps surround us and guide us – Google Map, GPS location, navigators, personal navigation systems (PNS) – these are all linked materially to travel today, on land, sea, and air. Actually, cartography has become one of the great innovation potentials for the future. Smart phones have put the user in the mobile map hub, unlike in the past, when the central hub of maps was always a fixed geographical spot where everyone wanted to be. Simon Garfield has pointed out (Thorpe 2012):

> The amount of interest in maps and globes at the moment has probably got something to do with the fact that we are all able to find ourselves on maps now at the touch of a screen. – It used to be Jerusalem that was placed at the centre of Christian maps, or in China, it would have been a place called Youzhou. Now for the first time we are all at the centre.

The mapping of the world and voyages of exploration have a long history. There was a time when possession of a map also meant power, like the great seafaring nations and trading cities. Metaphorically, one can also chart the future with voyages of exploration. Like explorers, it is possible to develop skills and knowledge with which to understand and navigate flux and the opportunities of the future. In his book *Futuring: The Exploration of the Future* (2004) Edward Cornish recognizes seven characteristics in the work of explorers which are also significant in probing the future (Cornish 2004).

The seven lessons of the great explorers (as interpreted by the author):

- *Prepare for what you will face in the future*. One cannot forecast the future with certainty, but the more one study the possibilities of the future, the better one is prepared to face it. This applies also to the constant change or flux.
- *Anticipate future needs*. This means to be aware of what kind of competences and capabilities is needed next. Old tools can hardly craft tomorrow's products and services. One should also be aware of the changing environment; what applies today will not necessarily apply tomorrow.
- *Use poor information when necessary*. Fuzzy logic is the essence of creative work; there is no definitive right or wrong answer for many of the questions related especially to radical innovations in their early stage. Creative work is built on possibilities and probabilities.
- *Expect the unexpected*. One should not be afraid of facing the strange and the unknown,

that is, the land or seas of truly creative and revolutionary ideas. The further the distance, the bigger the resistance by mediocrity.

- *Think long term as well as short term.* There should be the good understanding of the life cycle and the impact of solutions – great innovations are also sustainable, they support economic, environmental, and social balance for years to come.
- *Dream productively*. Even super-ideas must have their roots somewhere. They should have good soil for growth potential that will nurture their blossoming. Sometimes grassroots are the best ground for high-growing ideas and their implementation.
- *Learn from your predecessors.* Tacit knowledge is something that cannot be bought with any amount of money. The better the teachers there are, the better the understanding one can develop. Great minds have a lot to give.

Visionary innovation leaders have never respected known borders: they are not afraid to cross the boundaries between sectors, to blend divergent methods together, or to open up new perspectives. They have an inborn ability to integrate different scales, large and small, rational and irrational data, short- and long-term goals, as well as facts and visions. They chart the unknown, in many ways and from many directions, creating a unique, visionary whole. Creative leaders are today's cartographers, whose maps lead one into unknown waters with vision as a beacon. This is why they are trained to meet the challenges of a changing environment and to exploit them – according to the situation and in a timely manner.

> *I let them rest from nine till five,*
> *For I am busy then,*
> *As well as breakfast, lunch, and tea,*
> *For they are hungry men.*
> By Rudyard Kipling, *Elephant's Child* (1902)

Where: Openness Versus Ownership

In the future, research and innovation work will become increasingly open and global as well as decentralized and mobile. This will mean that companies will seek research partners where the best global expertise is found. Decentralized research will also support a new feature of corporate innovation work, that is, close presence and collaboration with its research and product development organizations located around the world. The 24-h clock speed of companies' product development work will require innovation no longer to be concentrated in a single, large research center, but rather it will be operationally fragmented worldwide as needed. Companies will increasingly seek research partners in various "creative centers" – urban innovation hubs, more and more of which will constantly be formed. Future innovation work will also be "brain hunting," in which individual talented people will be found both locally and globally. In all, it will be a matter of optimizing local and global manufacturing and research relative to the available and necessary creative capital.

Open research and innovation work will also necessitate open science, which means open data and open access to data such as transparency of publication as well as citizen science and participatory research. Open science will raise the standard of research, making it more transparent and raising its profile, thus accelerating the development of science as a whole. Ideally, open science will unite the common goals of professional researchers and those of (professional-) amateurs in the form of collaboration for the common good.

Another part of the future's open research and innovation ecosystem will be an open and innovative educational system, which will be geographically within reach of everyone through the Internet (Dizikes 2012).

> "This is the new classroom", as Professor Anant Agarwal, president of edX, said when showing a picture of Mongolian students, studying with the aid of edX online course materials, to the audience at the "Future of Education" conference. EdX is a not-for-profit enterprise of its founding partners Harvard University and the Massachusetts Institute of Technology that features learning designed specifically for interactive study via the web. Along with offering online courses, the institutions will use edX to research how students learn and how technology can transform learning–both on-campus and worldwide.

Both mentally and geographically, research and innovation work can today be done almost anywhere. In China, for example, the future innovation ecosystem is being dynamically developed through such things as redirecting research centers to think tanks. China is also encouraging both social and innovative entrepreneurship more than previously.

Future generations will learn and do research side by side, in a multicultural environment and simultaneously in many places around the world. With the help of the new networked model, teaching and research work will be more efficient and will have greater impact with the same resources. The most important influence, however, will be in the social dimension of the results: how well new innovations serve society and how broadly they affect people's living conditions, behavior, and culture.

> *But different folks have different views;*
> *I know a person small –*
> *She keeps ten million serving-men,*
> *Who get no rest at all!*
> By Rudyard Kipling, *Elephant's Child* (1902)

Who: Mavericks Versus Managers

The strategic application of design – *design thinking* – has gained ground in the past decade, not only in the development of products but especially in the development of service innovations. Companies have created the same kind of processes for design as for product development or manufacturing, in order to integrate and streamline its impact. However, regrettably often this has led to an opposite trend: the narrow-based use of design as one element in assuring a product's attractiveness and quality. Many leading thinkers of design have recently begun to talk about creative capital or creative leadership instead of design management and design thinking. A rising trend is to understand the total significance of creativity in research and innovation work: in ideation, research, processing, implementation, and even use. Creativity with all its dimensions is the connecting thread running through all innovation development.

The Creative Industries KTN in the UK has carried out extensive research on future priorities in innovation from the perspective of Britain's competitiveness. The research focuses in particular on the growing importance of experience-led innovation which is based on a deep understanding of human behavior and its drivers (The Creative Industries 2012).

Experience-led innovation is based on the notion that the producer of an innovation and/or designer takes first responsibility for designing a product or service. This takes place by deepening the understanding and vision of what people really expect from the future, but which they are not yet able to recognize and express explicitly. Experience-led innovation plumbs deep waters, seeking answers with the help of all six "honest serving men": the questions what, why, when, how, where, and who.

Today design is understood as a central, essential part of innovation, not only for consumer goods but also for many B-to-B products. Technology alone is no longer enough of a competitive edge – instead, companies stand out from the competition primarily through high-end design. Also in user interfaces and in the user experience, design plays a central and constantly growing part. When demand intensifies between well-designed technology products, it can already be seen that even design is no longer enough on its own to differentiate the product and make it desirable in the eyes of the user. This sparks the question: what next?

John Maeda, President of the Rhode Island School of Design, has recently stated how the requirement for good design will expand "beyond" the potentialities for design in the future and how the next vital innovation factor will be art – or rather the uncompromising stance of artists, creative individuals, and their passion for their work, reflecting their profound values continuum and their strong commitment. Maeda has said (Maeda 2012):

> But what people want today goes well beyond technology and design. They don't just want four wheels and a means to steer, or to be surrounded by music and information wherever their eyes and ears may roam. What people are looking for now is a way to reconnect with their values: to ground how they can, will, and should live in the world. – The innovation now needs to occur elsewhere. Outside the design. Into, quite frankly, the world of art.

According to research called *Artistic Interventions for Innovation* (2012) in the CreativeClash program carried out by the European Union, artistic intervention has a generally positive impact on innovation and especially in the following three cases:

- *Developing services, products, and processes innovation*: disruptive thinking, creative approaches, and new methodologies of interaction generate new ideas.
- *Supporting social innovation*: improving social relations among employees and enhancing new skills contribute to creating better working conditions, social cohesion, and inclusion.
- *Rethinking ways of relating to users and communities*: artistic processes help identify or refine corporate culture and values, supporting the development of creative communication strategies.

But above all, the passion and unremitting stance of creative individuals is the factor that makes the difference. Creative individuals' desire to ask tough questions and to find tough answers – their ability to seek the truth is unmatched. Maeda describes this complexity as follows (Maeda 2012):

> Designers create solutions – the products and services that propel us forward. But artists create questions — the deep probing of purpose and meaning that sometimes takes us backward and sideways to reveal which way "forward" actually is. The questions that artists make are often enigmatic, answering a why with another why. Because of this, understanding art is difficult: I like to say that if you're having difficulty "getting" art, then it's doing its job... The artist needs to understand the truth that lies at the bottom of an enigma... Art speaks to us as humans, not as "human capital." Art shows us that human beings still matter in a world where money talks the loudest, where computers know everything about us, and where robots fabricate our next meal and also our ride there. Artists ask the questions that others are afraid to ask and that money cannot answer.

According to the current concept and practice, innovation is not exclusively produced by engineers – it is a joint development (co-creation) by engineers, designers, and researchers, a multidisciplinary team of science and economy. In the future, this multidisciplinary sphere of innovation will also include artists and independent, creative individuals with the ability to see intuitively into the future, to build a vision and to navigate there, at the same time serving as a catalyst in transforming the innovation culture. Future innovations will be made in a genuine multidisciplinary environment, in the nexus of art and science, technology and design, and natural sciences and anthropology, where ideas that transform the world and our understanding of it will be enriched and refined.

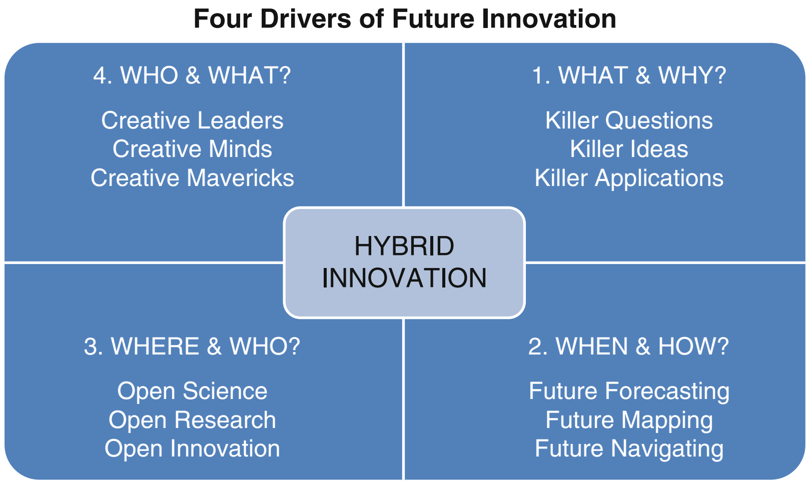
Because of the extensive availability of data (everyone has access to the same data), competition over ability and talent (editing and application of data) will intensify in innovation. In reality, we are already moving on from an information-based innovation system to a talent-based system. It has been found in many contexts that competition for talent will be the core of innovation work in the future, as innovation will tomorrow be primarily the work of pioneers – mavericks, who are independent thinkers and incorruptible visionaries. They will open the window to the unknown and take development forward. They will be at once interpreters and cartographers of the future. Many artists are by nature independents of this kind, going their own way, rather difficult members of the working community – but they are essential to innovation precisely because of their bold characters and visionary attributes. As Bob and Gregg Vanourek has said (Vanourek 2012):

> Mavericks are the independent innovators or performers – often quirky – who do not run well with others. They think and act differently. Many mavericks take mischievous delight in shaking things up... Mavericks can be exceptional innovators, critical in our ultracompetitive world.

> *She sends 'em abroad on her own affairs,*
> *From the second she opens her eyes –*
> *One million Hows, two million Wheres,*
> *And seven million Whys!*
> By Rudyard Kipling, *Elephant's Child* (1902)

Future: Six Honest Answers

Many successful innovations of the future will be social by nature – meaning that they will have



Innovation in Business: Six Honest Questions, Fig. 1 The hybrid innovation model. Four drivers of future innovation based on the six honest questions (Source: Anne Stenros 2012)

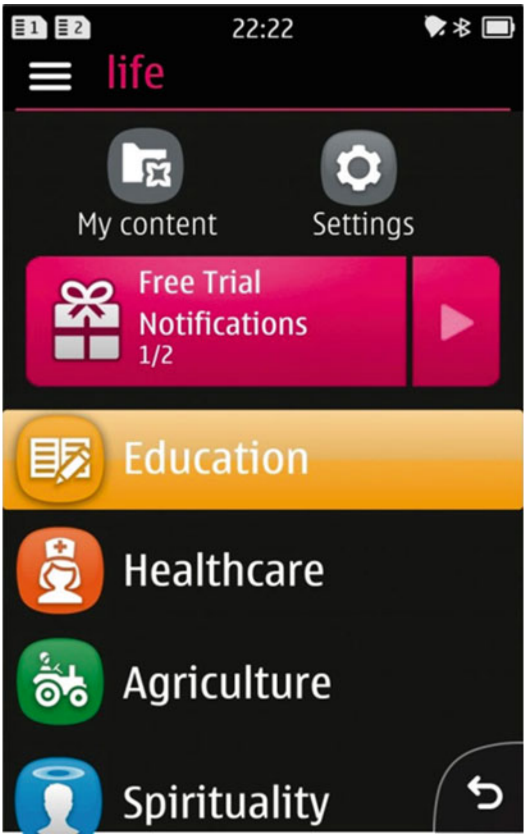
a significant impact on society. Tomorrow's innovations will be sustainable in nature – that is, they will change human behavior and habits for the better and improve the quality of life. Significant innovations of the future will also be the best examples of transformation between technology and art, science and art – they will be not only of instrumental value to their users but their significance will itself be greater than their practical value.

However, the most important innovations of the future will most often be hybrid models, in which, for example, collaboration between art and technology or art and science generates a social innovation. These hybrid innovations will also provide a solution to the great global challenges: environmental questions, the trend in urbanization, food and water supply, and renewable energy sources. Hybrid innovations will also in general answer all six honest questions – with profound and honest answers (Fig. 1).

Of the social innovations made possible by technology, more and more will come from the bottom of the "pyramid," that is, from developing countries and from the needs of their populations. A good example of this is the Nokia Life service (2009), which featured India-focused, hyper-local, SMS-based service and content production for people in developing countries. The service is intended for the 1.2 billion people who do not have phones with data communication capability. The basic idea of the service is that access to information and data supports and makes it possible to improve people's lives and living conditions. The starting point is content-driven design and the aim is to create social experiences around increasing and distributing information.

Nokia Life services involve education, health, agriculture, and entertainment. The service producers include local ministries, NGOs, and international specialist organizations. A mobile phone gives the user access to learning content for school grades and English and local information about various everyday matters such as health, weather conditions, and selling prices of agricultural produce. The service does not aim to make a profit, and income is ploughed back into further developing the service. The innovative service now has some 80 million users in India, China, Indonesia, and Nigeria (Fig. 2).

A classic example of an innovation spanning the boundaries of modernity, technology, and art is the BMW Art Car concept dating back to 1975. What began as a one-off artistic experiment by Hervé Poulain has grown into a considerable collection over the decades. Poulain, who was enchanted by speed and its beauty while taking part in races at Le Mans, first invited four artist friends – Alexander Calder, Frank Stella, Roy Lichtenstein, and Andy Warhol – to paint BMW racing cars. Since then, artists including Ernst Fuchs, Jeff Koons, and Olafur Eliasson have added their visions of speed to the BMW Art Car collection. The end result is the



Innovation in Business: Six Honest Questions, Fig. 2 Nokia life tools (Photo credit: Nokia)

transformation of a practical object into a work of art – the conversion of concrete into conceptual, everyday into timeless, and technology into pure art. In its essence, the Art Car – concept is all about humanizing technology – giving a face and personality to the anonymous (BMW Classics 2010) (Figs. 3, 4).

A good example of a new kind of pioneer, an independent creative, is artist/designer/inventor Thomas Heatherwick, whose diverse output is astonishing in its innovativeness. Heatherwick combines technical wizardry with artistic vision and functional implementation in an extraordinarily interesting way. A famous example of his work is the sculpted, rolling bridge; the aim of which is to make movement itself a particular feature of the bridge (Fig. 5).

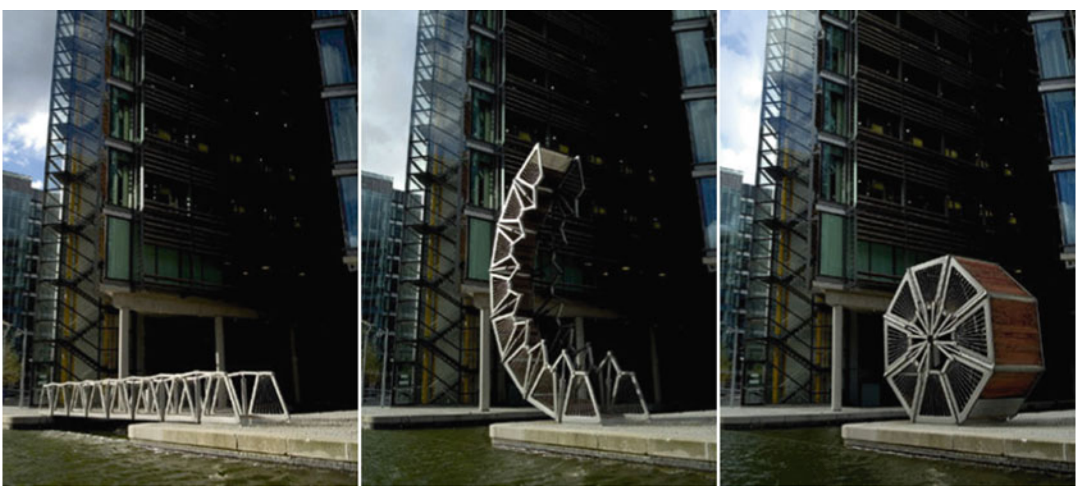
Multidimensional innovations may appear just as much among services as in products. The world-famous chef Ferran Adrià, who is renowned for his experimental cuisine and creative cookery, has started the elBulli Foundation in connection with his restaurant – "a centre of innovation allied with digital technology that would rethink haute cuisine in a way that would offer other creative endeavours a road map for innovation." According to Adrià, in cooking as in business or art, there is no process without an idea. The foundation focuses on understanding the nature of creativity and its fundamental question: where do ideas come from, and how do we best foster them? As Adrià has said it by himself, "Creativity is important. Innovation is also important. But the capacity to transform yourself is even more important" (Williams 2012).

Adrià's work has always been characterized by experimentation and a radically innovative take, and this has made him a leading name in his field. In accordance with its character, an innovation center must break barricades: Adrià aims to unite science and art and philosophy and technology "into a creativity-generating universe," which will yield today's most valuable raw material: creativity and talent. In accordance with the experience of the elBulli restaurant, operations are guided by five subdivisions: organization, philosophy, products, technology, elaboration, styles, and characteristics (Williams 2012) (Fig. 6).

A pioneer of the future's multidimensional hybrid innovations is *Little Sun*, a small and simple portable flashlight using solar energy, which is also an everyday art object. The lamp was designed by artist Olafur Eliasson, who is famous for his treatment of light in his works. *Little Sun* is intended particularly for conditions in developing countries where grid electricity is not available. The object combines the latest LED technology and artistic vision in a way that creates something new. The lamp makes it possible to work and read after sundown without electricity, which is beyond the reach of one fifth of the human race. Eliasson believes his Little Sun can change these people's lives in a positive way. A 5-h charge in sunlight provides 5 h of light in darkness (Fig. 7).

Innovation in Business: Six Honest Questions, Fig. 3 BMW art car by Alexander Calder (1975). The first car in the collection. *I am crazy about beauty and speed*. –Hervé Poulain (Photo Anne Stenros)

Innovation in Business: Six Honest Questions, Fig. 4 BMW Art Car by Sandro Chia (1992). *You can see the beauty of the car and yourself reflected in the surface. It is an interchange of beauty*. – Sandro Chia (Photo Anne Stenros)



Innovation in Business: Six Honest Questions, Fig. 5 Rolling bridge by Heatherwick Studio, London, UK (Photo credit: Steve Speller)

Innovation in Business: Six Honest Questions, Fig. 6 The Ideario of elBulli Foundation by architect Enric Ruiz-Geli. Costa Brava, Spain (Photo credit: Enric Ruiz-Geli)

Innovation in Business: Six Honest Questions, Fig. 7 Little Sun lamp by Olafur Eliasson (Photo credit: Little Sun)

Eliasson himself replied in an interview in The Guardian to the question of why he got started on this social innovation project (Higgins 2012):

> Art is always interested in society in all kinds of abstract ways, though this has a very explicit social component. The art world sometimes lives in a closed-off world of art institutions, but I still think there's a lot of work to show that art can deal with social issues very directly... People want beautiful things in their lives; they want something that they can use with pride . . . everyone wants something that's not just about functionality but also spirituality.

Little Sun superbly and profoundly answers the six honest questions:

What – a light for life

Why – improving the quality of life and inspiring to change

When – extending the hours of daylight in darkness by enabling more time for daytime activities

How – by transforming technology through art into an object of delight beyond its practical use

Where – giving access to light in areas not on the power grid

Who – to be used by those who are in the bottom of the pyramid, in this case 20 % of the world's population

As Olafur Eliasson sums up by himself: "An artwork is never just the object; it is also the experience and its contextual impact, how it is used and enjoyed, how it raises questions and changes ways of thinking and living. The same is true of Little Sun."

Future innovators will be creative leaders, creative individuals and creative mavericks who make their visions a beacon to others so that we can guide ourselves toward a better tomorrow for individuals and communities alike. Their role is to keep the light of creativity alive.

> *It is also a way of using the Little Sun to guide yourself, as*
> *if it were an eye*. – Olafur Eliasson

Conclusions and Future Directions

In today's world, the future is mostly unpredictable. However, the further we look, the better we will understand the transformation we face. The complexity of the everyday and great challenges calls for increasing creativity in solving problems sustainably. A new breed of hybrid innovations is emerging from demanding surroundings: responsible innovations which are capable of answering all the questions. In the future, art and science will bridge the gap between two different ways of seeing the world – and solve the problems of coexisting for the benefit of all. Creative industries will have a stronger say than ever before in building a better future and well-being. More artist-innovators – Leonardos of today – are on the way.

Cross-References

- ▶ Artistic Research
- ▶ Cognition of creativity
- ▶ Creative Leadership
- ▶ Creative Personality
- ▶ Creativity and Innovation: What Is the Difference?
- ▶ Creativity Definitions, Approaches
- ▶ Creativity from Design and Innovation Perspectives
- ▶ Creativity in Invention, Theories
- ▶ Divergent Versus Convergent Thinking
- ▶ Female Entrepreneurship
- ▶ Innovation and Democracy
- ▶ Innovation and Entrepreneurship
- ▶ Interdisciplinarity and Innovation
- ▶ Invention Versus Discovery
- ▶ Method for Creating Wisdom from Knowledge
- ▶ Multiple Models of Creativity
- ▶ Science of Creativity
- ▶ Social Innovation
- ▶ Strategic Thinking and Creative Invention

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Innovation in Defense Technologies

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Synonyms

Defense technology; Military technology

Introduction

Innovation in defense technologies has traditionally been both a driver of invention, creativity, and entrepreneurship and a beneficiary of these. Technology and knowledge acquired in the development of defense goods, services, and processes were critical elements in the development of commercial technologies, and civilian innovations have contributed greatly to new defense technologies (Ruttan 2001). This entry covers the topic of innovation in the context of defense technologies. It will first briefly discuss defense innovation as a public good. It will then present the concepts of "demand pull," "technology push," "spin-off," and "spin-on" in a defense innovation context. Lastly, this entry will use these concepts to present two models for thinking about innovation in defense technologies. Note that this entry does not cover social innovations for national defense, i.e., innovations in the way defense establishments organize for and fight wars, as expressed in their organizational structures and in military doctrine, strategy, or tactics.

In discussing innovation in a defense context, it is important to accept that national defense is to a great extent an exceptional case in economics and public policy. As an almost pure public good, defense is nonrival (consumption by some does not leave less for others) and nonexcludable (nobody can be excluded from consuming it). As a result of the free-rider problem that exists for all public goods, public investment is a key element in the provision of national defense, and this also holds true for defense innovation. In effect, the benefits of an innovation that contributes only to national defense will not be captured by the entity delivering it. Furthermore, since the ability and legal right to acquire and wield military capabilities reside almost exclusively in national governments, the customer base for defense technologies, and therefore also of the creative and entrepreneurial processes that deliver them, is very limited. Essentially, the market for innovation in defense technologies is a monopsony with buyers almost completely dependent on – and reactive to – the end customer (Dombrowski and Gholz 2006).

"Demand pull" refers to the desire of users of defense technologies – whether they are national governments or nonstate actors – to access technologies that will contribute to achieving swift and decisive victory against an adversary. Ideally, these are technologies that an adversary is not aware of and/or cannot defend against,

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thereby creating what Lorber has termed "technological surprise" (Lorber 2002). However, such groundbreaking technologies are few and far between, and the more common demand is for defense technologies that will improve an organizations' ability to conduct its defense missions. "Demand pull" may also occur as a result of intelligence gathered on the capabilities of adversaries, which could require that new countermeasures be developed (Rosen 1991). The entity requesting the capability is often also the one that funds its development, and it is most likely to turn to technology suppliers that it has relied on in the past.

"Technology push" is the process by which new technologies are proposed to potential end users by the entities that developed them. For defense technologies, these entities can be organizations that have a history of supporting the defense establishment, such as defense companies or government laboratories, or entities that have generated a capability for a different customer but have also identified potential defense applications for it, such as individual inventors or companies developing commercial goods and services.

"Spin-off" occurs when technically sophisticated defense technologies are developed (often in parallel to institutional innovations), and the know-how accrued in their development is utilized in the development of goods, services, and processes for commercial purposes. "Spin-on," on the other hand, refers to the process in which civilian innovations are transferred to military applications. It is worth noting that the question whether defense spin-offs to the civilian technology base enhance economic growth or whether spending on defense innovation is a net cost due to its high opportunity costs and the ability to spin commercial technologies for military uses continues to be hotly debated in the literature.

Using the concepts discussed above and keeping in mind the public good nature of defense overall and defense innovation in particular, two basic models for innovation in defense technologies can be constructed. The first is the linear model, whereby a novel product, service, or process that is intended for military use is researched, developed, tested, and marketed to a military customer. The second is the nonlinear model, in which during testing or deploying of an existing product, service, or process – either military or commercial – a different application for use in defense is identified and explored.

The linear model of innovation for national defense has been observed throughout history but has been particularly prevalent in the decades after World War II with the rise of large-scale government defense research and development (R&D) establishments. The model fosters an innovation process that begins with basic or applied research, evolves into technology development and testing, and eventually delivers an end result to the customer which is deployed and disseminated within the defense organization. Key actors in this model are government laboratories and companies that make up the defense industrial base as well as certain research universities. Under this model, innovation can be initiated through a technology push by entrepreneurial innovators or demand pull from defense customers. This type of defense innovation is capital intensive and therefore usually funded either directly by national defense entities or indirectly through independent R&D (IR&D) of the institutions in which it is conducted. In the past few decades, it has resulted in innovations such as nuclear weapons, satellites, and stealth technology, as well as in commercial spin-offs such as jet engines and airframes, satellites, robotics, digital displays, and nuclear power.

The nonlinear model of innovation for defense purposes is also centuries old. It initiates innovations relevant to defense technologies at later stages of the innovation process (i.e., during testing and after deployment in the field as opposed to the R&D phases) and in institutions and disciplines that are not funded by defense establishments or by defense firms. In recent decades, many innovations in this model emerge from the global commercial marketplace in areas such as communications, sensors, cyber security, data fusion, and data management. As the commercial world demands higher performance and sophistication and reduces the life cycles of products, both the rate and the quality of nondefense innovation are constantly improving. Nonlinear innovations are also increasingly appearing in the hands of users, i.e., the soldiers who are issued a new capability – military or commercial – and utilize it in a way that is different from its original intent. This model presents more instances of spin-on than spin-off and more examples of radical innovation than incremental innovation (Boot 2006). The steam engine, the telegraph, the internal combustion engine, radio, the automobile, and the airplane are all examples of nonlinear innovations that originated from outside formal defense establishments yet resulted in breakthrough defense technologies. Many such nonlinear defense innovations were converted into defense technologies as a result of technology push on the part of their entrepreneurial developers, but demand pull is not uncommon either; formal defense entities have often recognized the military potential of commercial innovations and initiated processes to integrate them.

The policy implications for practitioners and students of innovation in defense technologies are different for each of the two models. For the linear model, the key policy challenge currently requiring attention is that of the increased complexity associated with providing innovative defense technologies via a linear process. While current and future security threats across the globe have created an appetite for increasingly complex R&D programs to deliver the next generation of defense capabilities, technology has evolved at a higher pace than have the policy frameworks and the management tools that are needed to bring R&D programs to successful fruition. As a result, defense innovation attempted under the linear model in recent years is costing significantly more and taking significantly longer to the point where it is no longer economically viable (Ben-Ari and Zlatnik 2009). This is not a new phenomenon; there has in the past been tension between the increasing complexity of required defense technologies and the policy and management tools available to provide them. To resolve this tension, new policy frameworks, governance models, and management structures were introduced that enabled organizations to advance to the next level of complexity. For example, the US Navy developed the Gantt chart to build the ships of World War I and PERT (the Program Evaluation and Review Technique) in the 1950s to help manage the Fleet Ballistic Missile program. However, the defense innovations that have been under development in the past 20 years or so require new policy frameworks and management models if they are to be completed within the time frame and budgets allocated to them and in a manner that is relevant to the military customer.

For the nonlinear model of innovation in defense technologies, the important policy challenge of the day is to identify and support innovations and innovators that are relevant for defense yet who emerge either in unexpected phases of the defense innovation process (e.g., within the testing, evaluation, and end-user communities) or outside the defense community altogether. Examples of the former include German soldiers in World War II using 88-mm antiaircraft guns as antitank weapons, the conversion of the C-130 cargo aircraft into the AC-130 ground attack aircraft during the Vietnam War, and, more recently, Canadian soldiers in Afghanistan intentionally driving their main battle tanks over improvised explosive devices, thereby using them as crude mine-sweeping tools. Examples of the latter include the use of smart phones as navigation and positioning devices and social networks as communications and knowledge-sharing tools in numerous militaries during operations in Iraq and Afghanistan. Such harvesting and reuse of military and commercial technology to generate innovative defense capabilities currently do not regularly occur at a formal, institutionalized level. Yet, the advent of what has recently been referred to as the BRINE revolutions, i.e., breakthrough technologies in biotechnology, robotics, information technology, nanotechnology, and energy, means that even more innovations with relevance to defense will be available for those militaries smart and fast enough to incorporate them into their arsenals (Wells 2012). Similarly, the increase in user-centric innovation (Van Hippel 2006) is not bypassing the military, and soldiers now have more ability than ever before to put both military and commercial technologies to use in innovative ways, essentially becoming inventors and technology entrepreneurs on the battlefield. The challenge for defense policymakers is to create an environment that fosters the harvesting of new commercial innovations and the creative redeployment of existing military technologies.

Conclusion and Future Directions

Ultimately, however, the most groundbreaking technology innovations for defense will not in and of themselves confer victory to the forces wielding them. If there is one consistent lesson that the history of defense innovation teaches, it is that without the social innovations discussed at the beginning of this entry, i.e., innovation's organizational structures, military doctrine, strategy, and tactics, innovations in defense technologies will be ineffectively utilized and sometimes not utilized at all. For example, during World War I, the British were the first to develop and use tanks but did so in small numbers and without adjusting their military doctrine accordingly; it was the Germans in the years before World War II who recognized the full potential of their adversary's innovation and innovated their own defense strategy to accommodate what by then was a well-known military technology. Thus, the military advantage gained from an innovative defense capability may go to the fastest adopter of the innovation and not to its first user. In addition to addressing the innovation challenges outlined above, defense policymakers will also need to tackle the issue of implementing organizational and cultural change to successfully incorporate new products, services and processes in their defense establishments.

Cross-References

- ▶ Corporate Entrepreneurship
- ▶ Models for Creative Inventions
- ▶ Political Leadership and Innovation

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Innovation in Forestry: New Values and Challenges for Traditional Sector

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Synonyms

Forest sector; Innovation policy; Innovation systems

Forestry as a "Future Sector"

Forests are known to produce timber in the first place, and this is also the main income source for most forest owners. At the same time, it is also widely known that forests provide many more benefits to society: They provide landscape amenities and opportunities for recreation; they conserve biodiversity and protect environmental features; they deliver clean water and offer protection against natural hazards such as landslides, rockfall, or avalanches; and last but not least, they are a source for renewable energy and are an important means to mitigate climate change through their ability to sequester carbon. All of these goods and services, in fact, are increasing in significance. It seems that the image of forestry is currently changing from a quite traditional and declining sector to a "future sector" which offers solutions to a range of challenges that our society is facing today. Innovation plays a key role in making the sector able to fulfill this promising role.

What this entry aims for is to understand current innovation processes in the sector, including supportive and hampering factors, institutional conditions and drivers, the relevant policies and innovation systems, and success and failures.

Relevance and Innovation Fields

In order to understand innovation processes, it is necessary to look at spatial and sectoral, individual, and institutional factors. In the case of forestry, there are specific features that characterize the sector as well as condition the related innovation processes (Weiss et al. 2011a). In respect of the spatial dimension, there are at least two specifics to be considered: First, forestry production is dependent on the natural site conditions and mostly takes place in rural areas. Second, some of the forest products are territorial goods and services in that sense that they carry the very place of production as a strong characteristic. While timber is (normally) a commodity which is traded globally and uniformly, other ecosystem services of forests are bound to the site of production: This is true, for instance, for some recreational services where the experience is connected to a certain landscape, and it is true for protective services when a certain forest protects the neighboring field from wind erosion. The marketability of forest-based territorial goods and services is often limited, a fact which makes business difficult but all the more call for innovation on institutional or policy level. The many forest-based value chains differ strongly, whether regarding, for example, the traditional timber construction that does not look so traditional any more today or the recent rise of the energy production on the basis of renewable sources that is still undergoing fast technological changes. Forestry and the forest-based industries thus look very colorful, particularly when studying innovation.

Relevance of Innovation in the Forest Sector

The study of innovation in the forest sector is relevant in several respects: First of all, as in any other sector, international competition is growing also in the forest-based industries. Steady innovations are crucial to keep pace with global competitors, in terms of costs and quality. Another aspect is that the forestry sector – providing a range of ecosystem services and amenities – contributes to the quality of life in rural areas. Furthermore, forest-based products (including energy) use renewable sources and, therefore, contribute to the sustainability goals that are formulated in many policies. The forest sector also provides income and employment opportunities in rural areas, which often face a decline in their economic significance. This in turn relieves urban areas from migration pressure and provides health and recreation to all citizens.

These particular roles of the forest sector are increasingly recognized by policy makers and included in policy programs. The new interest in renewable energy sources and renewable materials comes from various policy fields, and the related opportunities are often not yet seen so clearly by actors within the sector. Ironically, forestry actors continue to praise the many benefits that forests provide to society but often do not see the new opportunities that arise from nature conservation policies, integrated rural development, sustainable development, climate change mitigation, and many others. It can be said that forestry and the forest-based industries play an important role in rural economies and have a strong potential to contribute to a sustainable global future, particularly in the following fields:

- Recreation and tourism
- Nature protection, biodiversity conservation, and landscape amenities
- Protection against natural hazards and erosion and protection of clean drinking water
- Bioenergy production and climate change mitigation
- Bio-based products, including food, fibers, chemicals, and wood construction

The forest sector is often considered as a mature, "low-tech," and declining industry. With the notion that our economy changes into a service economy and that our society changes into an information society, research and high tech receive a high level of attention in the media, in the public, and in policy as if they were the only source for economic growth and innovation. This is not true (Hirsch-Kreinsen and Jacobson 2008): Studies show that low- and medium-technology sectors still play a major role for employment and growth. Although these sectors invest less in research and development, they are still relevant for innovation. Innovations in mature sectors occur in different forms. Wood processing industries, for example, use sophisticated technologies in their production. By this, they are important also for the future development of information technologies. In other fields, for instance, in the production of berries and mushrooms, innovations rather come from new networks, organizational forms, or marketing methods and are important even without any connection to high technologies. We will further see that – being a sector with high social and environmental importance – institutional innovations play an important role in forestry. This is, however, not yet clearly seen by policy makers (Weiss et al. 2011a).

State of Research

There is a broad range of aspects that are highly relevant for the study of innovation and that have been studied in the field of forestry (Weiss 2011). On personal level, several aspects had been studied in forestry, such as value systems, entrepreneurial orientations and business goals of forest owners, and the diffusion of innovation, for example, in Scandinavia and Central Europe. A considerable body of literature exists on the financing and marketing of forest ecosystem services (timber and non-timber forest goods and services), in particular but not exclusively in southern Europe. In respect of organizational innovations, especially the role and function of forest owners' associations was studied. The supporting and hampering factors in the innovation processes and the contribution of forestry to rural development were studied from innovation systems and regional governance approaches. The role of different actors, networks, and clusters were studied for territorial goods and services and wood value chains.

Research that specifically addresses innovation processes in the forest sector started rather recently. In Europe, a strong push was given by the work program of an innovation-oriented research group within the European Forest Institute (Rametsteiner et al. 2005) and by two recent COST Actions (COST is a European program for connecting researchers within certain thematic "actions"). The COST Action E30 on the "Economic integration of urban consumers' demand and rural forestry production" gathered researchers from the field of innovation and entrepreneurship in forestry and the forest sector and was especially dedicated to entrepreneurship aspects of small-scale forestry, the multifunctional use of forests, as well as the timber and wood industries (Niskanen et al. 2007). The COST Action E51 "Integrating Innovation and Development Policies for the Forest Sector" particularly looked at the policy dimension of innovation (Rametsteiner et al. 2010) and at the innovation processes on the ground (Weiss et al. 2011a). It covered the two major production fields: territory-based goods and services (the provision of recreational services, non-wood forest products, and carbon sequestration) as well as wood-related production chains (furniture, timber frame housing, bioenergy, and timber harvesting operations) and included institutional and instrumental aspects (networks, clusters, forest owners' associations, and the European Union LEADER instrument for rural development).

Currently Important Innovation Areas

Currently, important innovation fields in forestry are found within territorial goods and services and in wood-related production chains. According to an expert survey in 18 European countries (Weiss et al. 2010), new wood products are developed in the fields of bioenergy, wood construction, and wood modifications. Bioenergy production in various forms – including solid wood, biofuel, and biogas – is the innovation field that yields highest attention. Within territory-based services, different ecosystem services of forests are important, particularly environmental services and recreational and educational services. New recreational services such as guided tours or hiking or biking trails seem to be the most important in terms of frequency although it has to be noted that they are in most cases not so much developed for profit but rather because of external pressure (Rametsteiner et al. 2005).

There are important differences between the two innovation fields: Within the wood value chain, process innovations (new harvesting technologies, use of ITC, logistical rationalization, as well as prefabrication and modular systems in the timber industry) as well as organizational novelties are important in the countries (horizontal and vertical cooperations and cluster initiatives). While in the field of wood production, horizontal and vertical cooperation can be solved among firms, for territorial services institutional innovations such as regional cross-sectoral coordination processes seem of particular importance. It seems that for territory-based services, the coordination of actors is more complex and needs activities on institutional level. The significance of regional cross-sectoral coordination mirrors the challenge of how to organize the provision of territory-based services which often has to involve many providers (landowners) and users (e.g., tourism).

Forestry Innovation Systems

From several studies of innovation processes and policies on institutional and firm levels, we are able to characterize typical forestry innovation systems. They can largely be described as sectoral innovation systems in that they are strongly governed by sectoral actors and policies. Only in countries such as Finland, where the forestry sector is perceived as contributing significantly to the GDP, forestry and forest-based industries are recognized by the national innovation systems. Furthermore, regional innovation systems are highly relevant, particularly when it comes to territorial goods and services, but this is hardly realized by the relevant actors – both from outside and inside forestry.

Unfortunate Frame Conditions for Forestry

The preconditions in forestry are not supportive of innovations. The one main important obstacle to innovation is the high fragmentation of forest ownership in many countries. The average size of private property is very small in many European countries, often below 10 or below 20 ha. This implies that the income from forests is negligible or at least not the main income source for many forest owners. Very few owners actually work full time in forest management; most owners do not even have any relevant education or training.

According to a survey of forest holdings in Central Europe (Rametsteiner et al. 2005), practically all of the work in forest holdings <100 ha is done by family members, of whom virtually nobody works full time in forestry. In small forest properties, forest work is usually not outsourced. There are strong indications that forest work remains simply undone if family members do not find the time. It is evident that these owners hardly develop any innovative management approach for their forest property, even if they would be highly innovative in their main occupation. Even in farm forests, there is seldom an innovative attitude toward their forests when the main farm product is from agriculture. A large majority of forest owners thus have one simple goal, namely, to maintain their forest (Rametsteiner et al. 2005). On the other hand, only very few people intend to abandon forestry altogether or to sell their property.

Innovation Activity in Forestry

The described unfortunate conditions in forestry result in a rather negative picture with regard to the overall level of innovation activity in the sector: Particularly in small forest holdings, there is little innovation activity, innovations are mostly incremental, and there is hardly any start-up activity in the sector (Rametsteiner et al. 2005). When looking more into detail, however, there are a few remarkable facts that show a more positive picture: Larger forest holdings (>500 ha) are as dynamic as an average EU manufacturing SME. Furthermore, forest owners in many countries have, at least verbally, an entrepreneurial orientation. This implies that forest owners or managers are not by themselves unwilling to innovate (a widely held opinion) but that it is more due to the framework conditions. Given the right conditions, forest owners are possibly more prepared and willing to actively pursue market opportunities through innovative approaches than national policy makers often consider them to be. This result then also implies that the right policy measures might be able to successfully change the situation. In the following, we will see that the innovation systems, however, are not well prepared to support innovations in forestry.

Weak Support from the Institutional System

A range of weaknesses are found with regard to the forestry innovation system and related policies (Rametsteiner et al. 2005): First of all, the national innovation systems usually do not include forestry matters. There are hardly any interactions between forestry actors and actors dealing with existing national innovation policies. But also within the sector, there are usually no comprehensive innovation policies formulated. Furthermore, the group of institutions, which is active in innovation-related matters, is usually very small and restricted to the forestry field. Often, as in Italy or Austria, forestry interest groups dominate the picture, but public administration and research and education institutions are hardly mentioned. In other countries, public administration and research organizations dominate, but forest owners' organizations have no significant role there. It is very typical that there is a lack of interaction with other sectors. Forestry institutional systems have strong sectoral boundaries, even to the wood and agricultural sectors and even more to other sectors such as energy, tourism, and nature conservation, where a considerable part of innovations are currently occurring (and are expected to occur in the future).

The forestry innovation system is active in the fields of technological and organizational innovations and in the diffusion of certain preselected innovations. Typical areas of activity are mechanization of forest work and, recently, the forming of forest owners' cooperations. Except for some selected topics – such as bioenergy or forest education – product and service innovations are rather disregarded. Specific support aiming at the development of new products and services is practically missing (Rametsteiner et al. 2005). Case studies of forest-related innovations in tourism or bioenergy reveal that the initial support for the development of these new innovations rather comes from regional-level ad hoc networks and from other sectors but not from the forestry innovation system.

Misconception of Supporting and Impeding Factors for Innovation by Institutional Actors

It seems that the institutional system does not fully understand the needs of forest holdings when it comes to innovation support. The forest holdings survey in Central Europe (Rametsteiner et al. 2005) shows that institutional-level actors assume different factors to be important for innovation processes. They underestimate the importance of information as an essential factor. With regard to impeding factors, the institutional system actors tend to overestimate the difficulties forest owners face with administrative and legislative obstacles. These certainly exist and are also pointed out by forest owners to be important. However, financing and know-how are much more a concern for forest owners. This finding has quite important implications on the design of innovation support activities.

How Well Are Innovation System Functions Fulfilled?

Three basic functions have to be fulfilled by innovation systems (Edquist and Johnson 1997):

reduction of uncertainties by providing information, the management of conflicts and cooperation, and the provision of incentives. The institutional system actors in forestry do fulfill those functions yet with limitations:

– Information provision is lacking for new markets and opportunities: Forestry agencies – authorities and interest groups – provide important forest-related information. They provide good information on traditional forestry topics, but there are severe information lacks about new market fields such as tourism and nature conservation. Only when not too far from the traditional timber production, institutional actors have built up new knowledge on new areas, for example, on biomass use.
– Weak conflict management and coordination with other sectors: In the coordination among foresters and forest owners, the institutional actors do well, but they are weak in the coordination with actors from other sectors. Even the coordination with sectors in the wood chain proves to be difficult.
– Little consideration of innovation support principles when providing incentives: Forestry subsidy measures such as the support of investments for the mechanization of forest work (forest roads, harvesting machines) or the support of cooperations (e.g., forest owners' cooperations) are hardly written from an innovation perspective. Financial incentives are therefore mostly conservative, and their design often disregards basic principles of innovation support. Two such principles are to systematically support new and risky projects or to limit the support to the starting phase. In practice, considerable incentives are provided for the diffusion of already known and preselected technologies or organizational rearrangements, but only little incentives are provided for the development and pilot testing of new ones. It is furthermore only seldom that the grant of support is restricted to the starting phase of a certain project or the stage of innovation development in the sector.

As a result from these weaknesses, it can also be observed that a considerable financing potential is hardly tapped by forest owners, namely, non-forestry funding sources, for example, from innovation or structural funds. Forestry companies and also supporting agencies very often do not know about non-forestry programs that could be utilized for supporting and financing forest-related innovations.

Policy Support

Innovation in forestry may be supported by competitiveness, innovation, and entrepreneurship policies in general or by the forest sector policies. Unfortunately, the general innovation support is often not used by the sector, and comprehensive and focused innovation support policies within the sector are rare (Rametsteiner et al. 2005). A detailed analysis of in how far and in which way the aspect of innovation is integrated into sector-relevant policies (Weiss et al. 2010) found that the relevance that is put on the topic of innovation not always goes along with the same understanding of innovation policy, traditional or systemic. Policies that mention many innovation-related goals and give innovation a rather high importance are the national reform programs, rural and regional development programs, and forest sector strategies. These policies tend to follow rather a systemic understanding of innovation. The forest programs and renewable energy plans are much less innovation oriented and represent a rather traditional view on innovation. The sustainable development strategies are a third type: They do not mention innovation frequently but often follow a systemic understanding of innovation.

Innovation issues are not systematically integrated into forest policies, and innovation is not specifically supported. The policies hardly support radically new ideas but only the diffusion of current solutions and technologies that are already known. This confirms earlier results from innovation research which say that the institutional system of mature sectors rather focus on rationalization and diffusion of innovation and are less oriented at the development of new products or services (Breschi and Malerba 1997).

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For an effective support of innovation, the coordination of policy fields is important, the more so for a diversification into new forest goods and services. Formally, forest policy documents seem to be relatively well coordinated with other sectors, and even without a generally strong systemic orientation of innovation policy, there is a focus on cross-sectoral interaction. In relation to other traditional sectors, it seems that forestry is rather used to coordinate across sectoral boundaries (Weiss et al. 2010). These results contradict to what is known from extensive forest policy research in Austria. For the example of Austria, it can be shown in detail that other sectors hardly play a role in the sectoral innovation system; this is certainly true on national level, even if not so pronounced on local-regional levels. These contradictory results may be explained by the lacking implementation of the coordination goal. Furthermore, the coordination with other sectors is often rather forced because of strong interests from other social groups, and the mode of coordination is often more a negative than a positive coordination.

What are the factors behind the strong orientation of forest policies at timber production and the slow uptake of new policy goals and innovation fields in forest policies? The policy analysis explains it by the power of the related interest groups which are behind those goals: Forest industries aim to keep the production source oriented at timber and may hinder a stronger multifunctional use of the forests – as shown on the example of selected cases in Austria, France, and Scotland (Buttoud et al. 2011). Vice versa, new uses of the forest for other purposes are typically introduced from outside sectors such as energy, biodiversity conservation, or recreation.

Another factor may be the self-understanding of institutional actors with regard to innovation support: They often see innovation as a sole market issue and feel their role primarily connected to public goods. Traditionally, forest authorities were concerned with ecosystem services from a public good perspective: They provided regulatory limits for the use of the forest resource in order to secure a basic provision of the "nonmarket" benefits of the forest. Today, the trend is to give also their provision more in the hands of the market, but the role of the public administration is not yet clearly defined. At the same time, the private actors still expect state activity when it comes to the support of non-wood goods and services from the forest (Weiss et al. 2011b). This seems to be an indication that non-wood forest goods and services are still not seen as an important business opportunity.

In conclusion, the role of policy in innovation support in forestry can actually be seen paradoxically: Although innovation and market-based instruments become more important, state actors do not lose importance. The public financing of ecosystem services is growing, and public instruments need to be made more efficient through clearly defined goals. The scope and use of mixed public-private mechanisms such as contractual agreements, tendering schemes, or cap-and-trade schemes are increasing. The creation of new markets, for example, in carbon trade or nature conservation (conservation banks), is still only in an initial state. And finally, also in the field of traditional markets, the institutional-level actors have their tasks to fulfill: promoting entrepreneurship and innovation, providing market information, or supporting interaction among landowners and across sectors. As described, innovation support instruments such as the provision of seed money or providing support infrastructures for the development of new business activities such as extension services or rural development agencies are still a field to develop in forestry (Weiss et al. 2011b).

Conclusion and Future Directions

Although forestry is a traditional sector, there is an increasing interest in the important role that forests, wood, and non-wood products have for the sustainable development in Europe: These contributions range from recreational services and biodiversity conservation to the possible reduction of greenhouse gas emissions through the use of wood in construction and to the provision of new jobs in rural areas. Still, policy measures for the provision of forest ecosystem services do not come under innovation support while this is the case in the field of new timber or bioproducts.

This entry argues for a stronger role of institutional actors and policy in innovation support in the sector and a more systemic orientation of innovation policies. There is a too narrow focus on research which totally misses the needs of the sector enterprises in their innovation efforts which rather lie in the provision of information and cooperation support. Measures are needed to facilitate the two-way communication between researchers and the firms. Innovation support infrastructures such as cluster organizations and regional and rural development agencies need to be fostered as intermediary agents. They are important complementary knowledge and capacity providers. Developing and supporting networks, education, and training would be important fields of activity.

We always have to keep in mind, still, the particularities of the forestry production: The marketing possibilities are limited. All the more important are social, institutional, and policy innovations. Further specific challenges are the dominance of small and micro family businesses and the prevailing traditional business fields and non-research-intensive technologies. Traditional innovation policies fail because of their too strong focus on research and high-technology support and because of their orientation at larger firms. Small businesses are still disadvantaged by most industrial policies.

Cross-References

- ▶ Entrepreneurship Policies
- ▶ Innovation and Entrepreneurship
- ▶ Innovation Policy Learning
- ▶ Innovative Milieux and Entrepreneurship (Volume Entrepreneurship)
- ▶ Nonlinear Innovations
- ▶ Small Business
- ▶ Triple Helics

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Innovation in Green Technology

► Entrepreneurial Behavior and Eco-Innovation

Innovation in Practical Work in Science Education

► Fostering Creativity Through Science Education

Innovation in Radical Economic Thought

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Synonyms

Forces of production theories; Systemic innovation, theories

For Marxists, radical economists, but also Classical economists, the historical context determines for most part the order of priority of the scientific phenomena to study, the techniques (methods and tools) to use, as well as the social use which will be made of the results. They highlighted three stages in the transformation of the production forces of capitalism: meetings of workers isolated under the same management, followed by the division of the work and the differentiation of the tasks, then by the clear separation between intellectual and manual work. In today's global economy, a fourth stage in the productive organization appears: an organization based on the spatial de-concentration of the achievement of this production and on decisional, financial, and informational centralization that the applications of contemporary science allow. This fourth stage is the one of the unprecedented marketability of science, organized as a network by enterprises and states in a clear technological aim.

All science would be superfluous if the appearance and the essence of things became confused (Marx 2012, vol. 3). The research of the essence of things is generally commonly accepted as being the aim of the scientific activity but the historical context determines for the most part the order of priority of the things and the phenomena to dissect, to understand, and to know the techniques (methods and tools) to use to penetrate the essential, as well as the social usage which will be made of the essence extracted. At the moment in time when, according to Marx (1993), industry has already reached a very high level, invention becomes a branch of business, and the application of science to the immediate production determines the inventions, at the same time as soliciting them. Then, for Habermas (1973, p.43), with the arrival of industrial research on a large scale, science, technique, and exploiting found themselves part of the same system. Capitalism provided the framework for the systematic application of science to production, which in turn gave impetus to the development of scientific knowledge concerning laws of nature and of the world. Capitalism redirects, in accordance with a productive end, a reserve of scientific and technical knowledge built up, making science a productive strength at the service of capital. Giving a scientific character to production is therefore the tendency of capital. (Marx 1993).

The Myth of Innovation: From the Formation to the Private Appropriation of Production Resources

Science, in the same way as technique, is always historical. But in capitalism, science is considered as a tank of knowledge from where technique feeds (see Nef 1953). It is considered as a tank of forces of production because the work process has become a technological application of science (Marx 1993). The growth in the size of the company and the amount of capital held or raised has furthered the enrolment of science in immediate production. (a) The domestic markets of the big industrial and international countries are getting bigger. (b) The social division of labor is extended. (c) Enterprises, in a context of competition, have to bear rising total costs. (d) Enterprises focus their strategy, on the one hand, on the achievement of high external economies (or externalities) and, on the other hand, on business intelligence in order to benefit from all profit opportunity. The usual term is that of externalities which can be defined (A. Marshall 1890) as being positive or negative effects, which involve an activity of an economic agent outside this activity or that the agent is subjected to from outside. The most attractive for a company is to achieve, in a setting favorable to investment, substantial external savings, without having to bear the slightest cost that its activity creates for the community as a whole (pollution or various nuisances). It is important therefore, to underline, that taking private property for granted, the private agent will create various effects on the local community, but in return, he will expect from the community means and opportunities to enlarge his property (assets) or where necessary, to defend it. The application of science to the economic activity of such and such a company or group of companies makes innovation the main function of growth and commercial strength.

The liberal and neoliberal economic thinking has, only very recently, been able to find some arguments to justify forming, in the aim of making them available to private firms, scientific and technical resources. The liberal economists are quick to thank R. Solow (1956) who started new methods of research into the links between technology and growth.

Firstly, as a residual factor of growth, new techniques have become a very popular subject of research with the neoliberals. The standard neoclassic growth model was changed drastically by the introduction of technical progress and innovation in the liberal approaches to accumulation. To consider, for example, that the activities giving birth to the diffusion of technical and scientific information have a positive impact (in terms of creation of wealth and profits) which is greater collectively than individually is a significant advance compared with the mechanical and ahistorical equilibrium of the original model. The question of economic repercussions on the community, of individuals' actions, especially concerning scientific production and commercial development, points the analysis toward the socio-holistic approach to the economy applied successfully by the classical authors. Innovation, more particularly, defined by J. Schumpeter (1982) as a new combination of productive resources, corresponds to a process of generation and private appropriation of a set of resources (scientific, technical, and financial) which, combined by the company or a group of companies, results in new products, the opening of new markets, and new organization. The conception of new products is a very important element in innovation. It is here that the large firms, with huge resources at their disposal, have a great advantage. They can fund research teams and experiment with a large number of innovations in the hope that one of them will stand out from the crowd, wrote J. Robinson in 1977. The supply creates its own demand, thanks to the insight, and the fighting spirit of the entrepreneur, then of the large firm. The second stage of the innovation process (appropriation) prevails these days over the first one (the generation). The company tends to take advantage of its environment rather than to invest in it, for instance, in all the stages of technological creation, which can be explained by the fact that the investments in the acquisition (appropriation) of production resources are less costly than those devoted to the formation of these resources. This also makes the neoliberals say that the collective profitability of the capital can be high, whereas the private profitability can become insufficient.

If the neoclassical economists struggled to get out of their model's dead end, a long time ago Marx himself and the economists who applied his method showed, as did L. Karpik (1972), that science becomes the base of industry; it is in this way that "heteronomous science" (which corresponds to the research applied to both the experimental development of new techniques and production methods and to finished goods) marks time on "autonomous science" (let us say basic research with no recognized private profit-making aims). The production process therefore determines the appearance of new techniques and defines their use. To do this, it directs the application of the scientific knowledge and defines the boundaries of scientific research. An organic relationship is thus created between science, technique, innovation, and society. And it is in this that technology (and innovation), as a transformation of knowledge into production and accumulation knowledge, is a social fact.

Marx's reasoning is as follows. First theoretical statement: Capitalism cannot exist without revolutionizing constantly the means of production, and therefore the production relations, that is to say, all the social relations. The means of production required to produce the different goods (destined for consumption or for production), after they have been adapted and used for private purposes to be transformed into capital, characterizes the state of the social relations. The quantitative expansion and the efficiency with which the capital is developed as fixed capital broadly indicates to what extent the capital is developed as capital, as being the power over the living work and to what extent it is subjected to the production process in general (Marx 1993). The technological use of science is the essential factor in the development of fixed capital; this being an index which shows to what extent the universal social knowledge has become a direct productive force. The development of (fixed) capital enlarges the scale of production at the same time as prompting this enlargement, requiring in parallel the specialization and the overlapping of different work forces which are more and more complicated: simple work/complex work, living work/dead work, socially necessary work, collective work, etc. Salaried work, and the salaried class as a capitalist norm of participation in the accomplishment of production and the social organization becomes the driving force behind accumulation.

Second theoretical statement: The general development of the production forces is the development of all the means (material and immaterial) that science in the hands of the capital injects into the production, natural forces, in the form of means of production, enabling higher usage value with less work (Marx 2012, vol. I). Science becomes capital under the pressure of the competition and possible political and social disputes. The authority of the capital and the power on the market of a given company depends on its capacity to make profits, to accumulate. Innovation is therefore essential in the daily battle that firms undergo to avoid the numerous barriers (lack of demand, increase in price of production resources, emergence of new competitors, social problems, restricting regulations, etc.) which can block the road to prosperity. Science is therefore called upon more and more; the new technology which it will create must be more efficient (allowing a greater mastery of the work process) and must achieve new exchange values (i.e., guarantee accumulation). The speed of the renewal of the capital is dependent on the accumulation barriers which play a major role in defining the integration of science into both production and the general development of the forces of production.

Third theoretical statement: For Marx, competition requires a continual increase in capital and imposes pervading laws of capitalist production as external coercive laws to each individual capitalist (Marx 2012, vol. I). To limit the risk of disappearing (through over-investment in relation to the solvency of the market in question), the firm must innovate and at the same time grow. Depreciation and centralization go hand in hand. Innovation links the two together: It allows the depreciation of the already old capital whose profitability has slumped; it creates a favorable climate in which to make further investments and it favors "creative destruction" (Schumpeter) and the involvement of finance, the merging of capital (centralization) forming huge companies so that the capital and its development appear as the starting point and the end, like the motive for and the objective of the production. For this reason, the capitalist economy tends to develop its production forces as though it only had the absolute power of the company as a limit. But this tendency enters into permanent conflict with the restricted objective, taking advantage of the existing capital (Marx 1993). The periodic crises mean the destruction of part of the existing production forces. About a century later, J. Schumpeter described as "creative destruction" the process of destroying old capital by new productive combinations which create, from their introduction to the market, new opportunities for profit and investment (Schumpeter 2006). The resumption of accumulation after the said destruction will not be possible without thorough modification of the foundations and the norms of accumulation (new social organization of work, new competition rules, new technology, new institutional forms of management, and economic regulation).

Innovation, Networks, and the Power of the Firm

As soon as the capital takes over the social production, the technical progress reflects the more or less significant changes (marginal or radical) in the techniques and the production methods, together with the social organization of the working process and thereby the historical type of society (Marx 2012, vol. II). The three stages in the transformation of the production forces of capitalism (meetings of workers isolated under the same management, that of the holder of the capital, followed by the division of labor and the differentiation of the tasks with the setting up of a salaried management team in the factories, then by the clear separation between intellectual and manual work which determine the status of scientific and technical workers compared with the immediate commercial objectives of the production process) are conceptually linked to the formation and the evolution of the "collective worker."

Capital instigates cooperation among the workers for the accomplishment of a given production. This results in collective of workers all the while depriving the staff of any role in the organization of their work, any control over their contribution (value added) to the production, and finally of any role in evaluating the use value that their workforce represents for the capital. A. Smith's spirit lurks: The machine was created by the division of labor. He also remarked that the specialization of labor will lead the worker to discover sooner or later the means to reduce the difficulty of his task. But these "minor innovations" are not the only ones; according to A. Smith, other inventions are a consequence of the work of scientists which consists in observing distinct physical and technical processes (Smith 2012). These inventions, when marketed, will represent the major innovations of the future.

The stages of the capitalist production organization therefore precede the technical transformations and transform science into a productive force and define technology as production knowledge. Innovation and more particularly, technology, said J. K. Galbraith (1967), undergo a major organizational effort, but it is also the result of the organization. This basis of perception of the evolution of production forces under the constraints of accumulation has inspired some of the neoclassical economists. The positive externalities, the increasing returns, or even the human capital are the concepts which illustrate in different words the state of the collective of workers and the state of the socialization of the capitalist production such as has been noticed since the beginning of the 1980s. The current phenomenon of a "knowledge-based economy" (see, for example, Laperche et al. 2008) is the continuation of the formalization of the scientific and technical knowledge and of the organization of science as a domain for accumulation whose origins date from the middle of the nineteenth century. Indeed, with the creation of schools and specialized publications, knowledge and all sorts of scientific and technical information is diffused. The process goes therefore progressively from a series of empirical results, logically organized, to a strictly scientific knowledge which results from experiments willingly carried out, not more uncertainly endured (see particularly: Noble 2011).

However, what it must emphasize is that the explanation that the superiority of the social return on investment in research and in innovation in companies in comparison to the return on the individual capital lies in the increase in the number of factors determining the profit-making potential in a given company. These factors (education, environment, health, finance, inter-industrial relations, communication, requirements and aspirations, etc.) of a general nature influence the marginal cost of a company or an operation and, with everything equal, have an effect on the return on the capital invested. The firm, in a competitive situation, be it apparent or latent, must appropriate these factors or at least monitor their impact on the profitability, or even better, take advantage of (abundant production resources which could be taken over, the opening of new markets) the noncommercial logic which these factors generate and reproduce (and nowadays this is how innovation is defined).

The firm, by investing in R & D, or by taking over small innovative companies, or by collaborating with other companies as strong as itself (joint research programs, cross-licensing, etc.) or with government research bodies (universities, for instance), appropriates knowledge which is the essential factor of competitiveness. Large companies consider that the knowledge which is vital for competitiveness entirely covers fundamental knowledge and insist that the university research institutes, with whom they sign research partnerships, accept their own criteria on who should be considered as "public" or "private" (Laperche et al. 2008).

It is the fourth stage in the organization of production: the combination in the same group of staff paid by the company itself and a salaried staff paid by other organizations, but appropriated by this company which makes use of the said group. The company keeps control of the group which is itself composed of productive capacity, trained and employed in various areas and by various social production entities (Laperche et al. 2008). This decentralization process of the constitution and the management of the private work groups affects all institutions. The diversification of the canals of scientific and technical knowledge and information transfer from public training centers for production resources (e.g., universities) toward the companies is proof of this; the refinement of the legal and financial system for the appropriation of the value constituted in the public sector by the company is further proof of this; the multiplication of the different levels of social status and salaries of the salesmen of all sorts of manual and intellectual competence is yet more proof.

The large controlling firm (or on a joint basis several large companies) constitutes the crux of the deployment of the production process. Having concentrated its means of production, defined, and divided up the production tasks and put together directly controllable collective of workers, it is becoming these days a decentralized organization and management center for its production resources. Capitalist production operates at the moment as if the power exercised by a firm on the market (and the coordination of the functions and activities that it can impose on it) was a factor of economic power (and of centralization of the ownership of the capital) more important than the power given by its own assets (scientific, technical, industrial, and financial).

But this is forgetting that this firm's power is a result of its financial capacity and of its potential concerning information. This "information potential" includes all information (scientific, technical, industrial, financial, commercial, political, sociological, etc.) which a company has access to, and can transmit to the market. Information and finance together enable the constitution and management of working groups which are geographically dispersed and remote (investment in industrial cooperation relations, in protecting the technological assets, in the appropriation of scientific knowledge and the creation of new products, in the coordination, using telecommunication means, of the different activities, etc.) (Laperche and Uzunidis 2008).

Technological innovations are today the outcome of this integrating decentralized process. They also provide the possibility for the process to be achieved and to prove itself more efficient (in relation to the costs of large amount of capital) than the huge factory which employs hundreds of people. The debates on the "networks" focus as much on the flexibility (to create or destroy production capacity according to the economic circumstances) that the large firm's decentralized management of the production provides, as on the increase in the firm's capacity to appropriate a large quantity of resources without investing in their formation. The large firm has turned into a center of concentration of the production resources, but also of formation and flexible coordination of collective of workers, depending on the accumulation requirements and the fluctuation of markets. It calls for cooperation and goes on toward this convergence by applying the strategies of growth and integration.

This coordination and innovation process, both flexible and evolutionary, imposes on the firm the pressing need to be provided with the different types of technological and intellectual means to acquire and combine uninterrupted flows of material and immaterial resources. The "knowledge theory" applied to the company says: The ability to adapt and the efficiency of the company depends on its cognitive categories, on the interpretation codes of the information itself, on the tacit skills, and its procedures in solving the problems it encounters (Dosi et al. 1999). The scientific, technical, and industrial information as a system of knowledge (Knowledge-capital) which is articulated, formalized, and likely to be communicated or transferred is a means of production, identifiable as such the use of which provides innovation for the economic process and the accumulation of capital. The task of the "technostructure" consists therefore of finding the balance between managing the "partnerships" and developing the internal instruments of organization (see Laperche et al. 2006).

Faced with the complexity of the private innovation process, M. Castells (1998) went as far as to maintain, quite cleverly, that the fundamental unit of the economic system is no longer the entrepreneur, the family, the firm, or the state, but the network composed of different organizations. Regarding innovation, the division of labor and the very refined specialization of skills in scientific research and experimentation remove any possibility of autarkical organization of the technological production. The network unfolds as a private form of organization of the instrumentalization of science. Partnerships between companies and between state research bodies and companies, and a whole panel of technical, financial, and commercial contributions, illustrate the theories of the classical economists (e.g., A. Smith and K. Marx) for whom once the capital takes over the social production (and enlarges its market by appropriating the resources at the time), the economy is subject to technical transformations and changes in the social organization of the production.

Conclusion and Future Directions

The new era of capital is not so much apprehended by the technological progress, but by the new way in which the production process is organized and developed. The industrial applications of science are the result of this, but also what prompts accumulation, the means to succeed, and also the cause of crises (Noble 2011). The current theories of networks, externalities, competition, and open innovation are based on an acquired principle: the benefits of the market, and on common finding that the market must not only be developed, organized, and regulated, but that it must also be created and preserved.

For the radical economists, the socialization of capitalist production has indeed taken on such dimensions that from now on, the appropriation of the technological elements gathered by the large companies is less costly than the raising of capital for their formation. The big firms are becoming, using relations of power, convergence centers for science and techniques, which they combine to supply their innovation process. To get from the stage of the concentration of production to the current stage of the contractual integration of the centralized property, capitalism has invented a new accumulation framework; the economic policies of "contesting the monopolies," privatization, flexible work management, international financialization, and integration have to a certain extent succeeded in depreciating the old capital, but they have also created the context of securitization and marketability of all individual and collective assets (science is of course part of this). In these conditions, how can economists be surprised by the regulatory power of finance? The system works by trial and error, finance facilitates the task. But in doing so, it directs the applications of science to production, it becomes a selection criterion to the research programs and at the same time, it weakens the potential for radical systemic innovations.

The age of the "captains of industry" is a bygone era (Boutillier and Uzunidis 1999). State management of innovation which the neoclassical economists are calling for shows, on the one hand, that the appropriation of scientific resources by companies is considered as one of the State's main economic reasons and, on the other hand, that the obstacles to accumulation become insurmountable without the organizing and planning role of the state. The introduction of commercial logic into scientific research falls within the scope of an innovation policy, but more surprisingly, so does the economic efficiency of the "network."

Cross-References

▶ Creative Destruction
▶ Joseph A. Schumpeter and Innovation
▶ Knowledge Society, Knowledge-Based Economy, and Innovation
▶ Techno-Globalization and Innovation

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Innovation Internationalization

▶ Techno-Globalization and Innovation

Innovation Management

▶ Creativity Management Optimization
▶ Semantic Technologies in Knowledge Management and Innovation

Innovation Models

▶ Multiple Models of Creativity

Innovation Networks

▶ Innovation Systems and Entrepreneurship
▶ Nonlinear Innovations

Innovation of Democracy

▶ Quality of Democracy and Innovation

Innovation Opportunities and Business Start-up

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Synonyms

Opportunities recognition; Spin-off; Start-up; Technology

Innovation opportunities are often recognized and valorized by new small companies. This chapter goes into details about the capacity of firms to seize innovation opportunities depending on their size. Then, the mechanisms mobilized are described, and the main sectors where start-ups are operating are listed. The question of the financial structure of start-ups is finally studied.

Introduction: Innovation, the Ability to Grasp New Opportunities

Innovation may be defined as a dynamic process to modify the functioning modes and the organizations of companies in order to develop new businesses (Boly 2009). These adjustments may concern new equipment, production processes, core competencies, and organizational variables such as the type of responsibilities assumed by employees, control processes, and information procedures (Simon 1979). One particular and radical form of this type of evolution is company creation: start-up launching among others. Generally, a start-up company is considered as a structure recently launched and based on up to date technological knowledge. Its potential development capacity and its reward profile are potentially important, but the associated risk is also high.

The aim of the innovation process is to invest in new economical areas: the company faces new customers, valorizes new knowledge, takes into account new constraints, and manages new relations (in terms of the nature of the interaction) with its present external stakeholders but also with new ones (this includes suppliers, partners, institutions). Consequently, innovation does not only concern the technical domain and the development of a new activity. Moreover, the ability to identify new opportunities constitutes a major asset for innovators. The behaviors and thought processes mobilized by entrepreneurs to see the unique potential in a situation and create an organization to pursue it are key success factors, while other individuals, when presented with the same information, either fail to see the opportunity or choose not to pursue it (Parks 2005). Note that entrepreneurs' skills are not the only explanation of the capacity to seize opportunity. As customers needs, technology, regulation, and political context evolve, innovation opportunities may be seized by entrepreneurs able to determine these new economical areas and acting in a favorable environment.

Finally, Parks (2005) suggests that innovation opportunity recognition is based on three compounds. The first component is the founding entrepreneurs who decide to create firms to pursue entrepreneurial technology ventures. The second component is the organization they build around themselves and how this collective organizational knowledge and experience (mostly in customer problem solving) impact on the success of the venture. It seems that in the field of high technology, expertise and experience constitute requirements in order to recognize opportunities within a mass of information and observation. Up to 50% and 90% of start-up ideas come from prior work experience. The final component of the process is the technology on which the venture is based, how this technology develops and evolves due to interaction with the founding entrepreneur, and the knowledge of the firm. The paper goes into greater detail about this theoretical model.

Are Start-up Organizations Adapted to Invest in Innovative Domains to Grasp Innovation Opportunities?

Organizations grow by gaining efficiencies of scale and scope in specific core competence areas that, ultimately, become core rigidities (Leonard-Barton 1992) or core incompetences (Dougherty 1995). Some scholars use the term "knowledge tunnel" to describe the incapacity to detect new market emergence. Moreover, innovation requires new production processes and new skills, and as a result, innovation requirements are often in contradiction with mainstream organization. Consequently, companies often hesitate to launch innovative projects, which require long-term R&D periods before ensuring a real return on investment. As a consequence, scholars conclude that radical innovation cannot be effectively managed within the confines of the firm, and they prescribe external incubators or investments in start-up firms and venture funds as the source of organic renewal for large established companies (Campbell et al. 2003). On the other hand, big companies attest to financial, human, and material resources that strengthen the innovative processes, and the innovative capacity of many international companies is evaluated as high (Wang et al. 2008) (Yam et al. 2004). One hypothesis is discontinuous innovation processes associated with disruptive technologies are better adapted to start-ups, whereas continuous innovation processes associated with sustaining technologies is better suited to large companies. However, a better understanding of the link between the size of the company and its ability to seize innovation opportunities remains a major research concern.

In fact, three scenarios may be defined at the beginning of the innovation process:

– An individual launches a start-up: thanks to their own entrepreneurial skills, a manager creates an ex nihilo organization able to develop knowledge and valorize it on the market.
– A big company launches a project through a team organized as a start-up: some individuals of the company work in an autonomous context within the company; the venture group is in charge of R&D tasks but also of the launching period. This may include the standardization of the business activity.
– An existing company establishes a partnership with a start-up. Different forms of partnership may be distinguished. Some companies organize venture capital structures. They act as financial institutions and provide funding to newly created companies. Hence, Aster Capital is a corporate capital fund federating Rhodia, Schneider Electric and Alsthom. Aster is more precisely dedicated to start-up support and participates among others to the development of Optireno, a start-up in the field of insulation. The objective is to get financial rewards or to facilitate any possible further purchasing procedure. The start-up development is accelerated thanks to this financial support and represents a possible temporary external structure seizing an innovative opportunity in place of the big company. Some companies directly acquire shares in young technological structures but some others establish strategic and technology partnerships. Procter and Gamble as well as Veolia, put researchers and equipment at the disposal of start-ups in order to strengthen their R&D. They previously negotiate the exclusive valorization of the new technology on certain markets which are strategically important for them, while the start-up runs the findings in any other domains.

Linked with these three scenarios, different business models are established within the start-ups:

– Business models based on the autonomous development of the company: they are characterized by the progressive growth of the capital
– Business models integrating the future purchasing of the start-up by large companies: important funds are invested at the very beginning in order to accelerate the R&D tasks
– Codevelopment business models: investments are calculated aiming at an acceptable return on investment by each partner

In conclusion, even if inner structures such as interdepartment teams, new business divisions, or new venture groups may be dedicated to innovation, start-ups are common organizations in the field of innovation.

Opportunities Seizing Mechanisms Associated with Start-Ups

An innovation opportunity is defined as an exogenous favorable context (market demand, time to enter this market among others) associated with an idea of a new product, technology, or service.

Technology transfer from national scientific community to economic stakeholder represents a way for companies to seize disruptive innovation opportunities. The major implication for technology transfer and commercialization is that the more channels of communication that exist between the technology source and the technology recipient, the more likely the technology will find its way to the market (Kassicieh et al. 2002). The company, managerial (especially those centered on learning), and scientific competences have long been associated with the capacity to succeed in the technology transfer process. Thus, two scenarios appear:

– The development of laboratory spin-offs
– The creation of a start-up by a former member of a research laboratory

In these two cases, people developing the research are also involved in the definition of application opportunities and in the development of the corresponding activities. In some countries, these mechanisms are stimulated with specific procedures, including the ability for a national researcher to take entrepreneurial leave or to invest in a spin-off. Finally, opportunities are seized by "direct human transfer."

Another mechanism observed in the opportunity recognition phase can be found in the local social network that entrepreneurs manage. The meeting and confrontation of people from the same geographical area, each having part of the required knowledge to launch an innovative activity, is one source of development (Lakoff 2008). Opportunities are then valorized thanks to local confrontation. National institutions try to stimulate this mechanism through policies favoring networking or clustering. Klevorick et al. (2005) investigating the source of knowledge of start-up states that the primary sources are customers and suppliers before academic structures (biology is an exception). Then start-ups emerge when a combination of expertise and experience (technology, marketing, distribution) gives a new expertise large companies do not have (Carayannis and Alexander 2002).

Foreseeing is a third mechanism. After treating information, entrepreneurs develop a vision, a description of a scenario for the future. These include future market specifications, new uses, new production constraints, and new needs. Thus, they use their own expertise or external knowledge to elaborate a strategy and the associated technologies. Anticipation is then the very first step in opportunity recognition.

Main Start-up Launching Sectors

Statistical data is not easy to collect, as long as "start-up" is not a reference term in national statistics institutions; moreover, the term "new technology" corresponds to a wide range of situations. Consequently, company creation databases are used to evaluate start-up launches.

Start-ups seems mainly to seize opportunities in the fields of information technology (software and services), telecommunication, electronics and electricity, chemicals and pharmaceuticals, new materials, and biotechnology. In France, the two first domains represent 75% of the total number of start-up creations.

Start-up Financing

The financing of the different phases of the life cycle of an innovative process, product, or service is one of the main issues of innovative start-ups. Different possibilities exist at each stage; these include public financing, permanent capital, long-term loans, short-term loans, and the role of the different actors, shareholders, bankers, politicians/policy makers, suppliers, and clients. Based on data collection campaigns within a multisector start-up panel, it is possible to determine general trends about the capital required depending on the type of technology developed.

At the proof of concept stage, little money is generally spent at this stage. At least, it could even be a serendipitous result or a kind of "by-product" of a more global research activity (Table 1).

On a second phase, based on feasibility and repeatability, the enrichment of the concept is achieved; the aim is confirmation, still at lab level, that the technologies to implement the concept are reliable. The possibility of reproducing the experiment with other operators and machines and initial conditions are also tested. Finally, the opinion of some of the main market stakeholders may be collected. Consequently, money is spent on experiments, tests, characterization, industrial property studies, and protection and premarket studies. Equity capital (when the company is already created), other public funds, and/or semipublic funds contribute to the financing (Table 2).

Innovation Opportunities and Business Start-up, Table 1 Step one – proof of concept (Source: Authors)

Risk extremely high		
Start-ups Steps	Financing	
	Needs	Sources
Ideas, concepts detection	Initial tests	Generally invisible when performed by public
Valorization services? Industrial liaison offices		R & D activities
Sensitization of students/researchers		Generally not individualized when performed by private
IP concerns (initial initiatives)		R & D activities
Analysis of the other projects of the laboratory		

Innovation Opportunities and Business Start-up, Table 2 Step two – feasibility and repeatability (Source: Authors)

Risk very high		
Start-ups Steps	Financing	
	Needs	Sources
IP protection (formal) – partnership agreements	Support to IP protection	Equity capital (shareholders, finance market)
Choice of the next steps (internal valorization in other research projects, sale to external existing company, start-up . . .). Scenario building	Pre-market studies	National, regional, local public financing schemes for R&D and tech transfer . . .
	Research for R&D partners	
	Technology broker hiring	Risk capital setups
Complementary studies	Development specialist hiring	Business angels
"Production" of the first samples – trials/tests		

The third phase of industrialization is crucial and risky: it consists in developing knowledge to master the technology from lab level to an industrial scale. All the support activities are organized: sales and marketing, maintenance, and supply chain management. Generally, at this stage, larger investors are involved in the venture: initial investors have to adapt to this capital enhancement. Moreover, venture capital is needed and business angels may be associated. Other more institutional schemes may also be activated, technology transfer fund among others.

Innovation Opportunities and Business Start-up, Table 3 Step three – industrialization. Step four: Continuous innovation dynamic (Source: Authors)

Risk still high		
Start-ups Steps	Financing	
	Needs	Sources
Engineering studies	Cofinancing of innovation project – industrialization	Equity capital (shareholders, finance market)
Research of financial (technical market) partners (capital increase, participative loans)	Phase	National, regional, local public financing schemes for R&D and tech transfer
	Support to finance engineering	
Complementary studies (e.g., aging)	Support to market strategy elaboration	Risk capital set ups
Application exhaustive exploration, selection of first market segments)		Risk capital
		Long-term loans (quasi proper funds)
Investments (machines, people, demonstrators, market)		

The observation campaign within the studied start-up panel concludes that the ratio between the amounts of money required for step three is between 50 and 100 times higher than step two (Table 3).

At step four, processes are operating and products or services have been recently launched on the market, technical aspects required improved. A continuous innovation activity is managed, either to suppress defects observed at user level, improve performances, or allow access to new markets. At this stage, the necessary funds may be covered partially by the company outcomes, but complementary loans are often mobilized (Table 4).

If the new activity is successful (Table 5), operating costs are covered by the exploitation, but the increase in sales very often produces an increase in operating capital needs which could be covered by short-terms loans. Some contradictions have to be treated since some financing schemes (e.g., innovation loans) ask for the money to be paid back from the first sales when the needs in operating capital are highest. Precise treasury prevision and management is a key factor, and trust between all partners is challenged here. Finally, in order to wait for the dividend distribution period, different

Innovation Opportunities and Business Start-up, Table 4 Step four – continuous innovation dynamic (Source: Authors)

Risk		
Start-ups Steps	Financing	
	Needs	Sources
Technology (processes, products) updating	Support for consulting services	Equity capital (shareholders, finance market)
Services offer permanent analysis and upgrading	Support to strategic intelligence and knowledge management	Long-term loans (quasi proper funds)
New competitors ("fast second")		Short-term loans (running capital increase for exploitation)

Innovation Opportunities and Business Start-up, Table 5 Step five – operation (Source: Authors)

Normal risk		
Start-ups Steps	Financing	
	Needs	Sources
Strategic decisions: internal production investments, contracting, client/supplier relations. . .	Support for financing productive investments (warrant for banks, incentives . . .)	Sales (margin, profit) if necessary short terms banks loans
Networks, clusters	Support to market studies and market development	Shareholders running accounts
Market penetration	Support to export	Banks (running capital needs)
	Support do staff recruitment	

financial possibilities are mobilized depending on the different levels of risk: the higher the risk, the higher the need of permanent funds. Since innovative start-ups or innovation projects are risky, manager attention is directed toward structural funds and low interest rates. Consequently, short-term money is not suitable for their development. Securing the financing scheme and using various possibilities of constituting the permanent capital are crucial strategic actions which are to be taken into account as much as technology or market.

Conclusion and Future Directions

Start-ups are adapted to innovation opportunities through specific processes of recognition considering the type of sector and technology considered. Start-ups represent more or less sustainable organizations able to develop technological knowledge and the associated business activities. Their ability to seize opportunities highly depends on the manager profile, the organization, its structures, and the type of technological sector concerned. The phenomenon of start-up development highly proves that technology is a complex system based both on scientific knowledge and also on connected knowledge (any expertise allowing to valorize a specific scientific skill into an industrial competence).

Considering financial aspects, a better understanding of the adequation between the amount of money required and the nature of the corresponding funds at each step of the development cycle of start-ups still remains necessary.

Cross-References

- ▶ Angel Investors
- ▶ Business Creation
- ▶ Business Start-up: From Emergence to Development
- ▶ Entrepreneurial Opportunities
- ▶ Financing Entrepreneurship
- ▶ Risk, Uncertainty, and Business Creation
- ▶ Technological Entrepreneurship and Asymmetries
- ▶ Venture Capital and Small Business

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Innovation Policies (vis-à-vis Practice and Theory)

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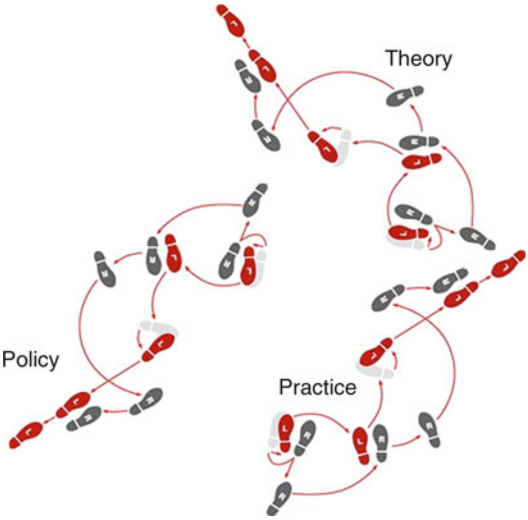
Synonyms

Governance; Innovation policy; Innovation practice; Innovation theory

Innovation-driven economic and social change is a significant characteristic of today's economies and a driving force for international knowledge production, competition, and trade; this holds certainly for industrialized countries, but increasingly also for a growing number of late industrializing countries. National, often also regional, governments pursue, more or less explicitly, *innovation policies*, which can be defined as "as the integral of all state initiatives regarding science, education, research, technology policy, and industrial modernization, overlapping also with industrial, environmental, labor, and social policies. Public innovation policy aims to strengthen the competitiveness of an economy or of selected sectors, in order to increase societal welfare through economic success" (Kuhlmann 2001, 954). Public innovation policies reflect the "innovation culture" of a given society, not at least characterized by the particular interrelation of economic, knowledge-producing, and policymaking actors and organizations ("Triple Helix"), at various levels of action ("multilevel innovation system").

The concept of public innovation policy is built on the assumption that "innovation" – a perceived or intended process of material, social, and often also cultural change, incremental or disruptive – can be "governed." The present entry (largely drawing on Kuhlmann 2007) offers four considerations of this supposition: First, an illustration will be presented of *why* the



Innovation Policies (vis-à-vis Practice and Theory), Fig. 1 Innovation practice, theory, and policy as dancing partners (Source: Kuhlmann 2007, 5)

governance of innovation is an issue of concern and that there are governance routes of different character and quality. Second, three forces of the governance of innovation will be addressed: The (1) dynamics of *innovation in practice*, the (2) role of *public policy*, and (3) the role of *Innovation Studies*, as "theory in action." In order to illustrate the mutual interaction of the three forces, a metaphor will be used (following Kuhlmann 2007; Kuhlmann et al. 2010). Innovation practice, policy, and theory can be seen as "*partners on a dancing floor*," moving to the varying music and forming different configurations (see Fig. 1). Taking a closer look at the dance floor, one can see two of the dancers, innovation practice and policy, arguing and negotiating about the dance and music while the third, theory – not always, but often and to an increasing extent – provides the other two partners with arguments and sometimes also with new music: Practice and policy increasingly have expectations vis-à-vis the contribution of social science-based intelligence to their dance. Hence, the third consideration: (3) *Innovation Studies*, by now a widely respected academic field of interdisciplinary knowledge and research, may experience a tension between participating in the dance and academic discourse at arm's length to practice. Yet, there is a chance that Innovation Studies can cope with this tension and, in fact, make it a source of increased *reflexivity*. The fourth consideration will (4) exemplify some ways of deliberate interaction of Innovation Studies as theory in action, taking a closer look at *"fora" for the debate of innovation issues* and the role of research-based "strategic intelligence."

First Consideration: Why "Governance of Innovation"?

A better understanding of the governance of innovation both in terms of driving forces and with respect to the room for maneuver in policymaking is a precondition of successful practical attempts at shaping the character and direction of innovation processes or even changing them.

Innovation occurs within or vis-à-vis evolving "regimes." The term *regime* was first introduced by Nelson and Winter (1977) to characterize patterns in technical and economic change such as the frameworks of engineers in an industry constituting the basis for their search activities. Van den Ende and Kemp (1999) define a technological regime "as the complex of scientific knowledge, engineering practices, production process technologies, product characteristics, user practices, skills and procedures, and institutions and infrastructures that make up the totality of a technology" (835). Rip and Kemp (1998) add to the "grammar" of a regime explicitly the policies and actions of other innovation actors including public authorities.

Regimes differ in terms of the character and quality of their *governance*. The notion of governance is used here as a heuristic, borrowed from political science, denoting the dynamic interrelation of involved (mostly organized) actors, their resources, interests and power, fora for debate and arenas for negotiation between actors, rules of the game, and policy instruments applied (e.g., Kuhlmann 2001; Benz 2006; Braun 2006). Innovation governance profiles and their quality and direction are reflected not at least in the character of public debates between stakeholders, policymakers, and experts. Think of the debates on genetically modified organism (GMO), or debates on the governance of an emerging, cross-cutting innovation field such as "nanotechnology."

In a report of a European Expert Group on "Science and Governance" (Felt et al. 2007), two basic types of what the authors call "regimes" of innovation were identified:

- The regime of "*economics of technoscientific promise*": Promises to industry and society, often far reaching, are a general feature of technological change and innovation, particularly visible in the mode of governance of emerging technosciences: biotechnologies and genomics, nanotechnologies, neurosciences, or ambient intelligence, all with typical characteristics: They require the creation of a fictitious, uncertain future in order to attract resources and political attention. They come along with a diagnosis that "we" are in a world competition and that "we" (Europe, the USA, etc.) will not be able to afford "our" social model if "we" don't participate in the race and become leaders in understanding, fuelling, and exploiting the potential of technosciences. The regime "works with a specific governance assumption: a division of labour between technology promoters and enactors, and civil society. Let us (= promoters) work on the promises without too much interference from civil society, so that you can be happy customers as well as citizens profiting from the European social model" (Felt et al. 2007, 25). Under this regime of technoeconomic promises, politics, science, and industry take the lead, while the innovation needs and expectations represented in the society appear to remain in a rather passive consumer role.
- The second regime, "*economics and socio-politics of collective experimentation*," is characterized by emerging or created situations which allow to try out things and to learn from them. The main difference with the other regime is that "experimentation does not derive from promoting a particular technological promise, but from goals constructed around matters of

concerns and that may be achieved at the collective level. Such goals will often be further articulated in the course of the experimentation" (Felt et al. 2007, 26f). This regime requires a specific division of labor in terms of participation of a variety of actors, investing because they are concerned about a specific issue (see also Callon 2005). "Users matter" in innovation (e.g., Oudshoorn and Pinch 2003). Examples of such demand- and user-driven innovation regimes include the information and communication sector (where the distinction between developers and users is not sharp), or the involvement of patient associations in health research (e.g., Boon et al. 2008). The concept of "open innovation," debated around the user-driven development of non-patented Open Source software, and more generally in Chesbrough's influential book (2003), is largely overlapping with the collective experimentation concept. The governance of such regimes is precarious since they require long-term commitment of actors who are not always equipped with strong organizational and other relevant means, and there is always some room for opportunistic behavior. Nevertheless, the promise is innovation with sustainable effects.

In other words, the governance of innovation and related policies are neither neutral nor innocent. The precarious governance of the experimentation regime or the missing emphasis on stakeholder inclusion and demand-orientation indicate that strategists and policymakers may run the risk of missing valuable opportunities offered through variety and experimentation in the development of innovation processes. This leads to the second consideration.

Second Consideration: Three Interrelated Forces of Innovation Governance and Their Dance

An analysis of the governance of innovation has to cope with at least *three major forces*:

First force: While since the 1950s in economics and sociology "*science*," "*technology*," *and* "*innovation*" processes were plotted as a sequence of activities of institutionally and organizationally distinct units ("linear approach"; Bush 1945), this has changed in the course of the 1980s and 1990s. Today science, technological development, and innovation are conceived by most scholars as *overlapping fields of social practice*, forming a shared "space" of interactivity, driven by knowledge dynamics, economic forces, and framed by inherited institutions. Most concepts emphasize the interactive character of idea generation, scientific research, development, and introduction of innovative products and processes into markets or other areas of use – take as a simplifying tag the pervasive concept of an alleged new "mode 2" of knowledge production suggested by M. Gibbons et al. (1994). Eventually, the mode 2 perspective on knowledge production and innovation is building on a long strand of studies into the relation of science and technology (e.g., Zilsel 2003; Rip 1992) and, at least implicitly, alluding to older, more systemic concepts (e.g., List 1856). The evolutionary approach of Nelson and Winter (1977), the innovation system tradition as inspired by Freeman (1987) and developed further by many others (e.g., Lundvall 1992; Edquist 1997; Hekkert et al. 2007), take on board an interactive, holistic understanding. Also studies into the social construction of technology (Bijker et al. 1987), "system transitions" in socio-technical landscapes, related regimes, "innovation journeys" and niche management (see e.g., Geels and Schot 2007; Van de Ven et al. 1999), technology assessment and its "constructive" turn (Rip et al. 1995), understand science, technological development, and innovation as a an interactive social continuum.

Second force: If the dynamics of science, technological development, and innovation are interwoven in practice, then "*policy*" and "*governance*" in a given innovation field will reflect this heterogeneity. Today, innovation policy is characterized by an "increasing 'sophistication' of policy instruments" (Boekholt 2010, 334). Concepts on innovation policy have evolved from a linear model to a more systemic and even "holistic" model of innovation policy (e.g., Smits and Kuhlmann 2004). Consequently, the scope and variety of involved organized actors (such as science organizations, industries, governmental agencies, parliaments, nongovernmental organizations) has become broad and heterogeneous. Actors have different interests, resources, and power, and they negotiate in various interlinked arenas on all kinds of rules and policy instruments. Political science studies have shown that the patterns of policy governance for science, technology, and innovation develop mostly in an incremental and only rarely radical way (Bozeman 2000; Larédo and Mustar 2001; Biegelbauer and Borrás 2003; Edler 2003). The organizations involved in policymaking and the arenas for the negotiation of options and decisions are mostly characterized by institutional inertia. They evolve to path dependence, interwoven with historical innovation regimes. One can analytically distinguish between two types of policy rationales in the context of science and innovation (EPOM 2007): "*Knowledge production policy rationales*," on the one hand, are built on causal beliefs, often derived from Innovation Studies' insights, about the production of knowledge, providing a theoretical framework for the type of policy proposed, especially with socioeconomic arguments. An advanced production rationale is characterized by the fact that knowledge is often tacit, partial, scattered and collectively distributed, and built through collective processes of creation, sharing, access, diffusion of knowledge, and more generally through learning processes. "*Governance policy rationales*," on the other hand, reflect general causal beliefs in the political system about how the state should govern (EPOM 2007). An advanced governance policy rationale is offered by a "decentralized multi-space model, with a growing importance of a large variety of public and scientific interest groups (public opinion, consumers, patients, NGO, etc.) willing to be associated into the policy design, with a high heterogeneity among them (in terms of level of knowledge, means of expression, financial resources, representativity, etc.)" (EPOM 2007). Following this rationale, the actual policy choice and mixes depend on negotiation and learning processes in the development of a given regime: Whether the future governance of nanotechnologies, for example, will be driven mainly by technoeconomic promises or by sociopolitical collective experimentation hinges not at least on the way how the involved heterogeneous actors in multi-space articulation processes will interpret the production rationales associated to nanotech.

Third aspect: Social science research, in particular Innovation Studies, can turn into "*theory in action*." Given the variety and potential complexity of governance in the practice of innovation as well as in related policymaking, actors tend to develop assumptions or "folk theories" on governance, simplifying, guiding, and stabilizing their action: Innovators and policymakers develop rules of thumb based on experience, own analysis, or prejudice – or they refer to and utilize expertise based on Innovation Studies. Take, for example, the utilization of the "System of Innovation" approach: This analytical concept, a heuristic developed by economists and innovation researchers since the late 1980s, has been increasingly utilized by policymakers around the world. Innovation systems have been conceptualized as the "biotopes" of all those institutions which are engaged in scientific research and the accumulation and diffusion of knowledge, which educate and train the working population, develop technology, produce innovative products and processes, and distribute them; to this belong the relevant regulative bodies (standards, norms, laws), as well as the state investments in appropriate infrastructures. Innovation systems would extend over schools, universities, research institutions, industrial enterprises, the politico-administrative and intermediary authorities, as well as the formal and informal networks of the actors of these institutions (Kuhlmann 2001). The innovation system concept turned out to appeal to policymakers a lot, not at least because the systemic perspective provided an argument for a broadened scope and reach of public innovation policy (Smits and Kuhlmann 2004). Many used it as a sort of programmatic device: Since a number of years, for example, the Swedish state office for innovation policy calls itself "Governmental Agency for Innovation Systems."

Actually, when taking a closer look, it turns out that the very concept of innovation systems while being designed by innovation researchers had at the same time been inspired and strongly supported by Scandinavian policymakers (see Carlsson et al. 2010) and by the Organisation for Economic Cooperation and Development (OECD) (Lundvall 2007) – the concept became "theory in action." Scholars could have tried to maintain academic distance to the lifting of their concepts and findings by policymakers or practitioners in innovation – but they chose to offer the policymakers information, heuristics, analysis, and theory, longing further than their "folk theories." In other words, they danced with innovation practice and policy and even jointly composed new melodies.

Considering innovation practice, policy, and theory as "partners on a dancing floor," moving to varying music and exposing different configurations, one can interpret the "regimes" of innovation and their evolution from the perspective of learning. The ideas, rationales, and instruments – finally the governance – of innovation and related policy emerge as a result of interactive learning between actors involved in innovation practice, intervention strategies and policies, and Innovation Studies and theory. Figure 1 (above) represented an attempt to characterize the dance of the three groups. Practice, policy, and theory can be conceived as dancing partners in a performance setting. The dancers observe each other and react on the partners' movements: They copy, comment, complement, counteract, neglect, learn, and thereby create and change configurations. Sometimes innovation practice is the driving force in a configuration, sometimes theory, sometimes public, or private policy.

Learning on the innovation policy dance floor may occur as first-order or as second-order learning. According to Argyris and Schön (1978), *first-order learning* links outcomes of action to organizational strategies and assumptions which are modified so as to keep organizational performance within the range set by accepted organizational norms. The norms themselves remain unchanged. *Second-order learning* concerns inquiries which resolve incompatible organizational norms by setting new priorities and relevance of norms, or by restructuring the norms themselves together with associated strategies and assumptions, hence escaping tunnel vision and crossing borders. In other words, while first-order learning would help to improve the expression, harmony or elegance of an otherwise unchanged dance (or make an innovation regime more effective), second-order learning would help to change the melody and the dance (or introduce new directions and modes of governance).

Third Consideration: The Potential of Innovation Studies as a Dancing Partner

Today, Innovation Studies are a respected academic field of interdisciplinary knowledge and research, loosely interlinked with Science and Technology Studies (STS; Hackett et al. 2007). In short, most of the enormous scope of topics covered by Innovation Studies and STS can be subsumed within two very general rubrics (Silbey 2006, 538): First, the institutionalization, reception, and appropriation of science and innovation and, second, the production of science and innovation as a social process. The first perspective is interested in the working of institutions, organizations, policies (expectations, rules, regulation, funding), strategy-making and planning, the assessment of potential developments and impacts of science and innovation, and their constructive shaping (Constructive Technology Assessment, CTA). The other, second perspective of studies adopts an anthropological view on the working of scientists, engineers, or users trying to reveal the intrinsic organization, culture, and epistemology of social groups. The ambition is to understand innovation not as a completely distinct realm of social action but like other social settings ruled by habits, rules, conflict, compromise, constructions, and narratives (Silbey 2006, 539). Consequently, this perspective concentrated rather on innovation as social practice than on policy. This approach, nevertheless, has an important impact on policy concepts: It helps to understand that modeling the governance of "innovation in the making" would fall too short if practice were conceptualized mainly in terms of functional and normative requisites, suggesting rather mechanistic designs of public policy ("mode 1"). Applying the constructivist approach to technological development and innovation as fields of social practice, strategists and policymakers developed more and more sophisticated policy designs ("mode 2"). The above-sketched "production governance rationale" can be understood as a result of this new perspective.

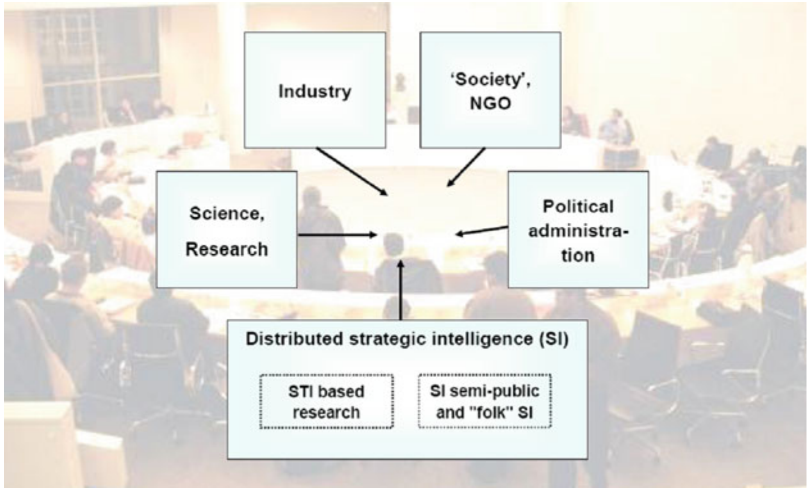
In short, one can state that Innovation Studies contributed a lot to a better understanding of the driving forces of each of the two other dancers, innovation in practice and policy, and became to some extent interwoven with them – sometimes very tightly, sometimes at some academic distance. Innovation Studies cope with this tension and even make it a source of increased reflexivity and enlightenment for their own purposes. The reflexive potential of Innovation Studies arises from the combined perspective of the interaction of practice, policy, and theory: Observing the dance and getting involved into it, Innovation Studies hardly can avoid adopting a *constructivist* position and *reflecting* upon their own impact on the dance and the evolution of images and beliefs of the other partners. And – one step further – Innovation Studies cannot escape questioning the origins and dynamics of their own beliefs. To which extend are they driven by concerns of practice and policy? Could such a drift be pictured as second-order learning, or are Innovation Studies scholars' beliefs sometimes also echoing the trends or fashions of their dancing partners or of the surrounding societal and cultural movement?

Obviously, Innovation Studies are not made up of one dominant theory; rather they appear as an assemblage of quite diverse intellectual strands, sometimes converging, sometimes diverting. Accordingly, innovation practice might prefer dances with other theory than public policy would like. In sum, there is no single recipe for coping with the ambiguity of being involved in the dance with practice and policy. Innovation Studies scholars moving with some passion on the dancing floor can only try to keep a precarious balance, based on some distance through reflection.

Fourth Consideration: Dance in Practice (Fora and Strategic Intelligence)

For a number of reasons, the governance of innovation and related policy has become ever more complex: Innovation processes themselves are subject of multiple forces and have become more uncertain; the number and heterogeneity of actors involved has grown, hence also the plurality of interests and values; and the borders between public and private spheres have become blurred. In order to cope with these challenges, actors seek to base their policy initiatives on increased interactivity, and often also on more evidence of actual or potential conditions, cost, impacts, etc. Interaction may be formally institutionalized and regulated, while in early phases, interactivity may occur in emerging spaces and semi-institutionalized platforms, where policymakers, public researchers, and industry as well as experts meet, articulate their views, provide intelligence in order to inform the process, and make attempts to set the scene. One means of organizing a policy-oriented discourse in semi-institutional environments are "fora," defined as *institutionalised spaces specifically designed for deliberation or other interaction between heterogeneous actors* with the purpose of informing and conditioning the form and direction of strategic social choices in the governance of science and technology (see Fig. 2, and Edler et al. 2006).

Fora can be seen as a dancing floor, a meeting place for innovation practice, theory, and policy with two related effects: (1) Interactive learning of policy analysts, policymakers, and relevant stakeholders and (2) improving the functioning of science and innovation policy and strategy. Fora can adopt several governance functions on the dance floor: They can offer a general, nondirected policy discourse, or offer policy information on specific issues, or prepare policy planning and development (visions, agenda,



Innovation Policies (vis-à-vis Practice and Theory), Fig. 2 Forum for debates of science, technology, and innovation issues (Source: Kuhlmann 2007, 17)

implementation), or facilitate the resolution of conflict and the building of consensus, or they can improve the provision and application of policy intelligence (e.g., see Edler et al. 2006).

In practice, there are manifold variations of fora. A specific characteristic of the sort of forum I am alluding to is the prominent role played by "*strategic intelligence*" (*SI*). SI has been defined as a set of sources of information and explorative as well as analytical (theoretical, heuristic, methodological) tools – often distributed across organizations and countries – employed to produce useful insight in the actual or potential costs and effects of public or private policy and management. Strategic intelligence is "injected" and "digested" in fora, with the potential of enlightening the debate (Kuhlmann et al. 1999).

SI can draw on semipublic intelligence services (such as statistical agencies), on "folk" intelligence provided by practitioners, and in particular on Innovation Studies. Meanwhile, a number of formalized methodologies, based on the arsenal of social and economic sciences, have been introduced and developed which attempt to analyze past behavior ("Evaluation"; e.g., Shapira and Kuhlmann 2003), review technological options for the future ("Foresight"; e.g., Martin 1995), and assess the implications of adopting particular options ("Technology Assessment"; e.g., Rip et al. 1995). Also, other intelligence tools such as comparative studies of the national, regional, or sectoral "innovation performance" were developed and used (e.g., the European "Community Innovation Surveys (CIS))".

Providers of SI play a number of roles in fora, often in combination: as a facilitator or moderator taking advantage of methodological capabilities, as an enabler or teacher supporting critical analysis and self-reflection (bird's eye view), as provider of issue expertise, or as entrepreneur using fora for advancing SI application in policymaking and for disseminating results (Edler et al. 2006).

Conclusion and Future Directions: "Strategic Intelligence" and New "Spaces" and New Models for Innovation Initiatives

Arenas of innovation policy have become more complex and sometimes unclear during the last two decades. Next to national governments, semi-independent regional and transnational institutions and agencies entered the arenas, partly as cooperation partners and partly as competitors. At the same time, public policymakers are confronted with multinational companies developing their innovation projects across the globe, drawing on public policy support wherever easily available, irrespective of the location of exploitation of innovation returns. National innovation policy will remain relevant, but actors will be urged to change their perspectives and policy designs: Hierarchical, fragmented, or stubborn strategies will fail in this complex environment.

Furthermore, many late industrializing countries have started to develop own innovation policy approaches, many of them drawing on the model of western industrialized countries. Yet, there are also more radical views, arguing that innovation policies are inspired on the wrong models, aiming at solving the wrong policy problems, too narrowly defined, too poorly managed and implemented, and/or lack the necessary supportive conditions from society due to historical, cultural, and political reasons (e.g., Rennkamp 2011). In particular, another concept of "innovation" will be required, beyond the presently prevailing business orientation, including aspects of social novelty and development, new ideas improving quality or quantity of life, not necessarily linked with economic profits. "The ultimate end of social innovation is to help create better futures" (Pol and Ville 2009, 884).

Hence, it will be crucial to systematically understand the diverging perspectives and interests of competing actors, to make them transparent and debatable – not aiming at weak compromises but stimulating learning capacity. This will require new interinstitutional and also international "spaces," fora where heterogeneous actors from different arenas meet and interact. "Strategic intelligence" can provide background information and alternative scenarios of potential future challenges for reflection. Otherwise, innovation policymakers will be reminded of the limits of an instrumentalist understanding and see "how great expectations in Washington are dashed in Oakland" (Pressman and Wildavsky 1973).

Cross-References

- ▶ Innovation Policy Learning
- ▶ Multi-level Systems of Innovation
- ▶ Political Leadership and Innovation
- ▶ Social Innovation

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Innovation Policy

▶ Entrepreneurship Policy
▶ Financing Innovation
▶ Innovation in Forestry: New Values and Challenges for Traditional Sector
▶ Innovation Policies (vis-à-vis Practice and Theory)
▶ Patents and Entrepreneurship

Innovation Policy Learning

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Definition

The term innovation policy learning stands for the change of innovation policy-relevant knowledge, skills, or attitudes, which are the results of the assessment of past, present, or possible future policies (Biegelbauer 2013).

Emergence of the Term and Development of Research

The approaches utilizing notions of policy learning share a conviction that the activities of policy-makers can be explained by understanding these actions in terms of feedback cycles used in order to assess previous actions. Policy-makers engage in learning in order to make sense of the world they live in, to gain a better understanding of the effects of their policies, and to arrive at better decisions in the future.

The notion "innovation policy learning" can be traced back to two different discussions, one rooted in political science and the other in economics. In political science, learning has been discussed as a category of policy analysis since the 1960s, when Karl Deutsch introduced his cybernetics of government (Deutsch 1966). Another milestone for the development of the term was Hugh Heclo's book on British and Swedish social policy (1974), in which he writes: "Governments not only 'power' … they also puzzle. Policy-making is a form of collective puzzlement on societies behalf" (Heclo 1974, 305). With this terminology, he captured one of the basic premises of the discussion on policy learning, namely, that political action cannot be explained alone by looking at interests and institutions and how they relate to power, which would be the classical categories of political science. Rather policy-makers also engage into efforts to solve what they perceive to be policy problems (Bandelow 2003; Biegelbauer 2013).

Similarly influential is the "advocacy coalition framework", developed mainly by Paul Sabatier (Sabatier and Weible 2007). In this framework, political processes are located in policy subfields, which are characterized by competing advocacy coalitions that may or may not change their belief structures through learning. At about the same time Peter Hall found that the change from Keynesian to monetarist economic policies in the early 1980s was best explained through social learning. His theory engulfs three targets of policy change, settings of policy instruments, policy instruments themselves, and finally policy paradigms, which are the ideational structure policies are embedded in and which most importantly explain the scope and the workings of policies. Social learning proper encompasses the change of policy paradigms, something happening only rarely (Hall 1993).

In the 2000s, policy learning approaches have been further developed, through, for example, critique of key terms (Maier et al. 2003), the further expansion of concepts of social learning (Oliver and Pemberton 2004), the advocacy coalition framework (Sabatier and Weible 2007), and of interpretative approaches (Grin and Loeber 2007), which also have integrated ideas from organizational sociology (Argyris and Schön 1978).

The second debate in which the term innovation policy learning is rooted stems from evolutionary economics. Neoclassic economic theory originally has exogenized innovation as a factor of economic development (Biegelbauer 2000). Yet with a number of empirical studies analyzing the production factors' input on growth carried out in search for new growth models, a new set of models was created in the late 1970s (Rosenberg et al. 1992). Joseph Schumpeter's vision of a dynamic and evolutionary economy (Schumpeter 1971) was integrated into a number of studies (e.g., Nelson and Winter 1982; Carayannis and Ziemnowicz 2007), which transcended the disciplinary boundaries of economics and led to a view of economic growth and technological change, which has increasingly been rivaling the neoclassical economic model ever since.

The key difference between the old neoclassical models and the newer Schumpeterian ones is that the latter are more dynamic in their evolutionary perspectives (Hofer 2003). With regard to technological change, this means an endogenization of the innovation process. Similar to the neoclassical model, the new models see technological change as the main driving factor for economic growth. However, since the new models are interested in explaining technological change, they assume the production function to include factors such as the level of technology or more broadly the stock of knowledge, investments into R&D, skills of the work force (human capital), indicators of the complexity of institutional arrangements, and the like, aside physical capital (Biegelbauer 2000).

In evolutionary economics, an important mechanism for the creation of knowledge and skills is learning. This notion has been developed especially by Bengt-Age Lundvall's concept of the "learning economy" (Lundvall 1992). Lundvall has differentiated between different forms of knowledge and skills, some of which had been rather neglected by economic theorizing before. This is especially the case with non-codified knowledge which accrues through "learning by doing" and forms an important knowledge base upon which a lot of innovation activities are based.

The wider framework of Lundvall's conception of a learning economy is the concept of "national systems of innovation" (Freeman 1987; Lundvall 1992; Nelson 1993), "the network of institutions in the public and the private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman 1987).

The notions of learning economies and national systems of innovation transformed in an ongoing process what was before science, technology, higher education, and industry policies into innovation policy (Biegelbauer and Borrás 2003; Edler 2003; Carayannis and Campbell 2006). This move impacts on the selection of policies as well as on the ways policies are perceived. Policy instruments have become more complex and are constructed to fulfill a multitude of purposes for the needs of a multitude of actors, and their effects are expected to be systemic (Kuhlmann and Smits 2004; Weber 2009). These changes have been interpreted as policy learning closely connected to the developments in the area of evolutionary economic innovation theory (Mytelka and Smith 2001).

Ramifications for Innovation Policy and Policy Analysis

A number of policy instruments have been devised to foster policy learning: evaluations, benchmarks, foresight exercises, impact assessments, expert commissions, and studies have been utilized to make policy-making ever more evidence-based and rational (Biegelbauer 2007, 2009; Biegelbauer and Mayer 2008).

Especially the European Union has built a whole learning architecture as part of the Lisbon Agenda and the Strategy 2020, both featuring the main goal of making the EU the most innovative and competitive region of the world. These strategies make use of the open method of coordination and its plethora of learning instruments. The exact nature of the open method of coordination, for example, the degree of its formality, differs from policy field to policy field (Borrás and Greve 2004; Borrás and Radaelli 2011). In RTDI policy, it engulfs a variety of rather informal networks, projects, and platforms in which experiences with RTDI policy-making are to be analyzed and exchanged (Lisbon Expert Group 2009). An important role plays a set of indicators, the Innovation Union Scoreboard, which has been developed in order to ease a systematic comparison of the EU member states' experiences – the Innovation Union Scoreboard covers the 27 EU member and 7 additional countries with 25 innovation research-related indicators as part of the EU's Strategy 2020, which has replaced the EU Lisbon Agenda in 2010 (Biegelbauer 2012).

In the 2000s, efforts have been made to integrate the two strands of research described here, one from political science and another one from evolutionary economics, in order to better understand innovation policy learning. This has taken the form of historical analyses of innovation systems and innovation policy on national (Biegelbauer 2000) and supranational (Edler 2003) levels, of comparisons of national systems of innovation (Biegelbauer and Borrás 2003), analyses of the relation between innovation theory and policy development (Mytelka and Smith 2001), critique of (naive) benchmarking exercises (Lundvall and Tomlinson 2001), and the open method of coordination in innovation policy (Lisbon Expert Group 2009).

Conclusions and Future Directions

From the research on innovation policy learning, several conclusions can be drawn for the further development of policy analysis. First of all, the concentration in the research field on rational decision-making in the sense of the maximization of personal utility should be balanced with other perspectives on decision-making processes. Policy-making is not only about a quest for power and influence, it is also about gaining knowledge, solving problems, and dealing with historically contingent norms and practices in the form of institutions, discourses, and culture (Gottweis 1998; Prainsack 2011).

Second, these different factors, for example, interests, cognition, institutions, discourses, and cultures, all play a role in the policy-making process, which is much messier, less sequential, and rational as usually depicted in the statements of politicians, accounts of journalists, but also social scientists (Hoppe 2009; Biegelbauer 2013).

Third, there is an urgent need for a fine-grained empirically driven policy analysis recognizing the messiness of decision-making processes instead of producing more schematic depictions of policy-making utilizing models of lower solution. Such a policy analysis could lead to a deeper understanding of the interplay of factors leading to policies and stay closer to accounts of policy-making one can hear from policy workers once the microphone has been turned off. Such a policy analysis could further our understanding of policy-making, and it moreover would be also useful for providing orientation and reflection knowledge for politicians and civil servants.

Cross-References

- ▶ Innovation Policies (vis-à-vis Practice and Theory)
- ▶ Innovation Systems and Entrepreneurship
- ▶ Joseph A. Schumpeter and Innovation
- ▶ National Innovation Systems (NIS)

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Innovation Potential

▶ Knowledge-Capital and Innovation

Innovation Practice

▶ Innovation Policies (vis-à-vis Practice and Theory)

Innovation Practices

▶ Innovation in Business: Six Honest Questions

Innovation Process

▶ Model for Managing Intangibility of Organizational Creativity: Management Innovation Index

Innovation Strategy

▶ Knowledge-Capital and Innovation

Innovation System of India

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Synonyms

Creativity; Jugaad; Knowledge economy; Quadruple helix model

The Concept of Innovation

Goswami and Mathew (2005) have given a detailed literature review on the definition of innovation. Myers and Marquis (1969), Zaltman et al. (1973), and Drucker (1985) looked at innovation in the point of view of technological innovation. Lundvall's (1992) definition of innovation includes non-technological innovations, including institutional innovations. Freeman (1988) emphasized on the role of social and educational innovations (pp. 339–341). Carlsson and Stankiewicz (1995) extended the definition of innovation to include the development of new organizational setups. Schumpeter's definition sums up the following forms of innovations: (1) introduction of new product or qualitative change in existing product, (2) process innovation new to an industry, (3) opening of a new market, (4) development of new sources of supply for raw material, and (5) other inputs and changes in the industrial organization. Boer and During (2001) defined innovation as the combination of creation of a new product–market–technology–organization. Carayannis and Campbell (2012) defined "quadruple helix" model, under which government, academia, industry, and civil society are seen as key actors which promote a democratic approach to innovation through strategy development and decision-making with the key stakeholders acting as catalysts resulting in socially accountable policies and practices. The authors speak of three modal approaches: the first mode is the primary educational system and basic research which create knowledge, second mode constitutes application of knowledge in practical solving of problems, and third mode is the creation of knowledge cluster or network for creation, diffusion, and application of knowledge.

India's Historical Quest for Knowledge and Innovation

Indian Upanishad (Dasgupta 2001) speaks of four forms of education: learning from the teachers, learning through self-reflection and introspection, learning through peer interaction, and learning in time context through experience. Upanishads describe five layers of knowledge: knowledge for satisfying basic needs, knowledge for developing means of existence, knowledge for psychological well-being, knowledge based on rational thinking, and knowledge of purpose.

India's quest for knowledge began in the prehistoric period, with the discovery of zero and alphabetic numerical from 200 BC to 600 AD which replaced all other forms of numeration systems. Arab traders picked up the new numeration system, which subsequently spread to Europe.

Indian discoveries in astronomical science have been popularized by Al'Beruni. The Srimad Bhagvat Gita is the treasure house of spiritual knowledge, morality, ethical way of life, and knowledge of highest pursuit of differentiation between good and evil. Kautilya's Arthashastra, which disseminated ethical codes of conduct in administration and accounting rules, arguably was the first work ever on principles of governance. India's expertise in various fields of knowledge had attracted expedition by foreign travelers like Huin Tsang, Marco Polo, and Vasco Da Gama. India had developed skills in metallurgy in ancient times, and the iron pillar near Qutub Minar stands testimony to the fact. One of the oldest universities in the world, Nalanda University, established in India sometime between the fifth to the twelfth century, catered to the needs of 10,000 students from all over the world.

The eighteenth century saw emergence of another string of famous scientists in various domains of science and mathematics like Meghnad Saha, Chandrasekhara Venkata Raman, Jagadish Chandra Bose, and Srinivasa Ramanujan. The twentieth and twenty-first centuries saw human interest in multidisciplinary studies like biotechnology, genetic engineering, neurophysics, biochemistry, and econometrics. Edward Jenner (1749–1823), known as "father of immunology" and discoverer of vaccination against small pox, had originated his work in India. Taj Mahal the seventh wonder of the modern world is a spectacular masterpiece of architecture built by the Mughal Emperor Shah Jahan to commemorate the death of his wife.

Some works on knowledge economy highlight the contribution of knowledge-intensive industries like information technology industries to national productivity (Brynjolfsson and Hitt 2000; Gordon 2000). There is no denying to the fact that India is still moving ahead to assimilate itself in the modern knowledge economy brought in by the information technology revolution of the 1990s and signing up of the Intellectual Property Rights under World Trade Organization (WTO). Information technology, in the present era, provides the basic framework for acquisition and creation of knowledge repository on various domains and application and distribution of knowledge for betterment of the society.

The focus now in India has shifted substantially toward R&D and innovation having successfully registered several applications under US Patent and Trademark. Internet and broadband connections have penetrated to most urban household, but rural areas are still lacking on IT infrastructure. India has been included in the 34 nations under World Knowledge Competitiveness Indexes (WKCI). India, along with China, is considered to form the knowledge cluster of South Asia with three of its cities, Mumbai, Bangalore, and Hyderabad, enlisted among the 145 cities which form knowledge powerhouse under WKCI report. Revolution in the ICT has brought forth new opportunities by easy accessibility of knowledge at all levels. The knowledge workers, the managers, information technology professionals, the medico-professionals, lawyers, and educationists form a substantial part of the population than even a decade ago. Bangalore boosts to have nurtured three of the global leaders in software solution like Wipro, Satyam, and Infosys.

Present Scenario in Innovation and Entrepreneurship

After the modernization of Intellectual Property Right (IPR) in 1995 with full compliance with the World Trade Organization, there has been much focus in India toward promoting research and innovation and IPR infrastructure. India is considered to be the 24th largest patent office of the world in terms of number of patent filings by WIPO 2010. According to WIPO Statistics Database, July 2009, there have been 34,285 patent filings in Indian patent office out of which there are 4,145 resident filings. In fact annual growth rate of patent filings in India in 2000–2007 has been second largest with 24.5 % next only to China which has a growth rate of 32 %. Out of total filings India granted, there are 2924 nonresident patents and 1,396 resident patents. Relative specialization index, which shows a country's share in foreign oriented patents in a specific technology as compare to country's share in all foreign oriented patents, is especially high in organic fine chemistry (1.88), pharmaceuticals (1.672), food chemistry (1.13), and medical technology (0.711). India has filled 1,635 patents through business houses, 730 through government-owned organizations, and only 6 through other research institutes in 2000–2007. No patent has been filled by universities. India's research development expenditure is a little over 1 % in the last few years. According to WIPO Statistics Database and UNESCO, July 2008, the research and development expenditure (in millions of constant US dollars, based on purchasing power parities and lagged by 2 years to derive the resident filings to R&D ratio) of India is 0.398 which makes India 22nd ranked in R&D expenses. The figures for comparable economies are Brazil (0.519), Russia (3.385), China (2.439), and Republic of Korea (5.597). The average annual salary of researchers is US$11,526, and when adjusted for purchasing power parity, it is US $56,780. Bulk of R&D spending (about 75 %) is by government. The government agencies and pharmaceuticals form the bulk of patent filings in the US Patent and Trademark Office (USPTO) like Council of Scientific and Industrial and Research (CSIR), Dr. Reddy's Laboratory, and Ranbaxy Laboratory. In 2004–2005, out of total of 229 patents granted to Indian innovators, CSIR had 140. The research innovation in CSIR and other Indian research institutes has been in areas of pharmaceuticals and food chemicals (Chakrabarti and Bhaumik 2009). Out of the top 1400 global companies with highest R&D expenditures, there are only 15 Indian-based companies. By R&D as percentage of sales, these companies are Tata Motors (10.5 %), Mahindra & Mahindra (11.7 %), Bharat Heavy Electricals (3.1 %), Corus now part Tata Steel (5 %), Novelis (Canada) now part of Hindalco Industries (1.6 %), Reliance Industries (8.7 %), Ranbaxy Laboratories (6.7 %), Dr. Reddy's Laboratories (17.6 %), Sun Pharmaceuticals (23.1 %), and Cipla India (17.9 %). The software companies included in the list are Polaris, KPIT Cummins, Infosys, Aztecsoft, and Prithvi Information. The R&D innovations in software sector have mostly been by foreign companies. Of the top 50 most innovative companies by Business Week and Boston Consulting Group Survey 2009, there are three Indian companies: Infosys, Reliance Industries, and Tata group.

The major knowledge clusters in India are National Capital Region of Delhi, Mumbai, Pune, Bangalore, and Hyderabad due to the simultaneous existence of research laboratories, MNCs with high innovative index, and quality higher education institutes.

Efforts and Achievements in Application of Knowledge in the Present Era

Global innovation is recognized in form of product innovation, process innovation, and service innovation. Indian IP laws earlier allowed only process innovation. Indian pharmaceutical companies copied and developed low-cost molecules discovered in Western countries. With change of IP laws in 2005, product innovation has been allowed. Some of the ventures in India on product and process innovation are as follows.

Nanotechnology

On realization of the significance of nanotechnology in fields of health science and defense, there has been growing impetus on R&D in nanotechnology in Indian Institute of Technology, Indian Institute of Science, National Institute of Pharmaceutical Education and Research, and National Instrumentation Organization.

Innovation System of India, Table 1 Public and private partnership in nanotechnology (Source: Bhattacharya (author) 2011)

1. Nano Functional Materials Centre, IIT Madras	Murugappa Chettiar and Orchid Pharma
2. Nano Technology Centre, Univ. of Hyderabad	Dr. Reddy's Labs
3. Centre for Interactive & Smart Textiles, IIT Delhi	ARCI, Hyderabad & Textile Industry
4. Centre for Pharmaceutical Nanotechnology, NIPER, Chandigarh	Pharma industry
5. Rubber Nanocomposites, MG University, Kottayam	Apollo Tyres
6. Nanophosphor Application Centre, University of Allahabad	Nanotech Corp., USA

Besides, there are private–public partnerships as given in following Table 1.

There has been evidence of successful use of nanotechnology in the health sector like development of Nanoxel – indigenously developed nanotechnology-based drug delivery system for cancer treatment in Indian market by Dabur India, patented technology for gene repair therapy by Virtuous Innovation, a group company of Khandelwal Laboratories, etc. Success of nanotechnology has also been seen in other fields like creation of nano-shirts under the brand name of Park Avenue by Raymonds and successful launch of nanotechnology-based water purifier by Indian Institute of Technology (Chennai).

ICT-Based Inclusive Growth

Some of the ICT-based initiatives to ensure inclusive development have been in the field of telemedicine connecting 180 rural centers to 20 superspecialty health centers and more recently a tele-healthcare project which includes teleconsultation, tele-diagnostic, and tele-treatment. The project was initiated by Apollo Group of Hospitals at 24 clusters covering 50,000 villages around Aragonda village in Andhra Pradesh. Further there has been introduction of Max Vijay scheme, an insurance product targeted for deprived section of society to be sold by NGOs, microfinance organizations connected with IBM-designed wireless handheld devices, which enable data transfer through general packet radio service (GPRS) to the back end system and facilitate on-the-spot issuance of insurance policies.

In the education sector, EDUSAT is a satellite connectivity system which is used for teacher training and higher education programs in remote villages by Indira Gandhi National Open University. National Council of Education Research and Training (NCERT) also holds satellite-based interactive educational programs for teachers all over the country.

EducompTM MagiKeys solution is a unique software application that allows millions of government school students to surf the web, email, chat, and write documents in their mother tongue. It supports 11 Indian languages, namely, Hindi, Marathi, Gujarati, Kannada, Tamil, Malayalam, Punjabi, Urdu, Telugu, Bengali, and Konkani. Reliance Communications is collaborating with One Laptop per Child Foundation to provide network facility for providing every child with a low-cost, handy, rugged laptop to have a collaborative, joyful learning experience in 25,000 towns and 6,00,000 villages of India.

MCA21 is a Ministry of Corporate Affairs and Tata Consultancy effort for e-business transaction using direct identification number (DIN) and digital signature. State of Gujarat which has won the national award for best e-governed state has the largest optical fiber wire area network of 50,000 km in Asia. All activities of governances like procurement of business, taxation, and public grievance management are carried out mandatorily through the Internet.

EnAble India, an organization started by two soft engineers, works toward increasing employability of handicapped people by ICT-based training by using software like SAFA, a low-cost screen reader software based on windows, which transforms text on-screen into synthetic speech aimed for visually challenged people and also by creating digital audio books and other educational tools in collaboration with other NGOs. It also acts as a link with organizations which can provide employment opportunity for these people, by helping these organizations to create a barrier-free workplace.

Lifeline, a project initiated by One World Foundation in collaboration with CISCO and British Telecom, aims at providing its clients, the farmers, with requisite information on their queries using telephony and Internet in their mother tongue. Queries made through landlines or mobiles are passed through interactive voice response to a knowledge worker who tries to solve the problem with the help of database of 30,000 frequently asked question (FAQ) with answers or else refers it to an expert.

For providing white-collared employment to various unemployed youths, a project SMSOne was started by Pune-based entrepreneur under which an unemployed youth builds an SMS community of about 1,000 cell phone users in his area and provides them with news and updates through an SMS newsletter. The service is free of cost for the user and revenue is generated through advertising. Only one message per week is permitted. The news can be government messages, news and advertisements of shops of the locality, birthday alerts, and election propaganda of local leaders and politicians. CGNet-and ICT-based forum of journalists created by Shubhranshu Choudhary of Chhattisgarh that aims at ensuring public participation in development is a web-based discussion forum of ordinary people of local community which feeds in news related to tribal life, culture, farming, Dalit issues, the Naxal movement, education, gender issues, health, mining, employment, etc.

Some Innovative Business Models

Indian Premier League

In 2008, vice-president of Board of Control for Cricket in India (BCCI) Lalit Modi partnered with IMG executive Andrew Widblood to initiate Indian Premier League, a T-20 version of cricket, in which each match is to be of around 3 h with each competing to face 20 overs each. Teams were auctioned to leading business tycoons and Bollywood celebrities which ensured pumping in of huge money. The IPL was expected to generate revenue of nearly $2 billion in the period 2008–2019, including proceeds from TV rights ($918 million), promotion ($108 million), and franchises ($724 million). Players are being offered $1.55 million for an IPL season of about 5 weeks as against $50,000 to $ 1 million which they can earn playing their national team in a year, depending how engaging schedule their respective national teams have.

VNL

VNL, a start-up company, awarded as Telecom Asia's best green infrastructure of the year in 2010 (http://www.telecomasia.net/content/ta-reader-choice-awards-2010-winner-list), is the first solar power-driven WorldGSM mobile service meant for rural areas with *low levels of average revenue per user (APRU)*. It has also been named as "Technology Pioneer 2010" by the World Economic Forum. It had to face the challenges of low power services, availability of less number of skilled engineers for installation and maintenance of the GSM system, and poor infrastructure.

The model developed requires less than 50 W power per base station and hence does not require power grid, nearly zero maintenance and entire base station can be packed into two carts and can be installed by even unskilled labor.

Narayana Hrudayalaya

According to the World Health Organization report, number of doctors per 1,000 population in India is less than one, and there is a requirement of 6,000 doctors, 1 million nurses, and 0.2 million dentists. Only 0.5 % of Indians have health insurance and out of pocket spending is about 85 %. About 2.4 million Indians require cardiac surgery per year and only about 60,000 operations are actually carried out. Narayana Hrudayalaya at Bangalore was established by Dr. Devi Shetty with the vision of providing highest quality healthcare services to patients with heart problem at lowest cost. It planned to achieve high volumes of OHS and catheterization operations per day which brought down the unit cost of surgery. Also high-cost machines are rented instead of purchasing to bring down the cost further. Suppliers are hired under short-term contract and low-cost dual medicines like cardio-diabetic medicines of Biocon are used for bringing down cost of medication. It has initiated India's largest telemedicine network and also has provision of mobile cardiac care. Dr. Shetty is also credited to have started the most successful microinsurance project in India called Yashwashini targeted for farmers of Karnataka. For INR 5 (US$0.11) a month, cardholders can have access to free treatment at 150 hospitals in 29 districts of the state for any medical procedure costing up to Rs. 100,000. It is now working to extend its clinical expertise to cancer with the launch of Biocon, a 1,400-bed facility providing treatment for head-and-neck, breast, and cervical cancers.

Apollo Hospitals which recently won the G20 Challenge on Inclusive Business Innovation has reached to masses in remote villages and semi-urban areas through their Apollo reach program.

Medical Tourism

Medical tourism in India as found by Brotman (2010) is outbound, inbound, and intrabound. Hospitals catering to both inbound and intrabound medical tours have shown significant profits with India's growing economy. Tourists from the USA prefer to go to developing nations for medical tours as many forms of surgery such as cosmetic surgery, dental reconstruction, and gender reassignments are not insured in the USA. Similarly, in Britain and some other European countries where healthcare is controlled by government healthcare system, long queuing for requisite operations may lead citizens to foreign lands (Horowitz and Rosenweig 2010). People also come here from different countries for certain specialized surgical operations like bone marrow transplant, joint replacement, and stem cell treatment for cancer which otherwise are not performed in their countries. Also, medical treatment cost in India is considerably lower. A heart valve replacement surgery would cost (Sinha 2008) patients $10,000 in Thailand, $12,500 in Singapore, $200,000 in the USA, and $90,000 in Britain and only $8,000 in India. While a bone marrow transplant would cost $30,000 in India, doctors in the USA would charge anywhere between $250,000 and $400,000 while those in the UK would charge $150,000. A cosmetic surgery would cost $3,500 in Thailand, $20,000 in the USA, and $10,000 in Britain and will cost only $2,000 in India.

According to the American Medical Association data, a spinal fusion would cost $62,000 in the USA, $5,500 in India, $7,000 in Thailand, and $9,000 in Singapore. Medical tourism in India is growing at the rate of 30 % annually. It is expected to reach $ 2 billion by 2012. Escorts, Apollo Group of Hospitals, Hinduja, and Jaslok are some of the major players in medical tourism. Indian medical treatments include alternative treatments like Ayurveda, Yoga, Unani, Siddha, and Homeopathy treatments (AYUSH). Medical tourism should be supported by insurance policy, travel support, online information on types of treatment availability, hospitality, and clean and hygienic condition in hospitals.

Teach for India Foundation

This is a nongovernment organization which trains young volunteers who are students of reputed educational institutes or professionals who are trained to educate underprivileged children through experiential learning. This initiative involves multiple credible stakeholders – Indian and United Nations' NGOs, corporates, educational institutions, and individuals – who will finally create an ecosystem of shared thought and knowledge.

Jugaad Innovation Complementing Systemic Innovation

Jugaad is an Indian method of playing around the legal system to create an innovative, sustainable economic product by mixing and matching local material (Radjou et al. 2012). For example, there is this product called MittiCool developed by Prajapati which is a refrigerator made out of clay.

Jugaad vehicles cost around INR 85,000 (less than US$2,000). They are powered by diesel engines which were originally intended to power irrigation pumps. They are known for having poor brakes and cannot go faster than about 60 km/h (37 mph). The vehicle is used to carry more than 20 people at a time in remote locations and poor road conditions. Today, jugaad is one of the most cost-effective transportation solutions for rural Indians. SELCO, which provides energy and power in underdeveloped villages in Karnataka, is perhaps a best example of jugaad technology. Another individual jugaad model was that adapted by medical practitioner Dr. Mohan. He experimented with a number of different ways to frugally yet effectively engage rural communities both as consumers (patients) and employees. He found that it was very difficult to motivate the team of highly competent technicians from his city hospital to continue work for a long time in remote villages. A training curriculum of three months duration was developed in the city hospital in Chennai to impart to youths of the villages basic skills of providing healthcare needs. These newly trained healthcare professionals would return to their rural homes, where they were more likely to want to remain. This in turn helped reduce costs and turnover. A cost-effective telemedicine platform was created with the help of Indian Space Research Organisation, which provided a roaming telemedicine van with a free satellite uplink to his clinic.

The dynamic director of SAP India is encouraging bottom-up approach for innovation through participative leadership. Employees are free to experiment with bold ideas during work hours which will improve their quality of life.

Shrishti, an autonomous organization under the government of India, promotes innovation at grassroots by awarding and supporting the best innovators and innovative ideas and creates a culture of participatory development. They are being supported by the Council of Scientific and Industrial Research, Indian Council of Medical Research, and Botanical Survey of India to add value to innovative ideas and traditional knowledge by converting them into useful products in areas of engineering, human health, agriculture, veterinary, and nutraceutical. Honeybee Foundation set up by Professor Anil Gupta maintains database of 10,000 grassroots innovations and helps to promote and commercialize them. Jugaad Innovation has already been adapted Indian firms such as Future Group, Suzlon Tatamotors, Yes Bank besides Indian subsidies like GE, Siemens, Philips, and PepsiCo.

Impediments to Innovation

1. *Lack of Innovation Culture*

As Welzel–Inglehart cultural map puts India along with other developing nation at a position of higher survival values and low in self-actualization value. Hofstede (1991) scores also indicate that India has a low to moderate uncertainty avoidance, high power distance, low masculinity, and low individualism. Although it is only indicative, yet it reveals that Indians are probably risk-averse, hesitant to make important decisions in work-related matters, and probably lack attitude to take initiative. Mashalkar (2010) in his speech says that there are several ideas by Indians which have been converted into successful patented product by Japanese after research papers written by Indians related to same were published. The recently discovered “God particle” or “Higgs–Boson” particle are based on the works of Prof. Satyendra Nath Bose. Way back in 1924, Bose realized that the statistical method used to analyze the existent theories on the thermal behavior of gases was inadequate. He first sent off a paper on quantum statistics to a British journal, which turned it down. He then sent it to Albert Einstein, who immediately grasped its immense importance and published it in a German journal. Bose’s innovation came to be known as the Bose–Einstein statistics and became a basis of quantum mechanics, which led to the discovery of this subatomic particle. Two of the most recent Nobel laureates from India in recent times, Amartya Sen for economics and Ramakrishnan Venkatraman in chemistry, are more known for their work abroad.

Educational system has long been encouraging “rotting” rather than experimental learning in form of problem-solving, design, experimentation, etc., in the education curriculum. Evaluation in education should encourage subjective responses rather objective answers. Competency-based customized career plan and curriculum are required to be designed for each child.

2. *Lack of Innovation Ecology*

According to a National Knowledge Commission survey, the most important barriers to innovation, as perceived by both large firms and SMEs, are skill shortages due to the lack of emphasis on industrial innovation, effective collaboration for research between universities and R&D institutions, excessive government regulation, as well as insufficient pricing power to derive value from innovations. Further, it has been found, out of the graduates passing out of professional institutes (Mckinsey 2005), only 25 % of engineers, 15 % of finance and accountancy professionals, and 10 % of graduates with Indian degrees are employable by multinational companies. Fifty-four percent of the universities under University Grants Commission (UGC) are giving education in general discipline (Table 2).

Further, the number of researchers in India has increased by only 20 % from 1991 to 2001 as compared to China where the comparative increase was about 80 % (Knowledge Commission Report). To develop quality researchers, India should promote university–industry link in running of PhD programs; for example, Reliance Life Sciences has developed a model under which they facilitate employees getting admission for PhD degree from Mumbai University. BITS Pilani similarly has Ph.D. program for working executives (http://www.knowledgecommission.gov.in/downloads/documents/moreQualityPhD.pdf). A report on 1473 NAAC accredited colleges between 2002 and 2004 shows that there are overall only 25.6 % Ph.D. teachers. Indian universities need to have good academicians with Ph.D. degree. According to Furqan Qamar and S. Sinha (2007), there are 57 % of teachers in higher education who are without M.Phil. and Ph.D. degree. With various universities not being able to fill up the posts under various reservation categories, universities are recruiting ad hoc and guest faculty.

To emphasize individual and industrial innovation, National Knowledge Commission (NKC) suggested to allow licensing and royalty arrangement in which the inventors as well as research institute would have share. To promote research several government programs have been initiated like the New Millennium India Technology Leadership (NMITL), Techno-Entrepreneurs Promotion Program (TePP), and Technology Development Board (TDB). To provide for need of talent pool, 8 Indian Institute of Technology (IIT) and 3 Indian Institute of Science Education and Research (IISER) are being opened. NMITL has so far evolve 57 largely networked projects in diverse areas, namely, agriculture and plant biotechnology, general biotechnology, bioinformatics, drugs and pharmaceuticals, chemicals, materials, information and communication technology, and energy involving 80 industry partners and 270 research groups.

Innovation System of India, Table 2 Distribution of central and state universities into types of discipline (Source: UGC Annual Report, 2004–2005)

Type	Number	%
General	126	54
Agricultural	35	15
Technological	14	6
Language	11	5
Medical	9	4
Law	6	2.6
Woman	5	1
Animal and fishery	4	1.7
Open	11	5
Others	16	5.7
Total	237	100

3. *Lack of Venture Capital*

There is general lack of venture capital for start-ups who want to experiment with new ideas. The investment by venture capitalist has been in the late stage as can be seen from the Table 3 below.

To facilitate commercialization at early stage innovation, several incubation centers are being opened in all over the country like the ICICI Knowledge Park in Hyderabad; International Crops Research Institute for

Innovation System of India, Table 3 Venture capitalist investment at various stages of innovation (Source: Bhattacharya (author) 2011)

Stage of the company	Number of deals, 2006	Number of deals, first half 2007
Early stage	59	24
Growth stage	42	25
Late stage	104	67
PIPE	61	34
Buyout	11	6
Others	22	6

Semi-Arid Tropics (ICRISAT); Centre for Innovation, Incubation, and Entrepreneurship (CIIE) at Indian Institute of Management, Ahmadabad; National Institute of Technology at Calicut (NITC); and Society for Innovation and Entrepreneurship (SINE) at IIT Mumbai and at Vellore Institute of Technology (VIT). Some of the government initiatives taken are writing off research and capital expenditure in companies having in-house R&D centers, 10 years tax holiday to R&D companies approved by Department of Scientific Industrial Research (DSIR), no import duty charged on import for equipments by public R&D institute, and 125 % tax deduction on donation to research institutes carrying out social and statistical research.

4. *Corruption in the System*

Most studies validate the fact that either democracy or autocracy does not considerably able to combat corruptions. Corruption can only be prevented by greater accountability. In his keynote address at the Indian Independence Day Celebration of 2005 conducted by a nongovernment organization Nandini – Voice for the Deprived at Chennai, Mr. N. Vittal (2005), former Central Vigilance commissioner, said, "there are five basic reasons for corruption in India. (1) scarcity of goods and services; (2) red tape and complicated rules and procedures; (3) lack of transparency in decision-making; (4) legal cushions of safety for the corrupt under the "healthy" principle that everyone is innocent till proved guilty; and (5) tribalism among the corrupt who protect each other." The report of the Civil Services Examination Review Committee (October 2001), which was set up by the UPSC made the following observations:

> It is very crucial to understand what happens to the values and integrity, motivation and other qualities assessed at the time of recruitment after 10 years and 20 years of service. It is said that initially many of the officers have positive values, but they change during the course of service. When they appear before the UPSC interview boards, most of the candidates are idealistic, bright, committed and sincere. However, once they join the service, within a period of time they seem to become cynical, negative and possibly even corrupt. Even the most outstanding officers feel frustrated after their idealism has been dimmed by the systemic realities. Some of them succumb to pressures easily. Therefore, a deeper insight into the systemic mechanism is required to ascertain the causes affecting this change and take remedial action.

Corruption in the society has resulted in failure of several social development initiatives, like public distribution system and mid-day meal scheme. In a survey undertaken by Transparency International and Delhi-based Centre for Media Studies, it was found that value of corruption under PDS is as whooping as Rs. 375 crore per year. Kumar (2003) in his extensive study of corruption in India has indicated that implementation of the Prevention of Corruption Act (1988) has been a failure in India. He was of the view that the right to uncorrupted service should be made a fundamental right and right for jurisdiction against violation of this right should also be a fundamental right. Corruption can be thought of violation of human right as it has been established that only 17 % of the fund allocated by the government for poverty reduction actually reaches to the needy (Roy 2003) which is a great impediment to innovation for inclusive development. Citizens should be made aware of their rights and knowledgeable about government provisions which are meant for their development. The Mazdoor Kisan Shakti Sangathan, an NGO, had initiated awareness campaign and holding government accountable for any corruption or mismanagement of developmental fund in many parts of the country.

"India Against Corruption," a mass nonviolent movement started by veteran freedom fighter Anna Hazare to force the parliament to pass the "Lok Pal" Bill, which will put legislatures and administrators under its ambit for any acts of corruption, has been a huge success in the last few months.

Conclusion and Future Directions

India has an advantage of fast-growing GDP and large pool of English-speaking widely respected engineers and doctors. A combination of scientific temperament, quest for truth, and questioning mind which is the basis of Upanishad is required for India to innovate. Novelty will be developed if there is an infrastructure and ecology-supporting youths who think differently and seek a platform for their experiment with truth. A strong sense of ethics has to be inculcated from childhood to combat corruption which kills youthful zest for service and change catalyst. India must capitalize on its strengths in case of alternate medicine and supercomputers if it intends to be a global leader in knowledge economy. As defined in the "quadruple helix" model by Carayannis and Campbell (2012), there is need of a society which has a scientific and inquisitive spirit, government which stimulates entrepreneurial venture and industrial activism, and academia which envisages interdisciplinary research.

Cross-References

- ▶ Business Creativity
- ▶ Business Start-Up: From Emergence to Development
- ▶ Creativity, Intelligence, and Culture
- ▶ National Culture
- ▶ Triple Helix of University-Industry-Government Relations

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Innovation Systems

► Innovation in Forestry: New Values and Challenges for Traditional Sector

Innovation Systems and Entrepreneurship

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Synonyms

Enterprises; Entrepreneur; Innovation; Innovation networks; Innovative milieu; Proximity relations

Technological innovation is the surest way to restore, transform, and expand markets. The expansion of businesses and the globalization of markets have revealed the importance of local pockets of productive resources. The geographical proximity between science, technology, industry, and finance contributes to the emergence of innovations. Interactions are organized by the combined effect of private and public institutions. Currently, economists consider the "local economy" as a pertinent geographical and economic level of organization of production, and therefore, of new activities emergence, new goods and services, new jobs, new revenues... Over the past 40 years, the approach of innovation based on proximity – and especially the concept of innovative milieu (see for example, Aydalot, 1986) – has shown its always more and better relevance as a model of decentralized economic growth but also of enrichment of businesses' technological competencies, including international ones. These economists do not refer to a purely linear model of innovation (which would correspond to the idea that the increase in inputs – here the R&D – would meet the increase in outputs – innovations here) while identifying the need to increase spending on R&D to strengthen the knowledge base. They are more in an interactive vision, which emphasizes the importance of networks of public and private actors, at the territorial level, recognized as relevant to the development of the innovation policy (Tidd et al. 2005).

Indeed, in a changing and highly unpredictable environment, the enterprise, whether large or small, is at the center of public policies and of economists' concerns and sociologists' interests. Its main function – innovation – is regarded as the main source of job creation, wealth, and prosperity. But on two conditions: (a) the structures must be flexible enough so that the company can adapt itself to market fluctuations and (b) the constant renewal of its productive resources can only be achieved if the financial and industrial framework of the country or the region is sufficiently strong and diversified so that the company may combine networks of producers and consumers in the constitution of its supply and in creating a demand for its products. Once these two conditions are met, the creation of innovative small businesses and the strengthening of the innovative potential of large firms can be linked together. As a matter of fact, to strengthen the innovation potential of large firms and to facilitate the emergence of new businesses, specialists put forward the importance of innovation systems.

An innovation system describes the relationships between institutions (scientific, technological, industrial, commercial, financial, political), being public or private (companies, research laboratories and engineering, administration…). These relationships mostly consist of informational and financial flows and people movements. The purpose of such a system is to produce innovations (new organizations, new goods and processes, new resources, new combinations of productive resources). The systems are national (or local) with a focus in this case on the regulation framework. They can also be "private": In that case, the analysis focuses on the "network" which can be defined as a set of businesses legally and/or financially linked to one or several larger ones. The network is a system that is intended to make one (or more) production (s) integrated in a same value chain, and under the direction and coordination of parent companies.

An analysis from the innovative milieu gives the possibility to study the environment of businesses and understand their innovation dynamics. The systemic nature of relationships that characterize a social and economic environment explains what promotes or not innovation. But should we reduce innovation, product of the environment, only to interindividual exchanges leading to a new productive combination? Does it only result from a specific organization of economic relations? Our thesis is that the systemic environment does not only refer to economic interactions but also takes into account the social structures that are the source of innovative behavior. However, institutions (government, local authorities) take a significant role in the organization and evolution of socioeconomic structures. And in turn the innovative environment contributes to the performance of innovative companies by providing scientific and technical resources.

Proximity and Innovative Milieu as the Engines of Innovation

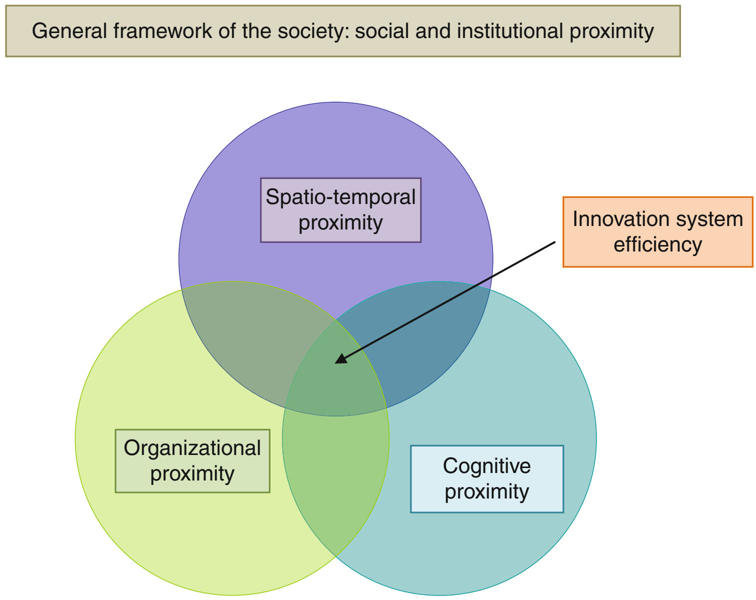
Proximity and Innovation

The notion of proximity is largely used today, both in industrial economics and economics of innovation. But the ambiguity of the term, as the variety and scope of its applications, implies a careful use of it. Proximity is linked to the existence of externalities that produce spatial agglomeration effects and territorial dynamics. **This is spatial and temporal proximity**. Other meanings were added to this first definition of physical or geographical proximity (Boschma 2005; Uzunidis 2008; Nooteboom 2009).

Another kind of proximity is **organizational proximity**. It refers to the coordination of activities within the organization and between organizations, whether this coordination is organized by the market (contracts) or by the hierarchy (ownership). The similar or different coordination arrangements within organizations (in the case of big corporations) or between the organizations may facilitate or not the creation of networks.

The specific activities involved in the production of new knowledge and in the associated interactions led economists to introduce, in addition to spatial and temporal proximity and organizational proximity, the concept of **cognitive proximity**. This refers to more or less formalized sharing of experiences, representations, codes, languages, and models resulting from and at the same time facilitating the communication of information within or between organizations. By nature, cognitive proximity has a special place in research activities, but it is also present through all kinds of communication flows within or outside the firm. In the case of interactions related to industrial research, cognitive proximity not only affects the internal interactions within research centers but also the external interactions with other centers of business services, as well as interactions with the environment (other laboratories and partners in research and innovation).

Other forms of proximity are identified and notably the **social and institutional forms of proximity**. They refer to the relationships



Innovation Systems and Entrepreneurship, Scheme 1 Forms of proximity and innovation system efficiency (Source: Authors)

that can be created at the microlevel (social proximity) and at the macrolevel (institutional proximity). They are the results of habits and routines built by the social and institutional history. As such, they can contribute to the good functioning or hinder the functioning of networks.

It seems relevant to suggest a three-dimensional approach to proximity, before presenting the importance of proximity in generating new businesses and launching innovations (Scheme 1). The following graph presents the ways the types of proximity interact. The more they are linked together, the more efficiently the innovation system may operate, that is to say generate new innovations and new businesses. The social and institutional forms of proximity are related to the functioning of the whole society and are not specific to an innovation system. This is the reason why there are presented outside the three dimensions of proximity.

The Local Economy as an Innovative Milieu

The local economy (or local productive system) can be defined as a geographic area formed as a set of systemic relationships between businesses and between businesses, state and local governments. These systemic relationships characterize the local area by a certain type of activities and final products. Economists observe and study this economy as a knot of productive relationships, which may contribute to the territorial organization (which has however remained national). They attribute qualifiers showing the dynamics of the combinatorial and complementary relationships between businesses of different sizes at the local level: "local production system" and "innovative environment."

The territorial efficiency of this mode of organization lies in what we call today the savings on transaction costs. The concentration on a single geographic location of the main players of the same production system (mainly the producers on the one hand and the users on the other) not only facilitates transactions but also the interrelationships of knowledge and trust between the partners. The formation and accumulation of skills will then form an "industrial atmosphere" conducive to condition the local labor market (Marshall 1919). This phenomenon, the industrial atmosphere, is connected to both the competence and experience of workers and also to the location of firms in the same area. In the sense of the Marshallian industrial district, the milieu gathers a population with proven expertise, a group of actors making up the various links of the same production system, and finally a know-how that defines the accumulated expertise. The main feature is the territorial organization of production, rather on a principle of collaboration and cooperation between different production units rather than on a hierarchical principle. Thus, the notion of solidarity among economic actors is very important. The local production system is mainly characterized by the proximity of productive units (individual businesses, services, research centers, and training...). These units maintain these relations of varying intensity that can take very different forms: formal or informal links, commercial or noncommercial alliances... These relate mainly to the flow of materials, services, labor, technology, and knowledge.

Basically, this is the GREMI (European Research Group on Innovative Environments: team of researchers from the Institute of Economic and Social Research at the University of Neuchatel, Switzerland) which, in 1985, developed the assumption that it is the regional communities that generate different forms of innovation (innovation-product-process innovations, organizational innovations, social innovations, innovations in training/qualification, etc.) (see Maillat and Perrin 1992). The explanation for the emergence of a "successful" region comes from the fact that it is primarily the latter that has managed its own capacity to develop new products, new technologies, and new organizations. This assumption, founder of the regional science, questions the traditional economic theories which on the contrary advocate a progress and a growth which main factors and engines mainly find their justification and their origin from the "outside" (so-called models of "development from the top").

Our central theoretical hypothesis to analyze the concept of innovative milieu, that is to say, the socioeconomic territory forged by history ("path dependence") is that it is the product of interactions of firms, institutions, and labor. These interactions are necessarily the result of reciprocal synergies (networks, linkages, partnerships, etc.) between the various local (public or private) agents of the economic and industrial development. We can take as an example the forms of cooperation between companies and research laboratories. Ultimately, it is primarily the socioeconomic, industrial, and scientific milieu that participates to the creation of new activities (including through entrepreneurship and spin-offs) and to the genesis of innovations. And it will "naturally" be done if certain conditions are met. Among them are the existence of, locally, a group of actors (companies, research centers and training, government, skills...); the existence of material, human, financial, technological, and informational resources geographically agglomerated; the existence of specific know-how giving the possibility of a quality of production; the existence of relational capital conducive to the formation of local, national, or international networks; and finally the existence of norms, rules, and values that determine the behavior of economic actors.

The concept of innovative milieu also highlights a strong principle in systems of innovation: it reinforces the idea that the innovative capacity of companies is closely linked to social, economic, and political issues surrounding them. The "innovative environment" most often designates the ability of a local economy to generate innovation through the emergence of new businesses and the location of more ancient firms in its geographical area, where the industrial exploitation of research organizes the creation of small innovative companies. The local economy takes the shape of a territorialized system of the exploitation/valuation of all kinds of capital and of market exchanges. Benefiting from a certain (legal and economic) autonomy of organization of productive resources, its primary characteristic is the formation and development of specific resources and the achievement of particular combinations of these specific resources. These are composed of capital and labor with specific forms and contents in relation to activities and specific sectors – specific in terms of technology, financial or demographic characteristics but also in terms of skills, qualifications, level of education, etc. The local economy becomes, then, an "innovative milieu," reducing the risks associated with the uncertainty of a given investment and initiator of the innovation process, including through business creation and the attractiveness of existing technology companies.

Enterprises' Strategies and Innovative Milieu

Understanding the Company

To understand and to study a company, the economist looks at the internal organization of production entities and their environment (market, competition, government...). His systemic vision leads him to consider the company as a living entity whose birth, growth, survival, and death are conditioned by a set of conflicting relations between the entity and its environment and between its internal organs. The economist goes so far as to say that a company as such has no meaning; what matters is its relationships with other companies, with the markets, or with institutions. This representation of the company highlights the role of trade, financial, or technology relations, generated by the company or to which it is subjected. Thus, we can then appreciate the role of a local innovation system or "innovative environment."

The company is commonly defined as an economic unit, a set of combined factors of production, whose activity results in the production of goods and in the provision of services sold in a market. Its objective is the achievement of sustainable profits, essentially higher than those of competitors and sufficient to finance its investments and growth. The expansion of its size is, for the enterprise, another condition that must preserve the attacks of competitors and of fluctuations in demand. The reality of the business is complex: the company is a legally independent center of decision that implements a strategy, sets goals, and creates the means to achieve it. The company is also a social organization that brings together people with different skills linked by hierarchical relations of power and responsibility. The economic independence of the company is relative. First, because the constraints imposed by its legal and commercial environment limit its room for maneuver. Its need to make a profit, a guarantee of good health, leads the company to get in conflict or cooperation with other companies, to change its status over the increase of its capital, to protect, diversify, and expand its markets. On the other hand, ownership of capital can sometimes belong, in whole or in part, to another company: subsidiaries and other companies subject to complex financial linkages and integration are dependent on decisions of the group to which they belong.

Decision and power are the hallmarks of business operations. The decision system of the company regulates its activities. It is constructed by the play of power and control between the company owners and is used to define the decision-making authority of its manager and staff. Generally, a decision is made at three levels of power: operational (production tasks in the company), management (organizational tasks and monitoring procedures), and strategic (task programming, planning, strategy). The charts that are set up according to this method reflect the administrative structure of the company. The chart of a company presents its hierarchies, its functions, and activities taking account of the place of decision, the information structure, the factors of consistency, and the center of dynamic operation. The functions provided by the organization are linked by (a) the order flow circulating from top to bottom between the three levels of authority which express some technical and decision-making rationality; (b) information, technical, economic, and financial flows between services, departments, and subsidiaries; and (c) financial flows generated by the activities of budgeting services, departments, and subsidiaries, but also through the implementation of contracts between the subsidiaries and the parent company and other independent companies.

The company is forced to increase its size (volume and value) in order to survive. It must indeed try to control its future in order to meet (in the best possible condition of profit-making and controlling as much as possible, financial and business risks) the expectations of its shareholders. To do this, it must reduce the market uncertainty by providing all necessary means to capture, sort, process, and use the largest quantity of economic, technological, financial, commercial, and political information. When the environment is quickly changing, the capital turnover and the pace of innovation evolve faster as well... the risk of failure in the process of "creative destruction" increases. The information then becomes the ultimate competitive weapon. Its mastery leads to the construction of barriers to entry. Not only does competition become imperfect, but it also becomes a power game (combining competition and temporary pacts of alliances and cooperation) between global industrial and financial groups. The place left to small entrepreneurs is then marginal and unstable.

Innovation and Investment Strategy

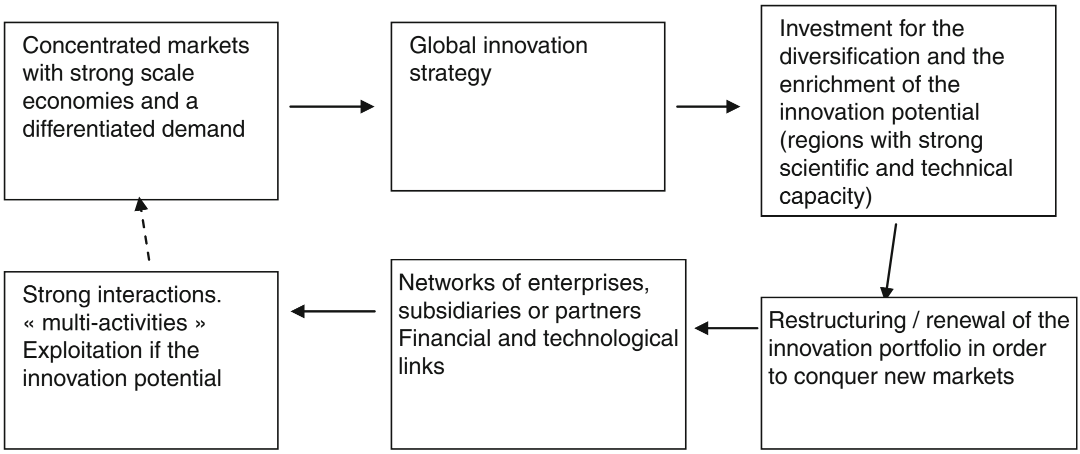
In this context, the choice of investing (whether to locate a company in a new place or to create a new business) is determined by the relative factors of centralization and decentralization. Centralization reflects the necessity to achieve economies of scale, to fertilize between projects, to communicate tacit information, to be in close contact with the functional departments of production and marketing, to control technology assets... Decentralization is explained by the need to access scarce skills, to benefit from externalities in an enabling environment, to be in close contact with customers and suppliers...

The nature of activities (technological level and degree of specialization) conditions quite well the level of compromise between, on the one hand, the search for externalities (agglomeration effects) and, on the other hand, the constraints of scale, of indivisibility, which conversely implies to concentrate locally the innovation resources.

Indeed, the enlargement, integration, and permanent renewal of markets, as determined by the combined evolution of profit and financial income, increase the business risks (how many products are withdrawn from the market before the investment made for their production is recovered and even before they are known by consumers?) and the financial risks (how many companies have faltered – see notably the examples of internet start-ups in the USA and Europe – for reasons of speculation and debt before they attack their market due to lack of customers?). The company has therefore to invest large amounts of capital to create an important information system, to protect itself from these risks, to constantly innovate, and to reassure its shareholders, its creditors, and its clients from all over the world.

The process of "permanent innovation" is the main feature of the global firm. This one is defined as a company whose organization is integrated by multiple information and financial flows and whose structures are largely decentralized: network firm with multiple affiliates and multiple partnerships with co- and subcontracting companies; company with a financial large amplitude in services and industry with high scientific and technical potential and benefiting from important external effects (clusters). It has a strong ability to innovate and to continuously adjust its structure and organization. It benefits from comparative and specific advantages of the different locations. It integrates into a "value chain" (R&D, logistics, innovation and financial engineering, manufacturing, assembling, marketing, and other services) all the activities it carries out all over the world.

The decentralized management options that the firm has added to the structural and short-term advantages offered by states and local governments determine the location of innovation activities of the global enterprise. This one in turn contributes to modify the development of chosen the territory. The globalization of firms' strategy (and notably of the innovative strategy) is explained by the concentrated structure of markets, characterized at the global by strong scale economies and a differentiated demand (for high, medium, and low income). To meet the consumers' demand, firms have to invest in the continuous expansion of their innovation potential (also called knowledge capital). To locate their innovative activities, they thus choose areas (territories) with a strong scientific and technical potential. These investments aim to renew their innovation



Innovation Systems and Entrepreneurship, Scheme 2 Location strategy of the global firm (Source: Authors)

portfolio to conquer new markets. Due to the costs and risks of the innovation process, big corporations develop networks gathering different enterprises, subsidiaries, and partners characterized by financial and technological links. Strong interactions emerge from these strategies. Firms develop multiple activities that aim to exploit their innovation potential (or knowledge capital). In turn, this contributes to the concentration of markets and leads to the deepening of inequalities between wealthy and poor regions (in terms of scientific, technological, and financial resources) (Scheme 2).

For global companies, the management of R&D and production aims to articulate the global strategic orientation with decentralized R&D – looking for a dynamic scientific environment and willingness to "stick" to the most dynamic markets. Then, "globalization" is not opposed to the strengthening of local interactions but tends to increase them.

Its local roots allow the company to benefit from a pool of resources (and sometimes a market) to amortize the costs associated with its investments in a constantly changing economy. But these local roots depend on the quality of the reservoir compared to the expectations of the company for its innovation and business development strategy. This explains the need for governments and local authorities to organize the development of resources. They have to facilitate the emergence of multiple innovation processes taking into account the competition-cooperation between the actors in an open economy. This is a system of supply of productive resources capable of generating a technological entrepreneurship and to attract large companies with assertive performance in innovation.

Policies of Emergence and Promotion of Innovative Enterprises

The Industrial Policy and the Formation of a Pool of Resources

Since the late 1980s, the financial, business, and production strategies of global firms have replaced the administered planning of territories, along with planning policy that has become deprecated. As a matter of fact, the opening of economies to competition (deregulation and contestability of markets in order to prevent the monopolistic practices) led to a strong overlapping of national economies to the point that the reasons (and objectives) of large international firms become reasons of state. Industrial policies are now focused on services and intangible and have an essentially territorial dimension. Cluster policy, implemented globally, reflects this orientation.

The role of the state in the formation and organization of a scientific and technological pool of resources for innovation and investment is essential and accurate. Public intervention has already exceeded the traditional areas of implementation and funding of a science and technology policy at the heart of which we find the public institutions of education and research. The conduct of the state in this area is increasingly comparable with the major industrial and financial groups, and the strong ties of interdependence between these organizations justify the transfer of resources from public to private. This means the formulation by the state of an innovation policy, in other words, the promotion of all means for scientific research, development, application, and technology choices to facilitate the creation and diffusion of new products and new processes. The intervention of the state and of local decision-makers in building and managing an "innovation system" can take various forms: granting activities that generate resources that can be individually or collectively appropriated by companies, creating mechanisms enabling enterprises to recoup their investments in research and development (e.g., patents that do not hinder the diffusion of innovation), and implementing procedures for cooperation between public and private entities aiming to ensure the financial feasibility of a private investment likely to have economic impact on a large scale.

The formation of a pool of productive resources that can be appropriated at any time by firms is now regarded by economists as the fundamental aspect of state intervention in the economy and in the organization of space. We may follow the reasoning of L. Branscomb and J. Keller (1998): noting that the creation and dissemination of knowledge increase the performance of a national or local economy (and of the companies that compose it), they put forward the idea that traditional science and technology policy (emphasis on finance and implementation of major research and development programs, primarily in the areas of defense, energy, space, and medicine) has been replaced by the policy of research and innovation. To be successful in terms of competitiveness, this policy must aim as much to the achievement of all public or publicly funded research programs as to the distribution of their results to "users" (businesses). The state should ensure the effectiveness of the procedures of research commercialization, by the regulations (protection of industrial property rights, antitrust laws, etc.), taxation, budget, etc., in order to create propagation effects. Economists conceptualize the formation of a "stock" (reservoir) of resources that are shared in these multiform, multifunctional, and multistakeholder cooperation processes.

The Promotion of Investments: Creation and Attractiveness of Enterprises

Local economies, in the "network economy," are now trying to grow by relying on private initiative, combined with a public and territorial focused policy. The attractiveness of investments, the ability to create business, and job creation define the performance of a local economy. All three indicators are related in time and space. But territorial institutions put forward a number of arguments to attract direct investment and create enterprises and jobs in the short term. There are two types of policies for growth and investment promotion: the short-term policy and structural policy.

The short-term policy refers to budgetary and fiscal measures with the aim of having rapid effects: create businesses to create jobs and attract production units to create jobs. As the expected results in terms of investment must be done very quickly, the government targets (a) companies with mobile production units (Fordist or heavy, for which the total costs of production are the factors that determine the choice of investment) and (b) potential entrepreneurs with low added value with an existing core business immediately exploitable. The main measures of this policy are:

– Financial incentives: direct allocation of funds to the investor (big company and entrepreneur) by the state or local government (investment grants, subsidies, subsidies for new jobs, subsidized loans)
– Fiscal incentives: reducing the overall tax burden of the investor (temporary tax reduction, exemptions from import duties of raw materials, intermediate goods, capital goods)

- Indirect incentives: to provide the investor with land, buildings, telecommunications facilities (see enterprise zones), privileged access to public procurement, flexible, part-time, fixed-term jobs, etc.

The structural policy refers to the industrial and innovation policy measures with the aim to establish or maintain a strong technological and economic specialization: enrichment of the scientific and technical potential in order (a) to facilitate the creation of innovative companies and (b) to attract large companies' centers of research and units of production specialized in high technology. The results are cumulative and visible in the long run. Governments develop instruments of commercial and technological watch to guide decisions in the constitution, the restructuring, and the enhancement of networks of innovation (investment and marketing).

The main measures of a structural policy of investment are:

- Public investment in creating the conditions for an endogenous growth in the long term: transport and communication infrastructures; facilities for education, research, and engineering performance; local financial system oriented toward innovation; complete health system; quality of life through cultural activities, organization of space, and leisure, etc.
- Implementation and funding of a research and innovation policy (instead of a purely industrial policy) whose objectives are: (a) the federation around a specific program of business skills, public institutions, and private research associations and institutions and (b) the networking of actors in research, industry, commerce, and forecasting for the implementation of value-added investment in a backbone area (and its niches) defined by the regulatory authorities.
- Creation of a center for the delivery of services and of financial means to businesses attracted by the project and to entrepreneurs specialized in the same field and in related activities (information engineering, development and socioeconomic studies), for example, the establishment of an observatory of the local economy with real organizational advisory power.

Innovation Systems and Innovation Networks

Business Creation in Local Innovation Systems

In a local innovation system, a particular emphasis is put on the creation of small innovative companies. In the current economic uncertainty and following the trends of decentralization, the creation of new businesses is as a matter of fact supposed to solve many problems related to the rigidities created by institutional intervention. Their flexible structures enable them to respond more readily to consumer expectations, and their failures do not threaten the financial and industrial structure of a country, region, or locality. The creation of small businesses is seen as a preferred means of industrial policy and planning. While large companies, made of various activities of production, finance, and marketing, are trying to organize markets and change technologies, through alliances, mergers, pacts, and political interference, the hope of economic revival is concentrated in small business. The small business fits perfectly with the needs of the economy. It is a formidable machine for the use and destruction of capital; it also presents itself as a sort of vector of values, to the extent that it establishes bridges facilitating the transport of productive resources (financial capital, technology, workforce different qualifications and skills) toward the activities, markets, and big businesses able to make a profit.

The entrepreneur is a figure, a concept, and a function difficult to define by the existing theoretical tools. Personal qualities and personality of the entrepreneur certainly play an important role in the decision to establish a small business. But undertaking, as a function and an act, is defined by the macrosystemic dynamics of accumulation and profit. This dynamics creates barriers and opportunities for personal enrichment which make an individual an entrepreneur and subsequently either succeed or fail. The fact is that "one is not born an entrepreneur, one becomes one": one becomes one through the mobilization of a potential of resources composed of capital, knowledge, and relationships (Boutillier and Uzunidis 2006). Capital is required for investment and operation; knowledge is needed for the choice and the decision; relations are important for the funding, the gathering, and the diffusion of the production.

The creation of a new business is thus the result of the emergence of a flaw in the economic structure made by (a) the differential of profit due to market imperfections and barriers to the mobility of productive resources and goods, (b) the institutional apparatus supporting and enhancing the entrepreneur function, and (c) the mobilization of the required expertise and capital. The current entrepreneur and his small business are therefore essential to (a) the coherence of large enterprises' entrepreneurial space, (b) the reactivation of local microsocial milieus, and (c) the alleviation of the burden of unemployment, inactivity, and precariousness. The creation of a business is a social act that is part of a social network or "social capital," which develops in a given social and economic environment. The network of social relations of any actor consists of a part of proximity social networks (usually consisting of parents and family), and other larger social networks (usually composed of neighbors, friends, professionals).

Entrepreneurs and Innovation Networks

We could say that currently small businesses are "created" by the combined action of governments and large industrial and financial corporations: to be competitive in international markets, a big business transforms its internal functions into independent units and often resort to small companies having a specific expertise. On the other hand, this process of outsourcing and the simplified organization of groups is facilitated by the legal and fiscal policies: the laws on tax relief for holding companies and on the extraterritoriality of financial subsidiaries give the possibilities to big companies to manage with more flexibility their partnership, subcontracting and licensing contracts. The financial control that this burst of production structures requires encourages the creation of small businesses that flourish in the "niches" of markets and in specific technology.

In the industrial history, a large enterprise concentrated its means of production, defined and compartmentalized production tasks, and built directly controllable collective of workers. It now becomes (it has now become) a center of organization and of decentralized management of its productive resources. The way production is now organized tends to mean that the market power of a business (and the coordination of functions and activities that it can impose) is a greater factor of economic power (and of centralization of ownership of assets) than the power that can give it its own (scientific, technical, industrial, and financial) assets. The market power of the company results from its financial capability (ownership of financial assets and ability to raise funds) and from its information potential. Information and finance are used to build and manage the group of small entities geographically dispersed and physically distant (investments in interindustry relations of cooperation, in the protection of technological assets, in the ownership of scientific knowledge, and in the design of new goods, in the coordination, by electronic means, of the various activities, etc.). The managerial coordination strengthens the role of the manager in industrial organization and subjects the entrepreneur to the decisions of the managerial power.

Small innovative firms are introduced into the networks formed by large groups and often coordinated in relation to the territory (Boutillier et al. 2008; Boutilier and Uzunidis 2010). This is the case of science parks where large firms having large technology and business advantages create themselves small innovative businesses (kinds of research laboratories) managed by entrepreneurs and researchers. In other cases, it is the managers of big businesses that are requested by the parent to create a company to experiment new technologies (intrapreneurship). It is not uncommon to see the emergence of a "speculative entrepreneurship" in favor of big businesses. These are highly skilled individuals who, assisted by soft loans and government subsidies, create a company to sell it to a larger one after the product or production process is developed. Connecting small businesses with large corporations is achieved through a financial and intelligence strategy. The venture capital (equity investment firms in the capital of a company that has just been created), business angels (wealthy individuals who invest in innovative projects), and other investors (pension funds are very active) commit capital in innovative new businesses (e.g., in information technology and biotechnology). In sum, complex innovation networks are built, characterized by diverse financial, technological, and informational links between different type of actors, which are all dependent from the ones to the others and which have strong (even if flexible) local roots.

Conclusion and Future Directions

Both the local and entrepreneurial aspects of innovation reveal the mechanics of formation and appropriation of all ingredients of productive activity. The issue of appropriability has become crucial for the operation (the location or creation) of a company. The company tends more to tap into its environment than to invest in the formation of its own resources, notably in all the phases of technology creation. This can be explained by the fact that investments in the acquisition (appropriation) of production resources are less expensive than those dedicated to the formation of these resources. This also explains the attractiveness (open economy) of an area benefiting from abundant scientific and technical resources. The creation of innovative or more traditional enterprises depends on the richness of the "milieu." If the factors related to education, environment, healthcare, finance, infrastructure, housing, etc., impact the marginal cost of a business or activity, they also impact the return on investment. Therefore, the idea of the "network" and of the "innovative milieu" appeared to establish itself in the observation and economic analysis.

The achievement of innovation networks follows four ways: reducing the spatial, organizational, and cognitive distance between firms of different sizes and between companies and institutions; the institutional support for the creation of a pool of resources into which businesses can tap; the creation of new scientific, technical, and commercial opportunities; and the support of the entrepreneurial process. These are the areas of industrial and innovation policy in most countries. The current focus is mainly placed on linking actors and less on investments in the constitution of the stock of scientific and technical resources from which the actors can act. However, the entrepreneurial dynamics of industrial countries will largely depend on this dimension in the coming years.

Cross-References

▶ Business Climate and Entrepreneurialism
▶ Entrepreneurial Opportunities
▶ Knowledge Capital and Small Businesses
▶ Proximity
▶ Risk
▶ Risk, Uncertainty, and Business Creation

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Innovation Systems and Individual Initiative

▶ Innovative Milieu as a Driving Force of Innovative Entrepreneurship

Innovation Theory

▶ Innovation Policies (vis-à-vis Practice and Theory)

Innovation Through Language

▶ Linguistic Dimension of Creativity, Invention, Innovation, and Entrepreneurship

Innovation Training

▶ Creative Thinking Training

Innovation Versus Critical Thinking

▶ Divergent Versus Convergent Thinking

Innovation Waves

▶ Nonlinear Innovations

Innovations

▶ Financing Entrepreneurship

Innovations in Geometry

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Synonyms

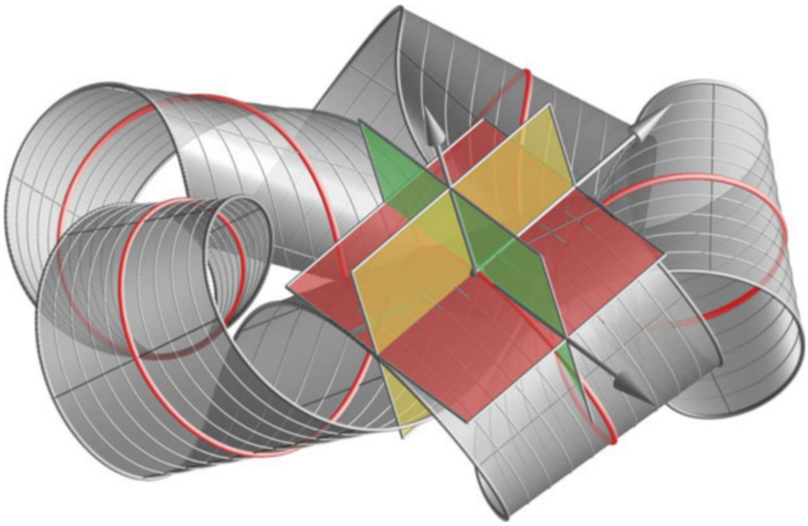
Architectural geometry; Geometrical design

Introduction

Geometry is one of the oldest sciences of mankind, dating back 5,000 years and more. Today it is considered a branch of mathematics and deals with questions of shape, size, relative position of figures, and the properties of space. The geometry of the ancient Greeks (Euclid, Archimedes and many others) served as a base for scientific developments in the two millennia that followed. From about 1800 until the computer age, Descriptive Geometry, introduced by Gaspard Monge, was the tool for developing many industrial products – especially for architecture. The rules and results of Descriptive Geometry also contributed to knowledge of design processes.

The introduction of digital production technologies in the automobile and aircraft industries required new geometric research for the design and development of 3D modeling software.

The last two decades once again brought remarkable innovations in the development of even more sophisticated software that – based on geometric and mathematical considerations – allows solving different kinds of problems that were more or less unsolvable so far.



Innovations in Geometry, Fig. 1 The accompanying "rectifying developable" of a *space curve* (Glaeser 2012)

Geometric Innovations in Modern Architecture and Industrial Design

Modern architecture and industrial design profit from the enormous increase of design possibilities. Creative architects and designers do not simply exploit the best CAD software, but rather want to engineer and design at the same time. This requires close cooperation between geometers, architects, designers and civil engineers.

Example 1: Approximation of Large Scaled Doubly Curved Surfaces

One of the problems that seemed impossible to overcome until very recently was to find surfaces that approximate doubly curved surfaces piecewise by single curved surface parts in a manner acceptable for the artistic designer. This requirement is so important because building costs of doubly curved surfaces tend to be very high. Figure 1 illustrates an important theorem of classic differential geometry: For any space curve, one can find a single curved surface (a "developable") such that the curve is a geodesic line that becomes a straight line when the developable is flattened into the plane.

The challenge is to choose space curves on a doubly curved designed freeform surface, such that the corresponding accompanying developables approximate the target surface as well as possible. When the chosen curves are geodesics on the surfaces, their rectifying developable will touch the target surface along the whole line. Neighboring rectifying developables intersect each other and form strips or "ribbons" like in Fig. 2 (Pottmann et al. 2008).

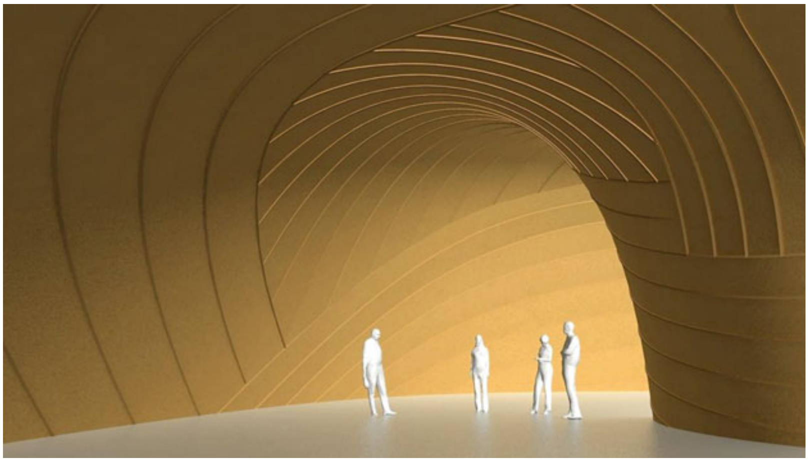
Figure 3 illustrates another way of finding developable strips by searching for series of planar quadrangles on the surface. Figure 4 shows an example of that kind of approximation.

Example 2: Curved Folding

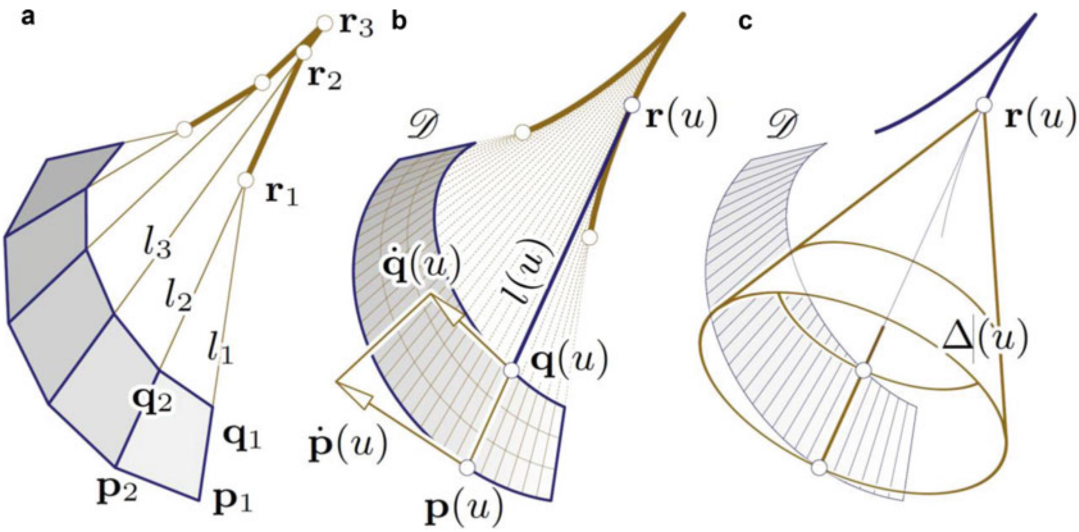
A problem that is also related to developable surfaces is a demand posed by industrial design: How could one fold interesting and practically useful shapes by means of scoring curves into a flat piece of material? Figure 5, e.g., shows what happens when only one curve – in this case a catenary – is considered (Kilian et al. 2008). Figure 6 shows two practically usable examples from industrial design and architecture. In both applications, construction costs are reduced considerably.

Geometry in Robotics

In robotics, geometric insights have lead to remarkable innovations (Lenarcic and Husty 2012). The kinematics of a manipulator or the



Innovations in Geometry, Fig. 2 "Rectifying developables" of geodesic lines on the target surface allow a rather smooth approximation by means of developable "ribbons" (Pottmann et al. 2008)

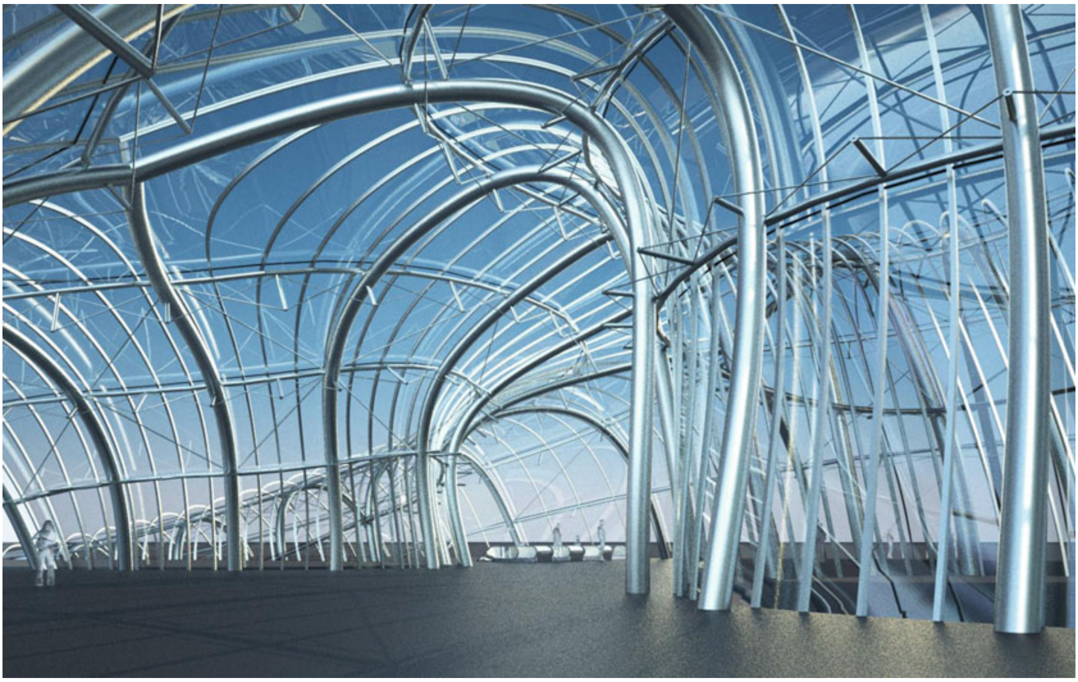


Innovations in Geometry, Fig. 3 Quadrangles on a discrete developable (Pottmann et al. 2008)

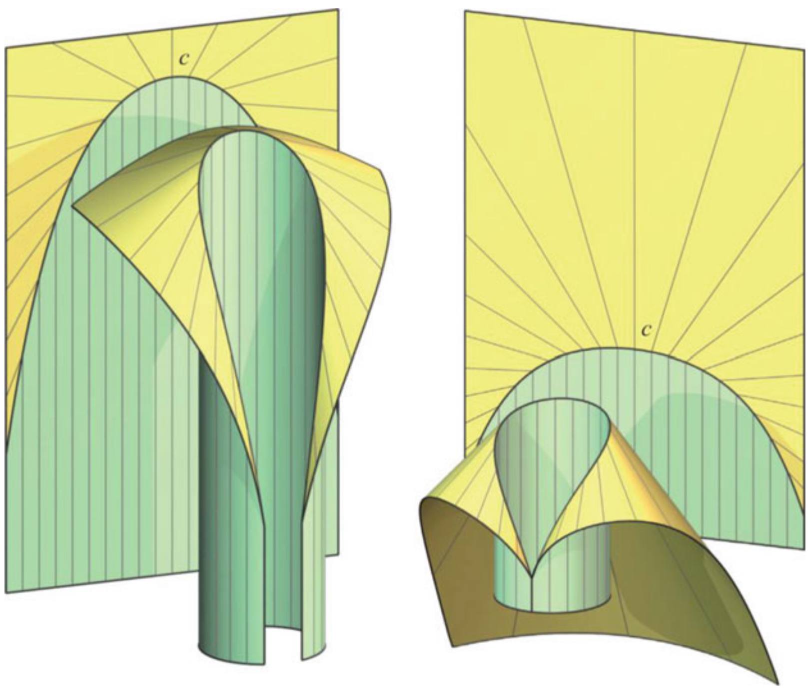
possibilities of moving the manipulator are meanwhile described by systems of algebraic equations. Thus, one can describe the working space of the manipulator by algebraic varieties which potentially split up into kinematically interesting components. In practice, one is mainly interested in mechanical restrictions or geometric limitations. The latter are called singularities and are – especially with parallel manipulators – described by fascinating algebraic objects (Schadlbauer et al. 2011). Figure 7 shows the singularities of a so-called 3-RPS manipulator which is a platform that is moved by the "legs" (consisting of the three different joints: rotational, prismatic and spherical) driven by linear motors that vary the lengths of each leg.

Flexible Magnetic Nets and Iterating Algorithms

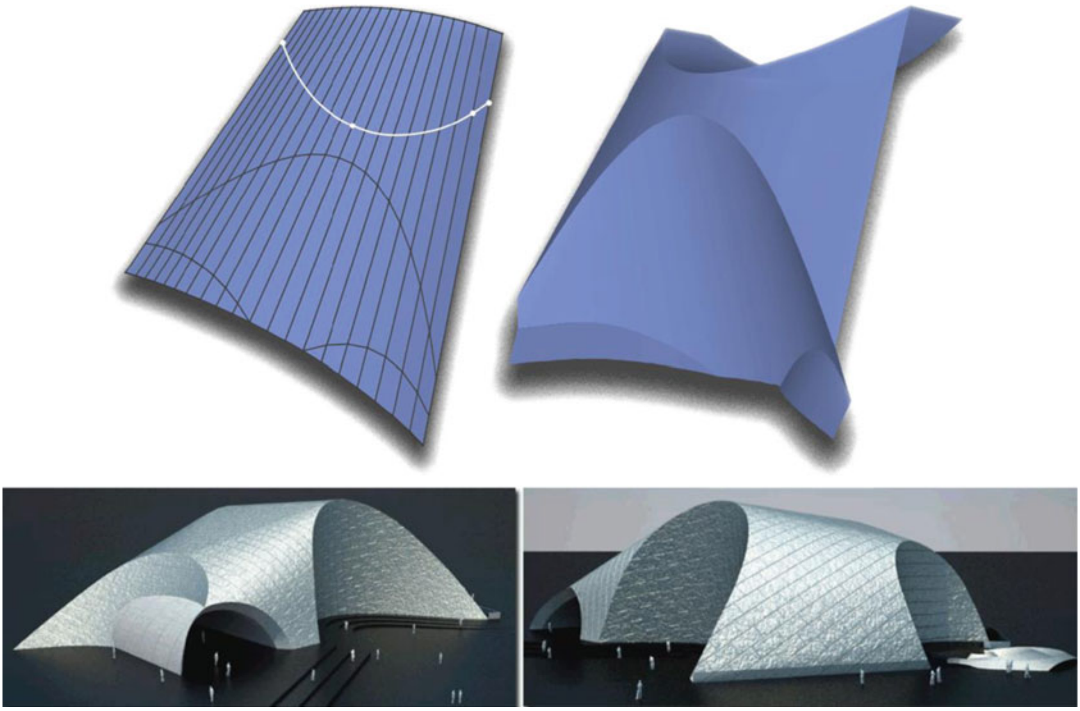
Many geometric problems do not have exact solutions, but algorithms may lead to good approximations and practically useful



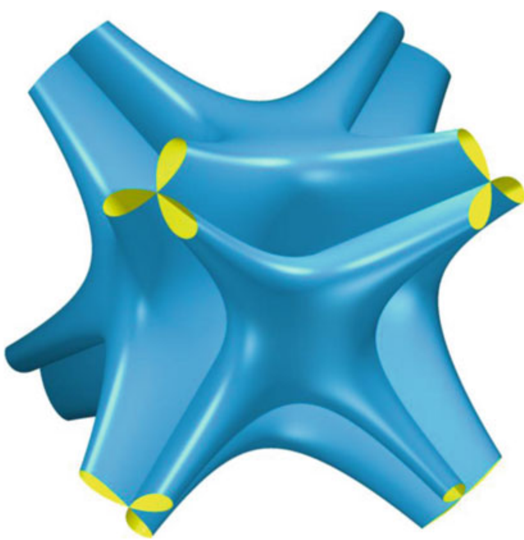
Innovations in Geometry, Fig. 4 Freeform surface entirely approximated by developable *strips* (Pottmann et al. 2008)



Innovations in Geometry, Fig. 5 “Collar surfaces” out of one piece (Glaeser and Polthier 2012)



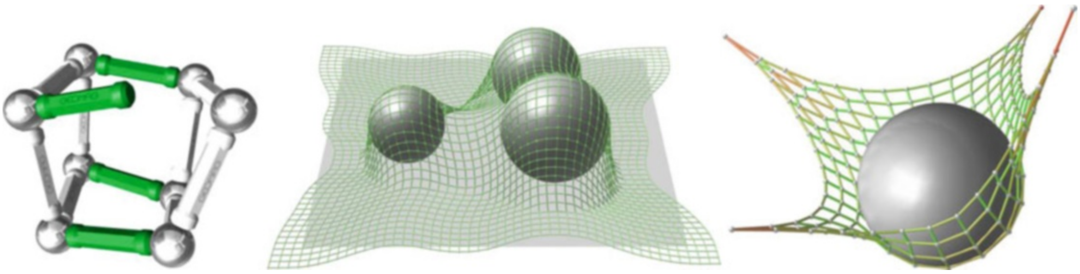
Innovations in Geometry, Fig. 6 Practical applications in design and architecture (Kilian and Flöry 2008)



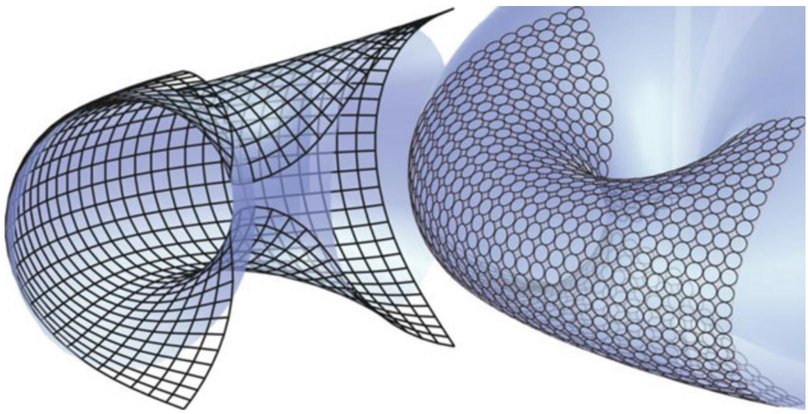
Innovations in Geometry, Fig. 7 Algebraic surface as the locus of all manipulator-singularities (Schadlbauer et al. 2011)

alternatives. A typical example is over 100 years old: The Thompson problem asks for the locus of a given number of points that are equally distributed on a sphere. Exact solutions only exist for a few special numbers (e.g., 20 points would lie on a regular dodecahedron). There are “best solutions” for all numbers, however, which can be found by various algorithms. One of these algorithms is based on magnetic repulsion: Points are considered to be magnetic and are allowed to “swim” on the surface. They push each other until a state of equilibrium is reached.

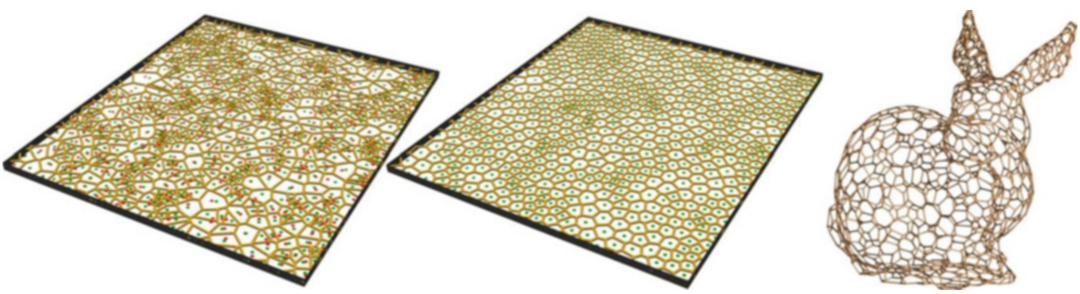
This algorithm can be extended and applied to various problems. Figure 8 illustrates the introduction of small magnetic spheres, from which four attached magnetic rods of equal length protrude. Such a flexible magnetic net can be fitted onto desired forms. In Fig. 8, the net was cast over three spheres. By means of stretching or compression of the rods – by as small an amount



Innovations in Geometry, Fig. 8 Simulation of magnetic repulsion



Innovations in Geometry, Fig. 9 Near orthogonal grid generation on surfaces (Gruber et al. 2010)

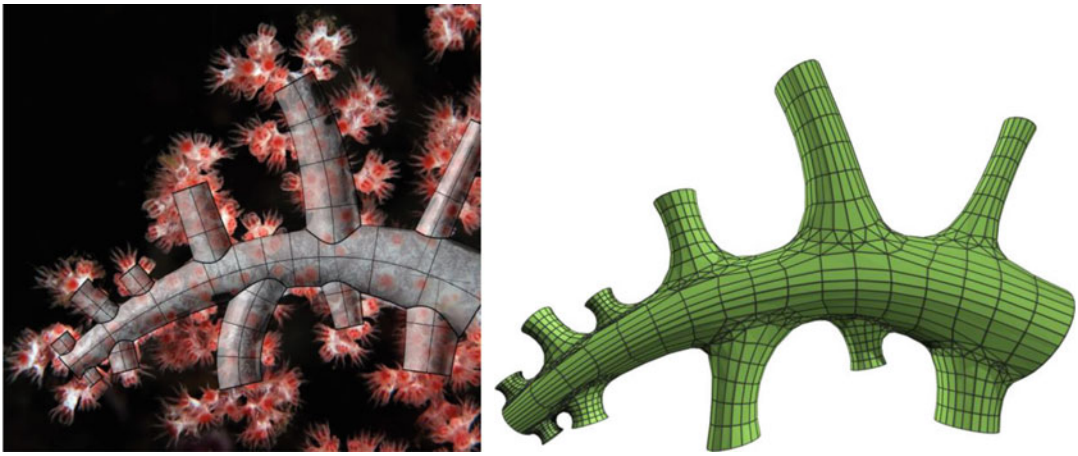


Innovations in Geometry, Fig. 10 Iterated Voronoi diagrams

as possible – the algorithm gets more practically useful for the solution of various problems, e.g., for force directed near-orthogonal grid generation on surfaces (Fig. 9). Such algorithms are iterative, i.e., small changes are made in various parameters, and the best result is taken as an input for the next step.

Comparable approaches can be applied in other situations. Figure 10, e.g., shows the generation of Voronoi-diagrams (in the plane or on surfaces) that can be improved iteratively (the area-barycenters of convex cells are the inputs for the next iteration).

Iteration of magnetic nets fitted onto geometric objects – with respect to area minimization – can also be the key for the generation of shapes that frequently appear in nature (Fig. 11).



Innovations in Geometry, Fig. 11 Iteratively minimizing the surface area of composed geometrical objects leads to organic forms

Conclusion and Future Directions

The computer is the main new tool of Geometry. It allows to realize otherwise hard to solve theoretical challenges. The underlying problems may be 100 years old (or even older), and large quantities of these problems have thus far remained unsolved.

Architectural Geometry has to provide construction-aware design tools that enable a completely digital work flow from design to manufacturing, especially for highly complex geometries, including animated geometry. This requires interaction of mathematicians, engineers and architects.

Cross-References

- ▶ Applied Design Thinking Lab and Creative Empowering of Interdisciplinary Teams
- ▶ Creativity from Design and Innovation Perspectives
- ▶ Innovation by Applied Mathematics

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Innovations of and in Organizations

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Synonyms

Innovative firm; Open innovation

Introduction

At a first glance "innovations" and "organizations" seem to be somehow contradictory phenomena.

Organizations are designed for ongoing operations. Their reason of existence is to coordinate actions and actors effectively and to strive for productivity and efficiency to make operations as profitable as possible. They have to serve their customers better than and more efficient than their competitors do. Their performance is measured by being on time and on budget and by producing products and services with a constant quality. Hence, they are always striving for specialization, repeatability, and predictability, and they are inclined to work smoothly and perfectly even.

Innovation is the ability to define and develop new products and services and to deliver them to the market. Looking at the nature of the innovation process from an organizational point of view, we have to point out first that innovation involves strong elements that cannot be planned. If "innovation concerns the search for, and the discovery, experimentation, development, imitation, and adoption of new products, new production processes and new organizational set-ups" (Dosi 1988, 222), then the dimensions of complexity, uncertainty, cumulativeness, interactivity, acting collectively, and learning play a major role in the innovation process. As a consequence the process of innovation is in clear contrast to processes of a rigidly planned implementation of well-defined action plans.

Despite this contrast it is quite obvious that organizations need innovation. Organizations that operate strictly within the bounds of their established norms and routines fail to develop. The better something works, the less excited, interested, and emotionally engaged people are. Organizations that operate strictly within the bounds of their established norms and routines get in danger to die. As a consequence the dual search for stability and exploitation on the one hand and change and innovation on the other hand poses a crucial challenge for organizations operating in the recent complex and dynamic business environment.

And as well innovation – defined as new products or services delivered to the market – usually is dependent on organizations. This is in contrast to mere inventions, which can be developed by single individuals or a group of people. The process of innovation is based on various activities of organizational creation. Different actors have to be coordinated and coupled with a wide range of activities across specialized functions, knowledge domains, and contexts of application. In the recent dynamic and complex "society of organizations" (Peter Drucker), society's problem-solving and innovation capacity rather is determined by the effectiveness and efficiency of its organizations then by individuals or groups. The processes of organizing and innovating may be seen as incompatible and mutually exclusive, but they are as well fundamentally interdependent and mutually enabling.

Against this background the following questions of (a) different perspectives to examine the relationship between organization and innovation and (b) organizational factors that influence innovation performance are focused on in this entry.

Innovation and Organizational Structure

Since the late 1950s classical organizational theory like Weber's bureaucracy or Taylor's scientific management have been challenged by the new approach of contingency theories. Classical organizational theorists like Weber, Taylor, or Chandler had based their work on the idea of universal organizational forms and the endeavor to find the "one best way to organize." In contrast contingency theories claimed that there is no best way to design organizational structures or to run a company. Rather variations in management styles and organizational structures are influenced and shaped by various aspects of the environment: the contingency factors of technology, suppliers and distributors, policy regulation, etc. Within this new theoretical context, Burns and Stalker (1961) investigated on the relationship between structure and innovation.

Mechanistic and Organic Organizational Structures

Burns and Stalker (1961) found that organizations operating in more stable environments tend to develop a more mechanistic organizational structure, while companies facing a more dynamic and uncertain environment tend to show a more organic organizational structure. Their main argument is that neither of the two types is right or wrong.

Mechanistic structures and rather rigid and hierarchical organizational patterns can be a functional and efficient structure for organizations operating in a more stable and certain environment where there is no need for quick decision-making or innovation.

On the other hand organic structures provide organizations with a more fluid set of arrangements to quickly adapt to conditions of rapid change and innovation. There, rapid communication and information sharing is necessary. Hence, departments and different functional areas need to be tightly integrated.

Building on these ideas Lawrence and Lorsch (1967) carried out a series of empirical studies in the chemistry industry. They recognized that organizations usually are not composed of one uniform structure, either mechanistic or organic. Instead mechanistic and organic structures can coexist in different subunits interacting with different demands of functional sub-environments.

Lam (2010) is pointing out that the arguments of these earlier authors developed under the theoretical umbrella of structural contingency theory had a considerable impact on both organizational theory and the provision of useful guidelines for innovation management. And they are still useful for understanding recent development in innovation and organizational change. Faced by the challenges of innovation pressures and an accelerated pace of change, we recently can better than ever observe how companies struggle to leave mechanistic patterns behind and to follow a more organic path of development. As well, the contemporary debate on hybrid organizations and ambidexterity is reflecting the most important argument of Lawrence and Lorsch. Mechanistic and organic structures can coexist within one organization and therefore strengthening the capability to deal with both revolutionary and evolutionary changes in the various technological and market environments.

Adhocracy as Organizational Archetype with High Potential for Radical Innovation

As a specialist in management theory, Henry Mintzberg (1979) aimed to prescribe effective organizational designs. Drawing on contingency theory and synthesizing much of the work on organizational structure, he argues that successful organizations develop a logical and consistent configuration of design parameters to cope with the specific challenges of their environment. As a result he concludes that organizations are likely to be dominated by one of the five pure archetypes identified he identified: simple structure, machine bureaucracy, professional bureaucracy, divisionalized form, and adhocracy. These archetypes exhibit profound differences with regard to their innovativeness (Lam 2010, 167 ff.).

Machine bureaucracy, divisionalized form, and professional bureaucracy are characterized by relatively low levels of innovativeness. The simple structure has higher innovation potential. Simple structures are characterized as being small and informal. They rely on direct control by one person, often the founding entrepreneur, who is free to searching for high-risk environments.

Adhocracy with the highest innovation potential is as well highly informal and flexible organization capable for radical innovation in a volatile environment. Distinctive traits are a highly organic structure, little formalization of behavior, low standardization of procedures, and a work organization based on specialized teams. Here it is not one single entrepreneur who searches for innovation but highly flexible and problem-solving project teams that can be quickly reconfigured in response to changes in the markets and technologies. The organizational boundaries of adhocracies are rather permeable and allowing for new ideas and knowledge from outside to come in. Adhocracies are characterized by an extensive absence of hierarchical structures. Within their areas of specialization and in coordination with coworkers, members usually have the authority for decision-making and to take actions affecting the future of the organization.

Innovation, Knowledge Creation, and Learning

In the organizational structure perspective innovation is perceived as an output of certain structural features and components of an organization. Organizations tend to shape their organizational design in line with the demands and challenges raised by the technological, competitive, and political environments they are operating in. If competitive, dynamic, and volatile environments demand for organic structures (Burns and Stalker; Lawrence and Lorsch), then innovation is an output of the structural features successful organizations are building within this context.

Another line of organizational theory is regarding innovation as process of problem-solving, knowledge building, and learning. These authors point out that innovation in the economy on the one hand and learning and knowledge building in organizations on the other hand are two sides of the same coin, since the increased speed of change confronts agents and organizations with new problems and to tackle the new problems requires new skills (Lundvall and Borras 1999). As a consequence, innovative firms select more learning-oriented employees and the market selects more change-oriented firms. Hence, the current market economy is characterized by a process of "circular cumulative causation" between innovation and learning.

These arguments reflect the fundamental shifts in the way knowledge is produced, organized, and utilized in the knowledge economy. The high rate of change and the new pressures of market competition force companies to obtain additional abilities, that is, to configure information resources in novel ways which cannot be easily imitated and replaced by competitors. Since ICTs make a vast amount of data and information available and easily accessible, the problem of information-based competitive advantages is to continually innovate and to stay one step ahead of other companies. Hence, in terms of innovation, the knowledge at the top end still seems to be insufficiently designed and hard to transfer in a routine manner that "provides the 'competitive edge' for firms which are trying to stay ahead of the pack" (Ducatel 1998, 11).

Tacit Knowledge and Organizational Knowledge Creation

Drawing on a concept of Polanyi (1958), this top end knowledge is referred to as "tacit knowledge," in contrast to "codified knowledge" or mere information. "Tacit knowledge is personal, context specific and therefore hard to formalize and communicate" (Nonaka and Takeuchi 1995, 160 f.). It refers to the observation: "We know more than we can tell" (Polanyi 1958).

Tacit knowledge has two dimensions, the "cognitive" and the "technical" elements (Nonaka and Takeuchi 1995, 60). The cognitive elements focus on "mental models" (schemata, paradigms, perspectives, beliefs, viewpoints), in which human beings create working models of the world by making and manipulating analogies in their minds. These cognitive elements, which help individuals to perceive and define their world, refer "to an individual's images of reality and visions for the future, that is, "what is" and "what ought to be." The technical elements include know-how, crafts, and skills. Both dimensions of tacit knowledge suggest that tacit knowledge defines how to use codified knowledge or even clearer: Tacit knowledge is a precondition to make use of codified knowledge.

Being "tacit" means that this knowledge is not migratory, as it is highly embedded in complex social interactions and relationships within organizations. Since tacit knowledge resides in the skills, shared experiences, and behavior of groups and individuals, it cannot be easily acquired or bought at the market place. Thus, it is different from codified knowledge, which can be obtained (through reading books, attending lectures, and accessing databases), transferred as information, and even sold in the market. Codified knowledge is accessible. Tacit knowledge, on the other hand, is rooted in practical experience and social contact. Since tacit knowledge is socially constructed knowledge, it can only be appropriated in a social context by interactivity and social interaction. It will typically have to be learned (Lundvall 1996).

The acceleration of creation processes and the use of codified knowledge via ICTs are intrinsically related to the increasing importance of tacit knowledge, which enables us to make use of information, in general, or to effectively acquire, select, and use the data and information created within a company or elsewhere. Hence, "codified and tacit knowledge are complementary and co-exist in time" (Lundvall and Borrás 1999, 33), and tacit knowledge seems to be necessary to define how to use explicit knowledge.

Having this in mind, Nonaka and Takeuchi (1995, 70 ff.) argue that only "when tacit and explicit knowledge interact (. . .) an innovation emerges." Their dynamic model of "knowledge conversion" "is anchored to a critical assumption that human knowledge is created and expanded through social interaction between tacit knowledge and explicit knowledge" (Nonaka and Takeuchi 1995, 61). According to this line of reasoning, the sources of innovation multiply "when organizations are able to establish bridges to transfer tacit into explicit knowledge, explicit into tacit knowledge, tacit into tacit, and explicit into explicit" (Castells 1996, 159).

The Knowledge-Creating Company

These collective and interactive knowledge processes imply that instrumental behavior will become mixed with "communicative rationality" where the common goal of the involved partners is to understand better what the problems are and what solutions can be developed. In this respect, interactivity, shared experiences, and learning stimulate the development and appropriation of shared beliefs and common interpretations of the social context.

Enhanced communication between (reduced) hierarchies, between departments, is intended to facilitate the "knowledge and competence puzzle" as a precondition for innovation. These strategies of social interaction are complemented by lifelong learning and HRD strategies for the whole workforce, since according to the principles of a "learning organization" (Senge 1990) "inventing knowledge is not a specialized activity.. (. . .).. it is a way of behaving in which everyone is a knowledge worker" (Nonaka and Takeuchi 1995). Guided by this line of argumentation, Nonaka and others (Nonaka 1991; Nonaka and Takeuchi 1995; Nonaka and Konno 1998) have developed the framework of a "knowledge-creating company," defining the firm as a collection of shared spaces for emerging relationships that provide a platform for advancing individual and/or collective knowledge and for generating collaborative processes that enable the transformation of this knowledge to other contexts (see the concept of "ba" developed by Nonaka (Nonaka and Konno 1998). These spaces exist in several different dimensions (Nonaka and Konno 1998):

- Physical: department within a firm, sphere of commercial influence, cooperation agreement
- Virtual: e-mail, teleconferencing
- Mental: shared experiences, professional interaction, shared ideas, and attitudes

These spaces enable the firm to become a permanent locus for the creation of dispersed knowledge.

The J-Form Organization with High Potential for Incremental Innovation

Knowledge-creating companies are commonly basing their innovation performance on knowledge embedded in organizational routines, team relationships, a shared culture, and tacit knowledge. Their knowledge strategy is emphasizing the continuous improvement of the existing and embedded knowledge. "If HP only knew what HP knows, we would be much more profitable" (former CEO Lew Platt).

In management sciences those organizations are often called "J-form" organizations referring to "Japanese type" of organizations (such as Aoki's model of the "J-firm"). The J-form of organizations tend to develop an orientation towards incremental innovation as a strategy and generally perform well in relatively mature technology fields characterized by rich possibilities of combinations and incremental improvements to existing products or components. Like adhocracy J-form organizations exhibit strong innovative capabilities; nevertheless, they differ markedly from adhocracy in terms of their knowledge configurations, their patterns of learning, and the type of innovative competences generated. J-form organizations are especially good in exploiting learning and incremental innovation, but they are not as effective in gaining knowledge from external sources and triggering radical innovation (Lam 2010).

Knowledge Management and Innovation Management

The reflections above provide the theoretical background for the extensive literature on "knowledge management" and "innovation management," which has emerged during the second half of the 1990s. Successful innovation requires the production of appropriate knowledge. In this perspective knowledge management is a complex and demanding task, aiming to gain access to fragmented knowledge domains and to organize cooperative processes, wherein the different sources of knowledge are integrated. According to Brödner et al. (1998), knowledge management has three important tasks: (a) to explicate and codify socially incorporated knowledge, (b) to connect people to these explicit knowledge bases for their effective use, and (c) to integrate the different perspectives needed for problem-solving.

However, the goal of innovation is more than production of new knowledge; it is geared towards new products or services delivered to the market. As a consequence the focus of innovation management in complementing knowledge management is on the provision of appropriate structures and spaces for managing the different phases of the innovation process. This starts with idea generation and comprises the stages of idea selection, idea evaluation, business decision, and finally the successful implementation of the idea into new products, services, processes, or business models. As a consequence a series of innovation management techniques (e.g., technology watch, patent analyses, brainstorming, lateral thinking, CAD systems, rapid prototyping) was implemented in organizations to support the process of innovation in organizations and help them in a systematic way to meet new market challenges.

Recently the innovation management approach is increasingly challenged by systemic and cybernetic perspectives on organizations. Peschl and Fundneider (2011, 44) suppose innovation management techniques to be a trial of classical managers to solve the mentioned contradiction between organization and innovation in a mechanistic way. "If innovation should be incorporated at all, it should fit into their routines and processes. In other words, their secret wish is to 'domesticate' innovation to a process, which is predictable, deterministic and scalable." Innovation management is not changing the structure or even the culture of an organization; it is rather based on the assumption that innovation can be produced or controlled like any other process.

Learning Organizations and Organizational Change

Nevertheless, throughout the 1990s and especially in the first decade of the new millennium, the debate about organizational learning got an increasing focus on deeper aspects of organizational change. In this perspective the organizational learning architecture is not restricted to the production of new knowledge and the facilitation for new products and services. Radical and sustainable learning in organizations means that the organization continuously transforms itself. Therefore, Mezias and Glynn (1993, 78) define innovation as "non-routine, significant, and discontinuous organizational change that embodies a new idea that is not consistent with the current concept of the organization's business."

Peter Senge is one of the most influential writers to promote the concept of the learning organization. Senge (1990) mentions five disciplines that characterize a learning organization: personal mastery, mental models, development of shared visions, team learning, and systemic thinking. The "fifth discipline" of systemic thinking comprises all other disciplines and is supposed to contribute to an integrated development of the other disciplines. According to Senge, people do not just learn in a learning company, it is rather the company's consistent concern to discern and to create structures that are beneficial for learning. A learning organization will foster learning at all levels, develop new and innovative processes, and continually reflect and transform itself.

Learning as Strategic Activity

Deiser (2010, 39) points out that a powerful architecture for learning and organizational change "needs to provide common spaces that instigate cross-boundary dialogue and ultimately create enabling mechanisms that foster collaboration, trust, and openness – important conditions for high-performing networks." The creation of relationship networks that emerge through integrating diverse perspectives is often a more important goal than the topical learning content. Hence, the careful and suitable design of learning processes and facilitation becomes more important than content expertise or any specialized activities of innovation management.

He further emphasizes that relevant learning happens by encountering differences. As a consequence boundaries between people, departments, or companies "are the very space where learning happens; they are the place where difference is established." The design and permanent redesign of smart and boundaries between these entities is the most crucial task of a learning architecture. As a consequence he suggests as a new strategic perspective "to design our business encounters with the world in a way that they maximize insights, and then design processes that turn the insights into strategically reflected organizational activity (Deiser 2010, 27)." This is the core of his model of a smart organization.

In a complex network society, the long-term strategic success of an organization is especially dependent on strategic partners and external stakeholders. Radically new learning rather tends to arise from interaction and feedback from those outside the company who are in a better position to create "designed spaces of irritation" and thereby shake existing perspectives and paradigms. The new innovation challenge is to develop the capabilities not only of one's own organization but of the entire network. If suppliers, customers, strategic partners, or even competitors should be integrated in this learning network, then this requires the competence of establishing external nonhierarchical relationships and arranging the collaboration of stakeholders across the value chain. Hence, the competences of sharing, collaboration, and designing spaces of collective interaction and development are the new critical competences for innovation.

Enabling Spaces for Innovation

Peschl and Fundneider (2011) develop the concepts of "enabling" and "space" as basic pillars of the innovation process in an even more explicit manner. In this perspective innovation processes cannot be managed, they just can be enabled. This implies to give up the principles of control, determining, and making and provide instead "a set of constraints or a facilitating framework supporting the processes of bringing forth new knowledge." (Peschl and Fundneider 2011, 45) Hence, an enabling space is a space supporting enabling and facilitating processes of innovation and knowledge creation. This space is designed as a multidimensional space in which architectorial/physical, social, cognitive, technological, cultural, intellectual, and other factors are considered and integrated like a composition, a piece of art (Peschl and Fundneider 2011, 49/52). As a kind of container, an enabling space is providing qualities like offering an environment of protection, of listening and observing closely, of openness, and of enabling the free flow of knowledge and of silence (52). These design qualities have to be translated and integrated into the concrete enabling space of a concrete innovation process. With respect to organizational issues, Peschl and Fundneider indicate that organizational culture is a key constraint and makes the creation of enabling spaces a real design challenge since there do not exist standard solutions or simple rules which one just has to follow in order to establish a ready-made enabling space fitting organically into the organization" (Peschl and Fundneider 2011, 53).

Conclusion and Future Directions

Even if at a first glance "innovations" and "organizations" seem to be somehow phenomena, they are fundamentally interdependent and mutually enabling. In response to environment and contingency factors, organizations develop structures, rules, norms, and processes that provide stability for complex dynamic, uncertain, and volatile processes of knowledge production, learning, and innovation. Depending on environment and contingency factors, this structural framework is looking different in various sectors or even within various departments of one organization and exhibits more or less potential for innovation. Simple organizations, adhocracies, and the J-form are three organizational forms with powerful innovative capabilities but markedly differing in terms of their knowledge configurations, their patterns of learning, and the type of innovative competences generated.

However, without the stability provided by organizations, the innovation process based on dimensions of complexity, uncertainty, cumulativeness, interactivity, acting collectively, and learning is not probable. The microlevel processes of knowledge production, knowledge conversion, and organizational learning we analyzed in part 2 of this entry all take place in spaces and environments offered and shaped by organizations. However, if organizations apply established processes of efficiency and control to the field of innovation, then the innovation process is in danger of becoming predictable, deterministic, and scalable and losing its potential. This is the criticism the approach of innovation management is confronted with.

In the first period of the twenty-first century, we are facing an increasingly complex, chaotic, and confusing environment for organizations. Increasingly unpredictable market and nonmarket conditions, a volatile and ever-changing economic landscape, a complex brew of rapidly advancing technologies and ecological challenges are creating an unchartered territory for more and more organizations.

In this environment of volatility, uncertainty and change organizations are forced to constantly and quickly change themselves and to find new viable organizational solutions. Their success is becoming more and more dependent on the ability to think in terms of organizational alternatives. Deiser (2010) pointed out that the ability to develop visionary organizational structures in dealing with customers, with partners, in connection to the organized civil society and within the company, is gaining critical importance. Especially in knowledge-intensive sectors, recent concepts like "cellular forms," "modular forms," "self-organization," "project-based networks," or "holacracy" mirror the increasing emergence of new dynamic and flexible forms of organizations with a strategic focus on entrepreneurship and innovation (Lam 2010, 170). In this new organizational context, the innovation paradigm seems to be changing as well, and the dimensions of stakeholder networks at the boundaries of the organization, of sharing, of collaborating, of enabling, and of appropriately designing multidimensional spaces for innovation become critical for success.

Cross-References

- ▶ Innovative Milieu as a Driving Force of Innovative Entrepreneurship
- ▶ Open Innovation and Entrepreneurship
- ▶ Organizational Slack and Innovation
- ▶ Risk, Uncertainty, and Business Creation

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Innovations of Direct Democracy

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Synonyms

Direct legislation; Direct say; Initiative; Referendum

Introduction

Direct democracy is often seen as the most pure and basic form of democracy. Representative democracy allows for indirect influence of citizens voting for representatives responsible for taking political decisions. Contrarily, with direct legislation each citizen has effective and direct control over political decision making and equal power to affect decisions through binding votes. The idea of direct democracy is not new at all. The ancient Greeks still knew some sort of assemblies where decisions were made directly by those few full citizens, who were entitled to vote. In Switzerland and some of the US states, forms of direct legislation have been installed since the nineteenth century. Today, some sort of direct democratic mechanisms can be found all over the world (for overviews, see Altman 2011; Gallagher and Uleri 1996; Scarrow 2001).

Given its long heritage and the widespread use, how can direct democracy be treated as an innovation? The reasons are twofold: First, direct democracy is increasingly seen as a remedy for the problems democratic states face in the twenty-first century. The growing mistrust of citizens regarding the political elites, the declining willingness for individual political engagement, and the declining output legitimacy of representative systems are interpreted as signs of a veritable crisis of democracy. It is argued that giving the citizens more direct say – that is, enlarging their possibilities for democratic decision making and control – has the potential to foster motivation to take part in politics, to craft trust, and finally to renew democracy. In this sense, direct democracy is an innovation for representative democratic states and holds great potential for a new democratic turn. Even if direct democratic institutions can be found in many countries, citizen polls are very rare events.

Second, direct democracy has an inherent innovative potential because it enlarges the scope of political arguments. In direct democracy, it is not only the political elite but – at least theoretically – all citizens who contribute to the discussion of politics. In this sense, the more legislation is direct, the higher is the probability of new and innovative political solutions. Direct democracy allows for policy innovation and inclusion of new ideas and approaches even from minorities and outsiders.

Of course, direct democracy also has its dangers. A careful evaluation of the innovative potential of direct legislation needs a look at both the benefits as well as the dangers of direct say and control by all citizens. An appropriate juxtaposition of pros and cons must be based on theoretical as well as empirical insights. Prior to this, there must be given a proper definition of direct democracy that indeed has very different notions, features, and instruments.

Notions of Direct Democracy

Basically, direct democracy means decision making by eligible citizens as opposed to representative democracy, where decisions are taken indirectly (i.e., by representatives for whom the citizens have voted). To distinguish the existing forms of decision making by the people, and to understand their different potential for innovation, three characteristics must be clarified: activation, approval, and definition.

Activation

The first important attribute of direct democracy relates to the question: Who has the right to start a process of direct legislation and under which conditions?

First, the activation of a process of direct decision making can either be a political right for each citizen (bottom-up) or explicitly rest in the hands of the political elite (top-down). In the latter case, direct democracy takes the form of a pure public opinion poll. The government or (a part of) the parliament submits a political issue aiming at hearing the citizens' opinion on this issue, at increasing legitimation for it, or at consolidating of power. Often, this form of direct decision takes the notion of "*plebiscite*" (sometimes also "ad hoc referendum"). When the right of the activation of direct legislation is given to the citizens, this instrument can be considered either as an abrogative or rejective veto or as a citizen's proposal. The veto allows for holding a vote on whether a given law (already implemented or not) should be rejected. To avoid misunderstanding, it is only this veto-form of activation that should be denominated "referendum." The citizen's proposal grants the possibility to suggest new laws. This suggestion can either lead to a popular vote – in this case, this instrument normally is called a "citizen's initiative" – or to a more or less binding request for the elected representatives to take into consideration propositions for new laws. In Austria or in some German Bundesländer, this form takes the notion of "citizen demands" (sometimes also called "agenda initiatives").

Second, the activation of a direct decision making process depends on different legal conditions. In some countries (e.g., Switzerland, Uruguay), the renewal or modifications of the constitution must lead to a popular vote by rights, normally called "mandatory referendum" (also called regulated referendum). In other countries (e.g., Austria, France, or Spain), the representatives have the right to decide whether the people should vote on a given law or not ("ad hoc referendum"). In contrast, the launch of an "optional or facultative referendum" or a "citizen's initiative" has to fulfill conditions, normally the collection of a given amount of signatures within a given timeframe. Of course, such hurdles can be more or less high. To call for an optional referendum in Switzerland – where direct democracy is most widely used – one needs to collect 50,000 signatures (roughly 1 % of the eligible citizens) within 90 days. For a citizen's initiative, 100,000 signatures must be collected within 18 months.

Approval

The crucial feature of direct democracy is approval – whether a decision in direct legislation in the end is legally binding or not. Most often, pure plebiscites in terms of citizen opinion polls are only consultative and non-binding. Thus, even if the citizens reject a proposal, the parliament can implement it. On the other end of the scale, there are direct democratic decisions that are binding without consent of the parliament

Innovations of Direct Democracy, Fig. 1 Different notions of direct democracy

<table>
<tr><td></td><td></td><td colspan="4">Degree of Definition Power of Initiators</td></tr>
<tr><td></td><td></td><td>Low</td><td>High</td><td>Low</td><td>High</td></tr>
<tr><td rowspan="2">Activation</td><td>Bottom up</td><td colspan="2">Citizen demand</td><td>Referendum</td><td>Initiative</td></tr>
<tr><td>Top down</td><td colspan="2">Plebiscite</td><td colspan="2">Counterproposal</td></tr>
<tr><td></td><td></td><td colspan="2">Advisory/consultative</td><td colspan="2">Legally binding (depending on quorum or not)</td></tr>
<tr><td></td><td></td><td colspan="4">Approval</td></tr>
</table>

or even against the expressed opposition of the elected representatives. Between these two extremes, there are several levels of conditions for the legal binding, mostly depending on approval quorums and participation quorums. Approval quorums ask for more than simple majorities such as super-majorities (e.g., a majority of all enrolled citizens) or double majorities (e.g., a majority of citizens plus a majority of federal states). As for participation quorums, whether a decision is binding or not depends on a minimum number of citizens participating.

Definition Power

Foremost in the case of direct democratic processes initiated by the people, one has to consider the power of definition. First, the use of a referendum or an initiative can be restricted to special cases only or be allowed for all policy fields. Second, a citizen's proposal can be more or less set out – that is, it can give more or less possibilities to the political elite to re-formulate the initial request of the initiators. In some US states and Swiss cantons, citizens are allowed to propose legislative measures (via a "statutory initiative"). The definitional power of this instrument is greater than that for a "constitutional initiative," where citizens are allowed to propose a constitutional amendment that must afterward be specified by the parliament. In some countries (such as Uruguay and Switzerland), the legislatures are allowed to make "counterproposals" against the citizen-initiated proposal. The above-mentioned "referendum" in the sense of a pure veto against a decision taken by the parliament has no definition power, because it only aims at the rejection of an existing law proposal.

The three defining elements of direct democracy are summarized in Fig. 1.

Innovations of Direct Democracy

Based on the typology in Fig. 1, considering the theoretical arguments of merits and drawbacks, and leaning on empirical findings of the advantages and dangers of direct legislation, the innovative potential of direct democracy can be estimated.

Bottom-Up Versus Top-Down

The vertical axis in Fig. 1 depicts the trigger of a process of direct legislation. The activation of direct democracy can either be top-down or bottom-up.

At first sight, innovative potential for direct legislation is greater when it is activated by citizens. At least two reasons underline this suggestion: the argument of the many and the inclusion effect of direct democracy. *First*, allowing citizens to bring in propositions for new legislation measures enlarges the scope of possible arguments and the range of political solutions. Marsilius of Padua (1967) already praised the idea of decision making by many. According to the medieval physician and philosopher, the probability that many citizens do find a better political decision than only parts of the people is high. The deliberative theory of democracy concentrates on the process of decision making and highlights the public discussion based on the mutual justification of political arguments as the essential element of democracy. *Second*, bottom-up direct legislation has an inclusive effect. Minorities – often excluded or only marginally involved in representative decision making – have the possibility to bring their specific preferences into the political arena. They can force the political elite as well as fellow citizens to think and discuss about the minorities' interests. In this sense, initiatives have an important function as a megaphone or a valve or can even help to break taboos. New, innovative, and even displeasing themes come on the agenda, and the political elite as well as the citizens are forced to argument for or against them. The innovative potential of bottom-up direct legislation lies in the inclusion and enlargement of political ideas, proposals, and arguments.

Furthermore, a citizen's right to directly take part in legislation has a system-stabilizing effect. The acceptance of laws that are directly made by citizens themselves is higher. Empirical research further shows that satisfaction with democracy and even with one's life as well as trust in political institutions and representatives is higher when there is direct democracy (for overviews on empirical findings of the impact of direct democracy, see Lupia and Matsusaka 2004; Maduz 2010). In this sense, direct democracy has the potential to innovate representative democratic systems that suffer from growing mistrust and political apathy.

Contrarily, top-down activation of direct democracy seems to have less innovative potential. Plebiscites normally only have a consultative function. The political elite quite selectively asks the citizens to legitimize a more or less disputed legislative proposal. This seems not to be innovative, neither in terms of content nor in terms of enlargement of arguments. However, enlarging the scope, one can find innovative potential in top-down activation of direct legislation, too. *First*, even consultation – compared to no direct democracy at all – holds the capability for renewal. Asking the citizens for their opinion forces the representatives to argue for or against their proposal and to explain their points of view. This can lead to a broader and probably innovative discussion on a given topic. Given the possibility of plebiscites, opposition parties could even use this instrument to force the government to take clear positions. *Second*, top-down direct democracy is not necessarily only consultative. In Switzerland, the parliament has the ability to formulate a counterproposal for a citizen's initiative. Normally, Swiss representatives absorb some requests of the citizen's proposal but reject those going too far. A counterproposal is a reformulated and attenuated form of the initial initiative. Sometimes the initiators recall their initiative when there is a counterproposal, but most of the time, both the initiative and the counterproposal are voted on. A counterproposal not only innovatively enlarges the discussion and the scope of arguments, but it presents an interesting interplay between representative and direct democracy. As such, it also can weaken a widespread criticism of direct democracy: the danger of misuse of direct democratic instruments by powerful groups aiming at promoting their own interests or constraining the power of the state (Bernhard 2012). With a counterproposal, the representatives have the chance to counter, attenuate, or enlarge one-sided proposals.

Advisory Versus Binding Decisions

The horizontal axis in the typology distinguishes binding from non-binding instruments of direct legislation. In combination with the vertical axis discussed above, the approval of a direct decision can strengthen the innovative potential with regard to contents: the motivation to find new arguments and positions is bigger and the scope of new ideas is wider when the stakes are high, regardless of whether activation is bottom-up or top-down. As for the systemic innovation, consultative plebiscites that only serve to consolidate power or that are not binding even if rejected by the people rather lead to more political disappointment of the citizenry. The very idea of direct democracy is reduced to absurdity, and the feeling that the political elite comes close to some sort of oligarchy is aggravated. However, and again, a rejection of a non-binding proposal has also some innovative potential because it cannot be completely ignored by the political elite – at least in democratic systems. If nothing else, some tiny reforms must be undertaken if the representatives want to secure their re-election.

The innovative potential of the horizontal axis should be discussed further in terms of responsibility. It is the citizens who have the final responsibility for decisions of legally binding direct legislation. As for the non-binding advisory proposals, it is the political elite who finally decide what will be done. The question of ultimate responsibility lies at the very heart of the debate between supporters and opponents of direct democracy. The former state that giving the people more direct responsibility to decide on political issues leads to higher political engagement, greater accountability and awareness of political problems, more acceptance of the democratic process, and finally even more trust in the political elite (Barber 1984). Supporters of direct democracy, thus, would state that only real direct democracy (i.e., citizen-initiated and binding law proposals) has innovative potential for widening the scope of arguments and reforming representative democracies. The critics of direct democracy are very skeptical in consideration of the capabilities of the citizens. They argue that problems of modern societies are far too complex for ordinary citizens who do not consider anything except their own interests and thus lack a sense of responsibility and accountability. Furthermore, direct democracy allows demagogues to launch populist proposals that violate human or minority rights (Schumpeter 1962). Thus, critics of direct democracy deny a responsibility of citizens. In the end, the people do not bear the consequences of their decisions.

Empirical investigation confirms neither the naïve belief in the salutary effect of direct participation that brings citizens to perfection, letting them find a Rousseauian common welfare (Rousseau 2006), nor the fear of the anarchical tyranny of powerful populist and self-interested majorities. There are hints that citizens in direct democratic systems are more politically competent and do not blindly abolish taxes or demand higher government spending. Compared with elected representatives, citizens who have the power to decide directly even seem to be more economical in spending money: the level of public debt is lower in direct democratic systems than in representative systems (Matsusaka 2005). Some empirical findings even show positive effects of direct legislation on an individual's development of civic virtues, such as political trust or efficacy (Smith and Tolbert 2004). However, there are also empirical findings that identify at least partially discriminating effects of direct democracy. Turnout at polls in Switzerland or California often is quite low. This is not a problem as such because the absentees often do not take part because they are not interested in the topic, are not concerned or feel not competent enough. The problem of this self-selection, however, is its bias: well-educated upper-class people with high income participate much more in direct legislation than do structurally disadvantaged citizens (Mendelsohn and Parkin 2001). Analysis of all polls in Switzerland further shows that the danger of direct democracy for minorities cannot be denied. Sometimes citizen's proposals collide with basic rights (Vatter 2011).

Definition Power

For some opponents of direct democracy, the notion of innovative direct democracy is a contradiction in terms. Direct democracy, rather than being innovative, severely hinders reforms and improvements. Giving citizens the possibility to veto and even cancel parliamentary legislation leads to backlogs instead of political innovation. Thus, direct democracy is seen as a brake.

The discussion on the backlog potential of direct democracy should be enlarged by the third feature of the typology in Fig. 1: the definition power. A pure referendum, as defined above, indeed only blocks a given law or legislative reform when it is adopted. This is the literal sense of such a veto- or control-instrument. However, to consider the whole idea of direct democracy as a paralyzing system would ignore some significant facts. Such a view does not account for the definition power of other instruments than the pure referendum, such as statutory or constitutional initiatives, launched by citizens. Proposals that can be more or less drafted out do indeed have a great potential for innovation. As discussed above, bottom-up induced impulses for political reforms can even break up lethargic representative systems and lead to important reforms. In this sense, direct democracy is not a brake but rather an accelerator for political change.

The degree of definition power affects the scope of the elected representatives' contribution to a specific legislation. Citizen-initiated legislation can range from a simple mandate for the representatives to create a new law to a specific proposal that must be adjusted by the parliament or even a fully set-out law that – given the acceptance by the people at the polls – must be adopted wholesale. The larger the degree of definition power of direct democratic instruments is, the less representatives will have control over the specific legislation but the greater the potential of law-giving innovation there is.

Conclusion and Future Directions

To define the innovations of direct democracy, one must clearly define what is meant by direct democracy. There are several different instruments allowing for citizens to directly join in political decision making. Thus, there is no such thing as the "direct democracy." Further, direct democratic institutions should be seen as complementary to representative democracy. There is no question of either representative or direct democracy. The distinction between direct and representative democracy is not exclusionary, but the two concepts are complementary. In fact, an enlargement of representative systems by direct democratic institutions seems to be an interesting – given the growing mistrust and apathy in established democracies, perhaps even inevitable – innovation of a democratic system. It is the complementation of representative democracy with direct forms that holds the most innovative potential for a transformation of democratic systems to semi-direct democracies.

Depending on the activation, the approval, and the definition power, the inclusion of citizens' ideas into the law-making process holds great innovative potential. As a rule of thumb, the more bottom-up the direct democratic process is organized, the more responsibility is given to the citizens in terms of approval, and the higher the degree of definition power is for citizen-initiated legislation, the greater is the potential for democratic innovation as regards content. The enlargement of the scope for different arguments, the potential of taboo breaking, and the possibility of accelerating political reform is highest when citizens are allowed to directly bring in specific law proposals.

However, there are trade-offs between the innovative potential of direct legislation and the danger of unequal and undemocratic direct decision making by citizens as well as between innovation and representative control. Direct democracy has incorporated perils such as the possible "tyranny of the majority" that harms basic rights, populist demagoguery, or discriminating demands. Such jeopardy is greater the more the responsibility for direct law making is given to the citizens. Furthermore, the more the citizens have to decide, the more the elected representatives must shift responsibility, political power, and control over the political process and output.

The challenge for established democracies in the twenty-first century is the search for a political system that gives possible solutions to these trade-offs. This should be a system that is open enough to tap the innovative potential of citizen-initiated direct legislation, but that leaves enough scope for the elected representatives to limit and control the potential dangers of direct democracy. Such a system will certainly combine elements of representative and direct democracy.

Cross-References

▶ Creative Behavior
▶ Innovation and Democracy
▶ Political Leadership and Innovation

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Innovative Activities, Creation

▶ Innovative Milieu as a Driving Force of Innovative Entrepreneurship

Innovative Businesses

▶ Knowledge Capital and Small Businesses

Innovative Climate

▶ Measuring Organizational Climate for Creativity and Innovation

Innovative Democracy

▶ Quality of Democracy and Innovation

Innovative Entrepreneur

▶ Entrepreneur's "Resource Potential," Innovation and Networks

Innovative Entrepreneurship

▶ Entrepreneur's "Resource Potential," Innovation and Networks
▶ Entrepreneurship in Creative Economy

Innovative Firm

▶ Innovations of and in Organizations

Innovative Management

▶ Creative Management

Innovative Milieu

▶ Industrial Atmosphere
▶ Innovation Systems and Entrepreneurship

Innovative Milieu as a Driving Force of Innovative Entrepreneurship

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Synonyms

Innovation systems and individual initiative; Innovative activities, creation; Start-up and proximity relations

Introduction

The geographical proximity between science, technology, industry, and finance contributes to the emergence of innovations. Interactions are being organized through the interplay between private actors and political institutions. Today, economists (see, e.g., Acs 2001; Den Hertog et al. 2001; Feldman et al. 2005; Florida 2003) consider the regional economy as a geographical and economic platform for the organization of production and, as a consequence, as an opportunity to create new activities, goods and services, new employment, and sources of income. For almost four decades, the innovative approach based on proximity and, in particular, on the concept of the "innovative milieu" has demonstrated its pertinence as a form of modeling of decentralized economic growth and also as a source of entrepreneurship.

An analysis starting from the innovative milieu makes it possible to study the entrepreneur's economic role and function and its contribution to the innovation process. The systemic nature of the relationships that characterize an economic and social milieu (Cooke 2001) makes it possible to identify what contributes (or not) to the innovative act. Innovation and entrepreneurship (as a product of the milieu) depend to interpersonal exchanges. Are they only the result of a specific organization of economic relations? The argument here is that the systemic nature of the milieu does not exclusively relate to economic interactions but more precisely also takes into consideration the social structures that are at the origin of innovative behaviors. Moreover, institutions (states, local communities) play an important role in the organization and development of socioeconomic structures. In its turn, the innovative milieu – thanks to the relations of proximity – contributes to the entrepreneurial innovative performance through the supply of scientific, technological, and financial resources.

The first part of this entry will examine the role of synergic (spatial, organizational, and cognitive) relations – named proximity – in the innovation and entrepreneurial process. The density of these relations reinforces the capability of a local economy to generate small independent enterprises (essentially start-ups). But in the contemporary capitalism, the entrepreneur, as the owner and the manager of a small enterprise, has a specific function (second part). He is not a hero (as Schumpeter it noted), but he is a socialized entrepreneur. The former is at the origin of the development of big industries and new areas of activities; the latter is the result of the financial strategies and industrial policies of the major actors of the economy (big firms, financial institutions, central and local public administrations, etc.). In the third part, this entry will focus on the "resource potential" of the entrepreneur as a necessary condition to business creation. This potential, composed by capital, knowledge, and social relations, can give value to the entrepreneur's function. In this case, the relations of proximity, applied on the territorial level of analysis, must be characterized by the logic of collaboration, confidence, and reciprocity.

Several studies on the territorial economy based on the network analysis and the systemic relations which are developed in this case. The entrepreneur is not an actor of economic system. He is studied like a systemic relation into the network or as the result of the functioning of this network. So, the article argues to analyze how the entrepreneur builds his potential of resources in a local economy and how he uses his resources (knowledge, financial resources, social relations) to develop new relations and new economic activities.

Proximity and the Innovative Milieu

Economic Proximity and Social Relations

The concept of proximity is now widely used in both industrial economics and innovation studies (see notably Boschma 2005). A priori, proximity seems to be related to the existence of localized externalities generating phenomena of spatial concentration and regional dynamics. From this perspective, economists propose a three-dimensional approach to proximity: spatial proximity, organizational proximity, and cognitive proximity. In this approach, the issue of localization is coupled with the organizational and informational/cognitive capacity of firms.

A local economy (or a local production system) may be defined as a geographical area consisting of a set of systemic relationships among enterprises and also between enterprises, public authorities (the state), and local communities; these systemic relationships characterize the area localized for a given type of activities or final production. That economy is observed and studied as a node of productive relations which contributes to regional and local development (Uzunidis 2008).

Alfred Marshall (1919) demonstrated that the regional efficiency of such an organizational mode resides in economies in transaction costs. The concentration in a single geographical location of the main actors of the same productive system (mainly producers on one side and users on the other) not only facilitates transactions but the mutual relations of knowledge and confidence between different partners (spatial proximity). The development and accumulation of expertise will therefore create what Marshall called the "industrial atmosphere" facilitating the functioning of the local labor market. This phenomenon is related both to the workers' qualifications and experience and to the location of several enterprises in the same locality. In the meaning attributed by Marshall to the "industrial district," this environment includes a specific density of population with proven qualifications, a set of actors constituting the different links of a single production system, and finally a degree of know-how strongly resulting from acquired experience.

Before Marshall, von Thünen (1826/1850/1867/2009) in the nineteenth century underlined that the free market mechanisms are not an abstraction, but they take place in a particular territory. In this approach, the territory is defined geographically, and it is also the place where relations of proximity between individuals are developed. The von Thünen's analysis shows that the question on territory and its role for the economic dynamics is not a new phenomenon. On the other hand, Braudel (1975) had argued in the Mediterranean case that the commercial activities are developed thanks to the networks of merchant entrepreneurs.

The main characteristic is that the local organization of production is not linked to a hierarchical principle regulating an enterprise but is rather based on a principle of collaboration and cooperation between different production units. Therefore, the concept of solidarity between economic actors is of considerable importance. The local production system is mainly characterized by the proximity between productive units (individual firms, service suppliers, research centers, training institutions, etc.). The relations between these units have a variable intensity and may take on highly differentiated forms: formal or informal relations, market or nonmarket, etc. Alliances mainly relate to the flow of materials, services, labor, technologies, and knowledge. The specific nature of the activities involved in the production of new knowledge and the interactions associated with them has led economists to introduce the concept of cognitive proximity in addition to spatial-temporal proximity and organizational proximity. Cognitive proximity and knowledge exchange means the more or less formalized sharing of experiences, codes, languages, and models resulting from and facilitating the communication of information inside – and between – organizations (Nooteboom 2002; De La Mothe and Foray 2001; Foray 2003).

Proximity contributes to the coordination of the innovation process. This one, both flexible and evolutionary, imposes on the firm or on the entrepreneur the pressing need to be provided with the different types of technological and intellectual means to acquire and combine uninterrupted flows of material and immaterial resources. The "knowledge theory" applied to the company says that the ability to adapt and the efficiency of the company depends on its cognitive categories, on the interpretation codes of the information itself, and on the tacit skills and its procedures in solving the problems it encounters (Dosi et al. 1999). The scientific, technical, and industrial information as a system of knowledge (knowledge capital) which is articulated, formalized, and likely to be communicated or transferred is a means of production identifiable as such (Laperche 2007), the use of which provides innovation for the economic process and the accumulation of capital. The task of the manager or the entrepreneur consists therefore of finding the balance between managing the partnerships and developing the internal instruments of organization (see Laperche et al. 2006). To survive or grow, a company is forced to acquire new knowledge to create new competences (Penrose 1959).

Piore and Sabel (1984) integrated the proximity in a flexible system of production founded on multidirectional and horizontal relations. The dynamics of the evolution of the structures and the organization of the local system of production highlights the importance of the small enterprises. Those being more flexible and more adaptable are committed to renew the local system of production and to create new jobs since flexibility facilitates the adaptation to the new economic context. Moreover, the proximity between the large companies and the small enterprises contributes to the emergence of the innovative milieu.

Table 1 identifies the main parameters characterizing the different categories of proximity as well as the operating field and the types of stakes related to them. It is worth noting that interactions are generally multidimensional: They represent a combination of different dimensions from which a major dimension emerges. In this case, this core dimension relates to space and time.

An Innovative Milieu

Our central theoretical assumption concerning the concept of the innovative milieu, namely, the social and economic environment of a region developed over the course of history ("path dependence"), is that all innovative milieus are the product of interactions between firms, institutions, and labor. Such interactions are exclusively the result of mutual synergies (networks, partnerships, etc.) between different local agents (public or private) participating in economic and industrial development. For example, authors may refer to the different forms of cooperation between enterprises and research labs. It is firstly the surrounding socioeconomic, industrial, and scientific environment that contributes to the creation of new activities (in particular, through entrepreneurship and spin-off) and to the genesis of innovations (see also Camagni and Capello 2009). In addition, this can only develop in a "natural" form if some preconditions are respected, among which are existence at the regional level of a community of actors (enterprises, research and training centers, public administrations, professional qualifications, etc.); presence of material, human, financial, technological, and information resources in the immediate geographical neighborhood; existence of specific know-how leading to high-quality productive activity; existence of relational capital favorable to the creation of local, national, or international networks; and the existence of norms, rules, and values promoting positive behavior among economic actors.

The concept of the innovative milieu generally relates to the capacity of a local economy to generate innovations through, for example, the emergence of new enterprises. The local economy is therefore represented in the form of

Innovative Milieu as a Driving Force of Innovative Entrepreneurship, Table 1 The three categories of proximity

Proximity	Parameters	Operating field and stake
Spatial	Distance/speed	Displacement
		Flows, time
Organizational (intra- and interorganizational)	Hierarchy/market	Coordination
	Intrafirm/extrafirm	Strategy, actions, routines
	Vertical/horizontal	
	Instruction/contract	
Cognitive	Code/content	Communication
	Context/understanding (awareness and interpretation)	Concept, ideas, knowledge

Source: Authors

a spatial system valuing all kinds of capital and merchant exchange. This spatial, economic, and social system must reduce the risks related to the uncertainty of a given investment; it triggers an innovation process that includes the creation of enterprises and the incorporation of already existing technological enterprises. International competitiveness of a territory is due to the richness of its innovative capacity (Porter 2003).

The organization of the innovative milieu is ensured by two logics: The first is related to the interaction between local actors and the second to the dynamics of the collective learning (Lundvall and Johnson 1994). Interactions contribute to organize a regional economy. They make possible to bring together local actors within a production process. The dynamics of the collective learning appears in a process where the milieu initially mobilizes resources and thereafter uses them to adapt to the change which comes from outside. The capacities of innovation are the result of the cooperation between the local actors and the use of specific resources (raw materials, capital, technology, knowledge, competencies, etc.) of the milieu. By the installation of the mechanisms of coordination, the milieu is able to ensure the balance of the cooperative relations between the local actors and internal and external competition.

Spatial, organizational, and cognitive relations of proximity form an innovative milieu. The regional anchorage of the enterprise enables it to avail itself of a pool of resources (and sometimes a market) in order to amortize the costs inherent in its investments in an economy undergoing constant change. However, this regional anchorage depends on the quality of the "pool" mentioned above, compared to the entrepreneur's expectations as regards innovation, business start-up, and consolidation. Hence, it arises the necessity for governments and local authorities to create a system organizing the resources with a view to generating multiple innovation processes taking into account the competition-cooperation behaviors between the same actors in an open economy (see, in particular, Pitelis et al. 2005). This system is a supplier of those productive resources that are capable of generating innovative entrepreneurship and also attracting other enterprises with confirmed performances in the innovation field.

The Entrepreneur's Function in the Current Stage of the Capitalism

The End of the Heroic Entrepreneur

At the core of an innovation milieu, specific attention can be paid to the creation of small enterprises. In the present economic uncertainty and following the trends to decentralization, the establishment of enterprises is supposed to solve many problems linked to the rigidities resulting from institutional interventionism. Its flexible structures enable much easier reaction to consumers' expectations. Moreover, the possible bankruptcy of an enterprise does not threaten the financial and industrial fabric of the country, region, or place. Establishing a considerable number of small firms is considered as a privileged instrument of industrial policy and national planning; financing and marketing activities seek to organize the markets and the development of technologies through alliances, mergers, agreements, and political interventions; the hope for an economic renewal is concentrated on small enterprises that are in full harmony with economic needs. A small enterprise is also a formidable machine able to enrich or destroy capital. It presents itself as a sort of carrier of values to the extent that it creates bridges for the transfer of productive resources (financial capital technologies, labor force with different qualifications, and competencies) to activities, markets, and large companies able to make profits.

Entrepreneurs have been at center of economists' concerns and public policies since the beginning of the 1980s in capitalist economies (Boutillier 2008). This fact is relatively new. Since the end of the Second World War, the paradigm of the big enterprise has prevailed. The years of growth that followed the Second World War were marked by phenomena of industrial vertical concentration and the evolution of managerial capitalism. Economy was directed by a "technostructure" and, in particular, by managers being salaried workers (Chandler 1977). Entrepreneurs, as founders-owners-managers of firms, seemed to belong to an age that had gone to the heroic period to which J. A. Schumpeter often refers. The big company imposed itself and together with it mass production and salaried employment. W. J. Baumol (1969) wrote in a famous paper that the entrepreneur had disappeared from the economic literature. For a lot of economists, the main economic actor is not the entrepreneur but the enterprise.

In Schumpeter's theory of economic evolution (Schumpeter 1935), the entrepreneur is the economic agent achieving new combinations of production factors. He is the hero of the capitalism. Five combinations must be taken into account:

1. Manufacturing of a new good, in particular, unfamiliar to consumers' circles or endowed with a new quality.
2. Introduction of a new production process that is almost unknown in the specific industrial branch; it is not imperative that it is based on a new scientific discovery, and it may also be found in the new commercial process applied to a commodity.
3. Opening of a new outlet, a market in which the specific industrial branch of a specific country has not yet been penetrated, respective of the previous of the market.
4. Acquisition of a new source of raw materials or semifinished products; again, it does not matter whether this source has to be created or already existed, has been taken into consideration, or considered inaccessible.
5. Formation of new organization, for example, creation of a monopolistic situation or sudden emergence of a monopoly: the heroic entrepreneur who creates a new industry, similar to what happened at the end of the nineteenth century (movies or electricity) or at the end of the twentieth century (electronics, computer).

In his ultimate book entitled Capitalism, Socialism and Democracy, published in 1942, Schumpeter was largely pessimistic about the future of capitalism. It was because the development of capitalism led, according to him, to the disappearance of competition. Companies were becoming bigger and bigger. In addition, these were powerful organizations and bureaucratic enterprises. Schumpeter insisted on the following idea: The entrepreneur is being replaced by an organization. Entrepreneurs are no longer responsible for innovative activities, which are now performed by teams composed of expert members who have no direct link with the market or the consumer.

The vanishing of the Schumpeter entrepreneur is a metaphor used to analyze the development of managerial capitalism, the evolution of big enterprises. In the 1960s, J. K. Galbraith (1967) pursued Schumpeter's analysis of managerial capitalism and demonstrated that the economy of capitalist-industrialized countries did not fit with the paradigm of pure and perfect competition. Six distinctive elements emerged:

1. Domination of a handful of big enterprises whose ownership is split between a myriad of shareholders, a plethora of small owners of enterprise

2. Presence of a considerable number of very small firms, however, rather marginal as regards the creation of wealth
3. Disappearance of the entrepreneur replaced by a division between the owners of capital (shareholders) and capital management (managers): the "technostructure"
4. Development of planning tools in order to minimize the uncertainty resulting from the functioning of the market
5. Presence of a plethora of small entrepreneurs who do not operate in a market characterized by pure and perfect competition but in markets dominated by big firms
6. The expansion of a huge bureaucracy related to technological and not political considerations

The Socialized Form of the Entrepreneurship

But since the 1980s, the entrepreneur, as a concept, is reappearing in economics because of the positive factors that contribute to create a propitious environment for the creation of enterprises. Economists hold the idea according to which the economic, social, and political environment facilitates the development of specific economic behaviors, as for example, entrepreneurial behavior. According to the OECD, the emergence of entrepreneurship is related to the rank it holds in the scale of values and to the intensity of incentives and support it receives. However, the beginning of the 1980s was marked by a whole set of major economic and social changes that consecrate a sort of rupture from the previous period:

1. Policy of liberalization of the economy (contestable markets theory) and the development of the financial markets: The privatization of the economy releases capital in huge quantities – new investment opportunities emerge; development of investment funds and pension funds; the aging of the population; and the withdrawal of the social state from the financing of pensions stimulated their development. The major problem was to identify new investment opportunities in a context of slow economic growth. Capital becomes impatient (Harrison and Blustone 1990).
2. Development of information and communication technologies and biotechnologies generated new investments opportunities.
3. The "garage mythology" and "the legend of the entrepreneur" prevailed. As in the early days of capitalism, an idea that was already considered outdated was revived and propagated: the heroic entrepreneur. However, one trend to forget that the knowledge the new innovative entrepreneurs used to succeed is the result of the institutional and the networking (military or civilian) scientific research.
4. The crisis of welfare state: G. Gilder (1985) argued that the welfare state generates poverty because it encourages too many people to rely on social services instead of looking for a job (since the 1970s, the public choice school and the theory of bureaucracy have strongly criticized Keynesianism). According to Gilder, only the entrepreneur is capable to fight against poverty and unemployment.
5. Increase of mass unemployment and growing insecurity of salaried employees (development of part-time employment and multiemployment): Is it the "end of work" or the beginning of the "entrepreneurial society" (Audretsch 2007)?
6. New public policy: The main question is to help unemployed workers to create their enterprises (their means of existence, their job), thanks to the emergence of an institutional environment (reduction of taxation, of administrative barriers, flexibility of labor market, etc.). For Keynesian economists in the 1960–1970s, the fundamental role of the state was to sustain demand and create markets. In fact, the main objective of J. M. Keynes was social peace and political stability. In the 1980s, the economists of endogenous growth theories (Aghion et al. 2001) explain that the state has a major role to play in order to sustain the supply and support enterprises to innovate. In this turn, innovation generates wealth and employment. Through an appropriate public policy, the state tries to facilitate the transition from the situation of job worker to that of entrepreneur or from wage earner to

entrepreneur, in short to introduce more flexibility in the labor market.

7. The big managerial enterprise with its pyramidal architecture (Sennet 2006) is no longer adapted and is compelled to change: The structure of the network enterprise is flexible and decentralized (to benefit from new information and communication technologies).
8. As regards the number of salaried workers/employees, the size of enterprises has also been reduced.
9. Since the beginning of the 1990s, entrepreneurship has become an academic discipline taught in universities. Awareness programs targeted at the youth are also elaborated upon.

Thus, economic theory has a definition of new capitalism: It is a socioeconomical organization based on private property and free market. The characteristics of the managerial capitalism were the same. The fundamental differences between new capitalism and managerial capitalism are (1) the organization decentralized of industrial production (network enterprise and enterprise networks) assisted and coordinated by the ICTs and finance, (2) development of the financial markets (which generate capital funds for investment), (3) flexibility of labor market, and (4) new role of state which is to build an institutional environment to create enterprises and jobs.

In the first decade of the twenty-first century, the economy of industrialized countries is undergoing major transformations at the scientific, technological, and productive levels. The financial crisis of 2008 is also the beginning of major changes in the productive systems. If one refers to Schumpeter's theory about entrepreneurship, this situation lays a fertile ground for innovation and for business creation (Langlois 1987; Perroux 1970; Heerjte 2006), a process that fuels the ascending phase of an economic cycle.

In this context, the entrepreneur is no longer heroic but rather socialized (Boutillier et al. 2008). He is stuck between three logics: that of the big enterprise that structures and outsourcers all or a part of its activities; that of the state striving to promote the creation of new businesses, on the one hand, to fight against unemployment and, on the other, to foster the development of innovations seen in the Schumpeterian meaning of the term (product, process, organization); and that of relations of proximity on a local (spatial) but also on a interinstitutional (networks) level. The concept of the socialized entrepreneur must be distinguished from the collective entrepreneur or even from the entrepreneurial corporation (Hagedoorn 1996) that characterizes the managerial enterprise: In fact, the socialized entrepreneur may be defined in the first place by his macroeconomic function (job creation, innovation, outsourcing of the productive and service activities of big companies, localization).

In the new capitalism, the socialized entrepreneur takes place in the networks. He is an entrepreneur sitting at the interface between two logics:

1. The logic of the big industrial and financial enterprise that seeks to stimulate the creation of enterprises in order to test new markets
2. The logic of the state that seeks by these means to fight against unemployment and promote innovation

Indeed, faced with the complexity of the innovation process, M. Castels (1996, 1997, 1998) went as far as to maintain, quite cleverly, that the fundamental unit of the economic system is no longer the entrepreneur, the family, the firm, or the state but the network composed of different organizations. Thus, this network gives birth to the new entrepreneur (Table 2).

The Entrepreneur's "Resource Potential" and the Innovative Milieu

The "Resource Potential" and the Entrepreneur's Function

The entrepreneur's individual qualities and personality undoubtedly play a major role in the decision to create or buy out a small firm. Nevertheless, the action of starting up that initiative is determined by the macrosystemic dynamics of accumulation and profit. These dynamics generate barriers as well as personal enrichment opportunities that encourage an individual to become an entrepreneur who will ultimately succeed or fail. The fact is that nobody is born an

Innovative Milieu as a Driving Force of Innovative Entrepreneurship, Table 2 Big enterprises and entrepreneurs since the second half of the twentieth century

	Since the end of the Second World War	Since the 1980s
Place of the big enterprises	Development of managerial enterprises	Reorganization of big enterprises (networks)
Organization of labor and production	Assembly chain	ITCs
	Fordism	Robotization and production and services
	Taylorism	Flexible organization
	Rigid organization	
Place and role of the entrepreneur	Entrepreneur = employer = authority	Entrepreneur = innovator = creator
Form of recruitment	Mass wage earning	Increasing precariousness of salaried employment
	Mass employment	Term contract
Financing of the economy	Indebtedness (important role of banks)	Development of financial markets
	Public financing	
Role of the state	Welfare state	Privatization/deregulation
		Public policies to promote entrepreneurship and free market

Source: Authors

entrepreneur but may become one through the mobilization of a potential of resources composed of capital, knowledge, and relations. Support involves capital for investments and operations, knowledge for choices and decisions, and relations for the financing, association, and selling of products.

Economists define the entrepreneur as the founder, manager, and owner of at least a part of the enterprise. In such conditions, he may also be an innovator (Say or Schumpeter analysis); however, unemployment may as well be at the origin of his decision. Nevertheless, he always remains the economic agent who bears the risk since he is, in every case, the main financial backer of his enterprise, together with his relatives. On the other hand, the entrepreneur may be defined as a set of resources. By using the concept of potential of resources of the entrepreneur, the researcher relocates the entrepreneur and his enterprise in the general logic of the capitalist system. The potential of resources is split up in the following way:

1. A set of financial resources including all the effective financial resources (own spending, family assets, heritage) or potential (access to credit, subsides, various public aids, etc.)
2. A set of knowledge including all entrepreneurs' knowledge whether they are certificate, by a diploma, or a result from professional experience: technological, organizational, economic knowledge, etc.
3. A set of social relations: personal, family, or professional relations that the entrepreneur may mobilize in order to fulfill his project. Two social relation networks may be distinguished: on the one hand, a network of institutional relations (relations with public institutions, enterprises, banks, etc.) and, on the other, a network of informal relations with relatives, family, friends, neighbors, working relations, etc.) (Granovetter 1973). In this example, these two networks develop interdependently. Thus, it is through the information given by a friend that the observer learns about the existence of a specific type of financing. However, the individual's social background plays a fundamental role because it largely determines the network of friendly or family relations (Bourdieu 1985; Coleman 1988; Putman 1995).

Innovative Milieu as a Driving Force of Innovative Entrepreneurship, Table 3 Resource potential of the entrepreneur

Resource potential	Major characteristics
Knowledge	Tacit and various types of knowledge acquired in the family context
	Scientific and technological knowledge acquired at school
	Knowledge acquired during relations with third parties (family, professional activity, etc.)
Financial resources	Own spending
	Affective inputs: parents, relatives
	Bank credit
	Institutional financial aid (e.g., direct assistance from the state)
	Financial inputs brought in by another entrepreneur
Social relations	Informal relations (family, friends, neighbors, colleagues, etc.)
	Formal relations (stat, banks, other enterprises, research centers, etc.)

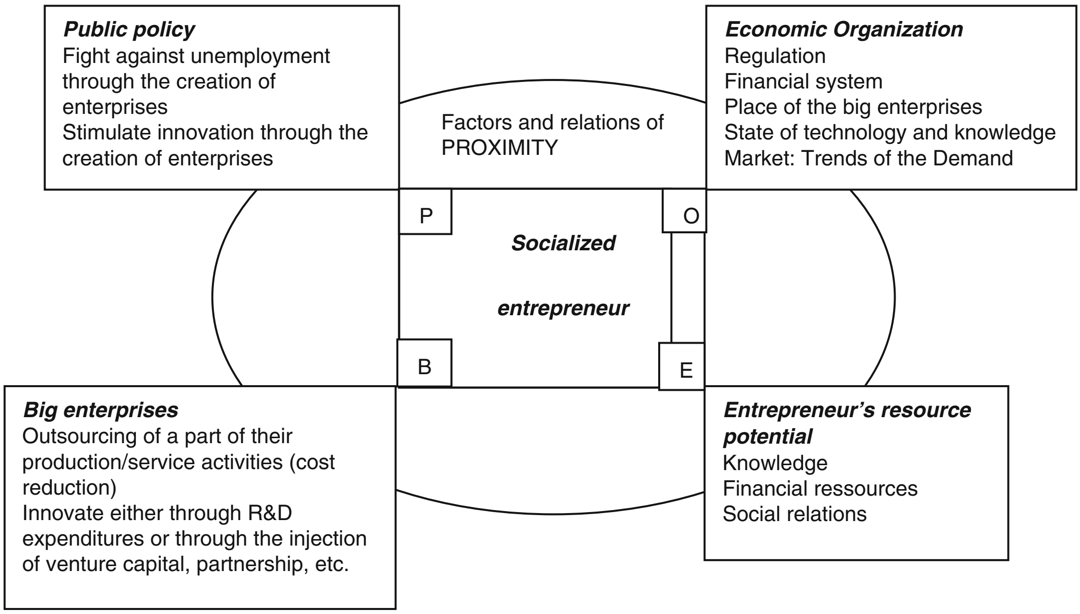
Source: Boutillier (2008), p. 80

The three components of the entrepreneur's resource potential are determined by the place he holds in the social organization chart – in spite of the increasing socialization of the economy. The elements assume a fundamental role. The family gives a taste to start a business; at the same time, it is a source of financing. This phenomenon can be observed in France, in the United States, and also in Russia where the business regulation is very new. A lot of entrepreneurs had a member of their family in business activity. In the Russian case, a lot of entrepreneurs have a member of their family in the Communist Party. It means that the Communist Party is a means to develop social relations. With the support of the family, the functions exerted by the entrepreneur draw their logic from public policies targeted at the dampening of the consequences of the crisis (employment of innovation policies) and from strategies aiming at the productive and financial reorganization of big enterprises (Table 3).

How the Relations of Proximity Increase the Resource Potential of the Entrepreneur?

The ability of the entrepreneur results from the variety and richness of the resource potential he has himself constituted. In its turn, the composition of that resource potential depends on factors that are external to the enterprise and entrepreneur. In particular, public policies of assistance for the creation of businesses (to stimulate innovation and/or to fight against unemployment) will largely determine the financial resources to which the entrepreneur will be authorized to have access in order to create his enterprise and ensure its survival. The economic and social organization has several dimensions and therefore several effects. The general level of development of knowledge and technology in the society will have an impact both on the knowledge acquired and assembled by the entrepreneur (on the basis of his education and the competences of the members of his team; activities related to economic and information watch) and the technological level of his activity. The nature of the financial system (e.g., ease or difficulty of going public, bankers' degree of "conservatism," level of development of venture capital, etc.) influences both the capacity of an individual to become an entrepreneur and the capacity of an enterprise to more or less accelerate its development.

The degree of concentration in the market, for example, the presence of big enterprises, also plays a considerable role in the dynamics of creation of small enterprises and in their type of activity (in particular subcontracting). Finally, it is necessary to underline the policy led by enterprises with a view to innovate either by their own means (R&D budget) or by implementing different types of partnership including the injection of venture capital. In conclusion, the presence and nature of the links between the "POBE" factors

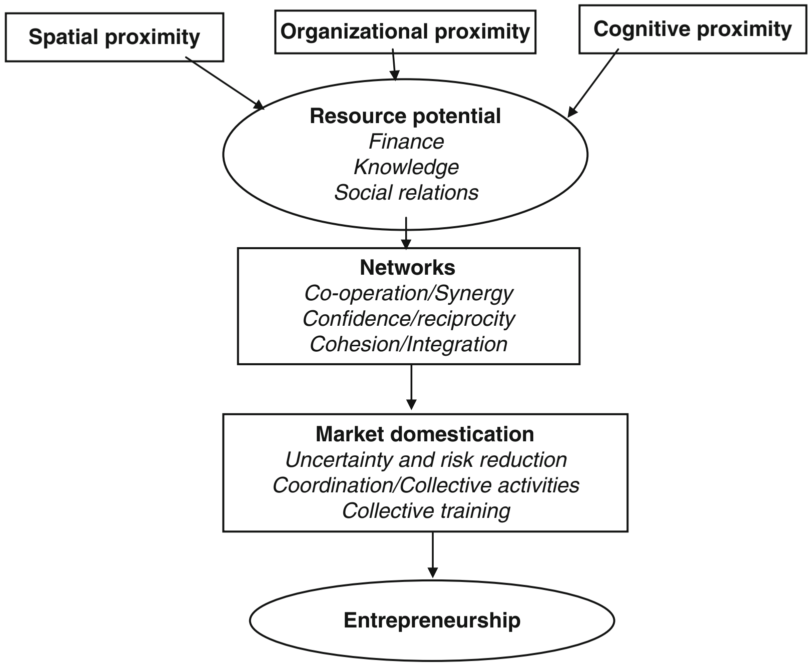


Innovative Milieu as a Driving Force of Innovative Entrepreneurship, Fig. 1 The socialized entrepreneur, the core of the organic square of business activity (Source: Authors)

(public policy, economic organization, big enterprises, entrepreneur's resource potential) lead economists to relocate the entrepreneur in his economic social, political, technological, and spatial context. This organic square provides a way to analyze the creation of enterprises at the scale of a specific local economy (Fig. 1).

The emergence of a "successful" region results from the fact that it is able to manage its own capacity to develop new products, new techniques, and new organizations. Thus, innovative milieu is the combination on a given geographical space of enterprises, training centers, and public or private research units involved in a partnership approach with the purpose of identifying synergies around common projects of an innovative nature. It combines attractiveness (agglomeration effects), diffusion (dispersion effects), and externalities: These three factors are essential for the generation and propagation of innovations. Externalities can be defined (Marshall 1891) as being positive or negative effects, which involve an activity of an economic agent outside this activity or that the agent is subjected to from outside. The most attractive for a company is to achieve, in a setting favorable to investment, substantial external savings, without having to bear the slightest cost that its activity creates for the community as a whole (pollution or various nuisances) (Krugman 1991). It is important therefore to underline that taking the enterprise will create various effects on the local community, but, in return, she will expect from the community means and opportunities to enlarge her property (assets) or where necessary to defend it.

What is favorable to an innovative entrepreneurship offering the possibility to support "network economies" is the existence of an area created, in economic and social terms, by the relations of proximity: infrastructures of transport, communication, telecommunications, education, engineering, etc.; contractual and cognitive interactions; confidence and cooperation; share same codes and business competencies, a dense network of enterprises; fiscal and financial supports and aids, etc. Figure 2 presents the links between the relations of proximity, the resource potential of the entrepreneur, and the realization of socialized



Innovative Milieu as a Driving Force of Innovative Entrepreneurship, Fig. 2 Proximity and entrepreneurship (Source: Authors)

entrepreneurship through the insertion in networks and the risk reduction.

Relations of proximity enrich the resource potential of an entrepreneur and create synergies and a large range of confidence and reciprocity links. With for consequence the reduction of the risks related to the uncertainty of a given investment (market domestication).

The entrepreneurial activities take place in a particular spatial milieu. It is in this milieu that the entrepreneur builds his potential of resources (knowledge, financial resources, and social relations). The entrepreneur develops his social relations in a particular territory, even if his objective is to develop more large-scale (and international) activities. The territory becomes a special innovative milieu by the density and the intensity of the three dimensions of the proximity: spatial, organizational, and cognitive. Enterprises (big or small) can be located in a territory for different reasons (costs reduction, demand access), and if public policy plays a nonneglect role to new business development and attractiveness, the entrepreneur, as a social agent, benefits principally from his relations to create his business. These different social relations (family, socialization, education, etc.) are also the engine of the future development of his enterprise (Ehlinger et al. 2007; Grossetti and Barthe 2008). So, economic activities are embedding (according the Polanyi's concept redefined by Granovetter) in a particular territory.

Conclusion and Future Directions

Since the 1980s, the entrepreneur has made its comeback on the forefront on the economic and political scene. In an approach combining economics and sociology, in this entry, authors tried to go deeper into the analysis of the origin of the entrepreneur's function, studying the construction of his "resource potential," that is, the set of knowledge, social relations, and financial resources gathered together by the entrepreneur in his environment. This resource potential is not stable and may be increased or reduced in different economic, political, and social contexts. According to the approach by the innovative milieu, relations of proximity reinforce the entrepreneur's potential. Business start-up becomes easier. The first meaning of physical proximity was soon supplemented by other interpretations in which the operating field of proximity (space, organization, or institution) is intertwined with the contents of the proximity relationship (information, training, knowledge, technology, etc.). The three types of proximity have made it possible to better examine the process of business creation. The systemic links between an individual and his socioeconomic environment create investment and profit opportunities. If this environment is oriented toward innovation, these opportunities will be more numerous. Thus, the innovative milieu can be studied as a major source of entrepreneurship in the current stage of the market economy.

An innovative milieu, as an innovation system, describes the relationships (scientific, technological, industrial, commercial, financial, political) between private and public institutions (enterprises, research and engineering labs, administrations, etc.). In general, the relationships consist of financial and information flows and the movement of persons. The purpose of that system is to produce innovations (new organizations, new goods and processes, new resources, new combinations of productive resources). This system facilitates business creation on the local level and contributes to define the socialized entrepreneur. This new entrepreneur is a socialized entrepreneur because he develops his activity in a particular economic environment which is structured by the business networks and by the financial, tax, and legal incentives of central or local public authorities.

In a network economy, local economies are now seeking to develop by relying on private initiatives coupled with targeted public and individual action. Investment attractiveness, the capacity to create enterprises, and the creation of jobs determine the performance of an innovative milieu. The milieu is integrated in a context resulting from the development of complex interactions between its actors. These actors and interactions constitute a system which is defined at the same time by its objectives and its composition. The analysis of the innovative milieu as a complex system leads economists and sociologists to study the whole of the local actors (enterprises, authorities, public services, etc.) in relation with the outside. Inside this system, the innovation plays a central role. The integration of the actors within the milieu contributes to the emergence of new enterprises by offering to the future entrepreneur the essential financial, relational, and cognitive resources.

Cross-References

▶ Creative Knowledge Environments
▶ Knowledge Society, Knowledge-Based Economy, and Innovation
▶ Quadruple Helix

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Innovative Milieux and Entrepreneurship (Volume Entrepreneurship)

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Synonyms

Productive local system; Regional cluster; Regional innovation system

Introduction

Spatial economic theory was structured to the 1980s around two alternative thesis: the first one was called the thesis of convergence and the second approach was the thesis of divergence. For the convergence approach, income of production factor should tend to equalize all over the world. On the contrary, for the divergence approach, central and richest regions will keep on winning from their past advantages. But Aydalot (1986) brought to the fore a third way he called "reversal." In such a situation, the old industrialized regions face a persistent decline, whereas new regions, without tradition of industrialization but service-oriented, appear and become richer. The same phenomenon was observed in many European countries and in the

United States. This phenomenon challenged scholars because these regions developed on an endogenous basis. As far as development is concerned, advantages are never permanent. Winning regions can lose their competitive advantages if they do not keep them up, whereas losing regions can overcome their drawbacks to create new advantages.

To revitalize themselves, regions have to develop an important endogenous factor: entrepreneurship. Scholars are still debating on the concept of entrepreneurship. Today, two main approaches exist (Bruyat and Julien 2000). The first approach takes up the work of Turgot and Say and considers that any actor which creates a new activity is an entrepreneur. The second approach, following Schumpeter's work, considers that entrepreneurs are only the innovators. The entrepreneur is the individual who originates the dynamic of evolution in the economy. He detects new opportunities to make profit and creates a new organization to generate the innovation. In this sense, the entrepreneur has a non permanent status. As soon as he stops innovating, he is not still defined as an entrepreneur.

Entrepreneurship can be defined as the creation of a new organization in the economy. This new organization can be created ex nihilo; the owner-manager was not an "entrepreneur" before the creation. The new organization can also be a spin out of a large incumbent company (it is called corporate entrepreneurship) or from a university or a public research organism (academic entrepreneurship).

Innovative Milieux Produce Entrepreneurship

Maillat and Perrin (1992) define a "milieu" as "a geographic space without a strictly defined frontier which is characterized by a kind of unity that one can identify by behaviours. Different kind of actors such as firms, institutions, and public organism of research and formation… are located into the milieu, they own material and immaterial ressources that characterizes the milieu." To sum up, for these authors, milieu has three components: (1) a productive system including various and diversified activities, productive activities, and activities of service (as funding, transport, and consulting); (2) a local workforce market with a work time, which corresponds to the productive specialization of the milieu and a system of training and research that also contributes to the productive specialization; and (3) a dynamic of interaction and learning. Actors located into the milieu interact locally and create between them this structure of organization that allows the functioning of the milieu and the development of innovation. Learning facilitates the adaptation of the milieu to the change of the economic environment. It allows the evolution of the milieu and allows to replace specific resources that are the basis of the competitive advantage of a milieu because these resources differentiate this milieu from the others.

Most of work on entrepreneurship and on the ability to concretize the project of creation insists on the importance for the future owner-manager of two kinds of factors: from the microeconomic point of view personal characteristics of the owner manager and from the macroeconomic point of view the characteristics of the environment (Fisher and Nijkamp 2009).

Schumpeter is the first author that defines the owner-manager as the economic actor who has a peculiar ability to detect new opportunities. This ability is an important component of the entrepreneur's personal characteristics and competences. This competence is differentiated between individuals. Following Audretsch and Aldridge (2009), this ability is linked in an endogenous way to the production of knowledge during the innovation process. When an incumbent firm produces knowledge during its innovative activities, it faces what these authors call the "knowledge filter," i.e., to the gap between produced knowledge and knowledge useful to develop a marketable innovation. The valuation of produced knowledge and its ability to be converted into marketable innovation becomes a competence of actors. The commercial value of knowledge is a source of incertitude for actors. The entrepreneur becomes the actor that detects that some piece of knowledge could acquire a bigger commercial value and tries to exploit that perception, leaving the incumbent firm to set up a new organization. Doing so, the future entrepreneur becomes the actor that will be the transmitter of knowledge spillovers. The entrepreneur will assure the diffusion of knowledge and its concrete use into the new organization. To sum up, the process of innovation activities impulses the apparition of non-exploited opportunities and at the same moment allows the apparition of entrepreneurs. So, the process of knowledge creation generates entrepreneurs endogenously because of the existence of spillover phenomenon.

Initially, most of the works took into account a large environment; it is only recently that scholars took into account spatial environment set up the works on innovative milieux and regional systems of innovation.

To accomplish the setup of the new organization an entrepreneur should be able to mobilize a set of diversified resources. He can mobilize his own resources but also the resources that are located into the milieu. Therefore, the entrepreneur is embedded into the "organic square" of the economy (Uzunidis 2010). The composition of the potential of resources depends of the entrepreneur's own resources, of the economic organization of the milieu, of the relative place of large firms compared to sme's, and of the public policy.

The entrepreneur's resource includes his personal knowledge and diversified kind of capital, including social capital that allows him to access to the social network that he will use at the different stages of the funding process. The economic organization of the milieu is linked to the degree of concentration of the market, to the state of the scientific and technical potential that will get an influence on the technical development of firms, to the nature of the funding system and especially to its facility to grant credits to the firms, and lastly, to the kind of regulation that exists into the milieu (public regulation vs regulation by private operators). The relative importance of large firms plays a part too because it makes the setup of sme's easier or not. Besides, the existence of networks between small and large firms will also make the creation easier. Lastly, public policy can support the creation of new firms with public measure.

Innovative milieux favor entrepreneurship combining three kinds of proximities: geographic proximity (the distances between the actors located into the milieux are small), organized proximity (networks between actors located into the milieu make the milieux function), and cognitive proximity (actors share professional, organizational, and even cultural knowledge. Their interaction leads to the set up of norms of regulation shared among them.). These three kinds of proximities contribute to aliment the potential stock of resources that are available for the actors of the milieu. Besides, networks between local actors contribute to the "domestication of the market," favor the entrepreneurship reducing the risks linked to the creation, and protect new organization during the first stage of the start-up.

So, when the three kinds of proximities are present simultaneously, the dynamic of interaction inside the milieux induces entrepreneurship endogenously and leads to the development of the milieux.

Perrin (1992) studies three different milieux and demonstrates that they have a different capacity to create innovation and entrepreneurship. In the Nice area, the milieu has remained few industrialized for a long time. Firms have only adapted products that were not new to the market using new process neither. In this area, the milieu fails to become an innovative milieu. On the contrary, in the Marseille area, firms belong to medium- and high-tech sector. Firms located outside the region create spin-off located into the city. Public policy played an important part in developing the creation of varied areas of activity and by modifying the productive specialization of the enterprises moving from an industrial specialization to a service orientation. Doing so, public policy managed to attract any large firms interested by the amenities of living into the area. The third case concerns the scientific park of Sophia Antipolis. In fact, this area managed to become a milieu only on the third part of its development, after a long period without any internal interactions between local actors. Lastly, large groups perceived the interest of local interactions and modified the functioning of their plants to impulse local interaction and innovation. In the third case, large groups are the major set up of entrepreneurship creating spin-offs.

However the part played by large firms is ambivalent as far as entrepreneurship is concerned. In fact, large firms can favor new organizations, creating spin out, as they can destructure the industrial tissue of a milieu. Large firms can favor spin outs, but the local milieu will function well only if these large firms will allow local interaction between the new spin out and other organizations of the milieu. Besides, the innovative milieu will survive only as longer as the large firms are interested by local interactions and are convinced of the efficiency of local geographic spillovers. On the contrary, large firms that prevent their local plant from interacting locally will contribute to limit the development of the milieu. Large firms that are located outside of the milieu can also contribute to the malfunctioning by buying the local firms and by using them in a global and nonlocal strategy.

Influence of Entrepreneurship on Innovative Milieux: The Missing Relation

Effects of Entrepreneurship on Regional Growth and Regional Employment

Scholars have identified the relationship between entrepreneurship and regional growth and employment for a long time. But empirical studies have not validated this relationship for a long time. Fritsch (2008) surveyed a set of studies that corroborate the relationship. The entry of new firms on a market affects the competition's process. The first consequence of this entry is to challenge the market position of the competitors and conduce them to more efficiency. Then, the creative destruction process takes place and revitalizes industrial tissue. Public policies generally consider that entrepreneurship has a positive impact on regional growth and employment. Empirical studies that take into account the spatial level of the influence of entrepreneurship are very scarce and generally conducted at the regional level. However, any studies bring to the fore a striking result: setup of start-up would lead to a decline in total regional employment in rural areas and in areas where the birth rate of start-up is weak. On the contrary, the growth of regional employment would be higher in urban areas and areas where the birth rate of start-up is higher.

Networks of the Entrepreneurs During the Setup of the Start-up and During the First Years of the Ongoing Business

Empirical studies about the spatial location of the entrepreneurship's networks during the phase of the setup of the start-up are very scarce. In the pre-start-up phase, entrepreneurs mobilize their social networks. This social network includes member of entrepreneur's family, friends, and neighborhood relationships (Schutjens and Stam 2003). In the setup phase, the entrepreneur's network evolves to include organizations that focus more directly on the direct needs of the start-up as incubators, funders, and various kinds of professional advisors. The creation device support is generally local. Lastly, once the new organization has set up, its network includes customers and suppliers. Besides, the new entrepreneur should set up quickly if he wants the new start-up manage to stay on the market. But many start-ups have no networks at all after many years as Quevit and Bodson (1992) illustrate for the city of Liège. From a spatial viewpoint, the network's start-up does not evolve from local space to international. In fact, start-ups choose the spatial extent of their network directly linking it to their strategy. So, any start ups will choose a local network, whereas others choose directly a national or international network. In fact 39% of the start-up began with an extraregional network and not a local one (Schutjens and Stam 2003). Besides, this network has remained extraregional for a long time.

So, firms have some difficulties to create their milieu because networks are not necessarily established locally. That point limits the interaction dynamic. So, a start-up, even if it locates into a well-developed milieu, does not necessarily take part in the dynamic of local interactions. Doing so, it does not contribute to reinforce the milieu.

Besides, the local dimension of the network will also depend on the firm's sector. Therefore, service firms use more local networks than industrial firms. Besides, the size of the firm will influence the need of a local network. Small firms have a more local network than large firms.

Implications

One of the limits of the innovative milieu approach is the question of their border. Scholars of the GREMI's group have deliberately not defined the border, because they consider that the border must be defined in reference to the interaction systems and the existence of a local culture shared among the actors. But this open definition leads to consider various kinds of spaces as "milieux," e.g., cities, set of cities, or area defined in reference to geographic attributes. This lack of indicator often leads to some practical difficulties to identify a milieu, and the comparison between many case studies of milieu becomes difficult.

Quévit and Bodson (1992) demonstrate that external relationships are as frequent as interactions internal to the local milieu. In such situation, can someone consider that the object identified can be defined as an innovative milieu? In fact, these two authors hesitate to qualify their case as a milieu and prefer to speak of "a nascent dynamic."

The second limit of the approach is due to the fact that a well-functioning milieu is characterized by two dynamics: a dynamic of local interaction and a dynamic of learning. The learning dynamic favors the revitalization of the milieu. If the interaction dynamic has been well documented on various kinds of milieux, it is not the case for the learning dynamic. This dynamic is difficult to observe. Besides, the interaction dynamic should be local to allow the growth of the milieu. But at the same time, the milieu should open to the outside economic space if the milieu wants to remain efficient. So, actors of the milieu should establish both local interaction and external interaction to get some new ideas and sources of innovation and let the milieu renew over time. The way to link the two kinds of interaction is not often studied, whereas it is fundamental to understand how entrepreneurship appears in a milieu.

As far as public policy is concerned, two main points can be underlined. Firstly, Audretsch and Aldridge (2009) bring to the fore the endogenous development of entrepreneurship in the milieu because of knowledge spillovers. From this point of view, any public policy that encourages innovation and knowledge production will sustain entrepreneurship at the same time. Then the debate is to choose to encourage innovation of the public sector or of private organizations. As the social return of research is larger than the private one, public policies should encourage more innovation from the public sector to promote entrepreneurship.

However the experience of many countries, as far as entrepreneurship is concerned, does not corroborate this prediction. And it appears that many other factors can prevent the creation of start-ups. So, public policy has a very important part to play to protect nascent organizations and domesticate the market. Public policy should contribute to reduce the risks that new entrepreneurs take when they create their firm. Public policy still has many instruments to sustain entrepreneurship, but they are not all efficient. For example, incubators get a mitigated outcome. Besides, the financial system plays an important part too, in making the creation and the funding during the first years of the ongoing business easier or not. Public policy could intervene to sustain the funding or encourage financial system to give credit to small firms.

Secondly, public policy promotes entrepreneurship. But if its negative impacts have been brought to the fore by theory, with the well-known effect of Schumpeters' creative destruction, its concrete manifestations are not really taken into account by policies. In fact, today, there are no means of preventing the close down of firms in industries with important modification of competition regimes due to the innovators.

Lastly, the milieu approach can lead to competition between territories. The milieu approach focuses on the endogenous ability of a territory to create factors of development. If the milieu is not able to create these factors by itself, it can try to draw them from the outside, especially firms located in other regions by a policy of grants, for example. But doing so, one milieu can grow more rapidly than another one and become a winner region, but it is at the expense of the other territory. The milieu generates a dynamic of competition between another milieu and from the macroeconomic point of view, the total effect for a country can be negative.

Conclusion and Further Direction

One of the most promising further ways of research is to conduct more work on the missing relationship: one of the influences of the entrepreneurship on innovative milieu. GREMI's group demonstrated that the set up of new entrepreneurs could have negative effects on the future evolution of the milieu. An important change in the kind of activity in which the milieu is specialized, for example, often leads to a phase of decline before a potential recover. But the recover does not appear in all the cases studied. The part played by entrepreneurs into the milieu and their impact on the evolution of the dynamic of interaction is not yet theorized.

The milieu approach remains the most interesting approach to understand endogenous development in connection with entrepreneurship. However this will be true except the different milieu search to draw competitive advantage by drawing factors and especially firms from the outside, increasing competition between territories. In fact, milieu needs the openness to the outside to grow over time, so they should develop more cooperation with other milieux to be connected to various spaces to be able to benefit from the variety of these links.

Cross-References

▶ Entrepreneurship
▶ Entrepreneurship and Business Growth
▶ Innovative Milieu

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Innovative Thinking

▶ Creativity and Innovation: What Is the Difference?

Innovativeness

▶ Creativity and Innovation: What Is the Difference?
▶ Measuring Organizational Climate for Creativity and Innovation

Innovativity

▶ Measuring Organizational Climate for Creativity and Innovation

Innovator

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Synonyms

Entrepreneur; Inventor

The term of innovator is not specified in the economic works. Since some decades, this term has appeared in political statements or journalistic papers.

The nearest concept is entrepreneur and sometimes inventor or even growth leader. Since Cantillon, in the eighteenth century, the entrepreneur has been a man who manages its own business and takes risk. In his book "Theory of economic development" (1911), Schumpeter used this word for the "capitaines d'industrie" who innovate. So he began confusion between the two concepts of entrepreneur and innovator. Today, it appears there are two distinct words for one single concept: the nearly academic word of entrepreneur conceptualized by Schumpeter and the commonly used term of innovator.

This short study will clarify the differences between entrepreneur and innovator and will specify the characteristics and the functions of an innovator.

Definitions

Innovation

To define an innovator, one needs a clear definition of innovation, and strangely, this is not so obvious.

In this entry, an innovation is the implementation of a novel technique at the macroeconomic level, a novel tool, or a new organization in the broadest meaning of those words, in order to sustainably improve the overall economic efficiency of society as a whole.

The innovation value is the "technical rent" of the new efficiency that can be assessed as a Ricardo rent.

Innovation is the implementation of a new kind of value creation.

It should be noted that innovation is a societal phenomenon and that a social choice is required to move from the old to the new technology, organization, or process. This is a complex process that we call the "fragmentary social choice." See hereafter Section "Diffusion: The Fragmentary Social Choice".

The Innovator

The innovator is not totally an inventor or a scholar or a manager. He is not neither a "capitaine d'industrie" nor even an entrepreneur. He is a part of all and assumes the central decision-making functions in the innovation process. This complex function enables the invention (or the idea) to become an innovation through four near-simultaneous operations: financing (1), setting of technical standards (2), definition of the economic model (3), and then the first sales that confirm the previous choices (4). Thereby he initiates a process of "social choice" of innovation. He works more on the market side than on technics. A single person usually performs this complex function. Sometimes several people are needed.

The innovator is usually preceded by the inventor who has almost all the ideas, but the inventor does not know how to organize them for making them suitable for the public. Seizing the opportunity, the entrepreneur gives an industrial dimension to the innovation, follows the innovator. Sometimes, one individual supports two or three functions, mainly as an innovator and entrepreneur, and then begins the confusion between the different functions. In small-scale innovations, said incremental, this innovation function persists but in

Concepts	Kind of value creation	Recipients of value
INNOVATOR	- New kind of value, with a technical rent.	- Mainly, the society as a whole and sometimes the entrepreneur.
ENTREPRENEUR, Founder of any new company including one person company (excluding innovator)	- Value move with a new vector / often, cost cutting.	- Mainly, the founder and his company.
INTRAPRENEUR Growth leader	- Value move, but greater	- The company, and often poorly, the growth leader.
SOCIAL ENTREPRENEUR (Sometimes innovator)	- No market value but a great social value.	- The society as a whole.

Innovator, Fig. 1 Value created by entrepreneur and innovator (Source: Author)

a reduced shape, as J. Schumpeter had stressed it in 1942 (Schumpeter 1942/2008).

We have to underline that innovation is a matter of global efficiency of the society. That means that innovation may include all that has an effect on overall economic efficiency, including some laws or organizations.

Innovator and Entrepreneur

Entrepreneur is a self-ruling person with an objective of "value creation," whereas an innovator is a man who creates new kind of value.

All have a common objective of "value creation." But the nature of the value (or the quality of the opportunity) and its recipients are not the same: if there is an innovation, it is a new kind of value, with a "technical rent." Otherwise, it is only a move of the value inside the society from a recipient to another, not a creation of new kind of value. This is detailed in the Fig. 1.

The Fig. 2 shows the different kinds of innovator and entrepreneur and how these concepts are close, related, and nevertheless different.

As a consequence of the partial recovery of the two concepts of innovator and entrepreneur, we will see overlap between innovation policy and entrepreneurship policy.

Innovation Value and Innovative Company

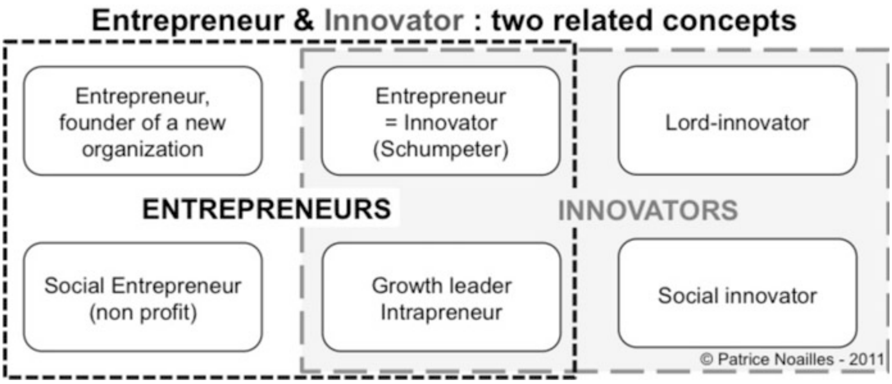
The innovation is a new kind of increase of efficiency and therefore is the source of new kind of value creation. And the value creation is the key figure of the innovation. It is the dimension of the innovation. This concept is a kind of the technical rent which is a Ricardo rent. The greatest this innovation value, the easier it will be to beat conservatism if there is any need of it.

From an economic point of view, the innovative company is the tool of the innovator to spread the innovation value among users, makers, inventors, and himself, through the price and the business model (see Fig. 3, below).

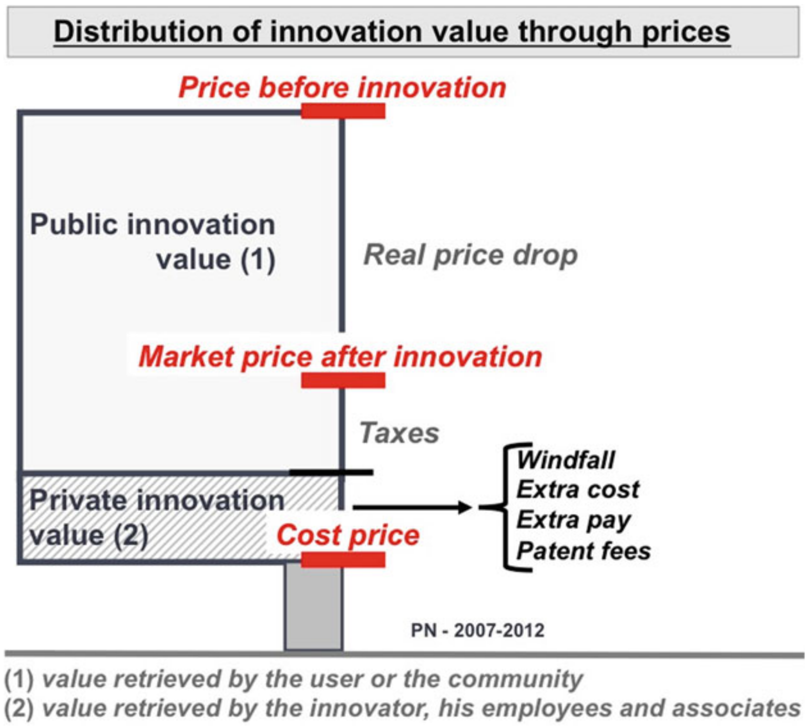
Innovator's Ecosystem

As the innovator is a living being, he has got an ecosystem for living with resources, regulation, and other people around (see Fig. 4). The capacity of innovation is therefore dependent upon environmental factors without quantity effect, except a minimum effect as for artists. But these minima are dependent upon laws, social values, or even civilization as a whole, and even unwritten social rules.

This ecosystem approach is rather new and has been developed outside classic economics by practitioners of law and venture capital. Seen in the "Rainforest" in the references section (Hwang and Horowitt 2012).



Innovator, Fig. 2 Entrepreneur and innovator (Source: Author)



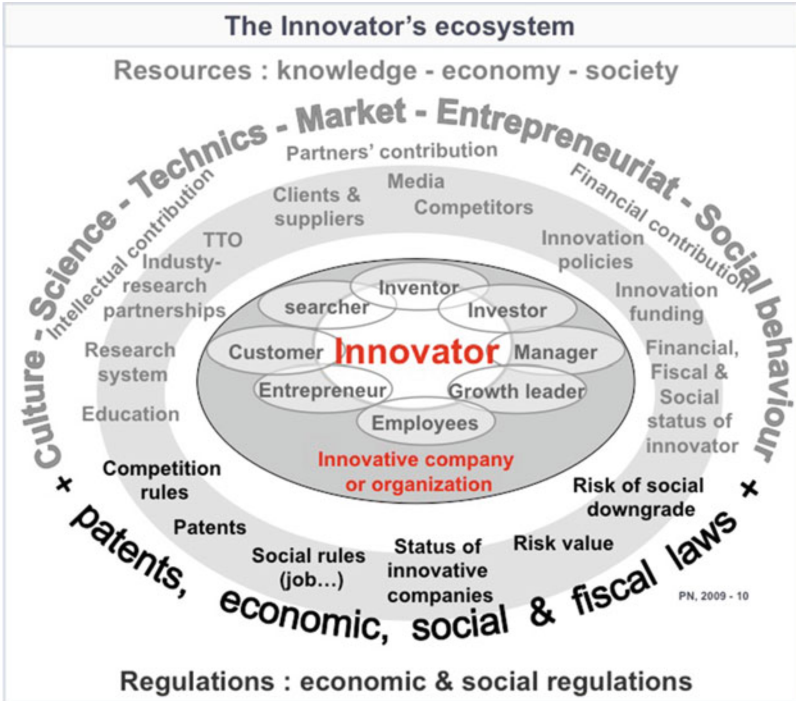
Innovator, Fig. 3 Distribution of innovation value through prices (Source: Author)

Innovators Cases

Through history, there are several examples of innovators. They may be also inventors or entrepreneurs in the same time. These examples help to understand the nature of functions and the profile of men.

Fifteenth Century: Gutenberg Created the First Innovative Company

The path of the printing invention before Gutenberg stays sketchy: some people argue that he may have got information about Chinese or even Korean tools. Nevertheless, he has to make, to finance, and to sell. History got



Innovator, Fig. 4 The innovator's ecosystem (Source: Author)

some information about the work of Gutenberg to finance and build the first printing press and complete set of movable types using metal alloy, including oil-based ink. And he did sell his product defining together the economic models of publisher and printer. At the end, he has got some big trouble with his financial partner.

He became a legend in innovation history. Please note that Gutenberg is the first innovator of the Western civilization with a name. He also is the first creator of an innovative company.

Eighteenth Century: Watt and Boulton Established the First High-Tech Venture

The story – maybe, the legend – of Watt is better known. He is not the inventor of the steam engine but (only?) an improver of the previous steam engine invented by Newcomen 60 years before (see Rolt and Allen 1997). The result was a sharp decline (75%) of coal consumption. Watt used to be an assistant at the University of Glasgow. Boulton has been the second business angel of Watt. The first one, Roebuck, went bankrupted.

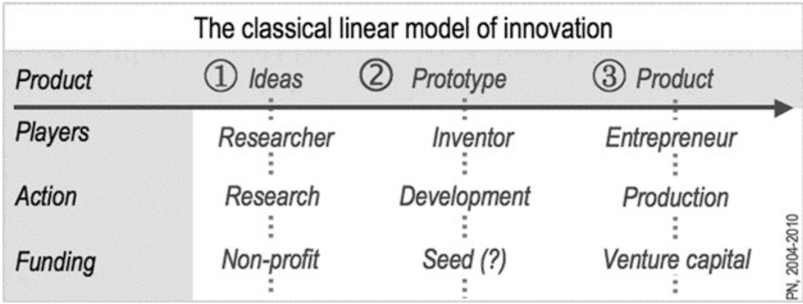
Watt has been considered as the inventor, and he was actually kind of an inventor. His partner Boulton was the main innovator. He brings the money, imagined the business model, and sold the steam machines. Nobody knows Boulton, as it is often the case for the main innovator. And nobody knows Newcomen who is the main inventor as it is also often the case for the main inventor.

Nevertheless Watt took part to the innovation by improving the technical standard of Newcomen. And for this reason, he is also an innovator.

The business model was very modern: the machines were rented (not sold), and at the beginning, the rent was half of the money saved by the leaseholder, by comparison with the Newcomen machine. Roughly, the lease ranged around 1–1.5 times the cost of the coal used by the Watt machine.

Nineteenth Century: Thomas Watson, Graham Bell, and Theodore Vail

Graham Bell is probably one of the most inventive people in the history. But few people know that he needed two more persons to reach success: an assistant (Watson) for inventing and a CEO (Vail)



Innovator, Fig. 5 The classical linear model of innovation (Source: Author)

to manage the business! Together, these three people assumed the innovator function in the Bell Company.

Twentieth Century: The Box of Malcolm Mac Lean (the "Container") Might Be the Biggest Innovation of History with Lowest Scientific Content

Malcolm Mac Lean is both a major innovator and totally unknown. He imagined the container while he was the president, owner, and driver of a "one truck" trucking company, but he developed it several years later when he became the president and owner of a shipping company. As it is explained by Levinson (2006), the Box allowed cutting cost of 90%! It is the main tool of the international trade. Without the Box, the economic development of the world would not be the same. He was an inventor, an innovator, an entrepreneur, and a "capitaine d'industrie." Although the technical side of the innovation was quite simple, the innovation was still complex due to social, legal, and business context. Perhaps the innovator function is often so complex that it requires two or three people to assume it.

Twentieth Century: Steve Wozniak and Steve Jobs

The design and the making of the first microcomputer are well known today. It required two people at least to manage this conception. One must note that neither Job nor Wozniak was CEO of the Apple Company at the beginning. There are pure innovators, but one is on the technical side and the other one on the marketing side. And there is a third one, the CEO on the management side (Gallo 2010; Isaacson 2011).

Theoretical Analysis

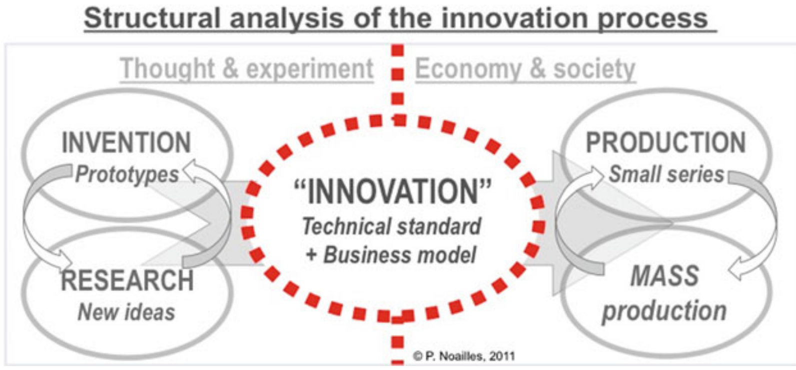
Few more details on the innovation process are needed to understand it and to specify the role of innovator.

The Process of Innovation and the Functions of Innovator

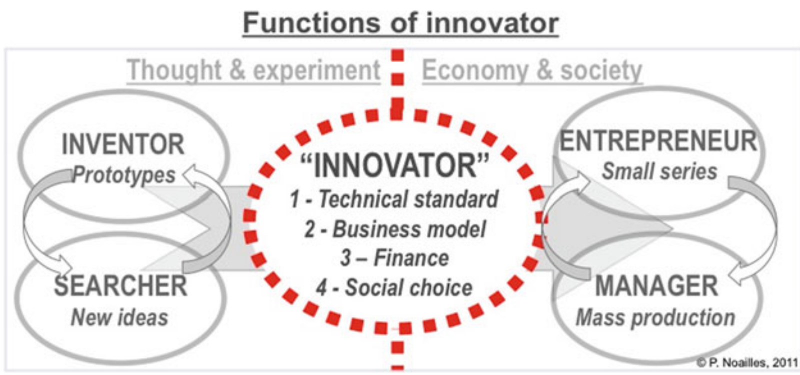
In 1911, J. Schumpeter described the innovation process for the first time. Almost always, people only memorizes a simplified diagram which can be summarized in a linear and seemingly rationale way (Fig. 5). In 1945, Vannevar Bush (inventor and director of the Office of Scientific Research and Development of President Roosevelt) has popularized this model in his report "Science, the endless frontier."

A more detailed analysis shows that there is no linear process but two kinds of complex, random, or unpredictable processes before and after the innovation, and a very complex "step" operation in the middle, named "innovation" which consists in finding in the same time the right technical standard and the good business model and then to finance and to begin to sell successfully (Fig. 6).

The history of technics often shows us that only one man holds this innovation function. We call him "Innovator" (see Fig. 7). The Innovator is the head of the innovation process: he is (or they are) the man (men) that organizes and finances the first definition of the technical standard and of the business model. Then he shows the quality of his choices by the first significant sales, thus initiating the process of fragmentary (or progressive) social choice that will transform the product "invented" into a product widely used (diffusion).



Innovator, Fig. 6 Structural (functional) analysis of innovation process (Source: Author)



Innovator, Fig. 7 The functions and the men (Source: Author)

He is not the inventor who creates and designs the object. He comes at the end of the chain of inventions. He is the man who makes the final choices, or more properly the techno-economic "arbitration" for matching the product to market. He is the man who turns ideas and prototypes into a concrete project suitable to the market and accepted by society. He is followed by the entrepreneur who expands the industrial scale of innovation. Sometimes, he is also a technician, an inventor, a marketing man, a social inventor, or an entrepreneur.

The core of innovation process with *"finance + technical standard + business model + marketing"* is a solution to a complex question. This solution is generally based on the combination of a wide range of knowledge and an extraordinary choice due to a nonrational analysis (e.g., inspired by a vision of the future). It was the case for microcomputer, later PC. The idea of IBM and other companies was a professional tool, whereas the idea of Steve Jobs, Bill Gates, and others was a home computer. The latter imagined and designed a home computer, whereas IBM designed a PC for offices. The market was the home computer concept with possibilities of professional uses. Or in other word a professional computer designed as a home computer. And more important, the business model was standard software and not specific software developments (Gundling 2000; Hargadon 2003; Wessner 2005; Christensen 2011; Goldberg et al. 2011; Cooter and Shäfer 2012).

Diffusion: The Fragmentary Social Choice

If we stay at a level of storytelling, the keywords for diffusion are the percentage of users, with a description: innovators, early adopters, early majority, late majority, laggards (Rogers 1962–2003).

If we want to go through process analysis, we may need a new concept, that is, the fragmentary social choice. This is mainly a market process.

This is a new concept and a significant part of the innovator's work. The innovator begins this process by completing the first substantial sales.

But this is just the beginning. The social choice is not over. New consumers should confirm it. During this period, the innovation (technics and economics) may be improved and sometimes significantly.

Usually, this fragmentary social choice lasts from 10 to 30 years. Among the shortest cases, there are mobile phone and compact disk, which need only few years to get a choice and 10 years to reach a high rate of diffusion over 80%. Among the longest, there is mobile steam engine for railways, which needed several decades from 1795 up to 1830 only to find the correct technical standard. The key problems are economics and technic. But as a whole, the apparent cost paid by the end user is often the main cause for delay. The real keys are the business model plus social behavior and habits.

Patent and imitation were the traditional technical keywords of the diffusion. Even if there are not the real main ones, it must be recalled that patent (invented in Venice in years 1570, to boost an imitator of Gutenberg) is often supposed to help innovators. The questions remain the existence and the length of patent. The only solid argument is history: during the last three centuries, only countries with a solid patent system were innovative.

Men and Functions, Typology of Innovators

The innovator function is different from the man (men) who assumes it. The innovator may be an entrepreneur or an inventor but also a senior corporate executive or a political leader. This typology is the first step in the way to linking man and function.

From Gods to Human People

Six thousand years ago, the ancient civilizations had imagined the "gods of innovation": the Mesopotamian Apkalus under the leadership of Enki must be seen as the distant base common to all Western technological civilizations. Closer to us, 2,000 years ago, and still more unknown, Lug dominates the Celtic pantheon, but he is on the losing side against the Romans. And that is why he has no descent. The Egyptian god Thoth and the Greek god Prometheus have a moderate significance, very far from the influence of Enki and Lug.

Now, let us go down from this pantheon toward the daily reality of innovation. Through economics and history, there are four main types of innovators. This is only a typology with overlaps between functions.

The Innovator–Entrepreneur (Sometimes Inventor)

It is the "mythical" innovator often discussed in economic literature devoted to entrepreneurship. This innovator has been characterized and named by Joseph Schumpeter as an entrepreneur. Sometimes, he is also inventor as was the case for T. Edison or even Louis Blériot. The greatest examples are Steve Jobs, Bill Gates, Thomas Edison, Henry Ford-I, Armand Peugeot, or Louis Renault.

The Lord Innovator (Who is also Often an Entrepreneur)

(Baumol et al. 2010) first used this word for history of enterprise. It refers to these gentlemen who have assumed the role of innovator during the Middle Ages and before. During the nineteenth century, there were many "lords" (rich people) who were committed to innovation from railway to water treatment. Often, they developed some key elements in the economic model as Rothschild and Pereire for French railways (Chemins de Fer du Nord et PLM, now SNCF) or Henri Siméon for the business model of water treatment in France (Compagnie Générale des Eaux, now Veolia, world leader of water treatment).

The "Intrapreneur," Growth Leader or Catalyst

The "intrapreneur" is an employee who develops new ways of working and new products as part of an existing business. He has to deal with hierarchy as well as with the market. In this field, there is no consensus on a well-defined denomination. Finally, one would add all the small players named "Kaizen." They all work on incremental innovations more than on breakthrough innovations. They are the main stakeholders of the "innovation machine" of Baumol (2002).

The Politician

The social choice is sometimes directly made by politicians, especially for the legislative innovations and for the national programs of "modernization." In these cases, the innovator will naturally be a politician. General de Gaulle in France was an archetype of this approach by launching innovative programs but focusing more on research than on innovation. His successor, Georges Pompidou, launched major innovative industrial programs (Ariane, Airbus, civil nuclear power, TGV) which are still the grounds of the industrial power in France 40 years later. Mustafa Kemal in Turkey and John Kennedy in the USA are other icons of this type of approach.

As a conclusion of this portrait gallery, we may add the copycats (Shenkar 2011), followers, and imitators who greatly help modernization, development, and even diffusion. But, of course, they are not truly innovator!

Perspectives on Economics and Sociology

The innovator is someone who not only changes economics, that is, the coefficients of the exchange board of Leontief, but even the rules of the world by finding and developing new products. This is obvious for Edison, Bell, Watt, et al. This is still almost true for small innovators (Kaïzen) who also contribute to change the economic efficiency of the world. This fact offers two prospects for development:

1. Nowadays, economics is based solely on a mathematical rationality that is expressed and summed up by the systematic search for quantitative relationships such as "cause and effect." The mathematic model is the archetype of this "school."

   The "innovator" approach proposes to fulfill the current void in innovation by introducing an element of "chance" in a world of "necessity." It deals with the everlasting question of "change" outside the rules. This question is reminiscent of the biology for the genetic mutations. Basically, it proposes that the innovator is the agent for change. He characterizes his action but does not specify causal relations.
2. The Innovator function initiates and conducts the changes of the society. This function of "innovator" seems to be the same type as that of a farmer, a warrior, or a priest detailed by Dumezil. In fact, their function is to modify the human condition.

Conclusions and Future Directions

This structuralist approach of the innovator function places the innovator at the center of the innovation process that is the Gordian knot of wealth creation. In other words, this put again the man at the center of economics, even if short-term regulation remains a mathematical science.

This approach opens three major debates on the deepening of new concepts, on innovation policies, and on rationalism and humanism.

Deepening New Concepts

All the concepts around the innovator are already known from a managerial point of view. The correlation table is rather quick to set up: the ecosystem is the environment, innovative company is often start-up company, social choice is market penetration, and breakdown of created value is business plan. But they are not the same and they have to be deepened from an economic point of view to become new economic concepts. This maybe the roadmap of innovator and innovation economic studies for the next years.

The Debates on Innovator Policy Versus Innovation Policy

This may be the most important consequence of the birth of a solid innovator concept: a new base for innovation policy.

After a long dispute over the past 20 years, it is now accepted by main *international organizations* that the key factor of development is innovation. The question remains how?

From many reports and studies on the path to success in fostering innovation and from our own experience, we can say that the following rules may avoid you the bitterest failures, but they cannot warrant any success.

Do Only Politics to Avoid the "Broken Dreams" of Traditional Innovation Policies

Through examples, Josh Lerner (2009) showed two points: in each leader regions in entrepreneurship and innovation, such as Silicon Valley, the public sector has played a significant role. However, merely every direct state intervention in the world went to failure!

This point seems to become the first part of the consensus of the policy makers around the world: be politic and not operator. Do not try to manage everything by yourselves. Stay on politics. Do influence your local leaders and establishment but do not try to manage the economy – except with public purchasing policy.

Entrepreneurship Policy is a (Major but not Unique) Part of Innovation Policy

The second part of consensus seems to be that the entrepreneurship policy is a major part of any innovation policy, meaning that innovator–entrepreneur is often the best way to transfer technology from lab to economy. Often, innovator policy is only entrepreneurship policy.

However, innovation policies have to include national innovation strategy with major projects such as the space program or the human genome program.

Take Care of innovator's Ecosystem Instead of Innovation Ecosystem

Following the innovation system during the 1990s, the current favored topic among policy makers seems to be the innovation ecosystem as a result of a systemic analysis. The word sounds well the green vocabulary but seems to be inappropriate, as the innovation is not a living animal. The right concept could be innovator ecosystem including technical, fiscal, financial rules but also social rules, including non-written rules, which may be the most important. Remember that all US states have merely the same laws, but only two small regions (Boston and Silicon valley) feature a high rate of innovation.

Tech Transfer (TT) through Start-up as a Key of Innovation Policies

At the end, the TT, by transferring ideas from laboratories to economy, is the key of the innovation capacity. But the shortest way from laboratories to the economy is not what could often be thought: from laboratories toward existing companies through tech transfer offices. On the contrary, in most cases, the shortest way is to transfer to start-up companies through people and mainly innovators.

Take Care of Local Scientific Base

On the long run, you will need a scientific base for innovation. And this scientific base needs a good education, a large university, and some large laboratories. This is the soil where innovations will grow.

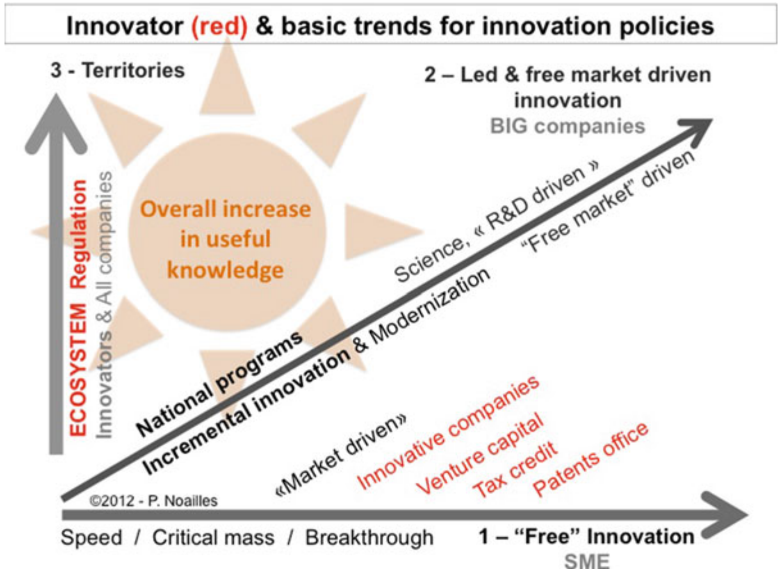
Be Ambitious, Realistic

Remember that innovation is global, complex, and diverse. Innovation policies may have several levels and shapes as shown in Fig. 8.

Rationalism and Humanism

In economics, the innovator is at the center of the dispute between rationalism and humanism. Since Adam Smith, economics is mainly a matter of market (offer and demand) and organizations. On the other side, the Marxist approach ignores the market and sees only structures. Even modern statistical approach focuses on markets and sectors. The best symbol of the rationalist approach of the modern economics is the input–output matrix of Leontief. Unfortunately, this does not explain all the economic activity but only its short-term rational side due to the organization of production. On the other side (nonrationalist), we find more people than structures: this is the human side (and humanistic) of the economy. And the innovator belongs to this nonrational side.

Economics has ignored innovation for two centuries. Technology was an external factor. Until now, 50% of the growth is unexplained by



Innovator, Fig. 8 Innovation versus innovator policies (Source: Author)

rational economics. By now, scholars try to explain 50% of growth with endogenous growth based on the knowledge economy. This knowledge economy totally relies on the combination of tech transfer and the marketing capacities of people. And the idea is to find innovation factors or the best structure to increase tech transfer and marketing. Unfortunately, history shows that there is no direct or rational relationship between laboratory capacities and innovation capacities. For example, research and innovation were not linked for IBM and the home computer, for USSR globally, for the "box" which was developed without any research at all. On the rational side of economics, you only would have to put people in structures and laws to generate innovation. The main objective of this academic science is to identify innovation factors. But they do not exist.

As sociology has to take into account psychology (Moscovici 1980–1991), the "other" side of economics tries to take into account some nonrational people like innovator to overpower the complexity of the modern economy. For instance, we underline that main laws and rules are the same all over the USA and that two small territories are leaders in innovation: Silicon Valley and Road 128. Innovation relies on innovators, not only on written laws. That is why you need an ecosystem approach and not only a regulation approach. Hwang and Horowitt (2012) use the term of "rainforest" for this ecosystem. Coming back to the question of tech transfer, we have to understand that it is mainly dependent on the innovator who is nearly the obligatory go-between from knowledge to the economy. The idea of innovator policies is to find and position the right people in the right ecosystem or even to foster the right people by establishing a right ecosystem.

However, we have also to consider that at the end, conclusions of both sides may join on some decisions like education, tech transfer organizations, fiscal status. Instead of being a question of fight, the innovator could open the door between the two economics: rational and nonrational, structured and humanistic. The combination of both sides is politics. But this is still another great disputation.

Cross-References

▶ Business Model
▶ Corporate Entrepreneurship
▶ Entrepreneur
▶ Entrepreneur's "Resource Potential," Innovation and Networks

▶ Entrepreneurship in Creative Economy
▶ Entrepreneurship Policy
▶ Informal Venture Capital

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Innovator, Competencies

▶ Knowledge Capital and Small Businesses

Insolvency

▶ Firm Failure and Exit

Instinct

▶ Effects of Intuition, Positive Affect, and Training on Creative Problem Solving

Institution – Establishment

▶ Institutional Entrepreneurship, Innovation Systems, and Innovation Policy

Institutional Coercion

► Planned Economy and Entrepreneurial Function

Institutional Entrepreneurship

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Synonyms

Embedded agency; Paradox of agency

Introduction

The term "institutional entrepreneurship" refers to the "activities of actors who have an interest in particular institutional arrangements and who leverage resources to create new institutions or to transform existing ones" (Maguire et al. 2004, p. 657). The term is most closely associated with DiMaggio (1988, p. 14), who argued that "new institutions arise when organized actors with sufficient resources see in them an opportunity to realize interests that they value highly." These actors – institutional entrepreneurs – "create a whole new system of meaning that ties the functioning of disparate sets of institutions together" (Garud et al. 2002). Institutional entrepreneurship is therefore a concept that reintroduces agency, interests, and power into institutional analyses of organizations. It thus offers promise to researchers seeking to bridge what have come to be called the "old" and "new" institutionalisms in organizational analysis (Greenwood and Hinings 1996).

The entry begins with some observations on institutional entrepreneurship stemming from its paradoxical nature. Research on institutions has tended to emphasize how organizational processes are shaped by institutional forces that reinforce continuity and reward conformity. In contrast, the literature on entrepreneurship tends to emphasize how organizational processes and institutions themselves are shaped by creative entrepreneurial forces that bring about change. The juxtaposition of these contradictory forces into a single concept generates a promising tension – one that opens up avenues for inquiry into how processes associated with continuity and change unfold, and, how such unfolding processes can be influenced strategically. Accordingly, the entry first discusses the two core concepts underpinning the focus of this special issue, institutions and entrepreneurship, paying particular attention to how they emphasize aspects of social life that are seemingly at odds with one another. It then shows how the apparent contradictions that arise when these concepts are combined into "institutional entrepreneurship" relate to the paradox of embedded agency.

Institutions

Institutions are commonly defined as "rules, norms, and beliefs that describe reality for the organization, explaining what is and is not, what can be acted upon and what cannot" (Hoffman 1999, p. 351). As taken for granted, culturally

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embedded understandings, they specify and justify social arrangements and behaviors, both formal and informal. Institutions can thus be usefully viewed as performance scripts that provide "stable designs for chronically repeated activity sequences," deviations from which are counteracted by sanctions or are costly in some manner (Jepperson 1991, p. 145).

Organizations exist in an environment of institutions that exert some degree of pressure on them; institutional environments are "characterized by the elaboration of rules and requirements to which individual organizations must conform if they are to receive support and legitimacy" (Scott 1995, p. 132). Institutions constrain behavior as a result of processes associated with three institutional pillars: the regulative, which guides action through coercion and threat of formal sanction; the normative, which guides action through norms of acceptability, morality, and ethics; and the cognitive, which guides action through the very categories and frames by which actors know and interpret their world (Scott 1995).

Institutional arrangements are fundamental to understanding organization because of the ways in which they tend to be reproduced without much reflection in practice, become taken for granted, and create path dependencies. As a result, organizational scholars, whether adopting economic, sociological, or cognitive perspectives, have traditionally focused on the critical role that institutions play in providing continuity and stability in organizational processes.

Among institutional economists, for instance, the appearance and maintenance of institutional arrangements are explained in terms of economizing on transaction costs (Coase 1937; Williamson 1985). According to this perspective, institutional arrangements function to reduce uncertainty and to mitigate opportunistic behavior such that transaction costs associated with negotiating, monitoring, and enforcing contracts between boundedly rational actors are reduced. Institutional arrangements, in turn, tend to reproduce – rather than change – existing social arrangements.

Sociological perspectives on institutional theory emphasize how institutional arrangements confer legitimacy, which is "a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman 1995, p. 574). As a result, some actions within a particular institutional field come to be seen as legitimate (Meyer and Rowan 1977) and may even be "prescribed," making it difficult for actors to deviate from them.

Literature on cognitive processes views actors as interpreters of ambiguous symbols and constructors of meaning. Thus, mutually understood schemas, mental models, frames, and rules of typification channel the sense-making activities of individuals, who are caught in webs of significance of their own making. Actors engage in organizing as a "consensually validated grammar for reducing equivocality by means of sensible interlocked behaviors," thereby translating "ongoing interdependent actions into sensible sequences that generate sensible outcomes" (Weick 1979, p. 3). With this view, institutions – shared cognitive frames – give meaning to inherently equivocal informational inputs by directing sense-making processes. Moreover, the shared nature of these cognitive frames makes it difficult to stray far from them in either thought or deed.

In sum, the institutional literature, whether it focuses on economics, sociology, or cognition, has largely focused on explaining the stability and persistence of institutions as well as isomorphic change in fields. More recently, however, there has been interest in how non-isomorphic change can be explained using an institutional lens, as well as what is nature of the "institutional work" needed to create, maintain, transform, or disrupt institutions (Lawrence and Suddaby 2006; Hardy and Maguire 2007). Associated with this has also been a emphasis on processes of contestation and struggle within and over institutional fields (Garud and Rappa 1994; Maguire and Hardy 2006), which are viewed as political arenas in which power relations are maintained or transformed (Lounsbury and Ventresca 2003).

Entrepreneurship

To understand the critical role that entrepreneurship plays in the functioning of the modern economy, one only needs to refer to insights offered by Schumpeter (1942). For Schumpeter, entrepreneurship is an engine of economic growth with the introduction of new technologies and the consequent potential for obsolescence serving to discipline firms in their struggle to survive perennial gales of creative destruction. The disruptions generated by creative destruction are exploited by individuals who are alert enough to exploit the opportunities that arise (Shane and Venkataraman 2000).

From a sociological perspective, change associated with entrepreneurship implies deviations from some norm (Garud and Karnøe 2001). Consequently, it is unlikely that entrepreneurial outcomes and processes will be readily embraced by actors committed to existing ways of doing things in a particular field. To be successful, then, entrepreneurial efforts have to gain legitimacy, an undertaking that is made more difficult as more social groups with heterogeneous interests are involved. Indeed, as novel outcomes from entrepreneurial efforts spread, more diverse social groups will be affected and possibly mobilized, and, in the process, new legitimacy battles will be spawned.

Lachmann's work (e.g., 1986) highlights the active creation rather than the mere discovery of entrepreneurial opportunities, and it is here that literature from cognitive psychology sheds light. Cognitive psychology notes that the genesis of novelty is frequently driven by "bisociation," the intermingling of seemingly unrelated ideas from different knowledge domains (Koestler 1964), and is facilitated by metaphors and analogies (Tsoukas 1991). Indeed, just as new technological artifacts may emerge from recombination of material resources, new insights may also emerge from recombination of intellectual resources, a process in which outcomes are indeterminate. As products of recombination, new ideas have to overcome problems of legitimacy that arise when categories are crossed.

Common to all these perspectives on entrepreneurship is an appreciation that the emergence of novelty is not an easy or predictable process as it is ripe with politics and ongoing negotiation. What may appear to be new and valuable to one social group may seem threatening to another. Thus, as with institutional theory, the literature on entrepreneurship has also had to come to grips with issues of agency, interests, and power, but it has approached these from the perspective of change rather than continuity.

Work on institutions has, then, traditionally focused on continuity although it increasingly acknowledges the importance of change. In contrast, the work on entrepreneurship has focused on change even as it acknowledges that change is difficult to accomplish. The juxtaposing of institutional and entrepreneurial forces into a single concept, institutional entrepreneurship, thus offers considerable promise for understanding how and why certain novel organizing solutions – new practices or new organizational forms, for example – come into existence and become well established over time.

Separately, each body of literature faces the limitations associated with the longstanding "structure-agency" debate. Privileging structure over agency leads to causally deterministic models wherein some features of the social world become reified and "structure" others, voiding agency and creativity from humans, which in the extreme are assumed to be automaton-like processors of objective information rather than interpreters of intrinsically ambiguous symbolic inputs. In assuming that structures frustrate and, in the extreme, render agency by individual actors impossible, this work explains stasis and continuity; but it is less equipped to deal with change. Theories that privilege agency, on the other hand, often promote heroic models of actors and have been criticized for being ahistorical, decontextualized, and universalistic. Moreover, by emphasizing intentionality, such theories give little attention to unintended consequences of action, which are important components of the reproduction of institutions.

Conclusions and Future Directions

Researchers from a wide range of disciplines have attempted to address these issues by offering theoretical perspectives that combine structure and agency in some form of mutuality constitutive duality. Giddens's (1984) work on "structuration" and Bourdieu's (1977) notion of "habitus" are, perhaps, the most well known (Mutch 2007). According to these researchers, structure is both the medium and outcome of social practices: Instead of being in opposition, structure and agency presuppose each other and are mutually constitutive.

Within institutional theory, this broader structure-agency debate is often referred to the paradox of embedded agency (Seo and Creed 2002). The theoretical puzzle is as follows: If actors are embedded in an institutional field and subject to regulative, normative, and cognitive processes that structure their cognitions, define their interests, and produce their identities, how are they able to envision new practices and then subsequently get others to adopt them? Dominant actors in a given field may have the power to force change but often lack the motivation, while peripheral players may have the incentive to create and champion new practices, but often lack the power to change institutions (Maguire 2007).

One answer to this puzzle lies in conceptualizing agency as being distributed within the structures that actors themselves have created (Garud and Karnøe 2003). Consequently, embedding structures do not simply generate constraints on agency but, instead, provide a platform for the unfolding of entrepreneurial activities. According to this view, actors are knowledgeable agents with a capacity to reflect and act in ways other than those prescribed by taken-for-granted social rules and technological artifacts (Garud and Karnøe 2003). Agency is "the temporally constructed engagement by actors of different structural environments – the temporal-relational contexts of action – which, through the interplay of habit, imagination, and judgment, both reproduces and transforms those structures in interactive response to the problems posed by changing historical situations" (Emirbayer and Mische 1998, p. 970). Conceptualized in this way, institutional structures do not necessarily constrain agency but, instead, may also serve as the fabric to be used for the unfolding of entrepreneurial activities.

Institutional entrepreneurship not only involves the "capacity to imagine alternative possibilities," it also requires the ability "to contextualize past habits and future projects within the contingencies of the moment" if existing institutions are to be transformed (Emirbayer and Mische 1998, p. 963). To qualify as institutional entrepreneurs, individuals must break with existing rules and practices associated with the dominant institutional logic(s) *and* institutionalize the alternative rules, practices, or logics they are championing (Garud and Karnøe 2001; Battilana 2006). Thus, strategies must be developed to embed change in fields populated by diverse organizations, many of whom are invested in, committed to, and advantaged by existing structural arrangements. It is not surprising, therefore, that institutional entrepreneurship is viewed as an intensely political process (Garud et al. 2002).

Efforts at theorizing struggles over institutional arrangements have generated interest in the linguistic and symbolic aspects of power where the focus is on the meanings that humans attribute to a situation which, in turn, influences how they act in relation to it. Lukes (1974) focused on the power of meaning when he introduced his notion of a third dimension of power (Levy and Scully 2007), an unobtrusive form of power to create particular meanings for desired outcomes (Hardy 1985). In the context of institutional theory, the relationship between power and meaning has been addressed through the concept of "translation" (Zilber 2006), which is premised on the idea that the meaning of practices is negotiated locally (Lounsbury and Crumley 2007), with practices becoming institutionalized as meanings become shared and taken for granted across the wider field (Zilber 2007). This work challenges the idea that new practices are transmitted intact and unproblematically and, instead, emphasizes negotiations "between various parties, and the reshaping of what is finally being transmitted" (Zilber 2006, p. 283).

Efforts at shaping institutions will not go uncontested, and, therefore, these attempts can easily go awry (Garud et al. 2001). Consequently, institutional entrepreneurs must be skilled actors (Perkmann and Spicer 2007) who can draw on existing cultural and linguistic materials to narrate and theorize change in ways that give other social groups reasons to cooperate (Child et al. 2007). To this end, institutional entrepreneurs use "framing" strategically (Khan et al. 2007), articulating their change projects in particular ways to "define the grievances and interests of aggrieved constituencies, diagnose causes, assign blame, provide solutions, and enable collective attribution processes to operate" (Snow and Benford 1992, p.150). Through particular frames, new practices can be justified as indispensable, valid, and appropriate. This, in turn, can help mobilize wide-ranging coalitions of diverse groups and to generate the collective action necessary to secure support for and acceptance of institutional change (Wijen and Ansari 2007).

In conclusion, research on institutional entrepreneurship remains popular, particularly because of the paradox of embedded agency, and a range of different approaches are being employed to learn more about these dynamics (see Hardy and Maguire 2008; Battilana et al. 2009; Garud et al. 2010). Future research will, however, need to tread a fine line between putting agency back into institutional analyses of organizations and unreflexively privileging heroic "entrepreneurs" (Hardy and Maguire 2008; Garud et al. 2010).

Cross-References

- ▶ Entrepreneurial Opportunity
- ▶ Extrapreneurship
- ▶ Network and Entrepreneurship
- ▶ Social Entrepreneurship

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Institutional Entrepreneurship, Innovation Systems, and Innovation Policy

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Synonyms

Entrepreneur – change agent, promoter, broker; Innovation – deviation, alteration, implemented novelty; Institution – establishment; Policy – line, program; System – arrangement

Key Concepts and Definitions

Institutional Entrepreneurship

Institutional entrepreneurs are actors who initiate changes that contribute to transformation of existing institutions and/or creating new ones (Battilana et al. 2009). Institutional entrepreneurs can be organizations or groups of organizations or individuals or groups of individuals who act as change agents. They are actors who initiate divergent changes and actively participate in the implementation of them (Battilana et al. 2009, p. 67).

The concept of institutional entrepreneurship was first introduced by Paul DiMaggio in 1988, and it is based on his observation that organized actors do not only comply with institutions but consciously aim to create institutions or to transform existing ones, and for this purpose, they mobilize resources, competences, and powers (DiMaggio 1988).

Institution

Different schools of thought define *institutions* differently. Scott's (2001) three-dimensional view cuts cross many schools. According to Scott, institutions are composed of regulative, normative, and cultural-cognitive pillars. The regulative pillar highlights institutions as constraining forces that regularize behavior. It frames individual actions and choices by rule setting, monitoring, rewarding, and sanctioning activities. The normative pillar includes values and norms that by prescription, evaluation, and obligations frame individual actions and choices. Normative pillar consists of factors that influence actors' choices and actions by informing what is preferred and/or desirable. It also informs about the standards on which existing structures are based (Scott 2001, pp. 51–54). For its part, the cultural-cognitive pillar stresses those external frameworks that shape actors' internal interpretation processes (Scott 2001, p. 57) and, therefore, demolished, renewed, and/or totally new institutions change the ways actors see, interpret, and understand themselves, their actions, and positions in wider structures (Sotarauta and Pulkkinen 2011).

Innovation System and Innovation

The dynamic and continuously expanding body of research shows how industries, firms, and the public sector actors, in their efforts to create new innovations, are embedded in national, sectoral, and/or regional *innovation systems* (Lundvall 1992; Braczyk et al. 1998; Malerba 2002) and how innovation systems are constructed on knowledge-creating and knowledge-utilizing subsystems (Autio 1998).

An innovation system consists all the relevant economic, social, political, organizational, and other institutional factors that influence the development, diffusion, and use of new knowledge (Edquist 2008, p. 5) and have an influence on individuals', firms', and organizations' learning capacity and hence on their ability to innovate (Lundvall 1992; Lundvall et al. 2002). All this is supposed to produce new creations of economic and/or societal significance, i.e., *innovations* that are widely accepted as primary sources of renewal in a global economy (e.g., Edquist 2005).

The various approaches on innovation systems stress, according to a narrow definition, "interacting private and public firms, universities, and government agencies aiming at the production of science and technology" (Niosi et al. 1993) and "networks of institutions that in interaction initiate, import, modify, and diffuse new technologies" (Freeman 1987). Additionally, according to a broader view, innovation systems consist of organizations and institutions affecting and supporting learning and innovation (not only focusing on science and technology), and thus, according to this view, innovation system embraces also such actors that earlier were not seen influencing innovation (Asheim and Gertler 2005, p. 300).

In the literature on innovation systems, such factors as intellectual property right laws; other laws; various standards; environment, safety, and ethical regulations; organization-specific rules; industry specialization and structure; governance structure; financial system; structure of the research and development; R&D investment routines; and training and competence building system as well as operational cultural factors are raised as institutions (see, e.g., Autio 1998; Braczyk et al. 1998; Edquist 2005, 2008).

Institutional entrepreneurs are here seen as those actors who consciously work to change the institutional environment to better support the many functions of an innovation system and hence creation of innovations.

Innovation Policy

In innovation studies, innovation policy is fairly generally seen as actions by public organizations that influence innovation processes (Edquist 2008). Innovation policy is usually seen to consist of explicit measures to promote the generation, diffusion, and efficient use of new products, services, and processes in markets or more widely in a society. Innovation policy often has wider objectives than those focusing only on science and technology even though it more often than not incorporates elements of these. Consequently, broad-based innovation policy may cover a wide range of initiatives that are linked to science, technology, user needs, societal demand, and education.

Recent studies emphasize that contemporary innovation policies are designed and implemented in multi-actor innovation arenas and related networks (state–region–municipality–firm–university–polytechnic) (Kuhlmann 2001; Sotarauta and Kosonen 2013). Consequently, multi-actor forms of innovation policy challenge the straightforward definitions of innovation policy that see it as something only the public sector performs alone. Innovation policy is one arena among many through which institutional entrepreneurs may work to change institutions, and on the other hand, changes in innovation policy may be a consequence of institutional changes.

Open-Ended Issues and a Selection of Main Challenges

Agency: What Actors Do to Change Institutions for Innovation?

Institutions being central in promotion of innovation following generic questions guide studies focusing on institutional entrepreneurship in the context of innovation systems: (a) how to promote institutional change for better innovation systems and, consequently, (b) how to create, demolish, and change something that is stable and a source of order and a product of emergent properties (Sotarauta and Pulkkinen 2011). Indeed, there are calls for explicit efforts to change institutions for innovation. For example, Lundvall et al. (2002, p. 255) call for deeper understanding of transformation processes of innovation systems at an institutional level. They also see that the institutions as such are not as important targets of study as the processes of institutionalization are.

Institutions by definition imply permanence and stability, and one of their key characteristics is that they are resistant to change. This kind of restrictive perspective reminds that actions deviating from what is framed as appropriate by institutions are often sanctioned, one way or another. In the literature, restrictive view has recently been actively complemented, and also the enabling role of institutions is being acknowledged (Hage and Meeus 2006). Therefore, an institution can be interpreted both as an object of change itself and as a constraining as well as an enabling and incentivizing structure for change (Soskice 1999, p. 102). Institutional approach has been criticized for its inability to explain transformation and institutional change and more generally for predicating compliance and conformity. This critique, for its part, has generated increasing interest in the role of agency in institutional change and thus also institutional entrepreneurship (Tracey et al. 2010).

Of course, in the literature that focuses on national, regional, and sectoral systems of innovation, there already are several notable examples of the efforts to understand how institutional systems affect innovation and how innovation may also affect institutional change. However, policy process and agency as well as institutional change still are black boxes for students of innovation system. Innovation systems are often treated as if they function well or transform themselves without conscious efforts to change them (Uyarra 2010). Additionally, as Uyarra (2010) also states, innovation scholars often do not peep into policy processes but assume that they progress step-by-step from analysis to policy design to implementation and action. For these reasons, institutional entrepreneurship is gaining more ground as it aims to add knowledge in how social actors work to change the institutions that govern their own activity. Indeed, it improves understanding of the ways power is exercised in these efforts and how actors strategize and mobilize tangible and intangible resources for institutional change (Garud et al. 2007).

The point of departure here is that by taking institutional entrepreneurship as a key organizing device also in studies focusing on innovation systems, an analytical leverage could be added and thus to better understand institutional change, agency, and policy processes.

Complex Social Process: What Is Going on in Innovation Systems?

DiMaggio and Powell (1991) maintain that when adopting institutional entrepreneurship as theoretical lens, institutions can be studied as outcomes of complex social processes and as products of human agency. Institutional entrepreneurship provides an analytical framework to study what various agents do in cooperation and/or competition with each other to change institutions; how they interact, relate, and evolve with wider institutional constellations; and importantly, what kinds of risks they take and what they invest personally in the change efforts. Consequently, this kind of approach highlights the importance of studying interests, legitimacy, strategy, and power (Levy and Scully 2007), while the more conventional approaches on innovation systems highlight the presence or absence of actors, institutions, and interaction patterns (Uyarra and Flanagan 2010, p. 683).

By definition, an actor needs to be intentional in action to be recognized as an institutional entrepreneur. In studies on institutional entrepreneurship, it is important to distinguish forms of institutional change that are relatively spontaneous and emergent from those that take shape with considerable strategizing, organizing, and coordination (Sotarauta and Pulkkinen 2011). This distinction may help in the efforts to understand what institutions can be shaped and how. Additionally, there is a need to ask to what extent and under what circumstances institutions can be directed. Clearly, conscious efforts to change institutions and emergent development patterns are in many ways intertwined. Intentionality of purposive change agents needs, more or less, to be adjusted to emergent properties, those being outside the reach of institutional entrepreneurs. For these reasons, it is not suggested here that there might be some kind of predestined causality between institutional entrepreneurs' actions and institutional change.

At best, institutional entrepreneurship studies are a form of process-oriented inquiry where the role of actors is fleshed out by analyzing the change processes in which the institutional structure coevolves with actors; thus, the interaction between structure and actors needs to be seen as bidirectional.

Embedded Agency: How Actors Aim to Change Something That Frames Their Own Actions?

Hall and Thelen (2009) divide the role of agency to institutional change into three main types: (a) reform (institutional change explicitly directed or endorsed by the actors), (b) defection (key actors cease behaving according to the rules and practices prescribed by a preexisting institution), and (c) reinterpretation (the actors learn new ways of thinking and consciously create new interpretations of themselves, rules as well as practices without abolishing the institution itself).

Institutional entrepreneurs may possess a formal position to attack institutional arrangements by applying above-mentioned generic strategies, but some of them may not have it. It would be tempting to assume that mayors, leading policy makers, CEOs of main firms, vice chancellors, and other authorities with formal positions would somehow automatically be institutional entrepreneurs. There is a need for both conceptual development and more fine-grained empirical analyses before it would be possible to reliably answer to the question who institutional entrepreneurs in different situations actually are (Sotarauta and Pulkkinen 2011). Of course, whoever institutional entrepreneurs are and whatever their change strategies may be, their freedom to push for institutional change is limited in situations of fragmented power and authority. Interestingly, institutional entrepreneurs are constrained by the very same institutions they aim to change, and therefore, their work is a form of "embedded agency" (see more, in Battilana 2006; Leca and Naccache 2006; Seo and Creed 2002).

A core belief underlying in the approach suggested here is the importance of understanding interactions between actors and their institutional settings. It is more or less impossible to understand institutional entrepreneurship without understanding how actors shape institutions they are embedded into and how institutions shape their actions. This calls for relational, contextual, and systemic understanding. This kind of *process and system-oriented approach locates institutional entrepreneurship not in the attributes of individuals but in the relationships connecting actors in an innovation system and institutional change*. To understand these kinds of institutional change processes, it is important to ask the following: How do institutional entrepreneurs deal with change? What kind of change strategies do they launch? What is the combination of change strategies they adopt in specific situations at specific times? How can actors innovate and renew institutional settings if the very institutional environment they wish to change determines their beliefs and actions? How do they resolve the paradoxical situation in which they aim to change those institutions that frame their very actions? How do they earn/take their positions? Who are the institutional entrepreneurs in different institutional contexts? (Sotarauta and Pulkkinen 2011).

Institutional Change: How Institutions Governing Innovation Change?

When studying institutional change, there is a danger to fall into a "radical change trap" and focus mainly on those changes that are easy to detect and observe and thus to see change as a discontinuous period between periods of stability and continuity. This kind of view on change might lead to simplified accounts on institutional entrepreneurs' roles in institutional change. It is suggested here, inspired by Streeck and Thelen (2005), that there is a need to be more sensitive to gradual transformations. Incremental changes are not only reactive and adaptive for the protection of institutional continuity, as often assumed. Accumulation of subtle, seemingly minor changes in longer periods of time can lead to considerable discontinuity that may surface beneath the apparent stability. Indeed, "creeping change" (gradual transformation) suggests that there are no optimum states but a constant search is a core in institutional change processes (Streeck and Thelen 2005) and thus also in the strategies adopted by institutional entrepreneurs. All this suggests that when studying institutional entrepreneurship, there is a need to be sensitive to continuity and discontinuity as well as incremental and abrupt changes and their combinations.

Broader View on Institutions Called for: What Are They?

In spite of the fairly generally shared understanding that institutions mediate in subtle but pervasive ways evolutionary trajectories of economies. Their specific roles in the innovation puzzle are still poorly understood and perhaps even underappreciated. While innovation system literature highlights the role of institutions, they have been conceptualized and empirically studied with fairly narrow lenses. In innovation studies, institutions are often conceptualized as rules of the game, while organizations are seen as players (e.g., Edquist 2005). Hodgson, however, argues that also an organization can be, but not always is, an institution in itself (Hodgson 2006). Some of the organizations may evolve so that they end up framing the actions and choices of other actors and thus become institutions by themselves (e.g., universities in their own countries and regions and Nokia in Finland).

All in all, the ultimate question is why and how certain institutional arrangements facilitate economic development and innovation while others seem to hinder them, and to answer this question, the fairly clear-cut distinction between institutions and organizations need to be reconsidered and the notoriously complex and context-sensitive nature of the concept appreciated. It is suggested here that institutions governing innovation systems ought to be approached as a context-specific and open empirical question. It is also suggested that by focusing on what actors actually do to change the conditions for innovation might enable us to learn more about the true nature of institutions.

Implications for Policy and Practice

Innovation policy has been stressed throughout the world as a way to renew economies and cope with challenges of globalizing world. Simultaneously, there is a growing understanding that there are no one-size-fits-all innovation systems or policies in circulation (Tödling and Trippl 2005). This suggests that institutions framing both innovation systems and policies differ significantly between many different types of regions and countries. For example, as shown by Asheim et al. (2011), even in relatively small countries like the Nordic countries, which in many ways are fairly similar to each other, innovation policies indeed differ from each other.

The Nordic countries are only one example among many how institutions mediate economic development paths and how historically rooted national institutions frame the choices of both individuals, firms, and policy makers. More explicit focus on institutional entrepreneurship might enable policy makers to better understand the nature of both institutional obstacles and ways to cross them, instead of searching for ways to adapt to latest buzzwords in global circulation. Additionally, by explicit focus on institutional entrepreneurship, it might be possible to identify the true roles of policy making in different situations, and thus, it might be possible to design more sophisticated policy approaches and policies.

Conclusions and Future Directions

The main challenge in studies aiming to understand innovation systems by an explicit view on how institutions change and on what actors do to change them is to understand the dynamics of institutional change with a microlevel analytical lens. This calls for (a) identification of institutions that are locking industries, countries, and/or regions into the past development path or slowing their transformation down; (b) analysis of the ways actors aim to demolish and/or renew these institutions; and (c) identification of strategies different actors adopt when aiming to create new institutions to support the emergence of a new development path (see also Sotarauta and Pulkkinen 2011). The concept of institutional entrepreneurship might offer a conceptual lens in these efforts by seeking for a balance between structure and actor.

Institutional entrepreneurship provides an analytical framework of how various agents aim to change institutions as well as how they interact, relate, and evolve with wider institutional constellations. Especially important for this line of study is the notion that micro-agent change leads to macro system evolution, i.e., before change at a macro level can be seen, it is taking place at many microlevels simultaneously.

Institutional entrepreneurship needs to be studied with three perspectives in mind: (a) the *process* perspective that informs a study on the dynamism of innovation systems and secures a temporally conscious approach; (b) the *network* perspective that informs about the social relationships of the actors in and beyond a innovation system; and (c) the *governance* perspective that informs about the wider systemic issues framing and molding both the actual systems and change processes as well as forms of institutional entrepreneurship.

Ultimately, to repeat and conclude, the aim of taking institutional entrepreneurship under close scrutiny is to add analytical leverage to endogenous innovation processes and systems and find a fresh lens that enables studies operating in between macro and micro issues.

Cross-References

- ▶ Academic Entrepreneur, Academic Entrepreneurship
- ▶ Co-conception and Entrepreneurial Strategies
- ▶ Corporate Entrepreneurship
- ▶ Creative Knowledge Environments
- ▶ Entrepreneurial Capability and Leadership
- ▶ Entrepreneurial Opportunity
- ▶ Entrepreneurial Organizations
- ▶ Entrepreneurship in Creative Economy
- ▶ Entrepreneurship in International Context
- ▶ Innovation and Democracy
- ▶ Innovation Policies (vis-à-vis Practice and Theory)
- ▶ Innovation Policy Learning
- ▶ Innovation Systems and Entrepreneurship
- ▶ Innovative Milieu as a Driving Force of Innovative Entrepreneurship
- ▶ Innovative Milieux and Entrepreneurship (Volume Entrepreneurship)

- ▶ Knowledge Society, Knowledge-Based Economy, and Innovation
- ▶ Multi-level Systems of Innovation
- ▶ National Innovation Systems (NIS)
- ▶ Political Leadership and Innovation
- ▶ Social Entrepreneurship
- ▶ Social Networks and Entrepreneurship
- ▶ Triple Helix of University-Industry-Government Relations

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Instructional Design

▶ Teaching as Invention

Intellectual Property Rights

▶ Intellectual Property, Creative Industries, and Entrepreneurial Strategies
▶ Patent System
▶ Patents and Entrepreneurship

Intellectual Property, Creative Industries, and Entrepreneurial Strategies

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Synonyms

Creativity management; Incentive-diffusion dilemma; Intellectual property rights; Open business model; Open source

The expression “knowledge-based economy” is one of the most used in the economic and managerial literature. This expression refers to the fact that, roughly since the mid-1970s, knowledge and, more broadly, intellectual capital is the most important input in the production process of the economy (as compared to other inputs such as tangible capital, land, and low-skilled labor). A tangible manifestation of the critical role of knowledge in the production process is provided by the raise of firms which are specialized in knowledge production, be it consulting companies specialized in supply chain management or quality management, technological start-up, and/or university spin-offs. The common point between those firms is that, since they produce only knowledge, they must be able to valorize it, i.e., to sell it on markets.

In other words, the prominent place of intellectual capital in the knowledge economy directly shed light on the importance of intellectual property, i.e., on the means for entrepreneurs to protect their intellectual creations. Entrepreneurs usually seek to secure their intellectual capital by relying on intellectual property rights (IPR in the following). Most used IPR are (the list is not exhaustive) patents, trade secrets, brands, copyrights, models and drawings, etc. From an entrepreneurial point of view, IPR are keys to secure intellectual capital and hence to provide incentives to continuously develop novelties and innovation. And obviously, needless to say that the more important intellectual capital in the value creation process, the more important the place granted to IPR and, most of all, the more important it is to adapt a coherent strategy to use them (Teece 2002).

The issue of intellectual property is therefore critical today in almost all inventive and creative sectors, be it in traditional industries, in art or in creative industries. In particular, since creative industries are at the intersect of art and industry (Caves 2002), the issue linked to intellectual property in those sectors is likely to be different than in more traditional sectors (and also more complex). According to Bach *et al.* (2010): “Creative industries typically include industries that focus on: Creating and exploiting intellectual property products such as music, books, film and games; or providing business-to-business creative services including advertising, public relations and direct marketing. To a large extent, these creative industries integrate artistic as well as industrial dimensions, thus narrowing the gap between the use of patents (traditionally used in industry) and copyrights (traditionally used in art)." For instance, in the case of the movie industry, the music industry or the video-game industry, to cite only some of the most famous creative sectors, firms must today be able to combine and to handle a multiplicity of IPR and a multiplicity of valorization strategies.

From a social perspective, at the era of Internet, the role of IPR is vividly debated in the economic literature (Andersen et al. 2007). In a sense, technologies of information and communication (TIC in the following) exacerbate the Arrovian dilemma between incentive and diffusion (Arrow 1962). In its seminal paper, Arrow described the problem faced by entrepreneurs who seek to sell informational goods, i.e., goods which are hardly appropriable and nonrival. He explained that no buyer would accept to pay for something that he has no clue about. Thus, sellers must disclose the information in order to be able to sell it. But as soon as they do so, buyers do not need to pay to acquire the information since they already have it. This dilemma explains why IPR are fundamental in markets for informational goods and in creative industries.

Now, with the advent of TIC, this dilemma is still made more relevant. On the one hand, it becomes more and more important to prevent imitation and to secure intellectual property since in many sectors the Internet makes it easier and easier to duplicate and to copy new creation, thus undermining the incentives of inventors and creators. But on the other hand, TIC also increase the value of the dissemination of those new creation, which reinforce the importance of a wide diffusion of new creations at a low (if not zero) cost. For instance, in the music industry, for incentives sake, it is nowadays critical to protect new songs via strong copyrights and to prevent as much as possible free download on the Internet. But on the other hand, since TIC make it possible to disseminate new songs within the economy very fast and almost for free, the value of the diffusion of new songs has also increased, which calls for a minimum of protection.

However, if on the one hand the emergence of the Internet modifies the equilibrium of IPR policies, on the other hand, it also changes firms' entrepreneurial strategies. Because it potentially generates new source of value and affects the mechanism of repartition of this value, the emergence of the Internet and improvements in TIC indeed triggers the adoption of new business models by entrepreneurial firms, often more open than more traditional ones.

The standard view of IPR focuses on their role to prevent copy and to secure monopoly power and thus to restore incentives to create. For instance, in traditional industries such as pharmaceutical or chemical industries, firms often rely on patents to protect new chemical compounds and therefore increase incentives of biotech start-ups to invest in R&D. Or, in the music sector, copyrights prevent consumers to copy new songs for free, thus increasing incentives of artists to produce new pieces of music. Here, in line with traditional thinking in management, the ability to exclude and to enjoy monopoly power is at the heart of entrepreneurs' business models.

Yet, the link between IPR and entrepreneurial strategies is not straightforward. In reality, there is a large spectrum of possible utilization of IPR and entrepreneurs might not always want to use IPR in order to exclude imitators. In particular, openness and diffusion may become interesting for firms in order to benefit network effects, to ease compatibility, or to develop business in complementary assets. Hence, the valorization of creations and inventions may not always require exclusion and full appropriation strategies. This is all the more relevant in the Internet economy, where network effects tend to be large, thus increasing the value of openness and information sharing.

Consequently, encouraged by the huge progresses of TIC, new business models have emerged recently. For instance, in software, the open-source movement demonstrates the possibility for entrepreneurs to become profitable without strong right of exclusion. Open-source software typically relies on copyleft, i.e., on a peculiar use of copyright which ensures not the exclusion but the maximal dissemination of produced lines of codes (Raymond 1999; Lerner and Tirole 2001; Dalle and Jullien 2003; Benkler 2006). Thus, in open-source communities, participants who produce lines of code cannot appropriate them and control their use. Yet, many firms do devote times and resources to contribute to open-source project although they know they will not be able to appropriate the produced software. This clearly illustrates that open business model can sometimes be profitable.

The success of open-source software has triggered many scholars to explore how and when to export this model in other sectors. In the field of arts, for instance, licenses based on creative commons' principles are now deeply rooted in the practices of many actors. Similarly, Lakhani and Panetta (2007, p. 98) explain that: "The achievements of open-source software communities have brought the distributed innovation model to general attention so that it is rapidly taking hold in industries as diverse as apparel and clothing, encyclopedias, biotechnology and pharmaceuticals, and music and entertainment."

If the example of open source is quite extreme, it suggests that, for entrepreneurs, IPR strategies based on strong exclusive rights may not be optimal. In many cases, it might pay for an innovative firm to weaken its IPR and to adopt open business model. For instance, in the case of open source, it must be noted that, technically, software "protected" by a copyleft is not automatically free. It can be sold. Yet, the copyleft means that nobody can prevent someone from distributing it for free, which seriously undermines the incentives to sell it. In practice, therefore, copylefted pieces of art are usually distributed for free.

Second, creators by opening their invention or creation do not usually abandon all their rights over it. Very often, they keep at least their name associated to their creation. It is the case, for instance, under the label of *creative commons*, which proposes some more or less permissive licences, but under which it is always very important to mention the name of the creator.

Third and more important, new business models can be designed around free and open invention and creation. For instance, in industries with strong network effect (where the value of the good largely increases with the number of users), it may pay for firms to open their technology, to favor its diffusion and wide use in order to benefit from network effects. Network effects indeed introduce the issue of standard and compatibility. And, needless to say that exclusive strategy is seldom relevant in order to favor compatibility. More generally, any times a market is multisided, the issue of openness, at least on one side of the market, must be addressed by firms who operate on those markets. It may indeed pay to offer the good for free (or almost for free) on one side of the market in order to increase the value of the good for customers on other sides, thus increasing their willingness to pay and the firm's potential of revenue.

Similarly, as illustrated by the case of software, weakening its IPR might lead to maximize sales of complementary assets (Teece 2002). Indeed, if complementary assets are exclusively controlled by the firm, providing a free good might enable entrepreneurs to increase their profits on those complementary assets. In other words, it is possible for artists not to sell directly their copylefted work but to make money out of complementary services that are combined with the open resource. This explains why, for instance, firms as Google or Amazon are strong contributors of open-source software. They do not sell the software but they combine it with assets that they hold exclusively (reputation, networks) in order to maximize their revenue.

Finally, open environment is critical in order to lever the work of creative communities. Bach et al. (2010) emphasize indeed that in creative industries, the process of creation is generally a collective effort that necessitates the interaction and coordination of a multitude of heterogeneous economic actors. Basically, Bach et al. argue that stakeholders of the creative process are talented individuals, firms, and creative communities. In particular, they stress the critical role of the latter. According to them: "the locus of creation is rooted within the diverse informal communities with which firms and individuals must somehow maintain links in order to keep introducing novelties. *Creative communities* refer here to informal groups of individuals who accept to exchange voluntarily and on a regular basis in order to create knowledge in a given field. As the knowledge-based economy expands, such communities take in charge some significant parts of the *sunk costs* associated with the process of generation or accumulation of specialized parcels of knowledge." This is, for instance, clearly the case in the video-game industry in which dominant firms must rely on the production of underground creative communities of artists (Cohendet and Simon 2007).

However, the point which is important to make here is that, with respect to IPR, creative communities have radically different needs than firms. Communities need openness and knowledge exchanges while firms need exclusion and knowledge retention. This is what Bach et al. (2010) call "the IPR dilemma in creative industries." Communities can only flourish under weak IPR. Creative projects entail integrating, cutting, and pasting, assembling creative elements dispersed among a vast array of technical and cultural activities carried out by diverse and distinct actors. Thus, in order to foster the production of novelty, firms, individuals, and communities must rely on some kind of open spaces. In particular, it is important for firms to moderate their use of exclusive IPR in order to preserve privileged links with creative communities. Lessig (2001, 2004), for instance, insists on the fact that creation is a collective process involving communities and that, for those creative communities, the issue of access is more important than the issue of incentives. According to him, creativity can hardly occur in a world of permission and the production of novelty requires the preservation of a free platform on which creators can freely draw to feed their creativity.

In order to reconcile those two opposed positions and to preserve the delicate balance between appropriation and creation, firms might therefore develop specific arrangements, which often means to behave less aggressively in order to be able to lever the work of the masses. These new strategies of intellectual property are clearly in line with all the recent literature on open innovation which stresses new innovative strategies based on user communities, crowdsourcing, etc.

Conclusion and Future Directions

In creative industries, the issue of intellectual property (and in particular intellectual property rights) and entrepreneurial strategy is critical. In many situations, it is important for new ventures to be able to prevent imitation. But, on the other hand, in some cases, it may also pay to adopt more open business models. Indeed, in creative industries, building an ongoing creative dynamics requires the preservation of a fragile equilibrium between exclusion and openness, which ensures the coevolution of individuals, firms, and a creative underground. In this sense, firms must accept to some extent new uses of IPR, in particular those based on copyleft strategies and creative commons in order to favor links with underground communities.

This discussion on the role of intellectual property and new entrepreneurial strategies is essential because it contributes to introducing new dimensions to comprehend the debate on intellectual protection in creative industries. Yet, future research will have to complete it at least with respect to two issues.

First, future research will have to improve the understanding of the business models that allows firms to exploit and use the strength of open strategies. In particular, it will be important to explore whether or not it is possible for firms to elaborate hybrid strategies in between exclusive and open access in order to reconcile their need of appropriation and of creation. If yes, under which conditions? For instance, crowdsourcing is often presented as such hybrid strategy (a mix of strong appropriability and peer production). Yet, it is well known that crowdsourcing in the case of inventive and complex activities raises many problems and is likely to work only in limited contexts (Burger-Helmchen and Pénin 2011).

Second, future research will have to understand the functioning and evolution of creative communities and their interactions with the business sphere. The dynamics of creative industries indeed strongly depends on the creation and development of local creative communities that are in charge of elaborating and diffusing the norms and rules which help to regulate the behavior of all the different actors. How those communities evolve, how they change and interact with other actors of the innovation process, is a fundamental research question that needs further investigation.

Cross-References

- ▶ Creativity Management
- ▶ Entrepreneurship in Creative Economy
- ▶ Knowledge Capital and Small Businesses
- ▶ Patents and Entrepreneurship

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Intelligence

▶ Speaking Pictures: Innovation in Fine Arts

Intelligent Cities

▶ Entrepreneurship in Creative Economy

Interaction, Simulation, and Invention

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Synonyms

Creativity; Human-computer interaction; Simulacrum

The information age, we still call it. Since postwar revolutions in technology (and above all in communications, we must remember), it has become commonplace to see the world and its events as information, as data. The processes of storing, accessing, and processing information are accepted culturally as central roles of contemporary technology, the central pillar of the trio of sensing, computation, and communication that characterizes and enables technologized life. The notion of "interactivity" is one of the foundational, defining concepts of the technological age. The idea that technology can respond to, appear to adapt itself to human actions or transpose those actions to other contexts transforms the scope of behavior of both human and machine. Over a generation, two developments have brought this relationship to a point where the interface often seems transparently thin: cultural practice and the common imagination have assimilated many of the implications, and technology has become faster, smaller, adaptable, and ubiquitous. This entry will explore the shape of the liminal space within this interface.

From Ubiquitous Concepts to Ubiquitous Reality

Interaction

Interaction is inevitably one of the broadest terms within technological culture. It is used to refer to all levels and modes of causal relationship between human and machine, however, conscious, intentional, or otherwise. The idea of interaction in a social sense or in dealing with the working together of machines, systems, or models is also relevant here. Interaction generally has a social context, and the modularity or complexity of systems means that intra-system relationships are equally important. Feedback is an important component in any interactive (rather than reactive) context.

Simulation

In its simplest sense, we might seem to be dealing with machine imitation of some behavior in the material or cultural world. In fact, the design and interpretation of such systems produces potentially complex and interesting meaning-generating relationships. More fundamentally, most systems designed for any kind of interaction can be seen as embodying a model. This might take the form of a set of simple assumptions, or of a population of dynamical systems designed to model complex behavior in the material or virtual world. Most crucially, the idea of simulation suggests an act of interpretation by a subject – a designer, observer, or user. It implies that the machine-embodied system is understood as a model or parallel of another system in a material or imagined world.

Invention

Invention tends to be understood as innovative application of science or technology – a new way to do something or something new to do. Here we will use a broader definition also encompassing means of producing new knowledge or understanding and aesthetic creation.

Interaction, Simulation, and Invention: A Reflexive Relationship

Invention, Creativity, and Cognition

Theories of creativity tend to emphasize the role of interaction rather than miracle birth. Indeed, the latter – the genius moment – we would now explain in terms of the process of emergence, as will be discussed below. Most such theories suggest that invention is the product of a more or less consciously observed encounter between internally modeled spaces or behaviors. The spontaneous reflexive process of the mind's generation of maps of its own conceptual spaces is at the root of such interpretations. Creative thought can be seen as the drawing of analogy between different mental spaces within interacting constraints of similarity, structure, and purpose. More recently, researchers have proposed an evolutionary explanation; that genius typically explores a wide range of potential behaviors, often in parallel, searching for complexity, novelty, and emergent structure. These explanations have in common an understanding that invention is the fruit of interacting simulations, of material of conceptual models. The action of imagination is the projecting of this interaction onto a new plane. Such a plane may be visual, aural, or temporal, for example, or it may be a new space of possibilities with its own potentialities, constraints, and dynamics.

In this respect, simulation must be considered an integral component of consciousness; every human behavior implies a model and projection on some level, and most involve some kind of interaction with the material or social world. In dealing with technology, external models and instrumentalities come into play, and in understanding this we must bear in mind that humans are optimized for engaging with humans. Indeed, we are disposed to understand behaviors in general (from the mythological actions of the gods to those of Disney cartoon animals) as human. This tendency is fundamental to our design of and interaction with machine behaviors. Interaction thus depends on a degree of credibility, an act of faith, or investment on the part of the "user" – the subject. The three key technologies are well tried; most advances in design and production transform practicality rather than concept. It is the capacity of the potential subject – the human – to imagine themselves into new technology-mediated contexts that carry such change forward. The special property of the technologies of interaction and simulation is that they create the very reflexive environment by means of which such vision becomes possible. They are the very instruments of invention.

Contexts for Action

Interaction with models is not exclusive to computational processes, of course. Maps, tools, pen, and paper and notational systems all function as extensions of human behavior. Heidegger's example of the hammer is a much-discussed theoretical reference in this respect. More generally, cognitive functions and individual and social behavior are mediated by tools, technology, representations, and social structures. External memory, representation and devices for manipulating the material world all become part of a feedback system that incorporates not only internal and external modeling, but also projections of how things might develop – simulation. In considering the prospect of digital craft, the *symbolic* nature of digital technology is crucial. This is how it is able to relate real and virtual actions and information. It also means that every relationship is mediated by a symbolic layer; technology is a medium. The computer provides a network of representational contexts for action. The power and flexibility of these contexts lies precisely in their symbolic nature, in their capacity to map representational spaces onto one another. The symbolic layer also facilitates and requires cross-disciplinary research and creation – invention that is the product of the interaction of different areas of thought and practice.

Representation, Modeling, and Emergence

Representation itself is thus a vital issue. Interaction and simulation both rely on symbolic models of a material, virtual, or informational space. Model making depends on reducing the number of parameters (degrees of freedom) to a non-infinite number tractable in the particular technological context and representing those parameters symbolically. Explicitly or otherwise, in identifying the system to be modeled a designer constructs a quasi-autonomous model of a situated system the behavior of which has enough overlap with that of an experienced, imagined, or comprehensible system for the user to engage with it meaningfully. The art of modeling is itself one of invention, of perceiving and defining as a quasi-autonomous system with limited links to its environment one which in the material world has a potentially intractable number of such relationships. The power of such an approach lies not only in its calculability, but also in its modularity and generalizability. More complex systems can be constructed of such models, to simulate and test the nature of relationships, and patterns if behavior and interaction can be abstracted.

Representation remains at the heart, however, complex, responsive, or contingent a system appears. Any difference between information and control systems lies in their use and design, in their mode of output rather than in their abstract structure. The nature of interaction (as opposed to remote or complex control) has tended until recently to continue such an information-based understanding of human behavior. Even beyond the confines of AI research, there has been an implicit assumption that an adequately rich and navigable knowledge base could form the basis of machine behavior with which humans are content to interact. While many interactive systems still effectively work on the basis of what is known as "good old-fashioned artificial intelligence" – "top-down" models, such as expert systems – most thought on machine intelligence over the last 20 years has moved toward an embodied, situated, distributed "bottom-up" approach. Interaction thus becomes one of the primary aspects of the model to be designed and observed. Most importantly, the knowledge potentially generated or revealed by such a system is not explicitly embodied in its structure and rules. Knowledge becomes a function of time and context; it is *emergent*. Definitions of emergence vary by context (Clayton and Davies 2008), but there is a general division those of weak emergence – emergence in the eye of the beholder – and strong emergence – new structure or behavior that has a causal impact on the behavior of the system itself.

Modes of Interaction

Similarly, many issues that are often connected with interaction are inseparable from questions of what used to be referred to as human-computer interaction. The parameters of interface design for interaction are well rehearsed: mode and degree of physicality, degrees of intuitiveness or necessary learning, analogy with other objects, systems, or models, and – crucially – feedback. Research in interaction design tends to focus on the individual; the concept of *joint cognitive systems* considers at the broader interaction of social and technological systems. The more recent notion of "experience design" acknowledges the dynamic nature of the relationship. Questions of the design of physical objects have become integrated with those of interfacing. Recent work points to the important role of skill acquisition in satisfactory and engaging interaction; successful design is the product of a partnership between designer and use. The design of interaction can enable the user to navigate complexity through structure, effective communication, and a learnable, sociable interaction, but the user must also seek to understand, engage, and learn. Interaction is thus not limited to the confines of the standard personal computer interface. Indeed, many screen-based exchanges might better be classed as iteratively reactive rather than interactive.

Developments in sensing technologies and data processing have greatly enhanced the potential of interactive environments. This might take the form of sophisticated multimodal interaction, such as immersive environments, or the intelligent processing of data that embodies complex actions, such as the abstraction of human forms from visual input. In both cases, the range of interacting behavior is vastly expanded from, say, a switch or dial. With this broadened palette of range and mode of input must come a thicker layer of software mediation between subject and response. This creates richer potential for learning on the part of the system; multimodal learning is also a more intuitive process for the subject.

Prosthetic Culture

Technological evolution drives the cultural understanding of human-machine relationships to another paradigm. If subject and computer are integrated such that the subject no longer perceives a distinction, then the situation is no longer one of interaction. Instead, we are dealing with a form of prosthesis, but one that is cognitive and experiential as well as physical. Theorizing of this situation generally pursues two lines: notions of the "posthuman," as state in which informational dynamics are no longer entirely constrained by material life, and the balancing view of human knowledge and understanding as being essentially and evolutionarily embodied. Both are vital lines to consider. The new situation will likely afford the emergence of concepts that could not form in the "raw" human situation, constructs which require the extended context for their formation. However, as with previous technological innovation – writing, communications, computing, for example – this will doubtless also add to the conceptual repertoire of raw human thought and culture. Theorists refer to such a dynamically mind-technology coupled process as *enactive systems*, within which technology becomes an integral part of human sense-making. The extension of the individual through simulation and interaction could lead to its dissolution into a dynamical pattern of evolving cultural constructs. In this reading, interaction is no longer an intentional exchange but rather an evolutionary, emergent process of continual invention in which the boundaries between individuals become dynamical and multiple.

The Crucial Role of Time

Temporality introduces an infinitely greater richness to interaction. Dynamical models represent the evolution of a system over time. They may be characterized by the mode and degree of interaction they afford:

– Autonomous systems (e.g., meteorological, social, or economic models, generative graphics or music)
– Systems that are quasi autonomous but allow or require data from outside (simple computer games, continuously evolving information systems such as finance)
– Systems that allow multiple or complex intentional relationships with the subject(s) (flight simulators, interactive performance systems)
– Systems that inhabit a real world environment (installations, immersive environments)

This might be better understood in terms of the *distribution* of interaction – the points in the cycle of imagination, design, and use at which imagination might intervene. Fully autonomous systems play an equally important part in the emergence of new modes of thought; the creative influence of concepts of chaos and complexity are obvious examples.

State variables within the system evolve over time. In a digital context, dynamical systems must be discrete time models (i.e., they proceed in steps, however small), which themselves are integrations of continuous time systems the behavior of which is represented by differential equations. In this respect, computational systems are themselves models of mathematical systems. Recursivity is an important characteristic of such systems; the state at time $t + 1$ is calculated from the state at time t on the basis of the equations of the model incorporating any changes to state variables from external sources. This property allows for relationships and feedback loops between variables that are generally the source of perceived nonlinear behavior or emergent structure – that is, behavior or structure over time that is not predictable from the initial state without running the system in time. We might posit interaction and invention in the observation of nonlinear behavior in a dynamical system. The design of modes of intervention in that system implicitly assumes a dynamical model on the part of the subject. Similarly, intervention by the subject is structurally equivalent to an evolving parameter or feedback loop within the system; the subject becomes part of the environment of a complex system, and vice versa. New knowledge and invention are two sides of the same coin. Given that no simulation can be absolute, the difference between simulation and interactive systems is largely one of design and use, of cultural convention.

Invention and Complex Systems

The modularity of modeling allows for complex simulations such as the massively multi-point calculations of contemporary weather forecasting – a vast number of interacting localized systems. It also affords the possibility of agent-based modeling, in which the global system behavior is the product of interactions between internal autonomous systems, each modifying the environment of the others. The paradigm of *Artificial Life* is based on the coevolution of such structures. Taking its cue from the "non-intelligent" design of nature, it views life as the organization of matter and explores life-as-it-could-be through the self-organization of complex systems. As a research tool, A-life models have been used to explore phenomena from the evolutionary to social to cosmological levels. They are naturally suited to the modeling of adaptive and emergent behaviors, and for the exploration of virtual worlds. The different modes of operation of A-life models and their artifacts provide a good example of how design at different levels generates different kinds of interaction and invention. A system might allow subject interaction simply in the setting of parameters before a particular system run, perhaps generating output graphically or as sound. It might permit intervention during its operation, such that the subject effectively becomes an agent participating in the evolutionary process, or it might be formed about the subject in a more complex set of relationships to effectively become an extension of the subject. Artists have also used A-life approaches to "growing" carbon-based life forms, by intervening in the genetic and environmental processes.

If, hypothetically, a simulation were absolute, that would itself transform our mode of knowledge and thus constitute invention. Baudrillard presents the canonical argument for the dangers of simulation; not by coincidence is his *Simulacra and Simulation* the book in which Neo hides his contraband in *The Matrix* (itself hollowed out to become an empty self-representation). In such an interpretation, wars are fought primarily on screen, other times and places are known through a distant lens, edited and manipulated. The here and now, represented in the same way, becomes at best undistinguishable, at worst less-than-real. In fact, of course, such factual-historical and anthropological misrepresentation is far from new; one might even interpret aspects of religious dogma as the manipulation of cosmological self-image. What is interesting is that the technologies of apparent immediacy are no more an absolute guarantee of objectivity than the mythologized reports of ancient battles, received months after the event. Baudrillard sees three levels of simulacrum: physical copy, mass production, and our present state of hyper-reality in which a reference "reality" ceases to be relevant; concepts of real and virtual dissolve. Recent theorists pursue the implications of this "desert of the real" in respect of the interpenetrations of cultural and political behaviors.

Simulation becomes simulacrum at the point when the subject no longer questions the material reality of experience. In William Gibson's novel *Neuromancer* such experience is likened to hallucination, for example. Such a metaphor points to the crucial role of consciousness. The simulacrum only really obtains when consciousness cannot or does not distinguish. Science fiction is replete with borderline cases. Yet crucial aspects of simulation function appropriately outside this state. Flight simulators present an example. Faced with an emergency, the subject's physical emotional responses reflect those of an actual situation sufficiently for the exercise to be meaningful without the pretence of "reality." The relationship with a simulation known *not* to be real is fascinating, and points to the crucial role of the relationship of the simulation with the subject – that is, the relationship is always interactive to a degree, regardless of apparent physical intervention. The simulation model of certain computer games would appear to present an authentically new paradigm – one deriving from the cultural diffusion of concepts from ecology – in that an environment has to be maintained in balance. This contrasts with the drive to imbalance of earlier games using metaphors from war (chess) or economics (*Monopoly*). Additional levels of cultural simulation can be seen in computer games that seek to recreate not the apparent reference experience but the depiction of that experience in another form – for example, wargames that simulate not the experience of war but its representation in film. This points an interesting cultural phenomenon: it seems that engagement with virtual environments relies to some extent on prior experience and conceptual models. As with film (or any other art form), interaction with virtual worlds can serve to reify preconceptions as much as to engender invention.

Interactive Aesthetics

Material and virtual realities are mixed the aesthetic concept of *critical fusion*. It has been called a "telegraphic art," an art produced by action-at-a-distance in space or time. One defining behavior of telegraphic art is its relationship with memory: rather than searching or indexing, telegraphic art can produce emergent memory or *anamnesis*. New media are by their nature programmable. Generative art produced by autonomous machine behavior might appear to stand in opposition to interactive art, an aesthetic mode in which the viewer develops an instrumental and changing relationship with the work. However, the distinction is not so clear; the process of invention is still fundamental at the stage of design (and perhaps of perception), and an interactive work based on some form of simulation or model also displays a degree of autonomous behavior. Key issues in interactive art include kind of experience, mode of engagement, phase of involvement, and viewpoint of evaluation. The engagement process can be articulated in terms of stages of adaptation, learning, anticipation, and deeper understanding. The concept of play is frequently used to understand the nature of involvement. In all cases, the machine behavior has to engage on some level with human behavior, perception, and models; it is clear that technological art must develop together with research in cognition. The close relationship between artistic and scientific research and the role of collaborative work have transformed the nature of artistic practice.

Conclusion and Future Directions

We should consider the understanding produced through simulation as a new kind of knowledge. This is another example of the reflexive nature of the situation. Both the artifacts and behaviors observed and the resultant new concepts are emergent; ontology and epistemology are in a double bind. DeLanda proposes that we see a simulated system as of a space of possibilities with a defined structure.

What simulation and interaction afford above all is an extension in complexity, contingency, and time of the reflexive process that makes us human, that is at the root of human invention. As a medium and a context for symbolic representation, simulation represents both a means for the externalization and exploration of ideas and a mirror reflecting their potential and consequences. Invention – whether of a global grand design or of a spark of personal meaning – is the product of cycles of interaction between model and subject. To return to our starting point of creativity, it is most likely to occur in a moment of perceived resonance with *another* model.

Cross-References

▶ Adaptive Creativity and Innovative Creativity
▶ Cognition of Creativity
▶ Creativity from Design and Innovation Perspectives
▶ Creativity in Invention, Theories
▶ Creativity, Intelligence, and Culture
▶ Imagery and Creativity
▶ Models for Creative Inventions

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Interactive Processes in the Form of Creative Cooperation

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Definitions

Creative cooperation: “The term creative cooperation captures the use of extensive cooperation between incumbents and new entrants initiated (‘created’) by an innovation that leads to a search for mutually complementary assets. Complementary assets such as marketing, manufacturing, and after-sale service are often needed to ensure the successful commercialization of an innovation.

Therefore, a 'complementary innovation' destroys the existing industry structure, but instead of destroying the incumbent firms with it as in the Schumpeterian model, it results in an industry structure of extensive cooperation between incumbents and new entrants firms that allows for a symbiotic coexistence in a newly defined industry" (Rothaermel 2000, p. 150).

Cooperation: Cooperation implies a relational system of organizations working together toward a common purpose. "A continuum moving from cooperation to coordination to collaboration moves generally from low to high formality" relationships between stakeholders of the system (Reilly 2001, p. 55).

Creative response: One can speak of "adaptive" responses when firms, in the face of major changes within their environments, respond by simply readjusting their existing practices. Conversely, "creative" responses (a) mobilize practices which are situated "outside of existing managerial practices" (McCraw 2007, p. 474), (b) cannot be planned or possess a nondeterministic trait, (c) depend on the specific leadership of individuals, (d) permanently change economic and social situations so as to create new environments, that is, affect the behaviors of other companies or a whole industry at large, independent of the size of the innovating firm in question.

Creative cooperation practices: Creative strategic management practices of firms (i.e., dynamic capabilities) resulting in creative cooperation and complementary innovation.

Knowledge-based economy: An economy in which knowledge and human cognition take a central role in the production process (Castells 1996; Rifkin 2000). According to Foray (2000), today's knowledge-based economy is characterized by a *marked increase* in knowledge externalities as well as by a *growth in the arena for change* (in the sense of activities dedicated toward innovation) within economic activity. During the past three decades, this new economy has imposed itself across massive investments in both production and knowledge transmission (research and development, education systems, patent acquisition and patent development systems, etc.), as well as by the advent of new information and communication technologies (Foray 2000).

Network-firm: Within the context of the knowledge-based society, organizations are comprised of internal networks, often non-hierarchical in nature, with a multitude of individuals, groups, teams, and communities which are dynamic and interconnected across formal and informal mechanisms. These organizations are, in turn, interconnected with other organizations within alliance networks and industrial, geographical, or sectorial clusters of activities. Hence, the network-firm (Sérieyx and Azoulay 1996) is particularly well adapted to a global and complex environment characterized by the interdependence and dynamism of technologies, products, or services. Such an environment calls for collaboration throughout the organization as well as around it.

Defining Creative Cooperation Through Creative Collaboration Practices

High-technology-intensive industries involve high degrees of collaborative practices whereby interfirm relationships, as well as the cooperative innovation management practices that accompany these, are constantly changing. The evolution of the biopharmaceutical industry is an emblematic case in point of how science-driven industries in this age of the knowledge-based society are continuously transforming. Here, with the acknowledged consecration on the necessity of biological sciences within the drug discovery process (Cooke 2003), biotech firms have become indispensible partners with the pharmaceutical industry. This entry aims to define and characterize these creative collaborative practices across an organizational re-reading on the concept of "creative cooperation" as proposed by Rothaermel (2000). This will be conducted in three steps: (a) a review on the notion of "creative response" to change as first explained by Schumpeter, (b) a synthetic review of the literature on contemporary "network-firms" within the knowledge society, and (c) an operational definition of "creative cooperation," and the specific management practices associated with this, based on theoretical and empirical literature covering the case of the life sciences sector.

The Disruptiveness of Practices Within an Innovating Context

Schumpeter (1942) used the term "creative destruction" to describe the now-classical idea of how innovation drives or stimulates capitalism. Furthermore, the firm's capacity to survive depends on its capacity to internalize this ability to innovate so as to render it as an organizational routine. In his 1939 work entitled *Business Cycles*, Schumpeter specifies that not all change within their environment engenders the same types of responses on the part of existing firms. He distinguishes "adaptive" responses from "creative" ones. Can these teachings on the art of change and the practice of innovation serve as a springboard toward describing and understanding the context of today's biopharmaceutical industry (and eventually, of science-driven industries in general)? An abundant literature on biotech SMEs shows how the dynamics of cooperation, via alliances and collaborations, is central within the industry's response to technological change (e.g., the advent of biological drugs) (Koput et al. 1996; Fetterhoff and Voelkel 2006). Rothaermel (2000) considers that the case for biopharmaceutical innovation does not engender a wave of "creative destruction" but rather entrains a "specific creative response" at the level of the industry's structure: "creative cooperation," as a symbiotic-like cooperation between incumbent firms (pharmaceutical companies) and new entrants (biotech companies), occurs with the ultimate aim of commercializing an innovation. Such cooperation is essentially motivated by the complementary assets and resources that can be achieved, which are necessary toward the industrialization process of life science inventions and innovations. Interfirm cooperation is, therefore, the preferred reconfiguration mechanism in response to a changing context. The following section of this entry aims toward helping us understand and decode this hybrid of "creative cooperation" at the organizational level.

A Look at the Evolution of "Creative Cooperation" Practices Within the Network Age

Throughout the past three decades, the conjugation of stakes related to the "knowledge-based economy" with those of the "network age" have helped lead toward the emergence of new organizational realities, and most notably, toward the multiplication of alliances and collaborations. More specifically, a number of authors have identified the network-firm (or the firm within a network) as the archetypal organizational form within biotech firms (Powell et al. 1996; Powell 1998; Baum et al. 2000; Cooke 2003; Patzelt and Audretsch 2008; Chiaroni et al. 2009). "Creative cooperation" inscribes itself within an emergent stream of theorization on network-firms and the open business model (Chesbrough 2006) within the age of the knowledge-based economy. As such, the specific literature on biotech sectors considers the locus of innovation to reside within both the internal and external knowledge exchanges by means of value networks (interconnectivity). This involves dealing with (a) uncertainties and risks related to the difficulties in measuring the feasibility of scientific projects in biosciences involving multiple research paths and multi-disciplines in required fundamental knowledge, (b) of creating new capacities for integrating the evermore tacit knowledge of scientific experts (or of that contained in patent portfolios and other intellectual properties) (Owen-Smith et al. 2002), and finally, (c) to forge long-term learning capacities for the transmission of knowledge developed over long periods by means of long-term partnerships (rather than by opportunistic "deals") (Pisano 2006). Along these lines, Baker (2003) argues that new distinctive capacities of biotech firms are to henceforth stem from the articulation of internal innovation capacities as well as from reticular capacities to detect knowledge which can stimulate innovation.

Toward an Operational Definition of "Creative Cooperation"

Based on a systemic and dynamic definition of the strategic firm, "creative cooperation" within the biotech sector, thus, involves at the organizational level (also refer to Table 1):

- A *creative strategy (and governance)*, which constantly re-questions the business model of the firm and the pertinence of its portfolio of products (or intellectual property), services, competencies, technologies, and relationships in regard to the evolution of its capacities (and of those of its partners) for transforming knowledge into assets (Durand et al. 2008).
- A *creative organization* which implies *organizational innovation* toward new partnership forms; toward the positioning of the firm within its value chain and value network; and toward transforming the ways of coordinating knowledge creation (scientific and technical) within networks by means of openness (e.g., Chesbrough's (2003) "*Open Innovation*"; or Leonard-Barton's (1998, p. 155) "*Fight the not-invented here syndrome*").

In the case of biotechs, at least four creative cooperation practices (or dynamic capabilities (Teece 2007)) have been mentioned within the literature of the past two decades, and were also described by managers of biotech firms in the Quebec case study (Saives and Desmarteau 2010; Bréchet et al. 2012):

1. *Thinking and acting in networks*: The building up of an open network of expertise and high-caliber experts so as to construct a credibility of developed knowledge by varying the locations of intervention where these independent experts bring forth the benefits of distanciation. In support of this thinking is Venkatraman and Subramaniam's (2002) argument that firms are just as much portfolios of relations as they are portfolios of capacities and activities, whereby factors toward their competitive advantage reside in economies of scale, of scope, and of expertise. Here, their key resources are tied to their position within a network of expertise such that the strategic unit of analysis shifts away from the firm itself toward a *network* of internal and external relations where the objective becomes a matter of profiting from intellectual capital. The strategic focus, therefore, aims toward transforming new *knowledge* into *products* or *services* across a *network of specialized entities* involved in a variety of innovating activities; and toward maintaining strong ties so as to coevolve with various sources of knowledge and ideas, such as universities, regional start-up clusters, companies providing risk capital, and other co-specialized firms (Floricel and Miller 2003, p. 50–506). For the firm itself, the issue is much less a matter of rendering its processes and routines inimitable than to ensure its *centrality* within the network. And if one were to pursue a research agenda on this theme, it should be noted that Biotech SMEs have relied heavily on networking with star scientists, star CEOs, or high-profile venture capitalists on their advisory boards in an attempt to signal the underlying quality of their competences and their business models, as well as to gain status and credibility. One possible research avenue would be to understand the comparative effectiveness of the different ways in which biotech firms attempt to gain such credibility.
2. *The construction of symbiotic and equitable partnerships* toward the valorization of joint intellectual assets of the firm throughout all stages of scientific discovery; and this, across the manifestation of an original organization of bidding-up the value of its knowledge and project portfolio. This new way of progressively negotiating payments and deposits reminds us of Kalamas et al. (2002) who predicted a shifting of contractual discussions between biotechs and pharmas toward much earlier in the discovery process on the basis that biotech firms have increased their power of negotiations as a result of maturing technical and administrative competencies. As such, biotech firms have become better negotiators for license and expertise networks by concluding business contracts that are based on a more equitable sharing of value spaced over time,

Interactive Processes in the Form of Creative Cooperation, Table 1 Operational dimensions of "creative cooperation" within the biopharmaceutical industry: a synthesis of creative cooperation practices

	Creative Cooperation Practices			
Dimensions	Thinking and acting in networks	Constructing equitable partnerships	Arbitrating in-house and outsourced activities	Engaging the academic toward the market
Strategy	Emphasizing external expertise to achieve credibility	Establishing lasting and reciprocally profitable partnerships (*New deal making*)	Systematically arbitrating all links within the logistics chain	Valorizing translational research *(from science to business)*
Organization (Structure, culture)	Establishing independent and varied governance instruments	Honesty and frankness within communication mechanisms based on long-term visions	Flexibility within all structural and cultural components (e.g., *the bidding-up of ideas*)	Proliferation of bridges (physical, cultural, cognitive) between science and the market

thus leading to more durable and reciprocal relationships. Furthermore, Chesbrough (2007) asserts that innovation practices are evermore conducted within an "open" mode whereby the arbitrage between in-house and outsourced activities is conducted by embracing more fully a partnership perspective. An example of such innovating practices (Chesbrough and Appleyard 2007) shows how pharmaceutical giant Merck finances and implements a research partnership network whereby the value and wealth created is more equitably redistributed. In short, Chesbrough's fundamental message is that the strategic evolution of innovating practices within today's organizational environments is (and must be) transcended across a reticular openness. Both biotech and large incumbent firms have come to realize that their respective skills are largely complementary and are engaged in a series of different symbiotic partnerships. Further research would be needed on documenting the best microlevel practices and interactions which facilitate successful inter-organizational relationships.

3. *The systematic arbitrage between in-house and outsourced activities across every link of the value chain*, and this, as a result of a "knowledge on outsourcing" made possible across the control of pharmaceutical research and clinical production quality standards.
4. *The proliferation of bridges (physical, cultural, cognitive) between science and market* so as to better enable, track, orient, and valorize scientific creativity and invention carried out within universities. The fact that the collaboration between universities and companies is an important key toward biopharmaceutical innovation is not new within the literature on national innovation systems. However, how does one render it more effective and efficient? Pisano coined the term "translational research" as a form of research that "translates" discoveries and fundamental scientific concepts into specific product opportunities. It connects in a much more systematic fashion fundamental research with clinical tests, including activities such as the identification and validation of targets, the screening of in vitro and in vivo candidates, and certain first-stage clinical tests.

In this sense, companies build creative organizations across a prolific bridging between the fundamental and the applied. Several levers are effective toward this end, which include (1) the hiring of liaison agents or "knowledge translators" (better known as Leonard-Barton's (1998, p. 155) *boundary spanners*), often being biopharmaceutical managers that were formerly researchers or vice versa, who support and ensure a cultural proximity between actors so as to enable the translation of science and assure the proper circulation of knowledge between the academic and economic spheres, (2) multipartied cooperation toward the bringing together of science and the market, and finally (3) the proliferation of opportunities toward the creation of knowledge across numerous technology platform applications within firms which also favor this science/market reconciliation.

Further research and studies, again at the micro-organizational level, could be conducted with regard to which types of bridges with academia have been the most effective toward inducing technological returns for the bridging firms; or again, on how different firms have interfaced with academia.

Conclusion and Future Directions

Creative cooperation is a new force toward the reconfiguration of innovating industries. It involves cooperative practices within the context of change and for which it possesses all the characteristics of "creative response" as defined by Schumpeter.

In today's age of open innovation, the biopharmaceutical sector is a probative example. In practice, the biopharmaceutical industry put forth creative responses to major technological changes and to increasing complexities which the life sciences have introduced within the drug discovery process. Starting from the "research workshop," a number of biotech VSE/SMEs have become partners in "creative symbiosis" with their peers, and more importantly with large pharmaceutical companies. The age of the bio-pharmacy is in full expansion whereby four creative practices have brought forward real signs of renewal within the art of cooperating, that is, of "creative cooperation": network-based credibility; equitable and symbiotic partnerships; network flexibility or arbitrage between in-house and outsourced activities; and finally, the proliferation of bridging between academia and market.

These four creative practices are based on new management principles, in part inspired by the Japanese approach (Nonaka and Takeuchi 1995) as well as more recent theory on governance. Indeed, *selective openness* (toward a network of expertise, toward commercial, production, or academic research partnerships), *complementarity and redundancy* (of information for decision-making across various governance instruments; of commercial partnerships for the proliferation of opportunities in innovation; of knowledge belonging to the committed parties involved in "translational" research), and *autonomy and equity* (of information belonging to independent experts; of control mechanisms for logistic chains; of knowledge sharing within "translational" research) seem to be the master words of future academic research and firms' practices of "creative cooperation" within the age of *open* innovation.

Cross-References

- ▶ Knowledge Society, Knowledge-Based Economy, and Innovation
- ▶ Network and Entrepreneurship
- ▶ Open Innovation

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Interdisciplinarity and Innovation

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I

Synonyms

Multidisciplinarity; Transdisciplinarity

Introduction

This entry is based on findings obtained from a cross-sector analysis of successful interdisciplinary innovation in the UK, sponsored by NESTA, the UK National Endowment for Science, Technology and the Arts, and conducted at the Centre for Research in the Arts, Social Science and Humanities (CRASSH) at Cambridge University.

Public policy for scientific investment emphasizes the need to support interdisciplinary research. The Royal Society report (2009) "The scientific century: securing our future prosperity" is typical, recommending that science and innovation can become "better aligned with global challenges" by reforming the UK research funding and assessment to support and reward interdisciplinary work: "Connections with and between the natural sciences and the social sciences, arts and humanities will be increasingly vital for innovation" (Royal Society 2010: 40). However, documents such as these are unclear with regard to the precise processes and mechanisms, or even the personal dynamics, through which such collaborative innovation occurs.

While the notion of interdisciplinarity has gained popularity due to a general association of innovation with processes of boundary crossing, collaboration, and the integration of different kinds of knowledge in general policy literature (e.g., in the UK see Council for Science and Technology 2001; Cox 2005; HM Treasury 2004), there is scant attention paid in this literature to what interdisciplinary research might consist of in practice. In academic accounts, epistemologically grounded frameworks for identifying and categorizing interdisciplinary research have been useful for the purpose of measuring interdisciplinarity in practice (e.g., Huutoniemi et al. 2009). However, they are limited in what they can tell us about the social aspects of collaboration between people to produce knowledge (Lattuca 2002) and, importantly, the critical role of the leadership of interdisciplinary teams (Brewer 1999). There is then a need to improve understandings of the actual processes of knowledge production as they occur on a day-to-day basis in order to avoid abstracting interdisciplinarity as an index of innovation and end in itself (Strathern 2004).

Definition: Family Resemblances in Collaborative Experience

The following analysis is informed by an anthropological perspective – that forms of knowledge do not exist outside of the specific social relationships in which they are constituted and reproduced (e.g., Brown and Duguid 2000; Chaiklin and Lave 1993; Engeström 1999; Latour and Woolgar 1979). Rather than reviewing policy recommendations and epistemological accounts of interdisciplinarity (of which there are many), the objective here is to describe interdisciplinary innovation in terms of the experiences of those who are recognized as achieving it.

The scope of the analysis was determined by a reputational survey of those considered by their peers in the UK to be exemplary practitioners of interdisciplinary innovation. Several rounds of "snowball sampling" asked leading practitioners which of their peers should be considered as exemplars, eventually making contact with 473 nominees from a wide range of disciplines. A second research phase involved a series of in-depth reflective workshops, to which a sample of these exemplary practitioners was invited as "expert witnesses." This phase was phenomenological in the sense that it focused on comparing personal reports of the experience of collaboration within the context of a professional career (Blackwell et al. 2009). The survey and workshop phases were supplemented with further site visits and interviews, and informed by reflection on the work of the Crucible network for research in interdisciplinary design, which has supported participants in more than 100 interdisciplinary projects over a period of 10 years.

The goal then here is not to construct a typology of interdisciplinarity or even a catalogue of what might be considered innovative practices. Rather, the purpose is to elicit the experiential aspects of working across perceived boundaries in the production of knowledge. Participants for the study were recruited from academia, the corporate, and public sectors. Workshop transcripts and survey responses were finally analyzed by a research team that was itself interdisciplinary and cross sectoral, comprised of both academic researchers and commercial strategy consultants with backgrounds in design, social anthropology, engineering, and economics. The result has been to treat the notion of interdisciplinarity as a "family resemblance" (Wittgenstein 1958). That is, not to assume practices categorized as "interdisciplinary" necessarily share a common set of properties, but rather are characterized by overlapping similarities in appearance.

In the remainder of this entry, these similarities are discussed in order to provide an introduction to the effective practices of interdisciplinary innovation identified here.

The Importance of Individual Leadership

While this analysis confirms previous studies of interdisciplinarity that emphasize the value of teams, of collaboration between different disciplines, and the ability to cross boundaries between different kinds of knowledge (e.g., National Academies 2005), it has also highlighted the essential role of the leaders of these enterprises. The majority of individuals that were identified from the reputational survey as exemplary interdisciplinary practitioners were managers and facilitators of projects. In this respect, the importance of key individuals to innovations arising from interdisciplinary collaboration cannot be underestimated. These individuals cannot be seen simply as charismatic leaders whose authority rests on their personal qualities, although the success of the projects they led was certainly reliant on the relationships they engendered between project members. What they worked to achieve was a personal engagement with the aims and goals of the project itself. In the sense that this does not involve normative values propagated through commitment to or faith in the leader, the authority of their leadership, while not impersonal, was depersonalized.

Narrative Construction of Events

Many individuals recognized as innovative interdisciplinary practitioners share an ability to narrate their projects to different audiences in ways that spoke to the relative value placed on the enterprise by interlocutors, negotiating differing needs and demands, and communicating in different registers to a variety of stakeholders. Whether this was representing the importance of research to funders, speaking to clients, or presenting arguments for policy, these leaders framed the narrative construction of the value and benefit of project goals to best communicate their goals and ideals to a variety of audiences. To be able to inspire and motivate diverse groups of disciplinary practitioners required framing project goals in ways that could appeal to all according to their own personal values and ideals. Researchers might, for example, be involved in a project because of the relative value placed on research outcomes – whether profit or the greater good, for career advancement, or the desire to broaden one's own intellectual horizons.

For some individuals, project goals might be subordinate to their personal aims, but the broader project narrative was able to accommodate and provide direction to various modes of personal and professional engagement. Meanwhile, project leaders might have to articulate the wider societal value of a project to a research funding body, framing arguments for its value within institutional and governmental funding priorities.

Shared Values

The importance of developing a sense of shared values and commitment to the research agenda was a theme frequently emphasized by expert witnesses. In some cases, this was a long-term commitment to an ideal, as in the work of the "Equator" consortium, a 6-year technology design initiative supported across eight UK universities to cultivate a community with diverse skill sets based in fundamental, curiosity-driven research. Consortium managers sought to create an environment in which teams could work together such that individuals derived their own value from the project while working within the framework of the consortium's research agenda. Mechanisms of appraisal were not merely measures of performance but placed key emphasis on critical reflection. This was a shared process of introspection that was seen to be a vital aspect of the management of the project, an egalitarian management style that allowed for people to engage with the project on their own terms and, importantly, implied a relationship of trust between all parties.

Commercial organizations are more typically concerned with incremental innovation that builds on existing products and business models. However, the egalitarian management ethos of commercial consultancy TTP bears a remarkable resemblance to that of successful interdisciplinary academic projects. TTP does not sell interdisciplinarity to its clients – clients already have a generalist understanding of their own business and come to TTP for specialist skills, not skill in interdisciplinarity. The core business of TTP relies on their being able to "sell" currently available staff as universal specialists – specialists in any problem that might present itself. The business cards of TTP staff do not reveal any specialization but present the holder as a representative of the TTP ethos. It is therefore essential that the company be managed in an egalitarian way, emphasizing social networks, collaborative personal styles, and matrix structure rather than strict disciplinary boundaries. There is then a strong sense of individual autonomy and flexibility in bringing people together in problem-solving teams in which knowledge and expertise might be combined in an ad hoc basis.

Polestar Leadership

The director of an interdisciplinary university research center for nanophotonics had consistently found that despite shared objectives, the most exciting discoveries from his work were not those expected at the start of a project. He gave highly skilled staff the freedom to pursue questions that interested them and noted the importance of motivating such a team through shared purpose. However, the tension between this leadership "from behind," and conventional expectations of leadership by vision and example, led him to describe his management style as neither from in front or behind but rather "sideways management," developing the metaphor of the "polestar," a long-term vision or goal that served as a common motivator to which multiple ideals and values might be oriented as a desired, ultimate research outcome.

Polestar leadership extends beyond the common notions of either intellectual leadership within an established tradition or of managerial coordination of activities within a project. It entails being able to recognize opportunities for alternative outcomes and being skilled at harnessing excitement among members of a team as it arises. This approach to innovation presents a number of challenges and paradoxes for managers and research sponsors. Few organizational structures are able to accommodate radical changes in the goals of a project, and it is hard for investment decisions to be made without articulating explicit outcomes that can be evaluated in advance. Although funding review and assessment procedures often distinguish between these intellectual ("scientific") and practical ("management") aspects of a research enterprise, the leadership of an interdisciplinary enterprise is not well characterized by either. Instead, leadership is manifest in the promotion of shared values and commitment to a community who share them. That community draws in, not only those directly employed in an enterprise but a wide variety of stakeholders, sponsors, and publics. The "polestar" vision that the interdisciplinary leader promotes and exemplifies does not rely on the knowledge structures of an established field (that would be a disciplinary research project) but on the potential to develop new knowledge and practices within a community that will value them.

Unanticipated Outcomes

The most valuable innovations arising from interdisciplinary research are often not anticipated at the outset, because successful interdisciplinary outcomes involve not only new answers but also new questions. Whether in contexts of professional problem-solving or open-ended curiosity-driven research, innovations arise in ways that cannot be foreseen at the outset of a new interdisciplinary enterprise, whether assembling a commercial team or commencing a research project. Most professional disciplines, or kinds of academic knowledge, bring with them ways of approaching a problem. This often involves restating the problem in a way that is compatible with the knowledge of the discipline – for example, the problem of obesity might be described by a physicist as being essentially one of "energy balance" – the result of people consuming more calories than they expend in exercise. However, the definition of a problem in disciplinary terms immediately excludes insights of other disciplines. Obesity might alternatively be described as a problem of social structure, to be addressed by investigating the fact that it is the wealthy and powerful who are obese in some cultures, but the poor and excluded in others. Neither formulation of the problem offers any direct assistance to the other.

Questions arise from the particular values of a discipline (in the obesity example, physicists are primarily interested in closed systems, while anthropologists are primarily interested in societies). It is only after significant periods of time or with specific attention and focus that collaborators from different disciplines are able to adopt each other's values to an extent that problems can be reformulated in radically different ways. Once this has been achieved, the ecology of interdisciplinary knowledge provides the context in which newly discovered problem formulations can be developed and exploited.

Ontology Versus Epistemology

It is often suggested that the main barrier to interdisciplinary collaboration is that disciplines develop their own jargon, such that those from outside cannot understand terminology. To a somewhat trivial extent, this may be true, although most experts are well aware of the technical terms and acronyms used in their field, and are easily able to adjust their discourse when speaking to nonspecialists. However, on the basis of findings of the study, it can be seen that the main obstacle to interdisciplinary innovation is not the need to find a "translator" or to develop a shared vocabulary. On the contrary, people from different disciplines seem to talk at cross-purposes because they are trying to achieve different things. They have difficulty understanding statements not because the words are unfamiliar but because the intention presumes different core values. In this respect, the issue of commensurability can be perceived as one of the ontological grounding of particular positions and perspectives rather than misunderstanding as a consequence of epistemological differences.

Many of the expert witnesses took the opportunity to reflect on their own personal histories and compare those histories to the attributes that they valued in collaborators, students, and employees. Individuals often seem to become "imprinted" with particular disciplinary styles as a result of early life experiences, especially first professional experiences and (for academics) early experience of higher education. This is not so much a matter of specific knowledge or disciplinary vocabulary (although vocabulary remains a consideration). Rather, it is a difference in ways of thinking, manner of approaching a problem, or the way in which goals are conceived. Expert witnesses referred to this obliquely or in passing as their "home discipline" or "native discipline," somewhat as though it were a first language, perceived ethnicity, or a country of origin. The literature on interdisciplinarity tends to assume that disciplinary knowledge is explicit rather than tacit, can be imparted via formal education, and can be articulated when necessary for comparison to other disciplines. It was found that those who work in interdisciplinary contexts, including among people who themselves have moved among many disciplines, suspect that their first academic training has left permanent traces that influence their intellectual style, wherever they have subsequently found themselves. The existence of personal and tacit disciplinary styles may form a natural limit on pace of disciplinary change, which could only be generational, if it is primarily the result of early career experiences. Interdisciplinary enterprises construct new communities that are composed of individuals who share willingness to step outside the knowledge boundaries within which they are trained. It is the diversity of the individuals that provides opportunities for unanticipated insight and innovation.

The Public Value of Interdisciplinary Innovation

While there are many components of innovation, encompassing both creativity and exploitation, this cross-sector analysis clearly brought to light the diverse targets for innovative activity in different sectors, encompassing the development of products or services for commercial exploitation, curiosity-driven academic research, problem solving of various scope, and the creation of social value through specific intervention. These may be summarized as follows:

- Commercial exploitation of new ideas, technologies, and processes is a primary concern of innovation, enshrined in definitions from business and economic policy bodies. The objective is to create, develop, implement, and sell products or services. To this end, commercial innovation is likely to be purposeful and managed. The result may be incremental – a minor enhancement of an already marketed or used product, service, or process. More spectacularly, commercial innovation may be radical, characterized by a greater degree of novelty, perhaps with a capacity to disrupt previous business.
- Curiosity-driven research is most often found in the academic sector. It seeks knowledge and new insights, creating unifying theories and models that describe a new understanding of perceived phenomena. Those phenomena might be equally well in the domains of science, of humanities, of arts and creative industries, of sociology, or of politics and policy. The aim is insight, not necessarily with the intention of action or intervention.
- Problem-solving activity is directed toward identifying some new approach that solves a situated problem. Here, there may be a problem of agreed boundaries – what is the scope of the problem and what kind of solutions are expected. The objective is an explicit intervention to solve or ameliorate the problem. In this context, success can be characterized by the extent to which the problem is resolved. New knowledge or new insights are a convenient but nonessential by-product.
- The enhancement of social value is another form of innovation, whether the health of a population or the social cohesiveness of a community. Here, the development may lie in the creation of a new intervention, or it may lie in the process by which change was exercised, for example, in an artistic endeavor that engages with marginalized parts of society.

So what is the value proposition of interdisciplinarity in these examples?

In the areas of problem solving or of the commercial development of a new product, service, or process, the objectives may be tightly defined. Here, the explicit intention of interdisciplinarity is the use of different skills or analytic perspectives – to frame the problem or opportunity, to bring to bear different repositories of knowledge, and to use the insights so gained to achieve a richer solution. It is believed that interdisciplinarity increases the likelihood of a radical solution to the problem or realizing the commercial opportunity. This requires more than the simple combination of professional skills to carry out routine business (as when a nurse, an anesthetist, and a surgeon work together in an operating theater). Radical innovations combine people and skills in unexpected ways, leading to results of different kinds to those that professional training is focused on.

In academic, curiosity-driven research, there may be new insights created by the new conjunction of differing interests and perspectives. In such cases, the different disciplines combine in ways that serendipitously stimulate breakthroughs. Indeed, in the pure research area, there is increasing enthusiasm for the unpredictable novelty and potentially radical nature of the results of interdisciplinary teams. Such research can also result in breakthrough opportunities for later commercial application or as foundations for innovative cultural and social action. However, such forms of exploitation often occur at a distance or a long time after the initial research investment. In these cases, it is not usually the goals of the original research project that result in long-term benefits. Instead, it is the creation of an "ecology" within which such exploitation can happen, where there is an intellectual and skills capacity of highly trained people, and these people have experience of working within other disciplinary contexts as well as networks of contacts giving them rapid access to other disciplinary knowledge.

A key policy concern at present is how one can prioritize and evaluate research activity that is supported with public funds. It is essential that value be demonstrated to the public and that those receiving public funds be held accountable for their use of funds. However, a paradox for responsible stewardship is that, while public funds should be directed toward known outcomes of public benefit, interdisciplinary research has essentially unknown outcomes. “Safe” or “incremental” research is considered less deserving of public support, yet it continues to be prioritized by mechanisms that assess performance within established categories. In order to maintain quality of academic enquiry, it is necessary to establish mechanisms that recognize and reward determined curiosity, willingness to step outside boundaries, and reflective development of personal and community practices.

Conclusion and Recommendations

Interdisciplinary innovation is primarily a social phenomenon, associated with the processes and experiences of crossing social boundaries, rather than an epistemological phenomenon as often implied by metaphors of “cross-fertilization” or “filling gaps” in human knowledge. Social structures are certainly associated with knowledge structures – every social group acquires and organizes its own characteristic body of knowledge. However, there is no reason to believe that academic disciplines as custodians of knowledge are any different from other social groups. Individual departments within large public organizations and corporations are equally likely to acquire, structure, and preserve special bodies of knowledge within which to define relative expertise, seniority, or originality among colleagues.

The instrumental agenda for policy advocates of interdisciplinary innovation is that new problems faced by organizations may need to be addressed by using knowledge from elsewhere. Of course, many routines and conventionally applied problems also include aspects that are well-defined as requiring a variety of specialist expertise (e.g., the design of a house may involve an architect, structural engineer, quantity surveyor, construction lawyer, etc.). Problems of this kind are ubiquitous but are not regarded as being “interdisciplinary” because of their conventional nature. The term “multidisciplinary” is often suggested as a means of distinguishing between routine collaboration and the innovative problem solving associated with interdisciplinarity.

When addressing a new kind of problem – one that requires an innovative solution – it may be clear from the outset that more than one kind of knowledge will be necessary to construct a solution. However, because the appropriate relations between disciplines have not yet been formulated, it will be necessary for collaborators to cross boundaries when negotiating a solution. Furthermore, even large organizations are unlikely to accurately forecast the problems they will face in future; in which case, the formulation of responses to future problems will require knowledge resources from outside the organization boundaries. The social need for crossing boundaries in interdisciplinary innovation is therefore a natural consequence of organizational life. Interdisciplinary boundary-crossing experiences are associated with innovation because they arise from novelty and from the need to prepare for the future.

This entry focused specifically on the personal experiences of those people who have gained a reputation for effective work in interdisciplinary innovation. These findings should be seen as being complementary to studies of organizational structure and to studies of the business and economic consequences that result from innovation.

The essence of interdisciplinary innovation is the experience of teamwork, where each member encounters people with different skills and perspectives to their own. However, those different kinds of knowledge are associated with boundaries. As noted above, knowledge is maintained within organizations – usually by the group of experts who are at the core of any organization and who maintain and develop its core knowledge. In many organizations, and especially academic disciplines, recruitment, induction, and advancement within the organization are often managed in terms of the extent to which an individual has acquired its core knowledge. Within traditional career structures (and again, academic disciplines are archetypal), the ultimate benchmark of expertise is the amount of knowledge that a person might reasonably acquire in a lifetime. Organizational knowledge boundaries, whether government departments or academic disciplines, are likely to be set in accordance with the lifetime capacity of the experts at the center of the organization.

Policy rhetoric advocating interdisciplinarity often denigrates the "silo," employing a metaphor that suggests knowledge would be better released into locations where it can be applied. However, the findings do not suggest that boundaries can simply be ignored or removed. Boundaries are essential to the social construction and maintenance of expert knowledge. The challenge of interdisciplinary teamwork is to find effective ways of working across those boundaries without disrupting them. In this respect, incommensurability might be perceived potentially as an enabler or driver for interdisciplinary engagement. The aim here is the facilitation of cross-disciplinary engagement – not to establish the ultimate veracity of a particular truth, model, or account of events but to generate the possibilities for new insights via engaging with those oriented practically in and perceiving the world differently.

There are, of course, obstacles facing those who wish to work outside their established organizational boundaries. Many disciplines have grown together as social groups precisely because of a set of shared values that motivated the creation of the discipline. It takes a wide range of skills, including substantial personal leadership ability, to manage a team of people who hold different values. In order to be effective interdisciplinary innovators, the team must develop shared values and culture, probably over a period of many months, leading to years. The leader of an interdisciplinary enterprise must create conditions to enable, encourage, and inspire that process. Furthermore, the leader must be able to recruit resources sufficient to maintain the team within an inherently uncertain environment.

The most valuable outcomes from an interdisciplinary enterprise were not anticipated at the outset. This is unsurprising, because future problems, or even novel problems that cross today's boundaries, are problematic because of the way they defy description in disciplinary terms. It is in the nature of such problems that they cannot be described or characterized in established terms. The leader must therefore be able to attract resources, maintain them over a considerable period of time, and be a competent manager of uncertainty and risk, while also being a skilled enabler of serendipity – providing the capacity to recognize and profit from unexpected events.

Cross-References

▶ Interdisciplinary Research (Interdisciplinarity)
▶ Knowledge Society, Knowledge-Based Economy, and Innovation

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Interdisciplinary Groups

► Creative Collaboration

Interdisciplinary Research (Interdisciplinarity)

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Synonyms

Cross-disciplinarity; Multidisciplinarity

Introduction

From the beginning the discourse on interdisciplinarity (ID) was "a discourse on innovation in knowledge production" (Weingart 2000: 30). Its basic objective has been to make science and higher education more responsive to the complexity of life-world problems and more relevant for the public good and the legitimate needs of the society. The criticism leveled in the name of ID against the disciplinary organization of the traditional universities was summarized under the oft-cited catchphrase "Communities have problems, universities departments" (CERI 1982: 127).

The term interdisciplinarity or interdisciplinary research (ID) can be defined in two distinct but intersecting ways: interdisciplinarity means either the collaboration of researchers trained in different fields of knowledge or the integration of different concepts, methods, and data from two or more different disciplines, no matter if this interdisciplinary integration is achieved by an interdisciplinary research group or by a single researcher.

However, an interdisciplinary *integration* of different knowledge fields requires at the same time new *divisions* of knowledge, since the definition of specialized topics between disciplinary knowledge fields is essential as interdisciplinary foci for any collaborative research across disciplinary boundaries (Weingart 2000: 36). The dream of an all-encompassing unity of knowledge belongs to the past, an ID integration of different knowledge claims can be reached only in a variety of local syntheses between research findings of carefully selected disciplines.

History of the Concept

The Organization for Economic Co-operation and Development (OECD) was in the 1970s one of the first organizations promoting interdisciplinarity with the aim to strengthen universities "which in the future ought not be the servant but the conscience, the analytical mind and the driving force in society" (Briggs et al. 1972: 288). Scientific research should become more relevant for the economic as well as the societal development of modern societies. It was the time of the starting discourse about "knowledge societies," which found 1973 its prominent advocate in

Daniel Bell's book "The Coming of Post-Industrial Society: A Venture in Social Forecasting" (Bell 1973).

Nevertheless, the concept of interdisciplinarity itself was from the beginning about the nuts and bolts of the day-to-day research in industrial laboratories and at universities. In contrast to the discourses on knowledge societies (Bell 1973), Mode-2 research (Gibbons et al. 1994; Nowotny et al. 2001), the Triple Helix Model (Etzkowitz and Leydesdorff 2000), and on Quadruple Helix Innovation Systems (Carayannis and Campbell 2012), the discourse on ID research does not presuppose any macro theories about societal developments or all-encompassing speculations about historical developments. Although to make a well-founded case for doing ID research, ID supporters are often relying on one of these theoretical forecasts and analyses of modern society. The concept of ID itself just asserts that for the solving of certain societal problems, researchers have to transgress disciplinary boundaries and engage in ID collaborations. The competence to engage in ID research is seen as an indispensable craft for modern societies: if someone wants to cope with the complexity of the modern world, the competence for ID research is a vital skill to be learned. Therefore, ID is basically a discourse on the how-to-do of successful disciplinary-boundaries-transcending scientific research (Arnold 2009).

As a matter of fact the term interdisciplinarity became since the 1980s a prominent key tender term in many newly established research funds aiming at more social or environmentally relevant scientific research (cf. Hackett 2000; Krull and Krull 2000). Soon ID was implemented in university curricula as well, teaching students – with an eye to their prospective field of work and to their role as responsible citizens in a modern democracy – to tackle with complex life-problems by the use of different scientific methodologies in a professional way (Kockelmans 1979; Frodeman et al. 2010: 345–403).

In 2004, the EU research Advisory Board circulated recommendations for interdisciplinarity in research (EU Research Advisory Board 2004), in 2005 the Finnish Academy of Science followed with a study promoting ID (Bruun et al. 2005), whereas in the USA the National Academy of Sciences together with the National Academy of Engineering issued a report evaluating past achievements of ID research and recommending ID as an important and successful way for innovations, stating that:

> "many of the great research triumphs are products of interdisciplinary inquiry and collaboration: discovery of the structure of DNA, magnetic resonance imaging, the Manhattan Project, laser eye surgery, radar, human genome sequencing, the 'green revolution,' and manned space flight." (Committee on Facilitating Interdisciplinary Research et al. 2005: 17)

Furthermore – as the report adds (ibidem) – many of today's "hot" research topics are interdisciplinary like nanotechnology, genomics, bioinformatics, neuroscience, conflict, and terrorism, as well as research in areas like disease prevention, economic development, social inequality, and global climate change.

Aims and Limits of Disciplinary Research

The First Obstacle for ID: The Disciplinary Organization of Science

Although the term *disciplina* was used as early as in the Middle Ages for the ordering of knowledge within universities, the invention of the modern scientific discipline (here and in that which follows including humanities and the social sciences) dates back to the nineteenth century and the invention of the modern research university in Berlin. Since then, disciplines are the basic units of differentiation within the system of science and the higher education system as well. They were established together with the emergence of modern scientific communities and the first scientific journals with their standardized ways of scientific communication with colleagues and specialized readers only. Amateur scientists, which were in the eighteenth century as educated public still an accepted part of the scientific community, became now excluded (Stichweh 1984, 1992). It was the arrival of what Thomas Kuhn later famously called "normal science." Its chief characteristic is its close alignment to approved "paradigms" (or what Kuhn later called "disciplinary matrix"), setting narrow limits for new methods and research questions:

> "Perhaps the most striking feature of the normal research problems [. . .] is how little they aim to produce major novelties, conceptual or phenomenal. [. . .] To scientists, at least, the results gained in normal research are significant because they add to the scope and precision with which the paradigm can be applied." (Kuhn 1970: 35 f.)

"Normal science" is nothing more or less than a kind of "puzzle-solving," since each paradigm identifies perplexing puzzles, suggests paths to their solution, and reassures that not scientific genius but the hard work of scientific practitioners will be sufficient for success (Kuhn 1970: 179). In other words, paradigm-led normal science is aiming at perfection, that is, incremental innovations, to find better answers to existing questions. Radical innovations, like paradigm shifts, are within the disciplinary organization of the sciences the exception and not the rule.

The Second Obstacle for ID: The Variety of Epistemic Cultures

However, it is not merely the disciplinary orientation of normal science which impedes ID collaborations. Even, should the need for an ID collaboration be acknowledged by scientists, cooperation may become difficult since different epistemic cultures are often in conflict when it comes to questions like: What are sound methods? How to measure quality, but also more subtle differences like differences in social values making day-to-day collaboration within interdisciplinary teams again and again vulnerable to conflict and fundamental misunderstandings (Arnold 2004; Becher 1993; Knorr-Cetina 1999)? Furthermore, different disciplines are often not considered as of equal rank and status within the disciplinary system:

> "[T]he interdisciplinary team is an open rather than a closed system. [. . .] Interdisciplinary teams in this respect are status systems that reflect external hierarchies and disciplinary chauvinism. [. . .] [T]he status system of a team will tend to follow the status system of the world outside the team if there is no strong alternative organization, though even a strong organization cannot eliminate status ambiguity and clashes in career goals, professional styles, and epistemologies." (Klein 1990: 127, cf. Lamont 2009)

The different disciplinary contributions by themselves, therefore, often do not add up to a coherent whole, that is, to an integrated research result, since they adhere to quite different epistemological principles or are the product of diverse research routines.

The Third Obstacle for ID: The Claims of Professional Jurisdiction

For experts (inside and outside the universities) to accept that other experts can contribute with their methods and disciplinary knowledge as much as oneself to the solution of a problem implies in the end to give up one's own disciplinary claim for exclusive professional jurisdiction over this problem field. Hence, interdisciplinary cooperation can conflict with professional aspirations to prevent competing scientific communities and professions from interfering in one's own field of expertise:

> "A jurisdictional claim made before the public is generally a claim for the legitimate control of a particular kind of work. This control means first and foremost a right to perform the work as professionals see fit. Along with the right to perform the work as it wishes, a profession normally also claims rights to exclude other workers as deemed necessary, to dominate public definitions of the tasks concerned, and indeed to impose professional definitions of the tasks on competing professions. Public jurisdiction, in short, is a claim of both social and cultural authority." (Abbott 1988: 60)

For that reason the demand for ID cooperation is seen especially by dominant disciplines and professions as infringement of their jurisdictional claims for exclusive responsibility; to admit the relevance of the expertise of other disciplines for a particular research project is like accepting a kind of defeat inevitably undermining the social and cultural authority of one's own disciplinary knowledge and expertise. The authority of jurisdictional claims is important for disciplines not least because jurisdictional claims, when acknowledged as legitimate, are directly translatable in further research funding and job opportunities on the labor market for their graduates (Turner 2000).

Innovations: Crossing Disciplinary Boundaries

Trading Zones: The Value of Multidisciplinary Perspectives

Although multidisciplinarity is not ID as such, since a multidisciplinary perspective on an issue is per definition not aiming at an ID *integration* of the different perspectives, multidisciplinarity can become an important, if only preliminary stage in the process of designing ID projects and research programs. Putting a multiplicity of disciplinary approaches together can provide a multifaceted outlook revealing the complexity of real-world problems pointing out the need for a truly interdisciplinary solution.

Peter Galison developed the concept of disciplinary "trading zones" in his attempt to describe the requirements of a difficult, but in the end successful multidisciplinary collaboration between engineers and physicists with different theoretical background in the development of particle detectors and radars (Galison 1997: 781–844; Gorman 2002). These different groups had not only to find an agreement over those objectives, the design of the particle detector had to achieve: to communicate their ideas they had to invent a common ("creole") language transcending their disciplinary idioms to explain their research programs and to share their disciplinary expertise commonly.

> "The point is that these distinct groups, with their different approaches to instruments and their characteristic forms of argumentation, can nonetheless coordinate their approaches around specific practices. [. . .] Note that here, as in any exchange, the two subcultures may altogether disagree about the implications of the equivalences established, the nature of the information exchanged, or the epistemic status of the coordination." (Galison 1997: 806)

Unlike ID, which aims at a comprehensive integration of disciplinary knowledge domains and shared epistemological models, *multidisciplinary* co-operations can differ about theories and their understanding of the collaboration, since they do not necessarily need unanimity and a common perspective.

Such "trading zones" between different scientific and societal groups are public spaces where the need for certain interdisciplinary co-operations and projects can become pressing and where innovations through brokering of ideas, methods, and theories are becoming more likely to emerge. Therefore, as Lester and Priore have argued, certain institutional and organizational arrangements to encourage this kind of brokering and trading of multidisciplinary information with the help of public domains have to be established and maintained within an innovation system. Particularly the modern research university with its diversity of scientific disciplines under one organizational roof is well-designed for this special purpose: to provide a kind of "sheltered space" that can sustain public conversations between a variety of scientific specialists and societal stakeholders:

> "To a much greater degree than in business firms, the disciplines dominate [within the university] the conversations; but the diversity of perspectives is greater than in firms because academic discussions draw in a broader range of participants [. . .]. Even accounting for the restrictive influence of the disciplines, a university, far more than a firm, is a public space." (Lester and Priore 2004: 166 f.)

These multidisciplinary public conversations within the universities (and at other places) give rise to "interpretative communities" enabling actors with different backgrounds to establish common definitions of societal problems and research questions, which are the indispensable precondition for the design of ID research programs and research co-operations.

Interactional Expertise: Communicating Across Disciplinary Boundaries

The competence necessary to build ID research co-operations within these "trading zones" is what Collins and Evans have called "interactional expertise" (in contrast to "contributory expertise"), that is, an expertise in understanding and communicating knowledge across the boundaries of disciplinary communities and specialized fields of expertise:

> "mastery of interactional expertise [. . .] is the medium of interchange within large-scale science projects, where [. . .] not everyone can be a contributor to everyone else's narrow specialism; it is, *a forteriori*, the medium of interchange in

> properly *interdisciplinary*, as opposed to multidisciplinary, research." (Collins and Evans 2007: 31 f.; cf. Collins and Evans 2002)

To cooperate successfully with other disciplines it is necessary to understand their problems, methods, and results, so one can talk with members of this scientific community about their research questions and findings on a certain level of expertise without becoming a member of this community by oneself. Obtaining this level of understanding is possible only with the help of insiders, who are willing to explain their work. Cultivating interactional expertise for an interdisciplinary cooperation requires an ongoing effort to make disciplinary knowledge accessible to a wider public, in other words by participating in efforts of "popularization" which itself is usually aligned with innovation and interdisciplinarity:

> "In modern science innovation, especially radical or revolutionary innovation is regularly coupled to interdisciplinarity as a mechanism of hybridization of scientific knowledge. And popularization is often based on interdisciplinary combinations of knowledge which sometimes are audacious. Therefore, there is a significant innovation potential in popularization [. . .]. Doing popularization is [. . .] an opportunity for experimenting with a level of intellectual risk which is not readily accepted in everyday scientific practice." (Stichweh 2003: 215)

Communicating scientific knowledge successfully beyond the confines of its disciplinary community is only possible if this knowledge is placed within a wider context: its relations to other sources of knowledge – how they match or mismatch with one another – as well as its societal relevance have to be explained, helping to understand the significance of this knowledge and why it should be considered as relevant in the context of certain research questions. Furthermore, concentrating on the relevance of scientific knowledge for societal problems is an effective way to connect disciplinary expertise to the expertise of other disciplines, to relate scientific findings to everyday knowledge and to widely hold cultural beliefs – in preparation for the development of ID epistemological models.

Interdisciplinary Epistemology: The Need for ID Models

For the integration of different disciplinary knowledge fields one is in need of a theory or an epistemological model of the relations between these different knowledge claims. For example, how can someone best analyze a historical period or – more generally – the "cultural" practices of a societal group: the evidence of social sciences based on statistical numbers is different from the evidence of historical scholarship based on archival sources. And both are different from the evidence of literary and media studies based on an interpretation of a novel or a film. However, each of these knowledge domains can provide a substantial contribution for the understanding of someone's "culture." Only a combination of these different disciplinary results, governed by a theoretical model of the epistemological relations between their methods and sources, can give an interdisciplinary perspective on the distinctive cultural features of someone's way of life, that is, a detailed explanation of one's culture.

Therefore, when the French historian Fernand Braudel proposed (together with the members of the so-called Annales School) a research program aiming to show how geography and economy have shaped societies and historical events in particular, he had to integrate findings from disciplines as diverse as geography, economy, and history within a theoretical model. Since these

> "systems of explanation vary infinitely according to the temperament, calculations, and aims of those using them: simple or complex, qualitative or quantitative, static or dynamic, mechanical or statistical. [. . .] In my opinion, before establishing a common program for the social sciences, the crucial thing is to define the function and limits of models, the scope of which some undertakings seem to be in danger of enlarging inordinately." (Braudel 1980: 40)

Braudel's epistemological reflections on the different disciplinary systems of explanations made him aware of what he called the *longue durée* (the long term) in contrast to the short-term events which lie in the traditional focus of the historians. To integrate these different levels of explanations, he established his famous distinction between three levels of time: (1) the geographical time of the natural environment, where change is very slow and almost imperceptible for human actors, (2) the long-term developments of the economic, social, and cultural history, and (3) the time of the historians dominated by short-term events and the actions of individuals, including those of politicians and soldiers. Only then could Braudel begin to integrate the diverse disciplinary findings within a methodological sound historical framework, as he did, for example, in his influential *The Mediterranean and the Mediterranean World in the Age of Philip II* (1949).

Another example is an ID model developed by the interdisciplinary Birmingham School of Cultural Studies to understand innovation in the "culture industry" analyzing, as an example, the invention of the Sony Walkman. Introducing the model of the "circuit of culture" they have tried to understand the interactions between five different cultural processes: the production of goods, the consumption, different kinds of regulations, the cultural representations within mass media, and the construction of social identities. In other words, how an electronic device "is represented, what social identities are associated with it, how it is produced and consumed, and what mechanisms regulate its distribution and use." (Gay et al. 1997: 3). The ID model is necessary to combine diverse types of knowledge about an electronic device such as the Sony Walkman. Only then is it possible to understand how every product is participating in various economic, social, and cultural processes: why success and failure of an innovation are always depending on the interaction of these processes, which are often mistakenly seen as autonomous and for that reason usually analyzed by separate scientific disciplines.

A theoretical model of the ID relations between different knowledge domains helps to understand how someone can integrate different disciplinary findings in a methodological sound way.

Organizing Interdisciplinary Research Teams

Each discipline or research area has to develop and care for its own epistemic culture. Therefore, it is important, which scientific disciplines should be integrated within an interdisciplinary project. Different methods, different kinds of argumentation and evidence, as well as different social arrangements of inner-disciplinary co-operations require customized solutions for every single ID-research project (cf. Piaget et al. 1972; Piaget 1973; Becher 1993; Klein 1996; Arnold 2009). But also the host institutions can differ regarding the type of ID research that they are supporting. There are on the one hand ID institutions with changing research topics and temporary research groups, such as the German Center for Interdisciplinary Research (ZiF, *Zentrum für interdisziplinäre Forschung*, University of Bielefeld), founded in 1968 (Frodeman et al. 2010: 292 f.), or on the other hand institutions with long-lasting ID research teams institutionalized in departments staffed with both permanent and temporary researchers, such as at the Austrian Faculty for Interdisciplinary Studies (IFF, *Fakultät für interdisziplinäre Forschung und Fortbildung*, Alpen-Adria-Universität Klagenfurt), with predecessor organizations dating back to its first formation in 1979 (Arnold and Dressel 2009). In the former case ID is seen as driven by changing scientific interests, in the latter ID is organized around societal problems, which require steadfast attention over many years if they ever should be solved.

Nevertheless, there are also some characteristics, which most ID research projects have in common. For example, to create an ID research team out of a multidisciplinary group of researchers, where at least one of the research participants has to think interdisciplinarily, working deliberately on the integration of the different methods and research findings (Parthey 1999). Much time has to be designated for periodic team meetings (not least at the beginning, but during the project as well), to elaborate not only a common understanding, but also to address personal irritations and conflicts between team members face-to-face. Since learning from other disciplines is an important element of ID projects, a successful ID research process can be seen as fostering a type of societal learning, where scientists share their different knowledge and expertise aiming to create a common understanding of the problems and the solutions, with the result that every team member has to acquire and adopt this knowledge during the research process (Arnold 2009).

However, ID depends on the individual researcher's competence and personal ability to cooperate with others in ID research teams. Studies suggest that there are certain character traits which many effective ID researchers have in common like "a high degree of ego strength, a tolerance for ambiguity, considerable initiative and assertiveness, a broad education, and a sense of dissatisfaction with monodisciplinary constraints" (Klein 1990: 183).

Evaluating Interdisciplinary Research

As Heinrich Parthey showed, a good indicator for ID is the percentage of researchers within a research group who formulate their own guiding research problem in concepts spanning across disciplinary boundaries. Because thinking from an ID perspective means to formulate and justify the guiding research problem on a different theoretical level and with different theoretical concepts than the methods with which these interdisciplinary problems are approached afterward by the participating disciplines. In addition, a second important indicator for ID research is the interdisciplinary character of the methods applied to the problem: when scientists borrow methods across disciplinary boundaries, for example, by transfer of methods from other specialist fields of research (Parthey 2011). Both traits have to be encouraged within research teams and both are valuable indicators for the evaluation of the "interdisciplinarity" of an ID research project.

But one main problem in evaluating the quality of ID remains: Who is able to judge about the quality of ID research? Disciplines have their standards and their peers, but ID projects are by definition transcending disciplinary boundaries:

> "Since interdisciplinary research is a new synthesis of expertise, peers in the strong sense of the word do not exist. When new combinations of knowledge are tried in interdisciplinary projects, no one but those conducting the work are competent in all aspects of that combination." (Laudel 2006: 57)

Furthermore, empirical research suggests a bias against ID in peer review since peers tend to favor proposals belonging to their own field of study (Laudel 2006) and are falling back on traditional disciplinary standards of the disciplines involved so that in the aggregate all too often an ID research proposal has to meet more quality criteria than disciplinary proposals, increasing the likelihood of getting rejected by research funds (Lamont 2009: 208–211, Mansilla 2006: 25, Huutoniemi 2010: 312 f.).

As already said above (Sect. The First Obstacle for ID: The Disciplinary Organization of Science), paradigm-led disciplinary science is aiming at perfection, that is, incremental innovations, to find better answers to existing questions. Disciplinary evaluations, therefore, endorse those projects which are "sound" and "mature" according to the existing disciplinary standards, they are looking for inaccuracies. However, innovations are per definition not "mature" and in the beginning not "sound" (as defined by disciplinary-oriented evaluators) as well. Since competing quality standards of different disciplines are often one of the reasons why disciplines cannot agree to cooperate in a common research project, ID research has often to develop and justify its own methodological standards, which are appropriate for its special research questions and its carefully selected new research objectives.

Conclusion and Future Directions

Creating an innovation and ID-friendly research environment will remain an important objective for the near future. Since despite critics who are still claiming that ID is nothing but a passing science policy fad: as long as modern research and teaching is primarily organized within disciplinary boundaries, ID research will assert its rank as one of the most important paths to innovation. Its major aim will remain to counterbalance the conservative and inward-looking character of strictly disciplinary research organizations, of their research questions and evaluations. For that reason the distinct quality of ID has to be recognized for the funding of research and the management of research organizations as well. Traditional quality indicators like publications in disciplinary journals can contradict the very intentions of ID-research: stipulating that the results should be published in different (disciplinary) journals forces research teams at the end of their project to dissolve the already achieved level of ID knowledge integration again into its disciplinary parts. By insinuating that disciplinary audiences are the only legitimate judges about the outcomes of ID research, ID is against its principal objective treated as nothing but a loosely connected "multidisciplinary" synopsis of disciplinary research questions and findings.

Hence, the assessment of ID should not solely consist of a post hoc addition of individual expert opinions, but of the deliberate attempt to integrate different disciplinary perspectives with the help of the consolidated judgment of an ID expert group, amenable to reason and time-consuming deliberations. Only a disciplinary-boundaries-bridging group of experts is able to appreciate the specific merits of ID research such as developing new research questions and research programs beyond well-trodden disciplinary paths.

Furthermore, since ID is not only aiming for innovations but also on social relevance, combining interdisciplinary research with participatory transdisciplinary research (TD) is a highly successful method to ensure within an ID research project both the non-disciplinary character and the social relevance of the research questions. Thus, proceeding from life-world problems and integrating not only knowledge of different scientific disciplines, but in addition also non-scientific expertise as well, can be seen as one of the most promising research strategies for the future of ID.

Cross-References

▶ Mode 1, Mode 2, and Innovation
▶ Transdisciplinary Research (Transdisciplinarity)

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Interest and Creativity

▶ Using Movement, Music, and Humor - Creative Approaches to Enhance Student Engagement

Interest and Enjoyment

▶ Intrinsic and Prosocial Motivations, Perspective Taking, and Creativity

Interfirm Alliance Networks

▶ Networking Entrepreneurship

Interindividual and/or Interorganizational Interdependence

▶ Social Networks and Entrepreneurship

Internal Factors

▶ Individual Determinants of Entrepreneurship

Internal Innovation

▶ Corporate Entrepreneurship

Internal Model

▶ Models for Creative Inventions

Internal Models

▶ Mental Models and Creative Invention

Internal Venturing

▶ Corporate Entrepreneurship

International Entrepreneurship

▶ Entrepreneurship in International Context

Intrapreneurial Project

▶ Business Project

Intrapreneurship

▶ Corporate Entrepreneurship

Intrinsic and Prosocial Motivations, Perspective Taking, and Creativity

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Synonyms

Empathy; Interest and enjoyment; Motivational components of creativity

Key Concepts and Definition of Terms

Creativity is a complex construct often defined as requiring the components of both novelty and usefulness. So how can organizations and managers activate both novelty and usefulness in encouraging creativity in the workplace? Broadly defined, motivation is a set of psychological processes that directs, energizes, and sustains action (Mitchell and Daniels 2003). People may be moved to action by several different kinds of motivations. Researchers have explored the effects of extrinsic, intrinsic, and prosocial motivations on creativity often with inconsistent findings. Perhaps alone, these motivational drivers encourage a focus on only one of the two main components of creativity, but activated together, different motivations may more consistently encourage creativity through increasing both novelty and usefulness considerations.

Intrinsic Motivation

The most common definition of intrinsic motivation can be stated as a desire to expend effort based on an individual's positive reaction to the task itself, primarily founded in a personal interest in and enjoyment of the activity that is being performed (Amabile 1996; Ryan and Deci 2000). Intrinsically motivated people often find themselves lost in their driven activity for the pure enjoyment of it. The need to explore this activity often leads one to focus on new experiences with little regard for their value outside of the pleasure derived from engagement in these activities.

Prosocial Motivation

The desire to expend effort based on a concern for others is a common definition of prosocial motivation (Batson 1987; Grant 2007). The target of prosocial motivation can be a single individual, group, or other people in general. Thus, this motivation directs one to act in a way that is intended to benefit others. This focus on helping others encourages one to have an understanding of what might contribute to others needs or wants.

Perspective Taking

The cognitive process of adopting another viewpoint in an effort to understand their needs, positions, and interests is often defined as perspective taking (Parker and Axtell 2001). Trying to view a situation through another's eyes can help one recognize what that other person is thinking, feeling, or interpreting from a given scenario.

Creativity

J.P. Guilford (1897–1987) is often considered the father of modern creativity research. He defined creativity as novelty bounded by some degree of evaluation that the novelty fits the needs of the particular situation. More recently, creativity has been broadly defined as a contextually based social judgment that an idea, process, product, or person is both novel and useful (Amabile 1996). The two factors of novelty and usefulness are contextually bound in that they are essentially comparative considerations. Novelty is compared to what is currently known or done. Usefulness is estimated with respect to a need, intent, or problem.

Theoretical Background and Open-Ended Issues

Positive Motivational Influences on Creativity

Creativity can be found in almost every aspect of human endeavors from art to science, from one's personal life to business interactions. The outcomes of creative efforts are often seen as important drivers of economic value and human achievement. Yet as creativity requires some component of differentiation from what is already present or currently accepted, there is a note of risk involved with being creative. In presenting a creative product or approach, one opens oneself to failure or rejection. Thus, this type of activity is not naturally a default but requires a motivational force to counterbalance the perceived risks of being different that are so integral to being creative. Even as creativity requires some amount of novelty, it also requires a second component: usefulness. Driving one without the other may leave an effort short of achieving an improvement in creativity.

Novelty and usefulness are the two main criteria for something to be considered creative. Novelty is the extent to which something is new or unlikely to have been considered by others. Usefulness is the appropriateness or value of a thing in a given situation. If one was asked to generate a creative new product to replace glass as a car windshield, corrugated aluminum might be a novel response, as it would be different and probably unlikely to have been considered by others. However, this response would probably not be considered useful as a key need in car windshields is transparency. This idea would thus not be considered creative as it only possesses one and not both components required for creativity. Just the same, a response of clear plastic might be useful but not novel. Creativity requires the presence of both novelty and usefulness factors.

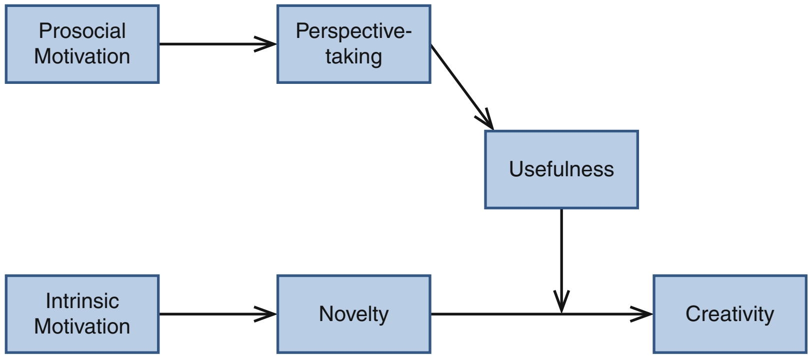
It is this dual componential nature of creativity that makes single focused approaches to driving its attainment inconsistently effectual. If one motivates a focus on novelty without consideration for usefulness, creativity may be increased via more novelty, but those gains may be offset by a loss of focus on usefulness. This could happen with a drive toward usefulness crowding out novelty, as well. To consistently motivate people to higher creative achievement, both components must be activated.

Amabile (1996) has tied intrinsic motivation to creativity as a central factor essential to developing creative ideas or products. When one is driven by intrinsic motivation, the engagement of the activity is the end, and the activity is not undertaken as a means to some external goal. Individuals so motivated experience a desire to explore their curiosities, to learn, and to continue the activity. This individually driven focus on the enjoyment of the task at hand leads to a feeling of freedom and escape from control that allows an individual to explore novel concepts. This feeling of freedom and intense immersion in an activity is well described by Mihaly Csikszentmihalyi in his book Creativity (1996).

This type of activation encourages creativity through cognitive exploration, positive affect, and persistence. On the cognitive side, the desire to learn often stimulated when one is intrinsically motivated by a task, encourages one to expand one's understanding of the activity and explore new avenues of the task. Positive affect has a similar influence on creativity in that positive affect has been linked to an increase in cognitive flexibility and a broadening of the information available to an individual. Additionally, persistence in the activity allows a longer time to explore new ideas and generate options, thus maximizing the effects of cognitive and affective benefits. This increase in flexibility and information increases the likelihood that combinations of ideas and solutions will be unique. Donald T. Campbell argued in 1960 that the more information available and the more combinations one can generate will logically lead to more novel options being developed.

When one is so engaged in an activity, the development of novelty can often be seen as an end in itself. Oftentimes, one can get so absorbed in the intrinsically motivated activity that other considerations are ignored. It is this aspect of intrinsic motivation that encourages a drive for novelty at the expense of external considerations beyond the activity. Sometimes, the results of these intrinsically motivated activities coincide with external demands. Organizational efforts at matching individual's personal interests with work duties, allowances for job crafting, or encouraging autonomy are several ways of encouraging alignment of novelty generation with organizational utility. However, these efforts may encourage a chance congruence of novelty and usefulness; they do not put a direct focus on the utility of generated ideas or solutions.

A focus on utility is often encouraged by motivation efforts imposed from external sources, particularly within organizations. Externally determined rewards for completing certain tasks or reaching milestones can be very effective at driving certain behaviors, but these rewards encourage activity in a task for an externally justified end. Often, these extrinsic motivational approaches are seen as efforts to control an individual and as such are often detrimental to intrinsic motivation and the resultant gains in novelty. This being the case, extrinsically focusing a person on an externally determined goal (usefulness to the organization) may come at the expense of novelty. If extrinsic motivation can be applied in a noncontrolling fashion, then there may be an opportunity for creative synergy between these motivational sources (see Hennessey and Amabile 2010 for a broader discussion).



Intrinsic and Prosocial Motivations, Perspective Taking, and Creativity, Fig. 1 Relations between intrinsic motivation, prosocial motivation, perspective taking, and the components of novelty and usefulness driving creativity

Creative synergy or a maximization of both novelty and usefulness can be engendered when intrinsic motivation is paired with an internal drive to be productive for others. Prosocial motivation encourages individuals to be concerned for and act in ways that contribute to the welfare of others. This is an internally generated desire and thus avoids the negative effects related to feelings of being externally compelled to engage. However, acting on a desire to help others necessitates at least an attempt at understanding of what may be helpful to them. This type of other-focused motivation may benefit creative efforts by providing a desire to focus on the usefulness of these efforts.

Being motivated to help someone may provide the intent for usefulness. Moving this intent to effective improvement in creativity requires understanding of what might be helpful to the target of one's prosocial motivation. This intent to help others encourages one to build an understanding of what might be beneficial to those one seeks to help. In this way, prosocial motivation promotes an attempt to understand issues from another's perspective. This perspective taking can help provide an external reference of what ideas or products may be ultimately useful to others.

Combining both intrinsic and prosocial motivations may be an effective way to maximize creativity. By activating increased focus on both novelty and usefulness, the motivational effects may be more powerful together than alone. This model as shown in Fig. 1 posits that intrinsic motivation influences creativity through increasing novelty and prosocial motivation influences creativity through perspective taking increasing usefulness.

Conclusion and Future Directions

This model of how motivation relates to creativity through its components of novelty and usefulness can be valuable in conceptualizing how different motivations may influence creativity to generate synergistic effects. Research in this area (Grant and Berry 2011) has supported this general model, finding a strengthening of the link between intrinsic motivation and creativity when perspective taking is encouraged through prosocial motivation. The inclusion of the novelty and usefulness components in this model is at this point theoretical. How these motivations and perspective taking exactly influence creativity efforts is an area for future exploration. Additionally, perspective taking may be engendered by different means other than prosocial motivation; thus, there are opportunities to explore the independent effects of perspective taking on usefulness and creativity.

These findings suggest that organizations might want to broaden their attempts to motivate employees for creativity through multiple avenues simultaneously to encourage a focus on both novelty and usefulness. By considering how different motivations influence creativity through the individual components of novelty and usefulness, this work attempts to explain inconsistent results often found when studying single motivations and their relation to creativity. Hopefully, this approach to expand the precision of how motivation relates to creativity can be applied to other areas of investigation into this complex concept we call creativity.

Cross-References

▶ Cognition of Creativity
▶ Creativity and Emotion
▶ Creative Mind: Myths and Facts
▶ Effects of Intuition, Positive Affect, and Training on Creative Problem Solving
▶ Promoting Student Creativity and Inventiveness in Science and Engineering

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Intuitive Thinking Versus Logic Thinking

▶ Divergent Versus Convergent Thinking

Invent

▶ Invention Versus Discovery

Invention

▶ Analogies and Analogical Reasoning in Invention
▶ Applied Design Thinking Lab and Creative Empowering of Interdisciplinary Teams
▶ Creativity and Innovation: What Is the Difference?
▶ In Search of Cognitive Foundations of Creativity

Invention and Innovation as Creative Problem-Solving Activities

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Synonyms

Creativity; Novelty creation

Background: Microeconomics of Novelty Creation and Problem Solving

Obviously, invention and innovation can be hardly analyzed from the usual cost/benefit perspective of economics. These processes are conjectural by their very nature:

- Because ex ante results of the search endeavor cannot reasonably be anticipated (or even expected)
- Because there is no guarantee for the social acceptance of a possible result
- Because there is the risk that an accepted result cannot be used as a source of (additional) private yield (Nelson 1959a, b, 1982)

Due to these intricacies, invention and innovation have previously been either considered as coming "out of the blue" (Kirzner 1979; Vromen 2001) or have been simply postulated as an outcome of mesopatterns in terms of paradigms, routines, and institutions (Dosi 1988; Lundvall 1992).

Notwithstanding these caveats and provisos, various attempts to conceptualize the novelty creating process from a microeconomic perspective have been made (Kline and Rosenberg 1986; Noteboom 2000; Witt 2009). The common denominator of these attempts is that these novelty creating processes have essential features which can be dealt with analytically: (a) there are boundary conditions or triggers making the occurrence of these processes highly probable; (b) these processes can be divided in different phases, each of which is characterized by specificities in terms of cognitive resources, uncertainty, and economic constraints; (c) time matters not only in terms of succession and path dependency but also in terms of feedback loops with different range; (d) multiple types of behavior are included in these processes (especially deliberation and intuition); and finally (e) their social embedding has to be taken into account (especially related to the issues of acceptability and appropriation).

The concept of problem solving initially figured out in Gestalt psychology (e.g., Wertheimer 1922) and afterward imported and specified for economic contexts by Herbert Simon (e.g., Simon 1965). According to Simon, problem solving is a cognitive device which allows bounded rational agents to make decisions in a complex environment. Simon especially proposes his approach as a more realistically conception of human (and organizational) behavior than the standard approach of economics, namely, the expected utility concept. Nevertheless, there is an ongoing controversy about the question if the former concept is suitable for analyzing novelty creating processes (including invention and innovation) in terms of the features (a–e) mentioned above. This might be partially due to the fact that the core of the problem-solving concept was developed by supposing simple problems or rather abstract themes (e.g., the "Tower of Hanoi" – problem and chess).

The Core Concept of Problem Solving and Its Restrictions

The starting point of the problem-solving procedure is the perception of a "problem." "A person is confronted with a *problem*, when he wants something and does not know immediately what series of actions he can perform to get it . . . . . To have a problem implies (at least) that certain information is given to the problem solver: information about what is desired, under what conditions, by means of what tools and operations, starting with what initial information and with access to what resources" (Newell and Simon 1972, p. 72; Cyert and March 1992, p. 121). Hence, the essential feature of a problem is a divergence between the given and the desired state of affairs. The conditions for eliminating this divergence are on one side the initial constraints of the agent (in terms of money, time, and knowledge) and on the other side the (virtual and real) transformation devices (in terms of heuristics and operators) for the given state of affairs. Yet, the applicability of these transformation devices is uncertain in that there is only a rough idea about the appropriateness of these devices.

"Problem solving" is the process of finding out a sequence of states between the initial and the desired final state under the given constraints. This process is based on a "mental representation, a mental scheme for holding information in memory and operating on it"

(Simon 1999, p. 674; Newell and Simon 1972). The elements of the mental representation are:

- An interpretation of the given situation
- A listing of the transformation devices (operators derived from heuristics) according to this interpretation
- A test and evaluation mechanism for the results of operator application.

Hence, selecting a cognitive activity under the constraint of available knowledge and the experience about the problem domain marks the starting point of the problem-solving process.

The listing of the transformation procedures within the mental representation is not complete because not all the procedures contained in the knowledge stock are activated. This would easily lead to a combinatorial explosion of transformation possibilities which, due to cognitive constraints, would have to be dealt with on a trial and error base. Therefore, the problem solver applies only a part of the available search procedures (heuristics) to reduce the size of the problem space, i.e., the space which is defined by applying all available transformation possibilities to all possible states. These heuristics might be either explicit in that they are explicable and even programmable or they might be implicit in that a given situation includes cues about what to do for the experienced problem solver.

However, only under ideal conditions problem solving will be a linear sequence of representation, operation, and realization. Normally, it will be a feedback process between the steps "operation" and "representation" as well as within the "operation" step. Furthermore, if several attempts to reach a given goal are not successful, the goal itself might be modified (in quantitative or qualitative terms).

This sketch of the seminal contribution of Simon and Newell to the analysis of the elements and process of problem solving shows that this is a pathbreaking alternative to the standard model of the deliberate decision process (a) in that it focuses an open-ended search behavior divided in the statement of the given situation, the figuring out of the problem space, and finally the solution of the problem and (b) in that it integrates the assumption of bounded rationality in terms of knowledge-dependent problem representation and in terms of limited capabilities of problem manipulation (by heuristics and operators). Due to these cognitive constraints, the process of problem solving might become sticky and path-dependent.

Nevertheless – at least in its original form – the concept has a rather narrow scope. *First*, it takes only the goal-related outcome into account which abstracts from basic abilities of the agents as well as from individual specificities. *Second*, according to the computer-oriented context in which this concept of problem solving was developed, it was mainly confined to clear cut ("well-defined") problems. This means that the goals of the agent as well as the heuristics used for reaching this goal are specified in such a way that the results of the application of these heuristics can be unambiguously evaluated with respect to their goal-reaching capability. Furthermore, it is assumed that this capability is even measurable in terms of a larger or smaller distance to the goal. *Third*, it is assumed that the definition of the problem and the finding of the problem-solving devices are two separable elements and that the problem-solving devices are merely instrumental for the problem itself. Thus, only these solution advices are varied during the problem-solving process. Taking these limitations into account, one might become skeptical about the essential difference between this problem-solving approach and the decision approach in standard economics. Furthermore, this simplistic problem-solving approach has been criticized due to its affinity to what computers can do (instead to what humans used to do; cf. Dreyfus and Dreyfus 1986).

Enhancing the Concept of Problem Solving: Ill-Defined Problems and "Creative Problem Solving"

Ill-Defined Problems and Creativity Research

Not all problems in the economic world are well defined in the sense of the standard approach of problem solving. Sometimes, even the understanding of the initial situation is not in such a way clear that it can be transformed into a mental representation. Consequently, it remains vague in which way such a situation can be influenced by any kind of operator and which goals are appropriate for it. However, even if the situation is well understood, it might be difficult to solve a problem because there are multiple incommensurable problem spaces and/or a lack of appropriate operators/heuristics making it intricate to find a sequence of reasonable operations. Finally, it is possible that the goal is not defined in a unanimous manner. These caveats are the background for admitting "ill-defined problems" (Simon 1973) and thereby broadening the scope of the concept of problem solving.

The inconveniences arising with ill-defined problems – which do normally occur in an uncertain world – change the character of the problem-solving process. *First*, it is not any longer "directed" insofar it successively reduces the gap between initial and final (goal-reaching) state; rather, it might circle around or even be regressive by broadening the gap. This is due to the lack of appropriate operators/heuristics and/or the goal ambiguity. *Second*, the instrumental role of problem-solving devices does not hold anymore if the problems are ill defined. Under this condition, heuristics and operators as emanations of the stock of knowledge are themselves influencing the way the problem is posed at every time step. Problem solving then becomes an iterative and simultaneous exploration of problems and solutions.

Solving ill-defined problems makes great demands upon the actors involved. At the core of the individual ability to look for new situations and to deal with them is the human creativity. Referring to the research on human creativity therefore helps to understand how ill-defined problems can be solved. This research has a long tradition starting when the ability to create something new is no longer considered as a divine inspiration but rather an individual capacity of the human being. However, even in the professional treatment of creativity in psychology, it took some time before single hypothesis approaches (such as the psychodynamic, associationist, and Gestaltist treatment) to this human ability have been overcome in favor of a broad treatment including all resources and processes known in modern cognitive psychology (Guilford 1950; Weisberg 2006).

The modern creativity research defines creativity as "the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)" (Amabile 1996; Sternberg and Lubart 1999). Hence, what is meant by creativity in the sense of modern creativity research are the individual creative traits and processes. Creativity research does not primarily deal with the wide range of tacit everyday creativity. Rather, creativity here implies that the individual creative output (product) is being assessed and accepted by the environment. Following this definition, three different – although interdependent – aspects of creativity are emphasized in the modern creativity research: the individual qualities, the process analysis, and the environment. All these aspects are relevant for solving ill-defined problems and thereby broadening the scope of the original concept of problem solving (Weisberg 2006).

- The *individual qualities* can be subdivided in knowledge and skill endowment, motivation, and personality features. For being creative, knowledge is required about the domain specificities (Weisberg 1999). This knowledge should be well organized giving the possibility for switching flexibly between different levels of generalization. Whereas this kind of knowledge is "declarative," also "procedural" knowledge is required in terms of knowing how to use available heuristics. These different levels of knowledge are accomplished by skills in terms of finding new heuristics and capabilities for recombination and association of given elements of knowledge (Chand and Runco 1992; Policastro and Gardner 1999). However, knowledge and skills are not sufficient for being creative: Additionally, a strong motivation for fulfilling a task is required. This strong motivation can either come from inside in that an individual views such an engagement as an end in itself (intrinsic motivation) or in that this motivation comes from outside following from external information or expectations without restricting the autonomy of the person under consideration (informational or enabling extrinsic motivation; Amabile 1996). Finally, some personal qualities are required for a creative activity. Among the most important ones are curiosity, the steadfastness of purpose, patience, and a fundamental willingness to bear risks (Csikszentmihalyi 1999b). Knowledge, skills, motivation, and personality are combined in two overarching features of creativity: *deliberate cognitive style* and *divergent thinking*. A deliberate cognitive style is a stable preference for using extensively deliberate (conscious) resources in sorting out the possibilities of action (Kirton 1989). Divergent thinking is a specific way to use these cognitive resources. Convergent thinking has only one direction; one conventionally correct answer is searched for. Contrary to that, divergent thinking proceeds in different directions (Guilford 1959). Hence, the approach of creative individuals to problems is original in that they are breaking with traditional formulation and solution of problems, and it is flexible in that many ideas about formulation and solution are held for a long time simultaneously in mind until a switch to one of these options occurs (Amabile 1996).

- The *process analysis* of creativity was initially heavily influenced by the idea that the creation of something new is a rather unexplainable operation in terms of rational process analysis. This gap in explanation was either filled by referring to mysterious abilities of the human genius or it was assumed that creative ideas emerge from a largely uncontrollable Darwinian process of random variation and natural selection. This gap is well documented in one of the first process models of creativity by Wallas (1946). In this model, four phases are distinguished: (a) the definition of the issue and the observation of the starting conditions in the phase of preparation, (b) then the phase of incubation in which the issue is laid aside, (c) the phase of illumination in which the new idea is born by picking up the issue after a while, and finally (d) the phase of verification. How this illumination can happen remained unexplained at that time. Furthermore, it seems dubious to separate this act of illumination from all conscious endeavors to analyze the issue. This lack of explanation was reflected in the process model of Rossman (1964). In this model, the preparation phase is composed of observation of need, analysis of need, a survey of all available information, and a formulation of all possible solutions. The incubation/illumination phases are replaced with a critical analysis of these possible solutions and a birth of the new idea out of this analysis. The last phase is analogous to Wallas (here based mainly on experimentation). How this "birth" of the new idea happens still remains mysterious. Meanwhile, these traditional conceptions have been challenged by at least two relevant approaches: On the one hand, the incubation/illumination paradox is explained as a cognitive process, relying on cognitive operations and not on mystical insights. Thereby, the features of the four-stage model are either updated (Amabile 1996; Cszikszentmihalyi 1999b) or rejected (Weisberg 1993). On the other hand, very promising endeavors have been made to propose new models to overcome the traditional perspective (Finke et al. 1992). Additionally, a lot of empirical and experimental work has been done to explain problem-solving (and problem-finding) processes (Runco and Sakamoto 1999; Lubart 2001).
- Creative operations do not happen in an empty space; they have an *environment*. This environment is relevant for the generation of a creative act as well as for the evaluation of the result of this creative act. According to the difference between the outcome of creativity (an idea, a concept, a physical product, etc.) and the creative person, the environment is seen to consist of a "domain" to which the product refers and a "field" to which the person refers (Csikszentmihalyi 1999a, b; Weisberg 2006). Unresolved problems in the domain as well as the way the experts in the

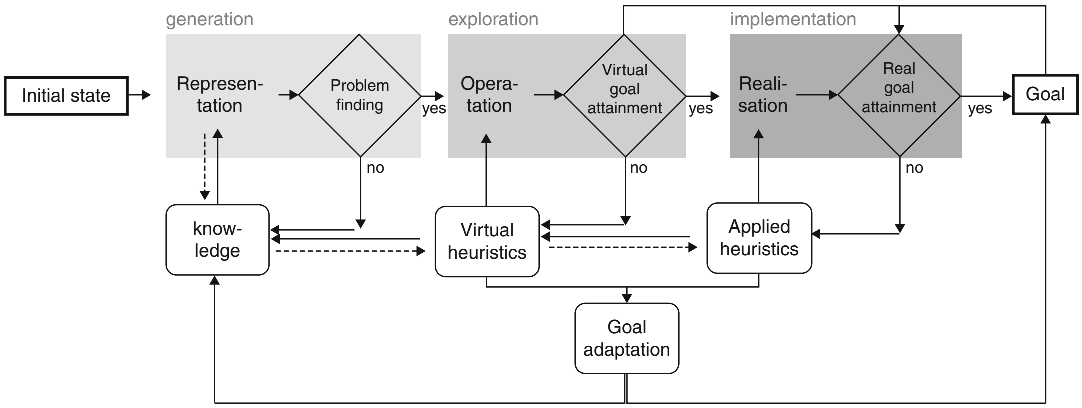
field deal with these problems determine the act of creativity: on one side, by the accessibility to the (incomplete) knowledge of the domain and, on the other side, by the degree of the open-mindedness of the experts in the field. This is related to the knowledge base and the motivation of the creative person and to the preparatory stage of the creative process mentioned above. But the domain and the field are also important "test beds" of the results of a creative act. It will become manifest how much the domain is altered by this creative result (To what degree hitherto unsolved problems are pretended to be solved?), and the experts in the field will have to evaluate this change in the domain (Is the solution accepted? How far reaching is it?).

What conclusion can be drawn from this sketch of creativity research for dealing with ill-defined problems? (a) Before problems of this kind can be solved, a creative specification of these problems in preparatory steps is necessary. (b) Unconscious illumination, imagination, and the like are not sufficient for explaining the creative process because a necessary condition for creativity is conscious endeavors. At the core of creating something new, there is a twofold process of synthesizing ideas, facts, etc., on one side and a transfer and transformation of these ideas, facts, etc., on the other side. (c) Insofar, as the solution of ill-defined problems requires acts of creativity, individual qualities as well as a creativity friendly environment are necessary for the problem-solving process. (d) Finally, the role of a variety of cognitive elements like knowledge, motivation, and memory is emphasized.

Creative Cognition and Creative Problem Solving

The separation of personal qualities, process analysis, and environmental conditions is a useful starting point for systematizing the insights of creativity research. But from the perspective of modern cognitive psychology, this separation seems arbitrary, and therefore, attempts have been undertaken to broaden the process analysis of creativity to include at least some aspects of personal qualities and environmental conditions. Such an attempt is "creative cognition," developed by T. Ward, S. Smith, and R. Finke. In this approach, a new model of the cognitive process and structure of creativity is proposed, incorporating thereby the aspects of individual qualities and – though at a different level – aspects of environment (Finke et al. 1992, 1999). The main feature of this approach to creativity is a heuristic model called "Geneplore" (Finke et al. 1992; Ward et al. 1999). According to this model, the creative process is a sequence of generative and exploratory processes (hence the name).

The *generative processes* take place in the initial phase. Here, mental manipulations of knowledge elements (retrieval, association, synthesis, transformation, transfer) lead to new mental representations, e.g., to a new interpretation of the initial situation, new (virtual) operators, new evaluation mechanisms, and/or new combinations of these elements. Such new representations may consist of discovered patterns, mental models, and the like. These results of the generative processes are not simply novel. Rather, they have some inherent ambiguity, incongruity, and divergence and therefore encourage the investigation of these results in the second phase, the *exploratory processes*. Because the problem definition is incomplete in that no definite goal is given, the applicability and usefulness of the new representations are now tested, and if necessary, the goal is adapted. What kinds of problems can be tackled with such new representations? Are new attributes of a problem at stake accessible? What kind of operators can be used to manipulate the initial context and what will be the result of such a manipulation? This can be summarized as a figuring out of appropriate virtual heuristics. Finding answers to these questions might include a modification (focus or expand) of the preinventive structures (new mental representations) which are the result of the generative process. Hence, multiple feedback cycles between generative and exploratory processes might be necessary until a useful novelty has been discovered.



Invention and Innovation as Creative Problem-Solving Activities, Fig. 1 Enhanced concept of problem solving

What kind of insights for a problem-solving process under the condition of an ill-defined problem can be gained from the creative cognition approach? Insights from creative cognition for the concept of problem solving are threefold: *First*, a specification of what is meant by "ill defined" is provided. By bringing in new cognitive devices (like mental models, analogy building, context shifting, and divergent thinking; Finke et al. 1992), it is possible to specify what generative/explorative method is used. Furthermore, the following questions can be answered: Is the "illness" of the definition due to not having a new representation or is it due to the unexplored usefulness of a new representation? Or is it due to both? *Second*, the generative processes constitute a specific determining stage of the whole problem-related process: the problem finding. This is tantamount to finding representations or heuristics by using the "Geneplore" approach. *Third*, the problem solving itself changes character in that it becomes creative. It deals with new heuristics/operators and makes of problem-solving proper a temporary operation in an overarching problem-finding/problem-solving feedback process. Given that, the focus of the core concept of problem solving (cf. section "The Core Concept of Problem Solving and Its Restrictions") can be enhanced by including the phases of generation and exploitation. Figure 1 shows the main features of such an enhanced problem-solving concept.

Applying the Problem-Solving Concept to the Microeconomics of Invention and Innovation

Invention as a Problem-Finding/Problem-Solving Activity

Invention means the creation of a conceptual novelty. It denotes the creation of an idea or a concept, waiting for being applied in a practical context. Such a new idea or concept might be based on new knowledge which is simultaneously created with the invention ("primary inventions" in the sense of Usher 1971, p. 50), or the invention is the result of new applications of a given set of knowledge ("secondary invention," Usher 1971, p. 54).

Considering invention as an act of creative problem solving means to specify the endowment of the inventor in terms of cognitive resources (cf. above section "Ill-defined Problems and Creativity Research"). A profound declarative knowledge about the domain, the ability to flexibly combine the elements of this knowledge, and knowing how to search in a given domain for new insights (procedural knowledge) is the *first* cognitive prerequisite for the creative act of invention. *Second*, the motivation for inventive activity is intrinsic in that this activity is seen (by the inventor) as an end in itself. Any environmental expectation about the result of the invention is either ignored or transformed in the inventor's individual motivation. This means that on one side there is no person who is directly forcing the inventor to follow a predetermined action pattern; on the other side, this does not exclude that the inventor has an open mind for scientific, technical, social, or economic needs in his environment. A *third* momentum of the inventor is a combination of all personal qualities which have been attributed to the creative personality (cf. section "Ill-defined Problems and Creativity Research") with a special emphasis on a deliberate cognitive style and divergent thinking.

For invention, the environment hence has the double role to be (a more or less) stimulating background and to be an evaluating context. The stimulation is given in terms of scientific, technological, social, and economic "driving forces" (i.e., strategic and/or global needs in these domains). This background for the invention process may be given by identifying "reverse salients" (Hughes 1978, pp. 172, 179), i.e., the bottlenecks of a global system development in the domains mentioned before. The focus on these reverse salients is determined (a) by education and expertise of the inventor, (b) by the prior activities of the inventor in the same or a similar domain, and (c) by anticipating some feasibility constraints in terms of funding, accessible R&D facilities and perhaps by referring to the expectation of an entrepreneur (Schumpeter 1983). The evaluation of the invention is one important function of the entrepreneur. This function can be incorporated in a special group of entrepreneurs, or it may be a temporary feature of actors, which have also other roles to play (as it is often the case in small- and medium-size firms). This entrepreneurial evaluation process of invented products may be influenced by the hostility of those vested scientific, technological, social, and economic interests for which the innovative development of the invention might be a threat (Nelson 1959a; Gilfillan 1970; Hughes 1978; Amabile 1998).

Given this background, the process of invention can be characterized (in a stylized manner) by referring to the features of an enhanced problem-solving concept: (a) it deals with ill-defined problems, (b) it includes a stage of problem finding, and (c) it solves problems in a creative manner.

ad (a): Taking "problem space," "goals," "heuristics," and "operators" as attributes of a problem definition, all these attributes can be in the state "none," "one," "multiple," and "vague." A vague problem space is given if there is a high uncertainty about the dimensions of the problem to deal with. The goals are vague if a goal is not known in a positive sense but only in a negative sense in knowing what is not intended. The heuristics and operators are vague if the appropriateness of both for any given goal is ambiguous. Then there are 4^4 possibilities to characterize the problem situation. The problem situation for an inventive activity lies somewhere between a situation which is well defined (all attributes are in the state "one") and a situation of total ignorance in which all attributes are in the state "none." The typical situation of inventive problem solving is defined, *firstly*, by a vague problem space and a vague fixing of the goals. This corresponds to the incomplete knowledge of the inventor about possible directions for transforming an initial situation and to a loose binding to the "driving forces" of the environment mentioned above. *Secondly*, heuristics are vague and possible operators are unknown (state "none") when the invention process starts. Hence, when the invention starts, the string of the attributes (problem space, goals, heuristics, and operators) is:

$$I_{vent} = \{vague, vague, vague, none\}.$$

This specific type of an ill-defined situation is called here a "strong ill-defined problem."

ad (b): Given such a strong ill-defined problem, the first stage of the inventive process is the solution of the "problem" of problem finding. This problem is coped with by the above mentioned generative processes (section "Creative Cognition and Creative Problem Solving") leading to preinventive structures in terms of a specification of the problem space, mental models about this problem space, and a discovery of new (virtual) heuristics and operators for "walking through" this problem space. Thereby, it is specified where this walk could go to, i.e., hopefully the vagueness of the goals is reduced by these generative processes. Ideally, at the end of this stage of invention, at least the problem space should be specified, and a couple of heuristics (e.g., heuristics for decomposing and for recomposing a problem space) as well as operators should wait for being explored.

ad (c): In the next stage of the inventive process, the heuristics and operators are explored. In this process, a feedback to the understanding of the problem space as well as to the goals of the whole operation takes place. One way to specify such a process more closely, is to assume that the inventor may use one of the available decomposition heuristics to discern the weakest point of a problem at stake, then he/she may solve this weakness by using an heuristic of analogy to a similar (better known) problem, and finally, this abstract solution is adapted to the real-world problem by using a recomposing heuristic (Hughes 1978, p. 173).

Invention as an economic activity is confronted with strong uncertainty. This uncertainty is twofold: *Firstly*, there is no clear relationship between input and output (Arrow 1971, p. 172). Hence, there is a high risk of either not finding any new idea or concept at all or to find something which is not applicable, i.e., something that cannot be used as a source of innovation (output uncertainty). This side of the uncertainty can be expressed as the problem of determining the direction and amount of search activities. *Secondly*, if the invention is successful, there is no guarantee that those who are not willing to pay for the use of it can be successfully excluded (exclusion uncertainty). Partially, this uncertainty can be reduced by juridical protection (e.g., application for patent). Especially the output uncertainty confines the applicability of the usual economic calculation framework in terms of costs and (expected) yields. Invention takes place due to a strategic orientation because only in the long run a pay off can be expected. In the short and medium term, the output uncertainty as well as the motivational requirements for the inventors imply the paradox that inventive activities are the more successful, the more this activity is delinked from the normal organization of economic activities and from the efficiency criteria coupled with this normal organization (Nelson 1959).

To resume, dealing with invention in a (broadened) problem-solving framework has several specificities. It shows that invention consists of a sequence of knowledge-using and knowledge-generating stages and their feedbacks:

- It integrates modern creativity research by demystifying the “act of insight” in that the latter is seen as a combined effect of cognitive resources, environmental conditions, and personality features. Thus, the inventive insight is not a sudden recombination or synthesis of given elements of knowledge; rather, it is a result of a – socially shaped – process of finding, defining, and treating a problem.
- The definition of this problem is influenced by a “supply push” in terms of new knowledge and a “demand pull” in terms of global needs. Hence, there is an “…interplay of moving frontiers of knowledge and growing need upon the direction and likelihood of success of individual ‘acts of novelty’” (Nelson 1959, p. 107).
- Finally, in this approach, it is possible to pick up the results of those case studies related to technological inventions which are not part of the creativity research and to interpret them in a problem-solving procedure.

Innovation as a Problem-Solving Activity

Innovation means the creation of an instrumental novelty. In many cases, it is the process of applying and thereby figuring out the result of the invention process. Generally, this figuring out has to meet two requirements: The feasibility of applying the inventive idea/concept has to be shown in technical, institutional, and behavioral terms. Furthermore, a path to the marketability of this feasible application has to be demonstrated. To deal with these challenges is at the core of the entrepreneur function.

The cognitive resources involved in innovation as a specific stage in the overarching creative problem-solving process are in most parts different from the cognitive prerequisites for invention. Whereas both processes have in common that a profound knowledge of the domain is necessary (declarative knowledge), the requirement for the procedural knowledge shifts in the case of innovation toward knowing how to solve a given problem. Due to an increasing focus on applicability and solution requirements, the motivation is no more intrinsic in that the innovation is seen as an end in itself. Rather, the innovator is – at least partly – animated by strong incentives in terms of either "motivational slack" or deficits in realizing some aspiration level as regards a given goal (March 1994).

The environment of the innovator is set by the ideas/concepts "offered" by the inventor, the given solutions to past problems in terms of products, processes, organizations, and behaviors as well as the competitors. Compared with the inventor, the stimulation for the innovator coming from this environment is more visible (in case it is there), and the driving forces for his activity become less global and less far reaching. In such an environment, the innovator has his role as entrepreneur to play: After assessing the opportunities given by the products of the inventive process, he has to focus on one option and implement it as a midrange improvement of his market performance. This implies that there is some acceptance for what he is doing on the side of producers or consumers.

Compared with the process of invention, the process of innovation differs in the way it poses and solves problems: (a) It still deals with ill-defined problems, but the "illness" is weaker than in the case of invention. (b) There is no stage of problem finding anymore. (c) Solving the problems at stake requires less creativity.

ad (a): The definition of the problem is shaped by picking up the results of the invention stage. The mental representation of the problem space as well as the goals are to a certain degree specified (turning from the "vague" to the "multiple" state) by the invented option the innovator wants to implement and by the triggering market conditions for such an innovative activity. Hence, the following questions arise: What are the technical feasibility problems of a given concept? What qualities of the product innovation promise what kind of advantage in the market performance of the innovator? Additionally, the innovator has to deal with remaining uncertainties as regards heuristics and even more as regards operators. Although these heuristics and operators are to a large degree determined by the invented option, at least a multiplicity of these heuristics and operators have to be checked. Furthermore, the implementation of the invented option may necessitate to find out and experiment with unknown (sub)heuristics and unknown (sub)operators. Hence, the string of attributes (problem space, goals, heuristics, and operators) at the beginning of the innovation switches now to:

$$I_{vat} = \{\text{multiple}, \text{multiple}, \text{multiple}, \text{vague}\}.$$

This specific type of an ill-defined situation is called here "weak ill-defined problem."

ad (b): Assuming that the initial condition for the innovative process is the application of an outcome of invention for improving the economic performance and given a weak ill-defined problem, no problem finding is necessary – the finding problem is solved!

ad (c): Solving the weak ill-defined problem of innovation still requires some creative resources. Even if heuristics and operators are determined by the option picked up by the inventor, the outcomes of these transformation procedures are uncertain. For example, which of the heuristics and operators discovered during the invention process may be appropriate for generating a desired product quality? Additionally – as already mentioned – new subproblems will arise and hence a need for new subheuristics and suboperators. Exploratory processes with respect to the whole problem at stake as well as regards the subproblems are still necessary.

Compared with the invention process, the overall degree of uncertainty is reduced. Although the implementation of an idea or a concept may be a source of additional

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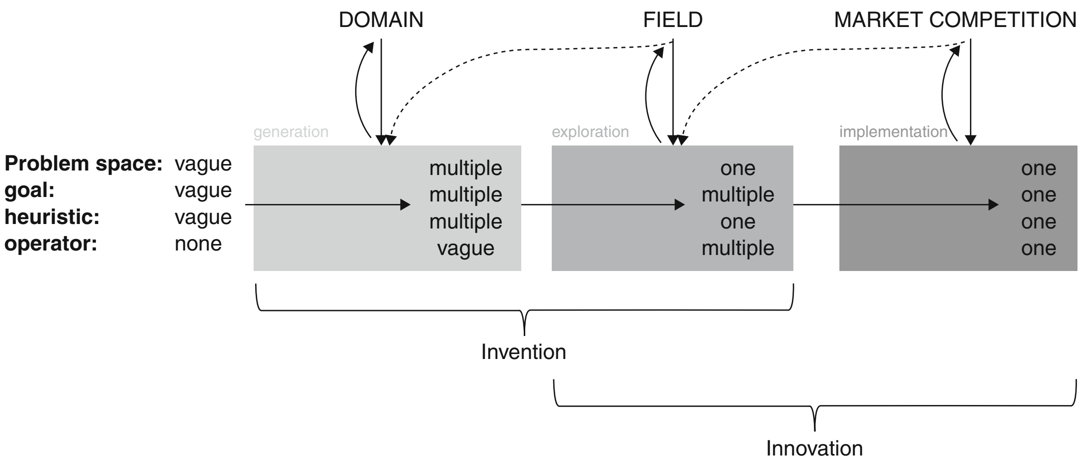

Invention and Innovation as Creative Problem-Solving Activities, Fig. 2 Features of problem solving during invention and innovation

uncertainty, the output uncertainty is reduced because the amount and direction of the search activities are much clearer now. Contrary to that, the exclusion uncertainty is increased because competitors may use the same invented option and similar heuristics and operators. Last but not least, the great challenge for the innovator is to transpose the figuring out of the invented option into a context which is determined by normal organizational procedures and economic evaluation criteria.

The Novelty Creating Process as a Whole and Its Embeddedness

Invention and innovation are stages of the novelty creating process as a whole (which also includes the diffusion phase (Rogers 1995)). They are distinct in terms of general definition, cognitive resources, environmental conditions, process elements, and economic character. Taking into consideration these differences, the whole novelty creating process can be deciphered by referring to the dimensions of problem solving and the social embeddedness of the latter (cf. Fig. 2). This is a process in which the state of the string of the problem representation (consisting of the components problem space, goal, heuristic, and operator) changes according to a process of "generation," "exploration," and "implementation." Starting with a situation slightly better than total ignorance in which at least some rough ideas exist about problem space, goals, and possible heuristics, the generation process leads to a reduction in the search space. It identifies different dimensions of the problem space and creates a finite number of heuristics and operators. This still very large search space is further reduced in the exploration process in which ideally a unique problem space should be found (being one condition for a switch to a well-defined problem) and possible goals of the process should be specified. The task of the final implementation stage is to find unique states for all the components of the problem representation. This means there should be definite answers to the following questions: What is the novelty about? What is it good for? What are the steps from an initial situation with a problem to be solved and a final situation, where the problem is solved?

The novelty creating process is not unidirectional (cf. Fig. 1). Because it is a process of search, discovery, and learning, there are feedbacks between the successive stages of this process (Nelson 1959; Heuss 1965; Usher 1971). In terms of the suggested process analysis, this means that the findings of the exploration stage stimulate new generation activities. This may be the case, either if the exploration shows that the generative activities went in the wrong direction (substitutive feedback) or if a further specification of the invention or a complementary invention is necessary (adaptive feedback). Correspondingly, it was observed in the research about innovation that "…often an innovation is changed or modified by a user in the process of its adoption and implementation" (Rogers 1995, p. 174). In terms of the process analysis above, this is tantamount to a feedback from the implementation stage to the exploration stage. The reasons for this feedback are analogous to the feedback mentioned before.

Invention and innovation are not disjunctive stages in the novelty creating process. Rather, there is a fuzzy border between these two processes in that they overlap. The final stage of the invention process in which an idea or concept is explored thereby reducing the ambiguity of a problem representation (or discovering potential problem representations) may be the first stage of an innovation process. In this process an understanding of the invention is obtained (specifying the problem space) and the range of goals is defined to which the invention can be related.

According to the analysis of the social embeddedness of creative activities given in the systemic approach of creativity research (Csikszentmihalyi 1999a, b), these different stages of the novelty generating process are influenced by different environmental conditions. The generation phase depends on the socially available knowledge about the domain at stake (apart from the individual tacit knowledge). On the other side, this domain knowledge is influenced by the new knowledge produced during the invention process in case that this new knowledge is communicated. When the generated ideas or concepts are explored and thereby related to existing ideas and concepts in the domain (including an assessment by the people in the given domain), the influence of a "field" comes in. This is the way the inventor is affected by needs articulated in the public. Furthermore, if the field is dominated by some order parameters, there might even be an influence of the field on the direction of the generating processes of invention. As in the case of the domain, the field is influenced by the results of the inventive exploration. Finally, the implementation stage is shaped by the embedding of the innovator in the economic competition which strongly determines his goals. If a strategic deficiency in his/her competitive performance is observable for the innovator, this will have an impact on his exploration activities.

Conclusions and Future Research

The skepticism against the suitability of the concept of problem solving in the context of explaining invention and innovation can be relativized if this concept is enriched by integrating the insights of creativity research and modern cognitive psychology. Most of the generic features of novelty creating processes mentioned in section "Background: Microeconomics of Novelty Creation and Problem Solving" can be explained in such a conceptual setup:

- "Generation," "exploitation," and "implementation" can be identified as specific phases each of which combines peculiar personal, economic, and environmental conditions and gives the dimensions of problem solving different expressions.
- The successive occurrence of these phases (including path-dependence) as well as the multiranged feedback loops between them specifies the critical role of time for the novelty creating process.
- The behavior involved in such processes is not monistic; rather, it includes different modes of action especially skills, intuition, deliberation, and choice.
- Finally, the issues of acceptability and appropriation are dealt with in taking into account the "domain," the "field," and the market competition as environmental conditions.

But, by simply postulating a problem to be solved as the starting point, the boundary or trigger conditions making the occurrence of the novelty creating processes highly probable remain rather void in the concept of problem solving. To meet this explanatory requirement necessitates a broader perspective of the agency

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under consideration especially including the social and organizational form in which invention and innovation take place (Dosi et al. 2011; Runco 2007; Nickerson and Zenger 2004; Bijker 1987). Given this, it should be possible to elaborate the conditions favorable for the temporary passing of the agency into the ambitious and costly mode of invention/innovation (Beckenbach et al. 2012).

Cross-References

- ▶ Convergent Versus Divergent Thinking
- ▶ Corporate Creativity
- ▶ Creative Behavior
- ▶ Creative Personality
- ▶ Creative Problem Solving
- ▶ Creativity and Innovation: What Is the Difference?
- ▶ Creativity, Experiential Theories
- ▶ Creativity from Design and Innovation Perspectives
- ▶ Creativity in Invention, Theories
- ▶ Divergent Thinking
- ▶ Divergent Versus Convergent Thinking
- ▶ Entrepreneur
- ▶ In Search of Cognitive Foundations of Creativity
- ▶ Innovation and Entrepreneurship
- ▶ Innovator
- ▶ Invention Versus Discovery
- ▶ Inventive Problem Solving (TRIZ), Theory
- ▶ Mental Models and Creative Invention
- ▶ Nature of Creativity
- ▶ Psychology of Creativity
- ▶ Radical invention
- ▶ Research on Creativity

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Invention and Modification of New Tool-Use Behavior

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Synonyms

Creativity; Evolution; Material culture, emergence; Technological innovation

Introduction

The invention and modification of new tool-use behavior is the essence of technological innovation. Although tool use can be found in both humans and nonhuman animals, humans are distinguished by the variety of their tool use and their invention of new tool-use behaviors by modifying previous types. Humans are also unique in their customary use of metatools, that is, tools used to gain or modify a second (primary) tool, which is then used to achieve the goal.

Human technology has been pervaded by metatool use, from the construction of stone tools by our Oldowan ancestors of 2.5 million years ago, achieved by knapping one stone with another, to the most sophisticated computer-controlled machines consisting of some tens of thousands of components (or sometimes more) in the twenty-first century. This entry discusses the invention and modification not only of the tool itself but also of tool-use behavior, which incorporates several aspects such as technique, function, target, and so on.

Tool Use

Background and Definition

Complex tool-use behavior is a hallmark of human beings. Until Jane Goodall observed a chimpanzee at Gombe in Tanzania using a twig to extract termites from their impregnable shelter in 1960, researchers had believed that tool use was a uniquely human trait. Even now that there is accumulating evidence that nonhuman animals also demonstrate tool-use behavior, some might say that the history of the invention of tools parallels the history of humanity. It is true that there are considerable differences in the variety and complexity of tool-use behaviors between humans and nonhuman animals. The mechanism of generating these differences has recently been one of the most controversial research topics. The invention and modification of new tool-use behavior is central to this question.

Several researchers have provided definitions of tool use. One of the earliest explicit definitions, proposed by van Lawick-Goodall (1970), focused on the abstract properties of this behavior: "the use of an external object as a functional extension of mouth or beak, hand or claw, in the attainment of an immediate goal." Beck (1980) offers a more detailed definition, one that has been used widely in the animal tool-use literature: "the external employment of an unattached environmental object to alter more efficiently the form, position, or condition of another object, another organism, or the user itself when the user holds or carries the tool during or just prior to use and is responsible for the proper and effective orientation of the tool." Matsuzawa's (2001) definition is simpler and makes the point clearly: "a set of behaviors utilizing a detached object to obtain a goal that is adaptive in the biological sense."

Tool Use in Humans and Nonhuman Animals

Nonhuman animals, especially some primates, dolphins, elephants, and birds, also demonstrate tool-use behaviors. They are known to use and make tools and also to demonstrate multiple tool uses. For example, chimpanzees, which are known as the most prominent tool users besides humans, demonstrate a rich variety of tool use with divergent tool materials and techniques aimed at various targets: fishing termites and ants from a nest with a twig or a stalk, dipping for ants on the ground with a rigid wand, scooping up algae floating on a pond with a stick, drinking water with a leaf sponge, cracking open nuts with a stone hammer and an anvil (Fig. 1), clipping a leaf for a courtship display, and so on. The most complex form of tool use found in chimpanzees is the use of a wedge in cracking nuts. Chimpanzees at Bossou in Guinea have been observed to insert a third stone underneath an anvil to serve as a wedge, thereby keeping the anvil stable and flat. While almost all other examples of tool use in nonhuman animals contain only a single relationship between a single tool and a single target (level 1-type tool use), nut cracking with a hammer and an anvil entails two relationships between objects (level 2-type tool use), and three relationships can be discerned in the instances of wedge use (level 3-type tool use): (1) a chimpanzee uses a stone as a hammer to hit a nut, where (2) the nut is placed on an anvil stone, and (3) the anvil stone itself is supported by a wedge stone (Matsuzawa 2001). There is no evidence that nonhuman animals can use tools at level 4 or higher.

Besides the chimpanzees' infrequent wedge stone use, there is no clear evidence in the wild that nonhuman animals use metatools, that is, using one tool to make or gain a second (primary) tool. This is considered to be because of the animals' cognitive inability to do so. Metatool

Invention and Modification of New Tool-Use Behavior, Fig. 1 Chimpanzees' use of stone tools for cracking open nuts at Bossou in Guinea (Source: Photograph by Nogami Etsuko)

use is very cognitively demanding because the relationship between a metatool and the goal object is not direct but rather mediated via the primary tool. Another possible explanation from an ecological viewpoint is that the animal can select or manufacture the appropriate type of primary tool in the first place, and consequently there is no need to use a metatool. The lack of metatool use might be one of the restrictions preventing technological innovation and expansion in nonhuman animals.

Because tools are used extensively by both humans and wild chimpanzees, it is widely assumed that the first routine use of tools took place prior to the divergence between the two species. These early tools, however, were likely made of perishable materials such as sticks or consisted of unmodified stones that cannot be distinguished from other natural stones as tools. The first evidence of stone tool industry that can be found in fossil records dates as far back as 2.5 million years: Oldowan chopper tools. *Homo habilis*, an ancestor of *Homo sapiens*, is considered to have started manufacturing Oldowan tools. Oldowan technology is typified by what are known as "choppers." Choppers are stone cores with flakes removed from part of the surface, creating a sharpened edge that was used for cutting, chopping, and scraping.

Thereafter, humans invented numerous kinds of tools that can be used in a variety of contexts such as feeding, clothing, housing, traveling, and social interactions. After the long Stone Age, around the fourth millennium BC, humans started to use metal instead of stones as the material for their tools. In the Middle Ages and thereafter, the incorporation of new energy sources such as water, wind, heat, and nuclear power caused major technological innovations. Humans evolved an opposable thumb, which is useful in holding and manipulating tools, and our brain size increased, which led to our understanding of the physical principles and causal regularities of how tools work. These features are considered to have contributed to the invention and modification of new tool-use behaviors in humans.

Origins of Material Culture

Not only for humans but also for some nonhuman animals, especially chimpanzees (Whiten et al. 1999), recent studies have revealed geographic variations in tool-use behavior among communities. For example, chimpanzees at Bossou in Guinea crack open oil-palm nuts, whereas chimpanzees at Gombe and Mahale in Tanzania do not demonstrate such stone tool use or hammering techniques even though nuts and suitable stones are readily available at these sites. This is interpreted as evidence of material culture in these species, and it proves that tool use is not totally inherent but rather acquired by invention and modification. These cultural variations are considered to be maintained and passed on from generation to generation through social learning and transmission. This social learning and transmission mechanism enables an individual to learn a novel behavior from others; however, this cannot explain the mechanism of the emergence of the novel behavior in the first place. The mechanism of emergence, that is, invention and modification, of a new tool-use behavior is a key to understanding the origins of material culture.

Invention and Modification of New Tool-Use Behavior

"Invention" and "Modification"

In many cases, it is difficult to clearly distinguish "invention" from "modification" because these two types of change are often continuous, and the difference is merely a matter of degree. For example, de Beaune (2004) examined changes in tools in early humans and suggested that new tools were the result of combining preexisting elements rather than creations *ex nihilo* (Fig. 2). That is, changes can be seen as the "invention" or as "modification" of tools, materials worked, techniques, or other elements.

There are very few records of the invention and modification of new tool-use behavior in nonhuman animals. At Bossou in Guinea, where "ant dipping on the ground" by chimpanzees is customary, a chimpanzee was observed to demonstrate a new tool-use behavior, "ant fishing in trees," which had never been observed over the past 27 years. In 2003, a 5-year-old juvenile chimpanzee was observed to be engaged in ant fishing in trees by employing wands of similar length to those used for ant dipping on the ground, which is a customary tool-use behavior of this community (Fig. 3a). Two years later, at the age of seven, his tools for ant fishing were shorter and more suitable for capturing carpenter ants living in a tree hollow (Fig. 3b). In this process, two steps can be recognized: the first is the change of the target ants from safari ants on the ground to arboreal ants, and the second is the change in the tool length. This can be considered an example of emergence of a new tool-use behavior in which it is difficult to clarify exactly whether the new tool-use behavior was "invented" at the first or second step.

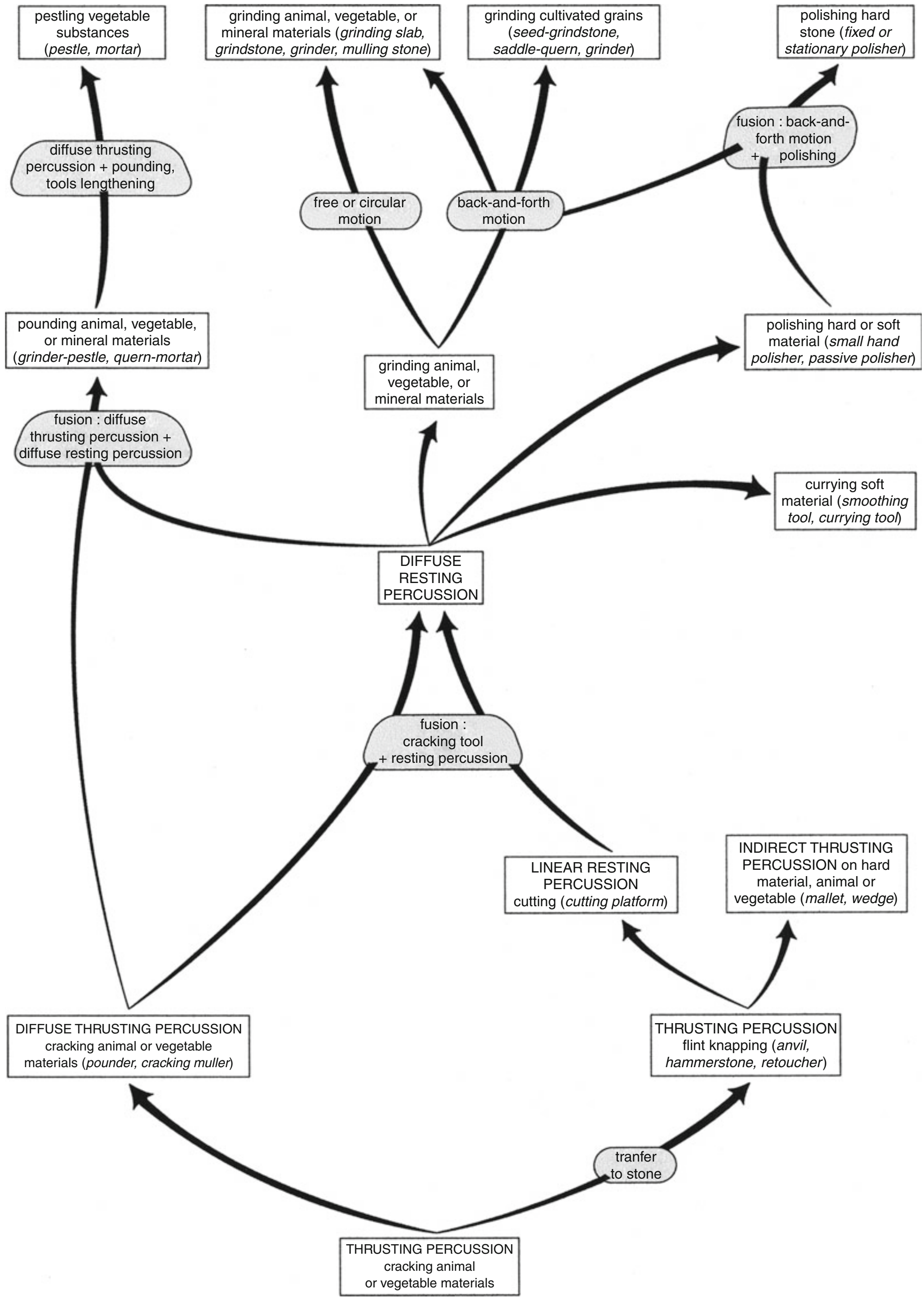
Elements that Could Have Been Newly Invented and Modified

As seen in the above example of the emergence of "ant fishing in trees" by a chimpanzee, there are several elements that could be invented or modified in the process of the emergence of a new tool-use behavior: tool shape, tool material, technique, target, function, and a combination of these.

Tool Shape: In Stone Age tool innovation, 2.5 million years ago, *Homo habilis* first made tools (Oldowan chopper tool, Fig. 4) by hitting one stone against another. About 1.5 million years ago, *Homo erectus* started to shape stone tools more carefully by flint knapping, so that they had long straight cutting edges, like a knife (Acheulean hand axe, Fig. 5). In nonhuman tool use, chimpanzees make fishing and dipping tools from natural plants by stripping off unnecessary leaves and biting off some of the plant to obtain the appropriate length. In the above example, the chimpanzee was observed to adopt tools of different length 2 years after he started to target the different ant species. Some captive corvids (*Corvus moneduloides* and *Corvus frugilegus*) are known to have invented a hook tool to retrieve an out-of-reach bucket containing a worm.

Tool Material: Nonhuman animals mainly use plant materials such as sticks and leaves. Plant tools are easily worked and shaped but are perishable and disposable. Stone tools are hard and tough but are difficult to process. Metal tools have the advantages of both plant and stone tools: they are hard, tough, and also easy to shape. The invention of metal tools stimulated the expansion of technological innovation in humans.

Technique: With the same tool, several different techniques can be employed. For example, when chimpanzees dip for safari ants with a wand tool, some chimpanzees dip for ants



Invention and Modification of New Tool-Use Behavior, Fig. 2 Tool-invention processes (Source: de Beaune (2004))

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Invention and Modification of New Tool-Use Behavior, Fig. 3 Invention and modification of a new tool-use behavior by a juvenile chimpanzee at Bossou in Guinea. (**a**) Ant fishing in trees first observed when the chimpanzee was 5 years and 4 months old in 2003. He used a long and rigid tool that is similar to tools used for ant dipping on the ground. (**b**) Ant fishing with a short tool when he was 7 years and 2 months old in 2005 (Source: Photograph by (**a**) Gen Yamakoshi and (**b**) Shinya Yamamoto. Reference to Yamamoto et al. (2008))

Invention and Modification of New Tool-Use Behavior, Fig. 4 Oldowan chopper tool (7.2 × 6.5 cm) found in Swaziland, Southern Africa (Source: Museum of Anthropology, University of Missouri)

Invention and Modification of New Tool-Use Behavior, Fig. 5 Acheulean hand axe (10.7 × 6.5 cm) found in the Sahara Desert, North Africa (Source: Museum of Anthropology, University of Missouri)

with one hand and then sweep the wand directly with their lips (one-handed technique), while others hold the wand in one hand, sweep the ants with the other hand, and hastily put the mass of ants into their mouth (two-handed technique). Different efficiency levels among techniques may drive behavioral changes in tool use, although chimpanzees are known to considerably stick to an acquired technique.

Target: It is sometimes possible to use the same tool for a target that is different from its original target. For example, in the above case of the chimpanzee's invention of ant fishing in trees, the chimpanzee seemed to first apply a tool and technique originally used for dipping for ants on the ground to ants in trees. Different targets normally have different characteristics and may require tool users to modify their tools accordingly. In this case, the chimpanzee changed the length of the tool 2 years later.

Function: Early stone tools in humans are considered to have had several different functions. For example, Oldowan chopper tools, the earliest stone tools, were used to cut meat off the bone, to crush bones to eat the marrow, to crack open nuts, to skin an animal for its hide, and to fashion wood and bone into other kinds of tools. Thereafter, according to their sophistication in stone-processing techniques, early humans invented tools shaped for specific purposes, such as sharper knifelike tools.

Combination: Combinations of two or more tools sometimes generate a new tool use, enabling an individual to achieve a goal that is otherwise difficult or impossible to accomplish. Three categorical types of combinations can be considered: sequential multiple tool use (tool set), metatool use, and fusion of multiple tools of different functions. As an example of the first category, chimpanzees are known to use a tool set, that is, the sequential use of a digging tool and a dipping tool and sometimes even more (up to five different tools) for obtaining food that is difficult to access, such as termites in a hard shelter and honey in an underground hive. Wedge stone use in Bossou chimpanzees can be interpreted as metatool use (see section "Tool Use in Humans and Nonhuman Animals"). An alarm clock in our modern life is an example of the fusion of a measuring tool (clock) and a perception tool (alarm).

Mechanisms of Invention and Modification

How can the invention and modification of a new tool-use behavior be achieved? Ernst Mach (1838–1916), an Austrian physicist and philosopher, noted: "The majority of the inventions made in the early stages of civilization, including language, writing, money, and the rest, could not have been the product of deliberate methodical reflection for the simple reason that no idea of their value and significance could have been had except from their practical use." On the other hand, Thomas Edison (1847–1931), an American inventor, stated, "None of my inventions came by accident. I see a worthwhile need to be met and I make trial after trial until it comes. What it boils down to is one per cent inspiration and ninety-nine per cent perspiration."

Despite the apparently contradictory remarks by Mach and Edison, both of these suggest an important issue: when we say "a tool-use behavior is invented," we have to recognize its significance and/or necessity. As clearly described in Matsuzawa's definition (see section "Background and Definition"), a tool has to be used "to obtain a goal," and therefore it should be "adaptive in the biological sense." In other words, without any significance or necessity of use, an object cannot be a tool. For example, a stone can be a tool only for animals that are able to use the stone for a specific purpose, such as cracking open nuts. For Mahale and Gombe chimpanzees who do not demonstrate nut cracking, a stone exists as an object, but not as a tool. Consider another example. A stone anvil (or a hammer) can be broken when a chimpanzee cracks open nuts on (or with) it. The shape of the broken stone with sharp edges is similar to that of an Oldowan stone tool. The chimpanzee sometimes reuses the broken stone as a hummer (Matsuzawa 2011); however, it is not used in a newly invented way like Oldowan chopper tool by the chimpanzee, which does not notice its significance or does not have any necessity for using it in this way. In short, we can say that necessity is the mother of invention of new tool-use behavior.

In the process of the invention of a new tool-use behavior, it is possible to consider three types of mechanisms: by accident, by trial and error, and by insight.

By Accident: An individual notices that an object (or objects), whether it has already existed or has newly appeared, serves as a useful tool for solving an overt or potential problem when the individual is not aiming to invent a tool for a specific purpose.

By Trial and Error: An individual, when struggling to solve a problem, finds out a way of using an object (or objects) to reach a correct solution or satisfactory result by trying out one or more ways or means until the errors are sufficiently reduced or eliminated. In this process, at least at the first trial, the individual does not fully understand the causal relationship between the tool use and solving the problem.

By Insight: An individual, when struggling to solve a problem, finds out a way of using an object (or objects) to reach a correct solution or satisfactory result with a full understanding of the causal relationship between the tool use and solving the problem. This is achieved without learning based on trial and error.

It is difficult to clarify which of these three mechanisms takes place in each process of

Invention and Modification of New Tool-Use Behavior, Fig. 6 Invention and modification of hook tools by captive non-tool-using rooks. The rook in this photo extracted the bucket containing a worm using a piece of wire she had just bent (Source: Bird and Emery (2009))

invention and modification. This has continued to be a matter of debate. In nonhuman animals, most tool-use behaviors are considered to have been invented by accident or by trial and error. There are few reports that indicate the insightful invention of tool-use behavior in nonhuman animals. Bird and Emery (2009) reported that captive rooks, which are not tool users in the wild, spontaneously used appropriate tools and modified the tool shape to solve several problem-solving tasks (Fig. 6). In most cases, the rooks did so without trial and error. The authors suggested that this provides evidence for insight in the problem-solving abilities of rooks, referring to Thorpe's (1964) definition of insight: "sudden production of new adaptive responses not arrived at by trial behavior . . . or the solution of a problem by the sudden adaptive reorganization of experience." However, controversy remains as to whether the rooks' invention of tool-use behavior can qualify as insightful because other possibilities such as learning and shaping during previous experiments could not be excluded.

Even in humans, insightful invention is probably not as dominant as we naively suppose. The term "insightful" is often used for behaviors for which we cannot fully explain the information-processing mechanism. People often attribute their own behavior to what they perceive as insight, but in many cases, they can be shown to be wrong, whereas in others the label simply reflects ignorance of the origin of inspiration (Kacelnik 2009). In the above remarks, Thomas Edison also emphasized the trial-and-error processes of his inventions. Nevertheless, it is also true that humans can accumulate their knowledge through their own experience, by social learning, and from shared knowledge passed on from generation to generation. With this capacity, humans may invent a new tool-use behavior through analogical reasoning: new problems and their solutions are stored in their long-term memory and later, if necessary, serve as a source of analogous situations from which to draw inferences about the current one (de Beaune 2004).

Conclusion and Future Directions

In conclusion, there is no doubt that humans and some species of nonhuman animals have invented and modified a variety of tool-use behaviors and have passed them on from generation to generation. So what is the difference between humans and nonhuman animals? What enabled humans to achieve considerable technological innovations in such an evolutionarily short period? One plausible explanation is cumulative cultural evolution, which is considered to be unique in humans. Humans have a capacity to recognize that a modification of a known behavior being used by another individual is more productive or effective in obtaining results than one's own and have the flexibility to switch to this alternative behavior. This is the core of the "ratchet effect" (Tomasello 1994), whereby incremental improvements in behavior occur in succeeding generations. So far, evidence of cumulative cultural evolution in nonhuman animals remains minimal and controversial. This is probably because nonhuman animals lack some of the essential abilities such as imitation, evaluation and comparison of efficiencies, and behavioral flexibility or just because they have not experienced any necessity to achieve such an evolution in their natural environments.

At this moment, the cognitive processes that lead to the invention and modification of new tool-use behavior remain for further investigation. Since the first observation of wild chimpanzees was achieved by Jane Goodall in 1960, the study of nonhuman animals' tool use does not have a long history, and we have not accumulated enough examples of invention and modification of new tool-use behaviors. It is difficult to clarify the mechanism even in human cases and much more difficult for human cases involving fossils because it is impossible to identify the "first" appearance from fossil records. Despite these difficulties, however, investigation of the cognitive processes underlying the invention and modification of tool-use behavior is worthwhile, as it deepens our understanding of how we can reach the production of a new idea, the origins of creativity.

Cross-References

- ▶ Adaptive Creativity and Innovative Creativity
- ▶ Analogies and Analogical Reasoning in Invention
- ▶ Cognition of Creativity
- ▶ How does Material Culture Extend the Mind?
- ▶ In Search of Cognitive Foundations of Creativity
- ▶ Invention Versus Discovery
- ▶ Patterns of Technological Evolution
- ▶ Psychology of creativity
- ▶ Radical invention

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I

Invention Versus Discovery

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Synonyms

Discover: Observe, Find, Unveil; Invent: Devise, Create, Innovate

The concept of discovery indicates the process of finding something that exists but that is not known or recognized yet. The concept of invention, on the other hand, indicates the process of devising something that does not exist.

The two concepts of discovery and invention form a dichotomy that portrays a central tension in epistemology. They highlight two different angles from which one can look at the relation between theory and experience.

Introduction

The relation between theory and experience has always been an issue of paramount importance in both philosophy and science. The first modern stand on this issue traces back to Francis Bacon, the father of the experimental method. According to Bacon, scientific theories are obtained directly by induction from observation: Scientific theories exist in nature and scientists limit themselves to discover them through observation. According to Bacon, science is a process that consists in a gradual and linear accumulation of truths about nature. This epistemological position can be conveniently indicated as the *discoverist* position.

The discoverist position has been challenged by a major breakthrough in physics: the refutation of classical mechanics. For more than 200 years, the Newtonian description of nature allowed scientists to obtain predictions that matched accurately empirical results both in the terrestrial and in the celestial domain. The crisis of Newton's theory came as a shock for all scientific disciplines. This shock affected also the epistemological foundations of science. In particular, the fact that classical mechanics, which had been considered for centuries as the true description of the universe, was superseded by relativistic and quantum mechanics challenged the very idea that science is about the accumulation of truths about nature.

The shift from classical to relativistic and quantum mechanics determined a major *epistemological shift*: the shift from the discoverist position to what can be named the *inventionist* position. This shift moves from the idea that science is made of truths that are discovered by induction from observation to the idea that science is about the construction of conjectures that are not obtained directly through experience and that cannot be definitively verified on the basis of experience itself. The dichotomy *inventionism/discoverism* can be used to highlight the tension between the two positions on the status of science that have characterized the scientific debate after the crisis of classical mechanics.

The Discoverist Position

The discoverist position has its roots in the ancient and medieval philosophy and relies on the idea that the ultimate structure of nature can be eventually known beneath the fallacious appearances. As already mentioned above, Bacon embodies such an epistemological position. Bacon's picture of science rests upon the idea that natural laws are obtained by induction from simple observation. Coherently, Bacon (1610) insists that the experimenter should avoid all theoretical anticipations that Bacon calls *idola*. The term *idolum* comes from the Greek *eidolon*, meaning image or phantom. Bacon uses this term to convey the idea that scientists should not observe reality through theoretical constructs: Scientists should simply stick to the data obtained from experience, which Bacon regards as completely objective and as the only source of knowledge. In the proper experimental phase, the experimenter should collect data and organize them in what he calls *tabulae*, which can be regarded as the forerunners of the contemporary databases. The experimenter should eventually derive by induction general laws from the *tabulae*. Two centuries after Bacon, John Stuart Mill (1843) further elaborated the discoverist view of science. Mill stated that induction is a necessary tool to acquire knowledge: It is the only genuine method that allows us to obtain general theories and to justify them. In a way, the discoverist view can be epitomized by the idea that science can eventually remove Schopenhauer's *veil of Maya* and reveal the truth about reality.

The idea that laws truly representing nature can be extracted simply and immediately from experimental data stands on the assumption that these laws are isomorphic to the reality to which they refer. Translated in more contemporary terms (see, e.g., Hastie et al. 2003), this assumption equates to the idea that the real system under observation belongs to the model space. This assumption is necessary if a scientific model is deemed to converge, when sufficient experimental data are available, to the real system itself.

The idea that it is possible to obtain a perfect account of nature underlies the development of modern science. Immanuel Kant's philosophy of science can be seen as the first modern attempt to articulate this idea. Though Kant cannot be seen as a discoverist thinker, he believed that the laws of natural science are indubitably correct because they are based on the a priori categories of cognition, which are applied to phenomena and to which phenomena conform perfectly. Clearly, the significant successes obtained by classical mechanics through the centuries strongly supported the conviction that the correct representation of the universe had been obtained and that science had reached the final truth.

The Crisis of Classical Mechanics and the Problem of Induction

The crisis of such a solid theory as classical mechanics undermined the key assumption on which the discoverist position rests: It undermined the idea that, on the basis of observation, it is possible to derive models that coincide with reality. The inadequacy of classical mechanics suggested that models are, at best, approximations of reality and that they remain ontologically distinct from it.

The crisis of classical mechanics revived one of the most controversial issues in epistemology: The Humean problem of induction according to which no matter how much evidence is accumulated in favor of a theory, the theory can be, at any moment, disconfirmed by further observations. The reemergence of the issues raised by Hume is testified by the fact that a significant number of critical works on induction are coeval to the crisis of the Newtonian paradigm.

In the early twentieth century, Henri Poincaré (1902) argued that scientific theories are not inductive generalizations of experience but are *conventions* that science uses because they yield to useful predictions. Just few years later, Pierre Duhem (1906) criticized Newton's contention that the theory of the universal gravitation was obtained by observation and generalized by induction. Through the well-known example of the "inductivist chicken," Bertrand Russell (1957) stressed the idea that the principle of induction cannot be either proved or disproved on the basis of experience and that it should be accepted as an a priori principle. Karl Popper (1935) firmly rejected the idea that science is characterized by the use of inductive methods. According to Popper, scientific theories are bold speculations that are not obtained by induction from experience nor are definitively verified by it. Following Kant, Popper held that scientists do not draw scientific laws from nature, but they rather apply them to nature. Yet, Popper opposed Kant's view that scientists must necessarily succeed in applying scientific laws to nature, and he insisted on the idea that scientific theories have a temporary status and that they are kept as long as they resist to the test of experience. Thomas Kuhn (1962) questioned, in his turn, the idea that science grows linearly by accumulating truths about nature, and he portrayed science as a process composed of irreconcilable steps. According to Kuhn, science is made of stipulations that the scientific community decides by agreement to use and eventually to replace with alternative ones, which typically lead to an innovative and often incompatible account of reality.

The Inventionist Position

The critical concerns raised in the twentieth century about the discoverist conception of science can be conveniently gathered under the above-mentioned heading of inventionism. Notwithstanding none of the thinkers mentioned in the preceding section, except Popper, explicitly uses the term *invention* to characterize the nature of scientific models, these thinkers share the idea that observation does not directly lead to theories and that it cannot be used to finally prove that theories correspond truly to reality.

Popper delineates the core idea of the inventionist epistemology through the thesis of the asymmetry between verification and falsification. With this thesis, Popper subverts the inductivist presumption that there is a positive relation between observation and theory: He puts forward the idea that the relation is rather in the *negative*. Though scientific theories can never be definitively verified by empirical observation, they can be definitively falsified by it. Coherently, Popper characterizes scientific theories as inventions of the human mind rather than as discoveries of the ontological properties of nature. It should be noted that, in this respect, the title "The Logic of Scientific Discovery" of the English translation of the original German "Logic der Forschung" appears contradictory and seems to suggest the opposite idea. Yet, at a closer look, there is no contradiction between Popper's inventionist view and the original title of the book as *Forschung* means literally *research* rather than *discovery*.

By delineating a composite inventionist and falsificationist conception of science, Popper aimed at forsaking the then mainstream logical positivist stance according to which *verifiability* is what distinguishes science from metaphysics. Popper's argumentation is that, since scientific statements cannot be definitively verified by induction from experience, verifiability cannot be used as a solid criterion to demarcate science from metaphysics. Popper found in the possibility of being tested, and potentially falsified by experience, the appropriate criterion of demarcation between scientific and metaphysical statements. Following Poincaré (1902), Popper considered the *predictive adequacy*, rather than the *ontological adequacy*, as the criterion to be used to justify a scientific theory. The predictive adequacy can be assessed on the basis of empirical tests and therefore pertains to science. On the contrary, assessing the ontological adequacy or, in other terms, the adherence to reality goes beyond the limits of the empirical method and therefore concerns metaphysics. A contemporary formulation of the idea that science should limit itself to what can be empirically assessed is Van Fraassen's *constructive empiricism* (1980). Constructive empiricism rests upon the assumption that the goal of science is to obtain theories that are empirically adequate and not to discover the truth about the unobservable aspects of nature.

By drawing a clear line of demarcation between science and metaphysics, Popper wished to preclude metaphysics from playing a role in the justification of empirical theories. Yet, Popper admitted that some speculative ideas, and he cited the example of ancient Greek atomism, had been of value for science as they have been subsequently turned into scientific theories. In acknowledging the value of metaphysics, Popper echoed Whitehead's idea that modern science owes much to metaphysics. As stressed by Whitehead (1926), science eventually rests upon the faith into the deterministic order of nature that should be seen as the reinterpretation of the medieval belief in a rational God. In particular, it can be noticed that classical mechanics relies upon the idea of an "intelligent and powerful Being" that is ultimately responsible of the order of nature (Newton 1713). Further, it can be observed that Leibnizian mechanics supposes that the world that an observer experiences is nothing but the one that God chooses as the best among many possible others (Leibniz 1710). Through the *principle of least action*, this idea carries on to the Euler-Lagrange theory, to the Hamilton-Jacobi theory, and ultimately to all contemporary formulations of classical mechanics (Lanczos 1986). Nevertheless, as far as Popper reasoning is concerned, the idea is that scientific theories should be justified only on the basis of their predictive ability. As explicitly argued by Popper (1963), metaphysical assumptions, like the one of the perfect adherence to reality, can drive scientists toward interesting research directions. Yet, the theories that are devised along these research directions are to be regarded as conjectures that can be justified only on the basis of the fact that they lead to reliable predictions.

By arguing that science does not rest upon truths derived by induction from experience but rather on bold conjectures that precede observation and that are then checked against it, Popper claimed that he had skipped the problem of induction. Yet, by emphasizing the inventionist character of science, Popper raised a central epistemological issue: the *objectivity* of science. Indeed, stating that science invents laws *about nature* and does not discover laws *in nature* amounts to abandon the idea that scientific knowledge is obtained from, and justified on the basis of the observation of, a reality that exists independently from our mental representations. Popper (1935) provided an answer to this issue by introducing the idea of the *intersubjectivity* of science: Though scientific theories are inventions, they are not arbitrary because the predictions derived from them are "intersubjectively tested" by the scientific community according to well-defined experimental protocols.

The very idea that science is about prediction rather than about the discovery of final truths traces back to concerns raised in the late nineteenth century. This idea is paramount to Mach's epistemology. Before the crisis of classical mechanics, Mach (1883) developed an *instrumentalist* conception of science according to which scientific theories have not to be intended as referring to real entities. According to Mach, scientific theories are rather useful instruments for making predictions. Mach's epistemology, in its turn, may be traced back (Popper 1953) to the one of Berkeley (1710). With his composite empiricist-instrumentalist position, Berkeley anticipated Mach in delineating the idea that scientific theories are justified by their practical utility and in denying that science can discover the intimate nature of reality.

The instrumentalist view of science remained marginal until the end of the nineteenth century. It became mainstream in the early twentieth century, as it appeared the adequate epistemological background for the then-newborn paradigms of relativistic and quantum mechanics. The discussion that confronted Niels Bohr (1949) to Albert Einstein on the interpretation of quantum mechanics shows that the Berkeleian and Machian views of science deeply influenced the epochal turning point that characterizes physics in the twentieth century. Although Einstein is typically presented as an advocate of a realist interpretation of the quantum theory, he agreed with the inventionist thinkers that scientists do not draw from observation theories that correspond perfectly to reality. As put by Einstein (1949), reality "is mentally constructed," and the constructs that are used by scientists to account for the sensory experiences must not be regarded, as Kant did, "as unalterable (conditioned by the nature of understanding) but as (in the logical sense) free conventions": These conventions are justified by their ability to provide a "logical representation" of sensory experiences.

Contemporary Incarnations of the Discoverist Position and the Current Debate

Notwithstanding the idea that science is about discovering the truth has undergone serious criticisms in the first half of the twentieth century, starting from the 1960s, a discoverist stream of thinking reemerged in the literature. This stream of thinking goes under the name of *scientific realism* (Smart 1963; Boyd 1973; Putnam 1975). This new version of the discoverist view revised significantly the notion of truth. Notwithstanding it considers truth as the final goal of science, it acknowledges that science cannot deliver absolute truths. This fundamental change of view emerged from the fact that the notion of truth was replaced by the notion of *truthlikeness* (Oddie 1986; Niiniluoto 1987). The idea behind this revised notion of truth is that science does not state absolute truths but only approximates truths by eliminating false theories and by devising more accurate descriptions of reality.

The notion of truthlikeness is formulated and analyzed within the *similarity approach* (Oddie 1986; Niiniluoto 1987) where it is adopted to provide an explanation of the predictive success of scientific theories. Scientific realists acknowledge, in line with the inventionist view, that scientific theories are selected on the basis of their predictive success. Yet, they claim that it is necessary to recur to the notion of truthlikeness in order to both decide which theory to select among competing ones that are equally predictively successful and to explain why the selected theory is more successful than its rivals: Through the so-called *no miracle argument* (Putnam 1975), a number of realist thinkers argued that the amazing success of science would be miraculous if scientific theories were not, at least approximately, true of the world.

The scientific realist strategy to move from an absolute to a softened conception of truth is motivated by the need to respond to the issue of falsification. Yet, accepting that science is about approximating truth rather than discovering it constitutes a breakthrough in the scientific realist epistemology. It heads the realist epistemology toward an *asymptotic discoverist* conception of truth. This asymptotic conception amounts to renounce the key realist assumption that scientific theories correspond to reality. It nonetheless implies the hope that eventually, and possibly in infinite time, theories converge to truth.

The realist attempt to revive the notion of truth has been seriously challenged in the 1980s by Larry Laudan (1981). Laudan questioned the very idea that the predictive success of a theory is an indication of the fact that the theory is a true account of reality. Laudan pointed out that the history of science indicates that the empirical success of scientific theories does not guarantee either their genuine reference to reality or their truthlikeness. Classical mechanics is a representative example in this sense. Recently, it has been argued that the reasons why the notion of truthlikeness has been perceived as unsatisfactory are related to the double role that this notion plays in the similarity approach: Using Kant terminology, Piscopo and Birattari (2010) clarified that the dissatisfaction derives from the fact that the notion of truthlikeness plays a *constitutive role* in the selection of empirical theories while it should play only a *regulative role* in their conception. Within the similarity approach, truthlikeness performs, on the one hand, the regulative function of a stimulus to continuously search for a more complete account of reality. On the other hand, it plays a regulative role while deciding which theory to select among competing ones: The conclusive criterion for preferring a theory to a rival one is the better correspondence to reality.

The problematic issue with the regulative use of the notion of truthlikeness is that the crisis of classical mechanics has definitively ruled out the idea that a scientific theory can be shown to truly correspond to reality. It is therefore hard to see how the criterion of truthlikeness can act as a regulative principle for the selection and the justification of scientific theories.

Notwithstanding the challenge posed by the crisis of classical mechanics to the idea that science is about discovering the truth, there is nowadays a propension in epistemology toward a discoverist position as it is testified by the reemergence of realist perspectives. This propension has a deep motivation. It should be seen as an attempt to preserve the objectivity of science: It is aimed at defending the idea that there is a reality independent from the observer and that this reality can eventually be discovered through observation.

At a closer look, the tension between the discoverist and the inventionist views of science is not a prerogative of epistemology. This tension emerges, for instance, clearly in the artificial intelligence and machine learning field that goes under the name of *knowledge discovery in databases*. As its name suggests, the field of knowledge discovery in databases rests upon the idea that it is possible to build programs that can discover general laws from data sets. The expert system BACON.1 (Langley et al. 1987) is a milestone in machine learning and should be regarded as a realization of the inductivist and discoverist idea. As it is made clear by its name, the assumption behind the implementation of BACON.1 is that this system is built to *extract* theories *from* nature rather to *construct* theories *about* nature. In other words, the very assumption that is made is that since BACON.1 does not devise theories but discovers them in nature, these theories are necessarily a true representation of nature itself.

It must be noted, yet, that though the discoverist view has pervaded the machine learning field for decades, some sectors of the community seem to have eventually switched to an inventionist position. In particular, nonparametric statistical methods such as bootstrap (Efron and Tibshirani 1993) and cross-validation (Stone 1974) do not rest on the hypothesis that the real system under observation belongs to the model space: If the system does not belong to the model space, the learned model cannot coincide with the system itself, and therefore, no discovery is possible. In such a case, the learned model can be at best an approximation of the system. The learned model can be therefore considered only as a useful invention.

Concerning the possibility of building inductive machines, just few years before BACON.1 was built, Popper raised doubts about the idea that a machine could discover scientific laws by induction from simple observation:

> [...] *we may consider the idea of building an inductive machine. Placed in a "simplified world" (for example, one of sequences of coloured counters), such a machine may through repetition "learn", or even formulate, laws of succession which hold in "its" world. If such a machine can be constructed (and I have no doubt that it can) then, it might be argued, my theory* [here Popper means the theory that science does not rely on induction] *must be wrong; for if a machine is capable of performing inductions on the basis of repetition, there can be no logical reasons preventing us from doing the same. The argument sounds convincing, but it is mistaken. In constructing an induction machines we, the architects of the machine, must decide* a priori *what constitutes its "world"; what things are to be taken as similar or equal; and what* kind *of "laws" we wish the machine to "discover" in "its" world. In other words we must build into the machine a framework determining what is relevant or interesting in its world: the machine will have its "inborn" selection principles. The problems of similarity will have been solved for it by its makers who thus have interpreted the "world" for the machine*. (Popper 1963)

Conclusions and Future Directions

A tension between the *discoverist* and the *inventionist* views can be seen both in science and in epistemology. The discoverist view is motivated by the need to preserve the objectivity of science, but this view has to deal with the problem of induction. The inventionist view skips the problem of induction, but it has to renounce the idea that scientific knowledge has an objective character.

The tension between the discoverist and the inventionist views appears unavoidable in future discussions about the nature of science. On the one hand, the discoverist view responds to the philosophical concern of ensuring that science is not an artifice but a rational and objective enterprise. On the other hand, the inventionist view is enforced by the pragmatic acknowledgement that even the best confirmed theories are simply conjectures that can be eventually abandoned and substituted by alternative ones that are expected, in their turn, to face the same destiny as their predecessors.

Further research is needed in order to solve the above-mentioned tension. Popper's falsificationist view and the related conception that science does not produce truths but rather builds intersubjectively testable theories appears to be a viable solution: Falsificationism describes scientific theories as not arbitrary though it accounts for their fallible character.

I

Cross-References

▶ Convergent Versus Divergent Thinking
▶ Creativity and Innovation: What Is the Difference?
▶ Ideas and Ideation
▶ Imagination

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Inventive Creativity

► Creative Mind: Myths and Facts

Inventive Problem Solving (TRIZ), Theory

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Synonyms

Systematic innovation

Introduction

How people invent? Famous scientists and engineers sharing their memories, as well as psychologists studying the creativity process, describe similar situations: An individual facing a difficult problem is mentally exploring various approaches, persistently trying and rejecting ideas until the right one comes. Psychologists call this process trial-and-error method (T&EM).

T&EM has a great history. It was used to create first stone knives, bows, guns, windmills, building, ships, and almost everything we can see around. Some results are astonishing: Polynesian catamarans, old Chinese, Norwegian, or Russian boats are practically perfect. Each element has the best shape. However, archeological research has shown that even 500 years ago, these vessels were rather far from perfect. One hundred years after another of repeating practically the same shapes, the builders yet were introducing slight changes into design. Some of them were unsuccessful, causing fatal accidents, and have been forgotten; the others, successful ones, were becoming a standard. It was a long evolutionary way similar to the evolution of life with similar consequences including fatalities and victims.

With the acceleration of technological evolution, T&EM became less and less acceptable as a method of design. It is absolutely unreasonable today to build thousands of samples to select the best design of a modern aircraft or a steam machine. Engineering science has stepped in offering various means, allowing identifying the best design with the help of scientific research, calculations, modeling, computer simulations, etc. As a result, engineering design today is rather systematic, structured, and well-controlled process, while searching for new ideas is still lacking all these necessary features.

In the typical creative process, people start from exploring apparent conventional solutions, usually governed by their *psychological inertia* slowly moving to the area of "wild" ideas. After hundreds of unsuccessful attempts, luck becomes a king: Someone occasionally can notice a café-maker in the room and wonder if steam could help to solve the problem.

The T&EM effectiveness depends on how difficult the problem is. It could be measured by a number of trials that have to be made to guarantee successful results. This number can vary within wide range – from dozens for simple problems to hundreds of thousand for difficult ones. T&EM is rather sufficient for the problems that do not require more than 10–20 trials; however, for difficult problems that require out-of-the-box thinking, it leads to an unacceptable waste of time and efforts.

In addition to low efficiency, T&EM contributes in poor problem statements. Often a problem is stated in occasional and incorrect format with a lot of unnecessary information while needed information is absent.

Until recently, the T&EM deficiency has been compensated via increasing number of people working on the same difficult problem. At the same time, since the mid-1950s, it had become obvious that even the most adequate utilization of human resources could not satisfy the required pace of invention production. Accelerating technological evolution demanded simple and affordable creative methods. So, the demand has originated the supply. To date, over hundred of various creative techniques and methods are available with different efficiency, area of application, and practical importance (Higgins 1994). At the same time, because it seemed fairly obvious that creativity was a product of the human brain, the main approach to creativity was focused on attempts to enhance the creative process by facilitating an individual's mental processes, that is, *psychology-based approach* to creativity. In summary, these efforts were aimed at the following:

- Unleashing natural creativity and eliminating mental blocks
- Stimulation and mobilization of resources helpful for generating ideas by a group or individual

Later, a fundamentally different, knowledge-*based approach* has been introduced including various analytical steps aiming to manage (organize, restructure, etc.) and utilize available internal knowledge and experience; eventually this approach led to utilization of specially developed and structured external knowledge (innovation knowledge bases).

The basic advantages of the innovation knowledge-base techniques are the following:

- Accumulation of the best practices in creative problem solving is possible.
- Proved knowledge can be assessed.
- Results are repeatable and do not depend on personal (psychological) issues.

The most significant result of the knowledge-based approach is the Theory of Inventive Problem Solving (TRIZ – a Russian acronym for the Theory of Inventive Problem Solving, pronounced as "trees" (Altshuller 1984).

TRIZ Origination and Early Discoveries

TRIZ was founded by Genrich Altshuller, who was born in former Soviet Union in 1926. He has made his first invention at age of 14 and was later educated as a mechanical and chemical engineer.

He also has a military education as a pilot. In 1946, he was employed as a patent agent in Soviet navy with the main responsibilities to assist inventors in filing their patents. However, because of his background, he was frequently approached by engineers stragling with difficult problems. While trying to help them, Altshuller began questioning if a certain systematic or even scientific approach to innovation is possible. After conducting preliminary studies in this area, he decided to embark on his own quest to develop such approach.

While traditional studies on creativity were focusing on psychological aspects of the innovation process, Altshuller chose studying thousands of patents looking for common threads, repetitive trends, and patterns related to innovation activities. The early results of this research brought discovery of *patterns of inventions* (inventive principles) and *patterns of technological evolution*. Other results included *definition of an inventive problem* and *levels of invention*.

In the history of TRIZ, two distinct periods could be identified: *classical TRIZ* and *contemporary TRIZ* characterized as follows:

Classical TRIZ	TRIZ as it underwent development led by Genrich Altshuller in the former Soviet Union (from the mid-1940s to the mid-1980s).
Contemporary TRIZ. Phase 1	TRIZ during *perestroika* in the former Soviet Union, when first commercial application started (from the mid-1980s to the early 1990s).
Contemporary TRIZ. Phase 2	TRIZ as it penetrated the Western world (beginning in the early 1990s to present).

TRIZ Fundamentals

Among the basic discoveries of TRIZ, the most important are:

- Any technical system develops according to certain patterns.
- The patterns of evolution for different systems have much in common.
- The patterns of evolution can be unveiled through researching the evolutionary history of a system (for the area of technology, this evolutionary history is contained in the patent library and other sources of technical information).
- Via application of these patterns, one could accelerate the evolution of that system to its next generation.
- Based on these discovered patterns of evolution, universal methods for searching for new ideas can be developed.

Patterns of Invention

Altshuller's analysis of patents showed that the same fundamental solutions had been used over and over again for different problems, often separated by many years.

Invention #1. Sweet Pepper Canning Method

To prepare green peppers for canning, the stalk and seeds must be removed. This is done manually in the kitchen, but automating the process for large-scale production is difficult because the pods are nonuniform in shape and size.

The following method was invented to core green peppers: The peppers are placed in an air-tight container, in which the pressure is gradually increased to 8 atm. The pods shrink and, as they do so, fracture at the weakest point, where the stalk joins the pepper. Compressed air penetrates the pepper at the fractures, and the pressure inside and outside the pepper eventually equalizes. The pressure in the container is then quickly reduced, causing the pepper to burst at its weakest point (which has been further weakened by fractures). The top is "ejected" from the rest of the pepper, taking the seeds with it.

Invention #2. Husking Sunflower Seeds

One method of husking sunflower seeds is to load them into a bunker, increase the pressure inside the bunker, and then decrease the pressure sharply. The air that penetrates the husks under high pressure expands as the pressure drops, thereby splitting the husks.

Invention #3. Filter Cleaning Method

A filter used to treat fine-grained sand consists of a tube whose walls are coated with a porous, felt-like material. When air passes through the tube, the sand particles are trapped in the pores. Cleaning such a filter is difficult.

The filter can be cleaned by exposing it to a pressure of 5–10 atm and then quickly dropping the pressure to normal. The sudden change in pressure forces air out of the pores, along with the sand. The sand particles are carried to the surface, where they can be easily removed.

Invention #4. Splitting Imperfect Crystals

When manufacturing tools made of artificial diamonds, crystals that contain fractures cannot be used. Splitting the crystals at the fracture yields useable diamonds, but efforts to do so often produce new fractures.

As an alternative, the crystals can be placed in a thick-walled, air-tight vessel. The pressure in the vessel is increased to several thousand atmospheres and then quickly returned to normal. This sudden change in pressure causes the air in the fractures to break the crystals.

Invention #5. Producing Sugar Powder

A technique similar to those described above is employed, at much lower pressure, to break sugar crystals into powder.

The inventions above span different areas of technology and appear at different times, yet they are clearly similar. Moreover, the problems addressed by these inventions are similar. Undoubtedly, had the later inventors known of the earlier solutions, their problem-solving tasks would have been straightforward. Unfortunately, the barriers that exist between different industries made this practically impossible.

We can imagine that a problem solver trying to devise a way to remove the shells from walnuts will know (or be able to find out) how sunflower seeds are shelled, and solving the problem will therefore be relatively simple. Let's imagine, however, that this solution did not yet exist in the food industry. In this case, it is very unlikely that our problem solver will look for a solution in the metallurgy or diamond production industries, and he therefore will be unable to apply a "ready-made" solution and instead must spend time and money reinventing it.

Altshuller realized that knowledge about inventions could be extracted, compiled, and generalized so that it would be useful to inventors in any technological domain. For example, all five of the above inventions can be described as follows:

Problem: Breaking Apart an Object *Solution:* Apply a gradually increasing pressure for some period of time, and then abruptly drop the pressure. The pressure differential will create an "explosion" that breaks the object apart.

This generalized knowledge can be organized and made available so that, when faced with a problem, an inventor needs to only match the problem with the generalized problem, then refer to the corresponding solution(s).

In this way, TRIZ provides problem solvers with access to the most effective solutions over a broad range of industries, based on the accumulated innovative experience of inventors throughout history. In TRIZ, these generalized solutions are called *inventive principles*.

Patterns of Technological Evolution

The first set of patterns of technological evolution was distributed by Altshuller among TRIZ schools in the mid-1970s. This seven-page manuscript became the most valuable component of TRIZ and established the foundation for TRIZ as a science.

The set of patterns included three groups named after the laws of theoretical mechanics as follows (Altshuller 1984):

Group 1 – Statics – determines the beginning of a system's life cycle, including:

1. Completeness of an engineered system
2. Energy flow in an engineered system
3. Harmonization of the synchronization rhythms or parts in an engineered system

Group 2 – Kinematics – determines the general evolution of a system, including:

4. Increasing ideality of an engineered system
5. Nonuniform evolution of subsystems comprising an engineered system
6. Transition to the overall system

Group 3 – Dynamics – reflects evolution in contemporary conditions involving certain physical and technical factors, including:

7. Transition from macro- to microlevel in an engineered system
8. Increasing substance-field involvement

Later, various modifications to the set above were introduced, including numerous lines of evolution (more detail step-by-step descriptions of evolution within the patterns).

Contradictions

One of Altshuller's key findings was that *nearly all great inventions* (*except serendipitous discoveries or inventions resulting from accidents or mistakes*) *are the result of the resolution of one or more contradictions* (*paradoxes*). This common thread – the relationship between contradictions and inventions – provided invaluable insight about problem solving that had previously been unavailable (Altshuller 1984).

A ***contradiction*** exists when attempts to improve one feature of a system cause another feature to degrade.

Altshuller identified two types of contradictions. The first is called a *technical contradiction*. A technical contradiction exists when an improvement to one characteristic of a system is associated with the deterioration of another characteristic. Indeed, engineers often talk in terms of such "dilemmas":

- If we add more functional capabilities to this machine, it will become more complicated and difficult to maintain.
- By increasing the speed of our process, we end up with more errors.

The second, more fundamental type is called a *physical contradiction*, when a characteristic must exist in two opposite states:

- A pen tip should be sharp to draw legible lines but blunt to avoid tearing the paper.
- Aircraft landing gear is necessary for landing but is undesirable during flight.

The conventional way to deal with a contradiction is to look for a compromise or trade-off. Revealed in the patent fund, however, are many examples of solutions that resolve contradictions. This means that *methods for satisfying contradictory requirements exist and can be applied.*

The discovery of the relationship between contradictions and inventions led to significant findings that were soon to simplify the process of solving inventive problems. Altshuller realized that the key to attacking an inventive problem was to reveal the contradiction that lies at its core. For recognized and formulated contradictions, tools for their resolution were created.

Ideality and Inventive Resources

Another Altshuller's important fundamental discovery was that *as technological systems evolve, they become more ideal*. By his definition, a completely ideal system would just perform its function without having side effects, cost, or any other undesired factors. Further, he concluded that all these negative factors that make the system less ideal are associated not with its function but rather with the system that performs this function. Based on this conclusion, *in an ideal system, the function is performed without the existence of the system* (Altshuller 1999). Accordingly, the best solution to a problem will be the one closest to the ideation ultimate result (IUR) that could be defined as follows:

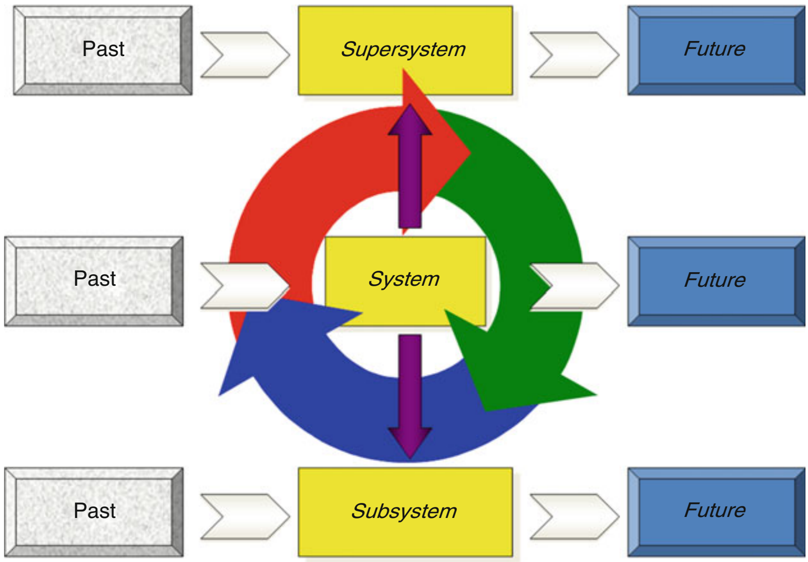
- Produces the desired improvement
- Does not make the system more complex and/or costlier
- Does not cause any side effects/consequent problems

These statements are obviously extreme and are never actually attainable, yet it is important to keep them in mind as we look for inventive solutions to difficult problems.

In real systems, *ideality* for a given system can be defined as the ratio of the sum of its useful features (benefits) to the sum of harmful (or undesired) factors. Given that, the way to increase system's ideality could be one of the following (or both):

- Increasing system benefits
- Reducing harmful factors

The general approach to achieving near-ideal solutions is using *inventive resources*. An inventive resource can be defined as an attribute of a system or its surroundings that could be utilized for system



Inventive Problem Solving (TRIZ), Theory, Fig. 1 9-screen model of creative thinking (Altshuller 1984; Ideation International 1995)

improvement instead of introducing (adding) external means. These attributes could be:

- Any substance or anything made of a substance (including waste) that is available in the system or its environment
- An energy reserve, free time, unoccupied space, information, etc.
- The functional and technological ability to perform additional functions, including properties of substances as well as physical, chemical, geometric, and other effects

Example

At egg farms, instead of using special devices for date stamping, workers use gloves with date-stamp on one of the fingers. The eggs get stamped as they are placed by workers into cartons.

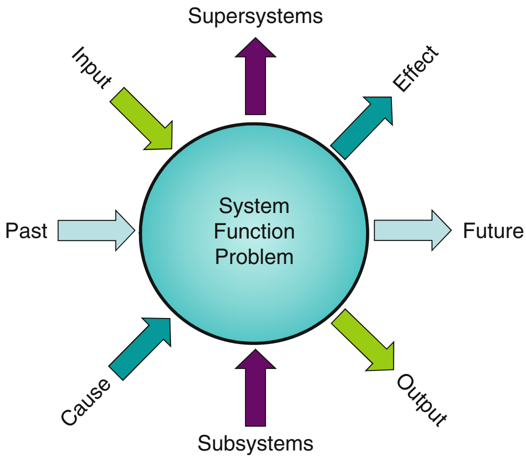
System Approach

Typically, when a problem arises in a system (or in its certain part, for this matter), problem solvers try to solve the problem by focusing on the *system*. But experienced inventors think differently. They understand that the system elements and the elements of the close environment are interconnected; because of that, changes in one part of the system produce sequential changes (both positive and negative) to other parts of the system and its environment. Given that, they simultaneously think about the system, the supersystem, and all associated subsystems and how they could be useful in problem resolution. For example, the system "airplane" is a part of the supersystem "transportation." Switching from the "airplane" to "transportation" changes our point of view for how to deal with a problem associated with an airplane.

Example

If we are looking for ways to reduce the time it takes to fly from Los Angeles to Tokyo, and we are targeting a system called "airplane," then our focus for solving the problem would be centered on making the airplane move faster. On the other hand, if we focused on the supersystem "business trip," we might consider *all* aspects associated with moving a person through the entire process, from the time he/she leaves the house until he/she arrives at the desired destination. This more expansive look at the problem now includes driving, parking, ticketing, security check-ups, baggage handling, entering and exiting the plane, directional signage in the terminal, and so forth.

Altshuller suggested that the thinking process of the most talented natural inventors could be illustrated with the diagram shown below (Fig. 1).



Inventive Problem Solving (TRIZ), Theory, Fig. 2 8-angle system approach (Ideation International 2004)

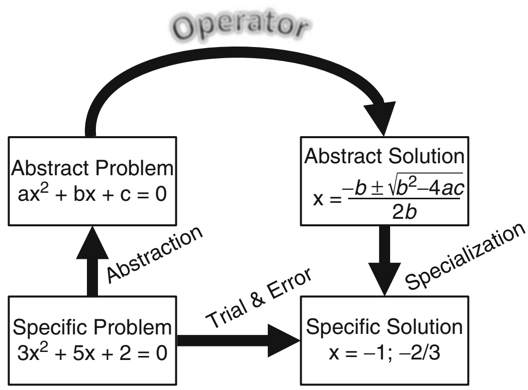
Because thinking about numerous aspects of the situation is extremely hard for normal human being, he recommended transforming this complex picture in a linear sequence of "boxes," allowing considering one direction at a time.

Later, the schematic above was convoluted in two axes, system axis and time axis, and two additional axes were introduced, suggesting eight angles to the problem situation (Fig. 2).

Main Approach to Inventive Problem Solving

Humans possess an innate approach to problem solving: When faced with a problem we do not know how to solve, we try to think of a similar, *analogous* problem for which we know a solution. Then, with this known solution in mind, we try to devise an analogous solution to the problem we are trying to solve. The chances that we will succeed using this approach are determined by:

- Our knowledge of problems with known solutions, accumulated through education and experience. This knowledge is needed to make the analogical "leap" from our new problem to the analogous problem.
- Our ability to devise a solution to a new problem from the analogous solution.



Inventive Problem Solving (TRIZ), Theory, Fig. 3 Principle of solution by abstraction applied to quadratic equation (Ideation International 1995)

If one's experience and/or ability to see analogies is limited, principle of abstraction can help (Fig. 3).

The example above is a well-established approach in math. TRIZ suggests that the same approach could be applied to inventive problem solving (Fig. 4).

Similar to math, each transition described above is supported with well-defined tools (Fig. 5).

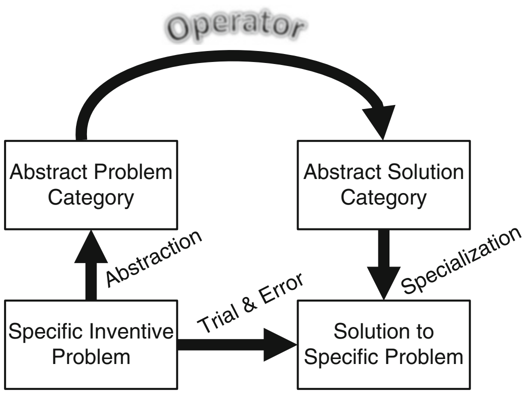
TRIZ Way of Thinking Versus Conventional Thinking

The main concepts of TRIZ, especially ideality, resources, contradictions, and system approach, constitute TRIZ way of thinking, which is different from conventional thinking of the majority of human individuals. The Table 1 below shows the difference.

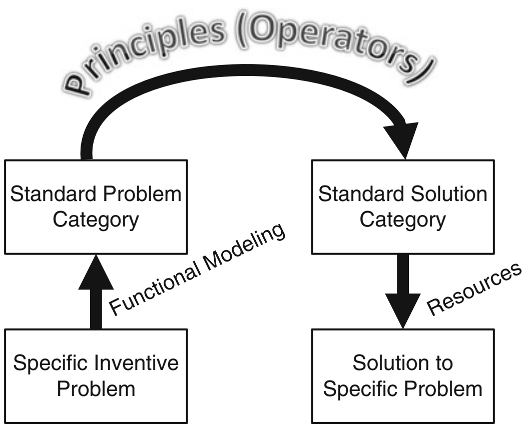
Simple algorithms and several well-formulated recommendations can help master TRIZ way of thinking, making it an inherent part of an individual's mentality.

TRIZ Tools

TRIZ tools for systematic innovation include *analytical tools* that help understand if it is necessary to reformulate the problem and



Inventive Problem Solving (TRIZ), Theory, Fig. 4 Principle of solution by abstraction applied to inventive problems (Kaplan 1996)



Inventive Problem Solving (TRIZ), Theory, Fig. 5 How TRIZ works (Ideation International 2004)

knowledge-based tools that represent the best innovation and problem-solving practices extracted from patents and other sources of information.

Analytical Tools

Analytical tools of classical TRIZ include:

- Algorithm for Inventive Problem Solving (ARIZ)
- Substance-Field Analysis

Later, two additional analytical tools have been developed to ensure complete support of all steps in the problem-solving process, including problem definition and formulation (Terninko et al. 1998):

- Innovation Situation Questionnaire®
- Problem Formulator®

ARIZ

ARIZ (Russian acronym for the *Algorithm of Inventive Problem Solving*) is an analytical tool organized as a set of sequential steps helping reveal contradictions and create a set of models of the problem that serve as pointers to apply appropriate knowledge-base tools. The first version of ARIZ was introduced by G. Altshuller in 1959. Since then, numerous modifications have been developed based on feedback and suggestions provided by TRIZ theoreticians and numerous TRIZ practitioners. The last standard version introduced by Altshuller was ARIZ-85C (1985) including over 60 steps. Since then, several modifications have been compiled by various TRIZ providers (mostly simplifications), but none of them has become a standard.

Substance-Field (SF) Analysis

Substance-Field (SF) Analysis is an analytical tool introduced by G. Altshuller in the mid-1970s with the following assumptions (Altshuller 1984; Terninko et al. 1998):

- The minimal model of a functioning technological system includes two objects or substances interacting through a field or force (energy).
- The system can be graphically modeled by a triangle relating the substances and the field.
- Depending on completeness of the given model (all three elements are present or some are missing) or the nature of interaction (useful or harmful), certain standard solutions are recommended.

The Innovation Situation Questionnaire®

(Innovation Situation Questionnaire®, Problem Formulator®, and Directed Evolution® are trademarks of Ideation International Inc.)

The Innovation Situation Questionnaire (ISQ) is a set of questions helping collect and organize available knowledge about a problem situation for the purpose of supporting the problem-

Inventive Problem Solving (TRIZ), Theory, Table 1 TRIZ way of thinking versus conventional thinking

Concept	Conventional thinking (attitude)	TRIZ thinking (attitude)
Ideality	Looking for incremental obviously feasible solutions	Envisioning the most desirable solution in assumption that anything is possible and, once it is envisioned, looking to realize it or the closest possible
Resources	Means for system improvement should be brought from the outside. To add a function or a feature, one should introduce additional element, energy, money, etc.	First, look for an unused resource (internal or from the close environment) that can perform an additional function or provide an additional feature
Contradiction	Avoiding; when confronted, looking for a trade-off or a compromise	Understanding that any difficult situation has an underlined contradiction. Formulating (verbalizing) this contradiction(s) and applying appropriate operators for its resolution
System approach	Limiting solution space within the area in which a problem has occurred	Understanding that elements of the given system and its environment are interconnected; changes in one part of the system produce sequential changes (both positive and negative) to other parts of the system and its environment; every problem should be considered as a problem situation with multiple angles to address the issue

solving process (Terninko et al. 1998; Kaplan 1996). Although typically subject matter experts for a given system know their system well, this knowledge is usually focused on performance and/or production. While this is helpful and even necessary, knowledge of this type can produce strong psychological inertia factors that hinder the creative process. ISQ questions have been carefully selected based on extensive TRIZ experience of leading TRIZ specialists; as a result, they help look into the problem situation from TRIZ point of view and allow for generating the first inventive ideas.

Problem Formulator®

The Problem Formulator is an analytical tool for transferring knowledge about a particular problem situation from the user's mind into a comprehensive set of Directions for Innovation (problem statements) (Terninko et al. 1998). Problem Formulation process included two steps:

- Building a diagram (visual model) that describes the problem (innovation) situation in terms of cause-effect relationships
- Converting the diagram into an exhaustive set of Directions for Innovation

Each computer-generated Direction for Innovation serves as a "pointer" to a relevant portion of the knowledge base.

Knowledge-Based Tools

Besides patterns/lines of evolution, knowledge-based tools of classical TRIZ include (Altshuller 1984):

- 40 Principles and Contradiction Matrix
- Separation Principles
- The System of (76) Standard Solutions
- Selected Innovation Examples
- Effects (Phenomena)

Historically, various TRIZ knowledge-based tools were developed with the expectation that older tools would eventually be replaced or absorbed by more advanced and effective tools (Zlotin 1999). As a result, by 1980s many TRIZ schools practically stopped teaching the 40 Innovation Principles providing only brief information about this tool and instead put emphasis on the System of (76) Standard Solutions. However, later it became apparent that excluding the 40 Innovation Principles from a practitioner's "toolbox" had a negative impact on one's practical problem-solving abilities, primarily due to the fact that the older tool had its own advantages, like simplicity. Also, several very effective recommendations from the 40 Innovation Principles were not included in the System of Standard Solutions (e.g., “transformation of harm into a benefit”). On the other hand, tools multiplicity led to duplication and confusion which tool to use in various practical cases.

Later attempts to resolve the issues above and to further enhancement of TRIZ knowledge-based tools went in two main directions (Zlotin et al. 2010):

- Development of an integrated operational knowledge-based tool (System of Operators) that included all recommendations contained in the 40 Innovation Principles, System of Standard Solutions, Utilization of Resources, etc. This new system allowed working with any problem model known in TRIZ: technical contradictions, physical contradictions, substance-field models, etc.
- Development of simplified sets of principles (operators).

TRIZ Applications

The first TRIZ application (reflected in the name of the methodology) – solving inventive problems in technological areas. However, inventive problem solving (IPS) is only one of the existing innovation needs. To address all needs and develop a complete innovation and problem-solving platform, the following steps have been taken:

1. Identifying all needs related to problem solving and innovation and development of a comprehensive set of applications that will address these needs.
2. Development of computer-aided processes for each application.

This approach resulted in the development of the following additional applications supported by the family of TRIZ-based software (TRIZSoft®) (Zlotin et al. 2010):

- *Anticipatory failure determination* (*AFD*) – proactive process for analyzing, predicting, and eliminating failures in systems, products, and processes
- *Directed evolution*® (*DE*) – predicting next generations of products, services, and technologies via inventing them and developing a comprehensive set of scenarios describing future generations of a system
- *Control* (*Management*) *of Intellectual Property* (*CIP*) – evaluation and enhancement of intellectual property (IP) related to proprietary technologies, inventions, patents, and patent portfolios

Furthermore, contemporary TRIZ possesses tools and processes developed for addressing various issues beyond technology, including problem solving and innovation in areas of business, management, logistics, organizational development, social aspects, and more (Zlotin et al. 2000). Together with inventive problem solving (IPS), the applications above could be considered as contemporary *office of innovation*.

TRIZ Education

Learning how to apply TRIZ concepts and tools takes time. In various ways, TRIZ could be counterintuitive to many people. Psychological inertia, fear of contradictions, lack of open mind, and other reasons make it difficult to learn and accept TRIZ concepts for adult professionals often overwhelmed with their everyday tasks.

Original typical TRIZ courses developed during the era without computers and support from academia were rather long (at least 240 h). The long learning curve was necessitated by the large amount of knowledge that must be acquired from various sources and through substantial practice before becoming a self-sufficient practitioner. Over the years, TRIZ has accumulated many tools of various degrees of complexity, yet there were no clear rules as to which tools should be applied to a particular practical case. Typical TRIZ knowledge included numerous examples and illustrations (learned from instructors and accumulated from one’s own experience) and other (mostly tacit) knowledge about how to successfully utilize TRIZ methods and tools. There was no doubt that this issue could become a serious obstacle in wide dissemination of TRIZ.

TRIZ for Professionals

Since the mid-1980s, the need to accelerate TRIZ learning for professionals became quite critical. One (rather obvious) way was to simplify TRIZ learning via focusing on the easy-to-learn TRIZ concepts. Unfortunately, the downside of this approach was substantial reducing of TRIZ problem-solving power. The other approach was development of TRIZ-based software tools. This approach also could be realized in two ways – (a) computerization of existing TRIZ tools and (b) restructuring TRIZ knowledge, making it more suitable for computerization (and thus more effective) (Zlotin et al. 2010).

Today, various TRIZ courses are offered (with or without software) for professionals, from 4–8-h orientations to extended ones. The most cost-efficient proved to be 3–5-day workshops during which the participants learn TRIZ fundamentals and use TRIZ software to simultaneously work on their project. The best results are achieved when these workshops are followed with coaching/mentoring for 30–60 days to ensure successful completion of the project.

At the same time, short TRIZ courses (even with the utilization of software helping achieve good practical results) cannot accomplish one very important objective – development of TRIZ mentality necessary to become a TRIZ professional (similar to the fact that one cannot learn math in a 3-day workshop to become an engineer). Naturally, it should be different if the main TRIZ concepts were learned at early age, like math.

TRIZ for Students and Children

Given the main difficulties with teaching TRIZ to professionals, it became obvious that most of the difficulties could be overcome if TRIZ were taught to college students and even school children of various ages. The first attempts to engage children audiences were made in 1970s in the Soviet Union, when G. Altshuller had a special page in the all-union paper, publishing basic TRIZ concepts and holding a contest for them to participate. Later, Altshuller summarized this 10-year experience in one of his books (Altshuller 1996). Since then, various TRIZ courses have been taught to school children and even in kindergartens.

Since the mid-1990s, some elements of TRIZ have been taught at various colleges and universities in USA and other countries. Lately, fully credited courses for undergraduate students and for continuous education have been offered.

Conclusion and Further Directions

Over 65 years of TRIZ development could be illustrated below (Fig. 6).

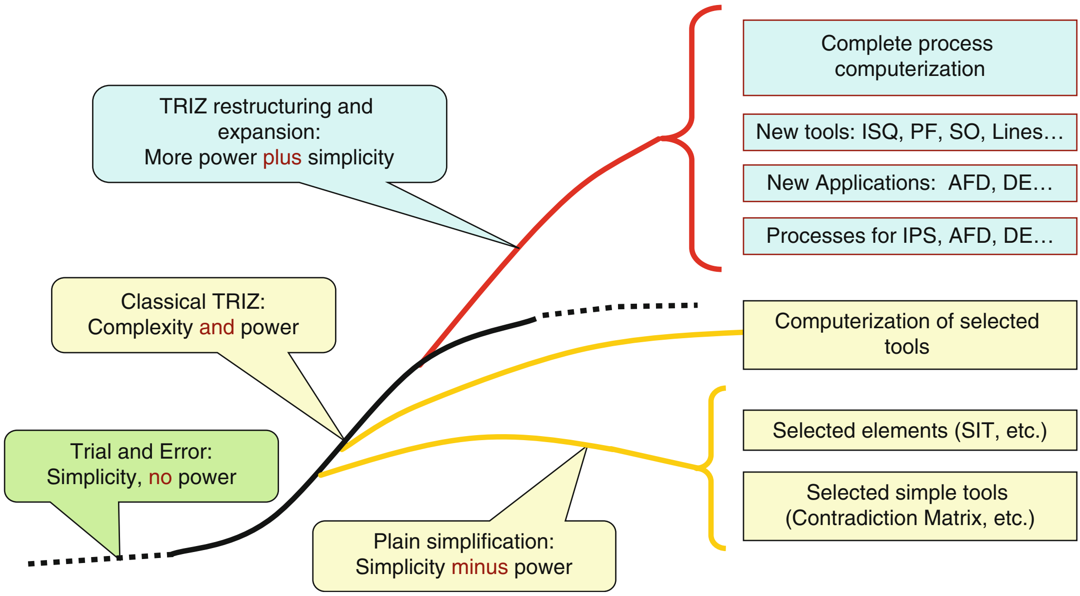
Started from revolutionary discoveries, it has resulted in creation of numerous tools and applications to satisfy all innovation needs and problem solving in practically all areas of human activities (Figs. 7 and 8).

The benefits from learning TRIZ for an individual are quite obvious – one can become a strong critical thinker, innovator, and problem solver.

For an enterprise, the main benefits of TRIZ utilization could be illustrated as shown below (Fig. 9).

When a project manager is about to start a project (starting point), he/she has to analyze possible directions and make a decision which way to go. Typically, the options to consider are few; theoretically, an exhaustive set of all possible options could have many more; however, it may take decades to find all of them if one relies on gradual accumulation of practical knowledge. Therefore, the manager has to make a “forced” decision within reasonable time in the situation of insufficient knowledge relying on his/her intuition, “gut feeling,” etc. Utilization of TRIZ with its powerful analytical tools and extensive knowledge base that accumulated the best innovation practices could significantly shrink this time – a typical problem-solving project can take 4–8 weeks.

The majority of more or less successful techniques introduced to the industry in the twentieth



Inventive Problem Solving (TRIZ), Theory, Fig. 6 Evolution and transformation of methods for innovation (Ideation International 2001)

Inventive Problem Solving (TRIZ), Theory, Fig. 7 Office of innovation: summary of key findings, tools, and applications (Ideation International 2001, 2010). Legend: Classical TRIZ (*in black*); Advanced (*in blue*); Newly developed (*in red*)

Four Original Key Findings • Definition of the Inventive Problem • Levels of Inventions • Patterns of Inventions • Patterns of Evolution ***Three Main Premises*** • **Contradictions** • **Ideality & Resources** • **System Approach** ***Four Analytical Tools*** • **Innovation Situation Questionnaire® (ISQ)** • **Problem Formulator®** • **Algorithm for Inventive Problem Solving (ARIZ)** • **Substance-Field Analysis (Su-Field)**	***Ten Knowledge-based Tools*** • 40 Inventive Principle & Contradiction Matrix • Separation Principles • 75 Standard Solutions • Effects • **Patterns /Lines of Evolution** • **Selected Innovation examples** • **System of Operators** • **Bank of evolutionary Alternatives™** • **AFD Checklists** • **IP checklists** ***Four Main Applications*** • **Inventive Problem Solving (IPS)** • **Anticipatory failure Determination (AFD)** • **Directed Evolution® (DE)** • **Management of Intellectual Property**

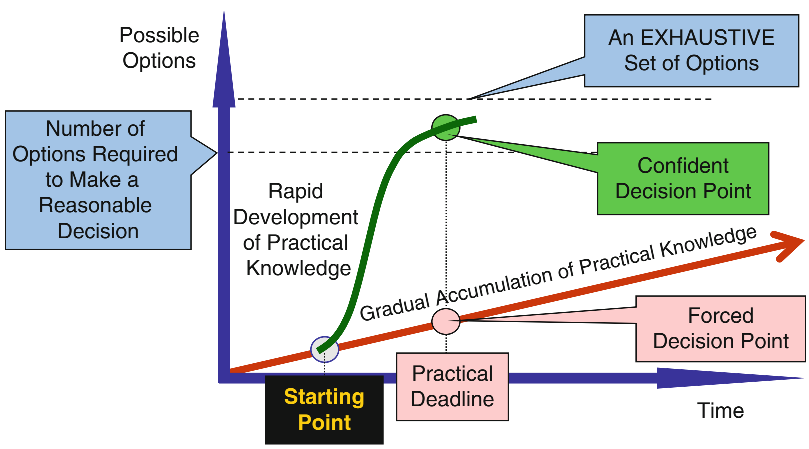
century (value engineering, quality function deployment, lean manufacturing, six sigma, etc.) have a weak link – luck of tools to produce creative solutions. Because the latter is the strongest point of TRIZ, it makes it greatly compatible with practically all other techniques and methods for quality improvement and cost reduction.

At the same time, TRIZ is neither a magic wand nor a silver bullet. If one would like to "calculate" the result of implementing TRIZ within an enterprise, the formula could look as follows (Fig. 10).

From the formula above, one can see that if such critical factors like subject knowledge, personal capability, motivation, and/or management support is missing, the overall results will be zero (with or without TRIZ). However, if all these necessary components are in place, TRIZ could be a tremendous multiplication of efforts and acceleration factor to the innovation process.

I-TRIZ Application/process	Education	Software	Publications	Analytical Services	Age of Application
Inventive Problem Solving	☆	☆	Multiple books and paper	☆	65 yrs
Failure Analysis	☆	☆	Two books multiple papers	☆	30 yrs
Failure Prediction	☆	☆	Two books multiple papers	☆	30 yrs
Directed Evolution	☆	Internal use	One book multiple papers	☆	20 yrs
Enhancement of Intellectual Property	☆	Internal use	Multiple papers	☆	10 yrs

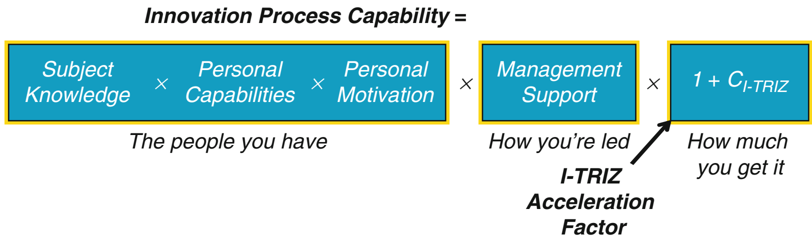
Inventive Problem Solving (TRIZ), Theory, Fig. 8 Commercial offerings of TRIZ education, software, and analytical services (Ideation International 2010)



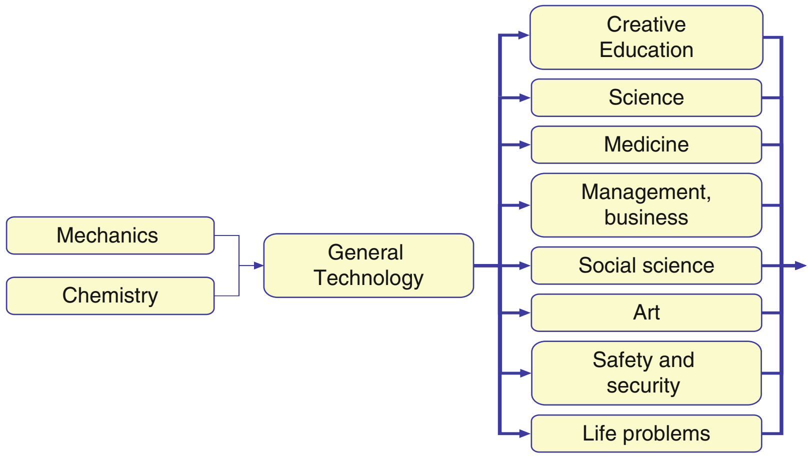
Inventive Problem Solving (TRIZ), Theory, Fig. 9 Accelerating innovation with TRIZ: more solutions, better, and faster (Ideation International 2001)

In spite of 65 years of development, research, and utilization and close to 5 M of search results on Google, TRIZ is still a very young science and technology. The strongest challenges are:

- Absence of Industrial Standards. Many companies tried some TRIZ products, services, and/or education from various providers with inconsistent results. While power of TRIZ methodology is quite visible to technical people, it is not so for the top executives who are focusing on bottom line rather than on technical issues. Although innovation has become a "buzz" word for the twentieth century, very few companies have the strategy and culture to embrace it and unleash its full potential. Because of many organizational and cultural factors affecting TRIZ implementation (see Fig. 9 above), there are not enough success stories to start TRIZ "tornado."
- Lack of Academic Research. Although being created using empirical approach, TRIZ was built as a science, with assumptions, definitions, and fundamental knowledge (patterns of evolution); however, during "Russian period" of TRIZ (1946–1992), most of the TRIZ research was done by individual enthusiasts, without sponsors or academia involvement. Even today, serious TRIZ studies are limited. Few commercial companies are



Inventive Problem Solving (TRIZ), Theory, Fig. 10 Innovation process with TRIZ (Ideation International 2004; John Dubuc 2010)



Inventive Problem Solving (TRIZ), Theory, Fig. 11 Evolution of TRIZ applications (Ideation International 2001)

more focused on sales and marketing strategies than research.

- Lack of Benchmark. Although there is a lot of offering of TRIZ products, services, and education on the market, potential clients have a hard time to evaluate the supply. As a result, certain negative experiences hinder wide TRIZ dissemination.

From the future direction's point of view, there are several aspects of TRIZ further evolution. As a methodology, it has gone through several transformations as follows:

- Way of thinking
- Set of tools
- Set of processes
- Complete system (office of innovation)

From application's point of view, TRIZ evolution could be considered as follows (Fig. 11):

Given the above, further directions in TRIZ development should be as follows:

- Theoretical base of TRIZ (TRIZ as a science)
  - Axiomatic foundation of TRIZ
  - Revised and extended system of patterns/lines of evolution
- Development of new and enhancing existing tools and applications, including productivity software tools
- Continue expanding TRIZ in new areas, for example:
  - Validation and enhancement of intellectual property
  - Solving scientific problems
  - TRIZ for nontechnical systems (business, management, politics, marketing, etc.).
- Integrating TRIZ with other creative techniques and business, quality, and knowledge management systems like six sigma, stage gate, etc.

At the same time, TRIZ has far overgrown its name. Solving inventive problems was a strong necessity of industrial era. There is still room for further development, including honing analytical tools, upgrading and extending knowledge base, finding new applications, etc. However, today, a problem in a certain system can be compared to a sickness; problem solving is equal to looking for a cure. This health care analogy shows us a better way – healthy lifestyle allowing avoiding problems in the first place. Similarly, the next step in evolution of TRIZ is transition to directed (managed, guided) evolution of technology and beyond that will eventually allow any individual or entity to be able to plan and control their destiny, including formulating goals and timely unveiling (anticipating) and solving problems that could arise on the way to a destination.

Cross-References

- ▶ Creativity and Innovation: What Is the Difference?
- ▶ Directed Evolution® Technology
- ▶ Invention and Innovation as Creative Problem-Solving Activities
- ▶ Inventive Resources
- ▶ Patterns of Technological Evolution
- ▶ TRIZ Software for Creativity and Innovation Support

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Inventive Resources

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Synonyms

Substance-field resources

Definition

An inventive resource can be defined as:

- Any substance or anything made of a substance (including waste) that is available in the system or its environment
- An energy reserve, free time, unoccupied space, information, etc.
- The functional and technological ability to perform additional functions, including properties of substances as well as physical, chemical, geometric, and other effects

The term “resources” is widely used within many contexts to refer to natural resources, financial resources, human resources, etc. In TRIZ, the creative utilization of the resources available in a system to increase the system's *ideality* is a cornerstone of *inventive problem solving*.

The concept was introduced in 1982 by Vladimir Petrov in the form of *excessiveness in technological systems* that could be utilized to increase the system's ideality. In 1985, Genrich Altshuller introduced "substance-field resources" as a component of the *Algorithm for Inventive Problem Solving* (*ARIZ*). These resources were grouped based on accessibility (internal, external, and from the supersystem(s)), readiness for utilization (readily available and derived (modified readily available resources) and cost (free, inexpensive, cheap). Later, this concept was expanded to include other types of resources such as functions, information, space, and time (Zlotin, Visnepolschi, Zusman). Other types of resources suggested were *differential resources* (Vertkin), resources produced by differing attributes or parameters; *change resources* (Royzen), resources produced by a change to the system; and *super-effect* (Gerasimov, Litvin), an additional benefit resulting from innovation that often goes unrecognized.

Until recently, the utilization of physical, chemical, geometric, and other *effects* has been regarded in TRIZ as another way to increase a system's ideality, as these effects often permit the substitution of a relatively complex system with a much simpler one. However, because an effect can be defined as a predictable (i.e., predetermined or statistical) response to a specific influence based on certain properties of participating elements and these properties (e.g., substance properties) can themselves be considered resources, one can suggest that the utilization of effects is yet another type of resource.

The concept of inventive resources is closely connected with a system emergence and its evolution along an *S-curve*. Typically, there are plenty of resources in the system in the beginning; fast growth is associated with intensive consumption of available resources; the amount of remaining resources is becoming scarce in the vicinity of maturity; the system's decline starts when initial resources are practically exhausted.

An abundance or lack of resources in the existing system can determine the success of problem solving; one can find multiple acceptable solutions in the system rich with resources. On the contrary, finding a solution to a problem in a system with nearly exhausted resources always represents a serious challenge; in certain cases, the solution could be provided only by transition to the next generation of the given system (new S-curve). In other words, certain resources should exist to enable invention. At the same time, every invention creates new resources that could be utilized for its further development and new applications (super-effect).

The most important issue associated with inventive resources is that they are usually unobvious or hidden (the easily apparent resources having already been utilized). A significant step in the formalization of the concept of resources and their utilization was the creation of checklists of typical resources (both readily available and derived) embedded in various TRIZ software products.

Cross-References

- ▶ Creativity and Innovation: What Is the Difference?
- ▶ Invention and Innovation as Creative Problem-Solving Activities
- ▶ Inventive Problem Solving (TRIZ), Theory

Inventive Thinking Skills, Development

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Synonyms

Teaching problem solving; Teaching thinking; Thinking skills, development

Background

Development of inventive thinking skills should be considered in the context of the so-called thinking skills approaches. Although hardly anyone disputes the need for teaching thinking, the actual approaches and programs can vary significantly as there are different theories and pedagogical traditions that underlie them. When analyzing the situation in the field of teaching thinking, it is useful to distinguish between specific programs for teaching this or that aspect of thinking, approaches to teaching thinking, and theoretical frameworks which constitute the basis for various approaches.

Teaching Thinking

Programs

There are numerous programs for teaching thinking. Traditionally, they can be divided into two types: stand-alone and infusion. The former offers a general training in this or that aspect of thinking as a separate subject in the curriculum, while the latter offers thinking instruction as an integrated part of a subject matter course. Thinking programs are usually developed within some approach to teaching thinking: numerous programs for teaching elements of critical thinking (Baumfield et al. 2004), programs developed within Teaching for Understanding approach (Wiske 1998), a large variety of developmental education programs (Davydov 1996), and many others. When such programs are developed by the authors of approaches or people close to them, they tend to become the programs – the ones mostly known and quoted, for example, Feurstein's (1990) Instrumental Enrichment program, de Bono's (de Bono 1973–1975) CORT Lessons, Lipman's (1985) (Lipman et al. 1984) novels and accompanying manuals, etc. As a result, they may often be situated somewhere between programs and approaches, as more specific programs can be developed on their basis when adapting them to peculiarities of a particular situation.

Approaches

While most programs are primarily aimed at solving a local problem, approaches are developed to solve a much more global problem. Contribution to solving this problem is the reason for the development of the approach. An approach should also follow a certain theoretical framework(s). Due to various reasons, approaches can be developed with a different degree of precision – compare, for instance, a very elaborate description of Teaching for Understanding approach developed within the Project Zero and rather general and fragmented data on educational approach to teaching lateral thinking developed by Edward de Bono. An approach gives a possibility to develop various programs for teaching thinking. Lipman's Philosophy for Children, Elkonyn and Davydov's Developmental Education, and what is known as the Montessori Method are examples of approaches. It is necessary to mention that in time, some approaches develop to a degree when just a name remains and there already exist many, often quite different smaller approaches developed within the umbrella one. Critical thinking is the most well-known example.

Theoretical Frameworks

Theoretical framework is a theory, or a set of theories, which constitutes the basis of a given approach. This theory should not necessarily be a pedagogical theory – it can come from a different field of studies. Moreover, the theory should not be pedagogical in most cases, as the scope of problems it is supposed to solve should lie beyond the field of education. For instance, formal and informal logic are the underlying basis of critical thinking approaches to teaching thinking, while dialectical logic (Ilyenkov 1984) and a number of theories developed by Russian psychologists (Leontyev 1974; Vygotsky 1982) constitute the basis for developmental education approach. Note that the understanding of a framework proposed here places some widely quoted "theories" of thinking, Baron's (1987) theory of intelligence, or Sternberg's theory of rationality (Sternberg 1985) to the group of approaches.

Development of Inventive Thinking Skills in Approaches to Teaching Thinking

Inventive thinking skills are required to effectively solve nontypical (creative) problems in various domains avoiding a large number of trials and errors, where nontypical problem is the one for which no solution exists or is not known to the problem solver (Sokol et al. 2008). Thus, education for inventive thinking should aim at helping one acquire skills for coping with the new and the unknown. It is often assumed that this aim is catered for by widely spread thinking skills approaches such as critical thinking, Teaching for Understanding, Philosophy for Children, etc. As indicated in the next section, despite numerous useful features of the approaches, their main focus is different from what is required for the development of inventive thinking skills.

Critical Thinking

General Description

Critical thinking is an umbrella term for quite a few different approaches. The content of a critical thinking skills instruction is not so easy to identify as practically each more or less distinguished author has come with his/her list of critical thinking skills. Paul describes 35 dimensions of critical thought (Paul et al. 1990). Facione (1990: 13) proposes six groups of critical thinking skills: interpretation, analysis, evaluation, inference, explanation, self-regulation, and two groups of dispositions, approaches to life and living in general and approaches to specific issues, questions, or problems. Robert Ennis (2002) suggests three main dispositions: (1) Care that their beliefs be true and that their decisions be justified, that is, care to "get it right" to the extent possible; (2) care to present a position honestly and clearly, theirs as well as others'; and (3) care about the dignity and worth of every person (a correlative disposition) and 15 abilities.

Critical thinking approaches stand out from the rest of approaches due to the most developed assessment tradition. In addition to a number of various critical thinking tests developed largely in the United States, there is an A and AS Level Thinking Skills exam administered by the University of Cambridge International Examinations where critical thinking takes a major role. Yet the range of skills tested appears fairly limited and includes largely various aspects of mathematical problem solving.

Aims and Theoretical Basis

Aims of critical thinking–based courses can be formulated on the basis of definitions of critical thinking. Ennis (1997) defines critical thinking as "reasonable reflective thinking that is focused on deciding what to believe or do." Bailin (1998: 3) says that critical thinking should be conceptualized in terms of things necessary for making reasoned judgments. Paul (Scriven and Paul undated) says that "critical thinking is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action."

Ennis's definition leads to a very general aim that might sound as follows: educate a learner who is able to think reasonably and reflectively and as a result make decisions on what to believe or do. A part about reasonable thinking would probably be the aim if formulated by Bailin's followers while Paul's approach would be generally the same but giving a more explicit understanding of "reasonable and reflective."

Constructivism is the educational theory that lies at the basis of critical thinking. At the same time, it is necessary to note that due to a large number of various kinds of critical thinking currently taught around the world, the degree of constructivism in this or that approach may differ. Even working with materials that presuppose a constructivist approach, the teacher may often keep very close to the traditional teacher-centered model of teaching. This can often be seen in language classrooms when the teacher exemplifies a classical authoritative pedagogy using a "communicative" course book. Yet, if it is teaching for critical thinking rather than teaching critical thinking, it is a constructivism approach that is essential for successful learning.

Conclusions

Instruments of critical thinking work best when applied to dealing with today's knowledge. They can be extremely useful for analysis, evaluation, and interpretation of this knowledge, making inferences and explaining, but they have not been created for dealing with situations when no knowledge is available. Critical thinking is a tool for today and to a lesser degree a tool for tomorrow. Its focus is not so much on solving inventive problems (and thus developing inventive thinking) as finding a place in the ocean of solutions, as Ennis puts it, "deciding what to believe or do."

Teaching for Understanding

General Description

The authors of the approach distinguish between knowledge, skills, and understanding. Knowledge is seen as "information on tap." Skills are "routine performances on tap." "Understanding is the ability to think and act flexibly with what one knows' (Wiske 1998: 40) and is recognized through flexible performance criterion (Wiske 1998: 42). It is stressed that the performance view of understanding should not be seen as just attaining a representation, a matter of "getting it." "Developing understanding should be thought of as attaining a repertoire of complex performances. Attaining understanding is less like acquiring something and more like learning to act flexibly" (Wiske 1998: 52).

There are four guiding questions underlying Teaching for Understanding Framework (TfU):

- What topics are worth understanding?
- What about these topics needs to be understood?
- How can we foster understanding?
- How can we tell what students understand? (Wiske 1998: 61–62)

These four questions are the basis for four elements of the TfU: generative topics, understanding goals, performances of understanding, and ongoing assessment. The authors speak about four dimensions of the TfU: knowledge, methods, purposes, and forms. The authors also describe the features that characterize the master level of understanding (Wiske 1998: 199–200).

Although it is not explicitly stated, a list of dispositions proposed by Perkins et al. (1993: 7–8) can also be considered a part of TfU-based syllabus. It would mean that there are seven main dispositions that are aimed to be developed in the TfU classrooms: to be broad and adventurous toward sustained intellectual curiosity, to clarify and seek understanding, to be planful and strategic, to be intellectually careful, to seek and evaluate reasons, and to be metacognitive.

Aim and Theoretical Basis

The view that "what students learn needs to be internalized, able to be used in many different circumstances in and out of classrooms, serving as a base for ongoing and extended learning, always alive with possibilities" can be considered the aim of the TfU framework (Wiske 1998: 13).

As well as with most thinking approaches, the theoretical basis of the TfU framework is constructivism, or as Perkins puts it, a brand of constructivism that might be called performance constructivism because of its emphasis on building learners' repertoire of understanding performances more than on cultivating the construction of representations (Wiske 1998: 57). The difference, according to the authors, lies in what gets constructed: representations or performance capability. "Learning a topic with understanding is not so much constructing a representation to fit the topic as developing a flexible performance capability around the topic" (Wiske 1998: 55).

Conclusions

Generative topics that lie at the heart of the approach are based on today's understanding. Thus, they cannot be either new or unknown. The same holds true about methods and forms. TfU is grounded in what we see as good performance today rather than what will be a good performance tomorrow. It is useful for the development of various thinking skills; however, it is not designed for working with inventive thinking skills.

Philosophy for Children

General Description

Although Philosophy for Children is sometimes seen as a critical thinking approach, its author Mathew Lipman (2003) says that critical thinking is only a part of the program. According to Lipman, there are deficiencies of critical thinking programs that "doomed it from the start" (Lipman 2003: 5–6). Philosophy for Children is offered as an alternative educational approach to improvement of thinking in schools. Its curriculum "is composed of novels for the students and manuals for the teachers. The novels are age-differentiated, and they aim to stimulate in children patterns of questioning and discussion that are first modelled by the fictional characters in the novels and subsequently continued, by internalization and appropriation, by the live children in the classroom, as they talk about what they have learned" (Lipman 2003: 156). Children are learning to become the community of inquiry which is seen as the only fully appropriate pedagogy for improvement of thinking (Lipman 2003: 5). "The community of inquiry wants to build a system of thought" (Lipman 2003: 103). In Lipman's novels, fictional characters serve as role models to children. Children are expected to gradually internalize the behavior of the characters (Lipman 2003: 102) and then demonstrate a similar behavior in the classroom.

Aim and Theoretical Basis

Philosophy for Children is aimed to develop three dimensions of thinking: critical, creative, and caring which collectively produce multidimensional thinking (Lipman 2003: 197). The ultimate aim of the program is to provide education for "an inquiry-driven society" (Lipman 2003: 204). Thus, the aim of the program may be formulated as follows: educate a learner who is able and wishes to think in a multidimensional way and is a part of "an inquiry driven society."

It is not surprising that Philosophy for Children is also based on the constructivist tradition in education. At the same time, Lipman's constructivism is much closer to the Russian school of psychology and it shares many commonalities with such an approach as developing education (Davydov 1996) which is largely based on the Vygotskian Cultural-Historical theory (Vygotsky 1982). At the same time, it is necessary to note that a number of important differences exist between the two approaches, such as different conceptualization of thinking, various objects of study, models of educational process, etc. (see Margolis (1996) for more details).

Conclusions

Constructive (creative thinking) and value (caring thinking) dimensions are important in the context of the development of inventive thinking. At the same time, the focus in the program is more on "protective" tools rather than "constructing" tools, as critical component seems to prevail over the other two. This is also reflected in the role given to the formal logic in the process of development of thinking skills. For the development of inventive thinking, Philosophy for Children novels should contain characters that face and resolve nonstandard (creative) problems rather than deal with the typical ones.

Specific Approaches to the Development of Inventive Thinking

An effective approach for teaching thinking should be based on a sound theory. The drawback of most current approaches and programs lies in the absence of a theory for inventive thinking that would underlie them (Baron 1993: 191; McGuinness and Nisbet 1991: 176; Moseley et al. 2004: 24). At present, the only widely recognized theory dealing with the inventive thinking is the Theory of Inventive Problem Solving (TRIZ) (Altshuller 1979). A number of simplified versions of TRIZ (e.g., SIT, ASIT, USIT) and its modifications (e.g., OTSM-TRIZ, ATRIZ) also underlie approaches to the development of inventive thinking.

Problem-Centered Education

Problem-centered education (PCE) (Nesterenko and Belova 2010) comprises interdisciplinary tools that allow to structure and transform information with the aim of analyzing and solving problems in various fields. Its basis is the General Theory of Powerful Thinking based on the Theory of Inventive Problem Solving (OTSM-TRIZ) (Khomenko and Ashtiani 2007).

The system of PCE didactic tools includes a system of models and procedures for organization of inquiry-based research activity of students. The system of models includes information and contextual blocks. The former comprises three levels of models for different types of descriptions of objects studied: the empirical description for mastering ways of researching and describing objects via their features, the systemic description where objects are considered as systems with a specific function, and the problem description where both material and immaterial objects are considered through the demands set to them by people. The levels are organized in such a way that each consecutive level is based on the previous one. The latter block allows to consider objects in three different "worlds": the real world, the world of images, and the fantasy world.

The PCE didactic tools include training for introducing and acquisition of thinking models, tasks construction sets, and diagnostic materials. Models are interdisciplinary and are applicable across subjects. Models are the basis for the procedures that provide for the organization of the inquiry-based research activity of learners. Among others, the procedures include research based on the bank of objects aimed at finding patters and developing rules, research based on the system operator that helps learners pose questions and develop a systemic description of an object, problem solving procedures that contain contradictions of various levels of complexity, etc.

Thoughtivity for Kids

Khomenko and Sidorchuk coined the term "thoughtivity" for the approach for the development of inventive thinking of children starting from the age of 3 (Khomenko and Sidorchuk 2006). The approach is the result of almost 20 years of research and approbation in over 30 kindergartens. There are three underlying principles: nonlinearity of teaching and learning, the use of both hemispheres in the learning process, and the demonstration of the way of thinking by the adult. The principles are implemented through three technologies: the Analogous Solution Technology aimed at helping children acquire the skills for solving problems by analogy, the Contradiction Technology aimed at helping children see and formulate contradictions that underlie problems, and the Algorithm of Inventive Problem Solving (ARIZ) Technology aimed at helping children acquire a sequence of steps for dealing with inventive problems. All technologies are implemented with children through specifically designed tasks and games supported by very detailed teacher guides.

The Thinking Approach to Language Teaching and Learning

The thinking approach to language teaching and learning (TA) (Sokol 2008) is aimed at an integrated development of language and thinking skills of learners. Initially developed for teaching English, the TA is now used for many other languages: German, Russian, Latvian, Chinese, etc. OTSM-TRIZ is the underlying theory of the TA. Any TA course is an infusion thinking course as learners are developing inventive thinking skills while mastering their language skills. TA offers a modular structure that is based on the five technologies that underlie the approach:

- The Self-Study Technology aimed at educating the learner who wishes and is ready to take full responsibility for his/her learning and knows how to make learning a success
- The Creative Grammar Technology aimed at learning to see language as a system
- The Text Technology aimed at learning to see language as a means used for solving problems
- The Yes-No Technology aimed learning to see how various problem-solving models work in a system
- The Research Technology aimed at providing learning with the possibility for transfer of knowledge and skills (Sokol et al. 2008)

The TA technologies offer systems of tasks to learners. Learners' work on tasks is organized through three steps: challenging their current knowledge and getting them to build algorithms for dealing with a task and organizing their reflection. These are referred to as the thinking task framework. The work through the framework allows to expand the TA to other disciplines as reflected in latest projects developed by the proponents (see www.ta-teachers.eu).

Some Other Important Concepts

Thinking Curriculum/Meta-curriculum

The thinking curriculum is often seen as a meta-curriculum that constitutes the foundation for various subject curricula. It offers learners most general skills and models that can be later employed for acquisition of specific disciplines. Thus, the thinking curriculum becomes the driving force for the integration of different subjects.

Importance of (Inventive) Thinking Dispositions

Although the word skills is widely used for teaching thinking approaches, most researchers agree that skills alone are not enough for any practical learning outcome. It is essential that learners also develop dispositions to support the skills. In the context of inventive thinking, it means that one is not only able to cope with nontypical (creative) problems but is disposed to do it. When inventive thinking dispositions are developed, one deliberately searches for the unknown and tries to reveal the contradictions underlying each problematic situation. The dispositional aspect is very important for any initiative aimed at the development of inventive thinking skills.

Infusion Versus Stand-Alone Courses

Thinking skills instruction can be brought to learners either as a stand-alone or as an infusion course. The former option is still used a lot in many approaches; however, researchers tend to agree (Perkins 2002; Swartz and Parks 1994) that the latter option is more effective. In addition to the actual thinking skills instruction, an infusion approach establishes a connection with a discipline, thus allowing for an integration of a thinking skills instruction in the subject matter. It should be noted, however, that infusion courses place significantly higher requirements on teachers and, therefore, are more difficult to administer.

Open-Ended Issues

Materials/Books for Teaching (Inventive) Thinking

Most educational contexts presuppose the existence of textbooks for any subject offered to learners. Apparently, this makes the administration of courses easier for both learners and teachers. However, from the learning point of view, an availability of a textbook is not necessarily an advantage. This is especially so in the case of teaching inventive thinking, where the focus should always be on nontypical issues, while a textbook by definition presents a collection of typical solutions to well-known problems.

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Teacher Education for Teaching (Inventive) Thinking

Traditionally, teacher training provides teachers with effective ways of conceptualizing the subject matter and mechanisms of successfully bringing it to students. No matter how modern the approach to either of this could be, from the point of view of inventive thinking, it is still dealing with a typical solution rather than facing the unknown. It is arguable whether the teacher who avoids facing the uncertainty can help learners develop the kind of thinking required for coping with ambiguity. It means that teachers themselves need to have developed dispositions for inventive thinking in order to be able to help their learners in the process. This puts serious implications for the process of teacher education.

Assessment in Teaching (Inventive) Thinking

Assessment is an essential component of any learning. Teaching for inventive thinking is no exception, and any approach to developing it should offer specific criteria on the difference between powerful and poor thinking when dealing with the unknown. However, this very same issue brings to a trap: if learners are aware of what exactly they are expected to do, it has become a typical problem that does not require any inventive thinking approach. This means, in turn, that assessment has stopped being assessment for learning.

Conclusions and Future Directions

It is widely accepted that inventive thinking skills can and should be improved. It is done best through integrating a thinking skills instruction into various disciplines. For achieving better results, the process should start as early as possible. Although programs may seem easier to adopt, one needs to start from the theory and approaches if aiming at a long-term innovation. TRIZ and its further developments appear the most effective theories for educational approaches, dealing with the development of inventive thinking. All materials for teaching thinking should be dynamic and “finalized” by teachers and learners involved in the actual learning process. Assessment for thinking should be developed and integrated in the normative education documents. Systemic approach to teacher education is essential: teachers who teach for thinking should be required to think.

Cross-References

▶ Creative Thinking Training
▶ Divergent Thinking
▶ Entrepreneurship Education
▶ Invention and Innovation as Creative Problem-Solving Activities
▶ Inventive Problem Solving (TRIZ), Theory
▶ Preparing Students for Learning Through Invention Activities
▶ Scientific Inventive Thinking Skills in Children
▶ Teaching as Invention

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Inventiveness

▶ Creativity: Cultural Capital in Mathematics
▶ Nature of Creativity

Inventor

▶ Innovator

Inventory on Creativity

▶ Measurement of Creativity

IP System

▶ Patent System

Irrational Versus Rational Thinking

▶ Divergent Versus Convergent Thinking