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Systems Thinking and Adult Cognitive Development

Introduction

In today's increasingly complex world, there is an imperative to work constantly to develop one's skills, self-understanding and other personal resources. This requires human capital – knowledge, creativity, innovativeness and an ability to solve ill-defined, complex problems – as well as communication skills and a rich social network. All individuals function as part of larger systems, and what they can achieve is largely determined by the opportunities and constraints presented by those systems. The ability to take appropriate action, the ability to solve problems and cognitive development as a whole is dependent on the systems of which we are part. This chapter discusses scientific systems approaches and their links to research on adult thinking. Our aim is to work towards a deeper understanding of the development of adult thinking.

Systems Thinking

The purpose of systems sciences is to model and understand different types of systems and the dynamics of the changes, feedback loops and interactions happening within these systems. Kauffman (1995, p. 24) points out that life is not to be located in its parts, but in the collective emergent properties of the whole they create, that is, the whole is more than the sum of its parts. The concept of system thus refers to a holistic entity composed of and dependent on a series of interconnected and interacting parts. Systems may be physical, biological, abstract, social or human. Systems thinking is not a uniform, fully integrated field of study, but rather a conceptual frame of reference. Its foundations lie in different systems theories that take a comprehensive and multidisciplinary view on exploring phenomena.

Systems thinking research is basically aimed at understanding phenomena in the systemic context and at applying that understanding to problem solving and learning, but it is more than that. Systems thinking has been described as a framework (Buckle Henning & Chen, 2012), a range of techniques or methods (Checkland, 1999; Checkland & Poulter, 2006; Ackoff, Addison, & Carey, 2010; Jackson, 2003; Stowell & Welch, 2012), and as a way of developing cognitive skills and abilities (Mella, 2012; Senge, 2006, p. 10). Furthermore, systemic understanding may be described in terms of systems intelligence (Hämäläinen, Jones, & Saarinen, 2014). In its broadest sense, systems thinking is seen as a philosophy or worldview (Capra, 2005; Capra & Luisi, 2014), or as an ethical code, identity and a collective membership of a wider school of thought (Buckle Henning, Wilmshurst, & Yearworth, 2012).

In the systems framework the development of thinking has been described as a double loop learning process in which a narrow, short-sighted and firmly established worldview evolves into a forward-looking, flexible and dynamic view that recognises and acknowledges the bigger picture (Sterman, 2000, pp. 3–40). While learning that does not change mental models is described as single loop learning, the deeper process of double loop learning has the potential to change the individual's or the community's thought models or actions (Argyris, 1977; Sterman, 2000, pp. 3–40)[1]. This kind of learning that changes mental models is often called conceptual change (Limón & Mason, 2002; see also Chapter 8). In studies of adult learning, these processes have been described by the concept of transformative learning (Mezirow, 1991). Critical reflection and the transformation of thought models are embraced by all major modern theories of learning, which in this sense come quite close to the latest modes of systems theories. Systems thinking is rarely adopted as an explicit starting point in learning research, but learning research shares many basic premises in common with systems thinking. For instance:

– Learning is approached not only as an individual cognitive process, but as a process happening in the complex interaction between individual and environment.
– Learning is seen as an all-embracing phenomenon composed of several systems with interconnected elements.

– Learning is not aimed at reproducing earlier, existing knowledge, but rather at effecting change in thinking or action, at creating or innovating new knowledge.

Systems thinking has addressed learning mainly through its focus on management and organisation research. Senge, known for his concept of the learning organisation, says that the development of systems thinking starts from changing mental models and worldviews by means of awareness and questioning (Senge, 1990, 2006; Goleman & Senge, 2014).

Towards Systems Theories

The roots of systems thinking lie in physics and the natural sciences. Ludvig von Bertalanffy, commonly acknowledged as the founder of the systems movement, was the first scholar to develop the concept outside the discipline of physics. Talcott Parsons, then, introduced systems thinking into sociology (e.g., Parsons, 1951), using system as an analytical tool for understanding social structures and the way they work. By the end of the 1950s, systemic thought had spread to almost all scientific disciplines. To coordinate the extremely heterogeneous field, the Society for General Systems Research was established in 1954 (von Bertalanffy, 1972, p. 28; Boulding, 1988, p. 33).

Von Bertalanffy (e.g., 1950, 1968) advanced the concept of open system as a counterpart to the closed systems models that had been developed in the field of physics. Open systems are adaptive to their environment through feedback loops and strive to maintain a steady state. Von Bertalanffy was followed by several other scholars who rejected the former mechanistic view in favour of the organic nature of systems. One of the main trends in the American branch of systems thinking was system dynamics. This concept was developed by Forrester (e.g., 1968), who began to apply the insights of electrical engineering to analysing the behaviour of human and other systems. System dynamics thinking has it that people live in a network of feedback structures (economic, political and ecological) whose properties are seen as the determinants of most problems (Bloomfield, 1986, p. viii). Direct or indirect applications of open systems thinking have produced many variations in the field (Ståhle, 1998, pp. 29–54).

In the 1960s a new systems thinking trend began to evolve that was not grounded in the open systems perspective, but which turned the focus to the unpredictable and chaotic behaviour of systems (instead of the steady state) and towards the unpredictable dynamics of systems (instead of feedback processes). This new viewpoint, which later became known as the 'science of chaos' and/or 'complexity research', evolved from the work of numerous scholars in different fields (Ståhle, 2008).

These trends led to a new research approach known as complexity theory (CT) or complex adaptive systems (CAS) theory (Holland, 1995; Kauffman, 1993; Mitchell, 2009; Poutanen & Ståhle, 2014). Although the two terms have been used interchangeably, CAS is possibly a more coherent strand of study, whereas 'complexity theory' refers in general sense to the use of approaches and concepts derived from the study of complex systems. Complexity refers to phenomena like non-linear relationships, systemic interaction, boundary problems, emergence and adaptation (Cilliers, 2011; Poutanen & Ståhle, 2014). The CT and CAS perspectives have been applied in many studies from organisational and management studies to public policy, health, communication, and engineering research (ibid.). CT originates in the natural sciences, but there is now a growing trend to study social organisations as CAS. Complex systems, such as the human brain, organisations or markets, are capable of adapting and responding to environmental changes and exhibiting self-organising, emergent patterns of behaviour (Ståhle & Åberg, 2015; Poutanen, Soliman, & Ståhle, 2016; Poutanen & Ståhle, 2014). Along with CT research, there has also been growing interest in *innovation ecosystems*, which refer to complexity and to the multifaceted co-creation of innovations and the role of virtual innovation platforms (Karakas, 2009).

Three Systems Paradigms

Systems have been studied from a variety of different perspectives. Over time the types of systems in focus have also varied, which has led to many different systems theories. Three paradigms can be identified in this development of systems research, as outlined below (for a full elaboration of the paradigms, see Ståhle, 1998, pp. 13–98).

The first presentation of a concrete system with scientifically verified laws was Isaac Newton's model of the solar system as put forward in his Principia (1687/1972), which created the foundation for the first systems paradigm. Since then, the Newtonian model has been applied to almost all scientific research. The Newtonian perspective to studying systems is characterised by linear thinking, cause-and-effect thinking, determinism, predictability, universal laws, principles and regularities, as well as preservation and quantification. The research conducted under this paradigm aims to explain and define natural laws and principles and to predict events conforming to the formulated theories. Ultimately, this perspective resulted in a theory that considered systems as machine-like entities following predetermined laws.

The second paradigm started from von Bertalanffy and his understanding of open systems. Systems were now no longer seen as machines but living organisms, and the perspective shifted from closeness to openness. While a closed, mechanistic system had just one optimal way of achieving its goal, an open system has access to multiple avenues. Open systems are flexible, self-regulating and depend on their environment for survival. They are constantly striving towards equilibrium, as instability is hazardous to the system. Feedback is crucial: the system needs input, throughput and output in order to maintain its stability (von Bertalanffy, 1950). This research tradition has gained substantial ground since the 1950s and is still very popular today. Although the open systems view originates in biology, this hypothesis is theoretically grounded in physics: all open systems thinking stems from the second law of thermodynamics, which says that all systems, when left to themselves, are destined for disorder and disintegration. Since the system's survival is thought to require this steady state, maintaining stability is the primary focus of open systems thinking.

The third paradigm concentrates on dynamic, chaotic systems that are capable of self-organisation. While the focus was earlier on systemic order, the research emphasis has now shifted to disorder and to the relationship between chaos and the emergence of order. The starting point for the new emerging paradigm was Edward Lorenz's chaos research and the famous 'butterfly effect' (Lorenz, 1963), but the broadest theoretical contributions have come

from two sources. First, Belgian physical chemist Ilya Prigogine published his studies on non-equilibrium statistical mechanics in 1962 and on dissipative systems in 1967. His studies provided systems research with a completely new perspective on how systems reorganise unpredictably and without external control. Prigogine does not contradict the second law of thermodynamics, but instead shows its limitations and argues that most systems are capable of self-organisation (see e.g., Prigogine, 1980). The other revolutionary approach was the autopoiesis theory put forward by Chilean biologists Humberto Maturana and Francisco Varela in the early 1970s. They introduced the term autopoiesis to describe how each living system reproduces its nucleus and struggles for self-renewal (see e.g., Maturana & Varela, 1980, 1992).

The third systems paradigm marked a fundamental break in the understanding of systems. The relationship of individual and system (every individual is always part of a system) and the internal dynamics of systems (self-organisation requires a chaotic state) were now seen in a new way. Theoretically, all these changes profoundly altered the starting point for systems sciences. This radical paradigm shift in the 1970s brought to light the extreme complexity of systems and the significance of chaos for the self-renewal and transformation of systems. This evolution towards quantum physics opened up a broader theoretical perspective with its emphasis on discontinuity, non-determinism and non-locality.

These three systems paradigms highlight diverse characteristics and dimensions of systems. Although they date back to different eras, all three continue to have relevance today. Nonetheless they do differ in terms of their explanatory power. The third systems paradigm has particular explanatory power in today's volatile world where ecosystems and connectivity are created by the internet and virtual platforms. This does not mean to say it has universal applicability, however. We still have problems that can be well-defined and systems that are controllable and relatively stable. Furthermore, most real-life systems consist of various subsystems that can be closed, open or dynamic. For instance, business organisations usually are system holograms, that is, simultaneously comprise mechanistic, organic and dynamic subsystems (Ståhle & Grönroos, 2000; Ståhle, Ståhle, & Pöyhönen, 2003). Recently, however, the dynamic systems paradigm has gained increasing prominence because of its

substantial explanatory power, which at once has demonstrated the limitations of the other system paradigms (see Table 12.1).

Paradigm	Originator	Type of system	Research interest	Operative interest
I Closed systems	NEWTON	Static Deterministic Mechanistic	PRINCIPLES, LAWS	Predicting Controlling
II Open systems	von BERT-ALANFFY	Near Equilibrium Equifinal Living	FEEDBACK PROCESSES	Steering Sustaining
III Dynamic systems	LORENZ PRIGOGINE MATURANA VARELA	Far-from-equilibrium Uncontrollable Emerging	SPONTANEOUS ORGANIZATION	Understanding and cooperating with natural evolvement

Table 12.1

Systems Theory Paradigms With Originators and Some Key Dimensions (Ståhle, 1998, p. 63). Printed with permission. Copyright by Faculty of Educational Sciences, University of Helsinki, Finland

Systems Paradigms and Adult Thinking Research

Systems paradigms have their roots in the natural sciences, and thus reflect the changes occurring in the academic realm as a whole, including theories of adult thinking. The dominating worldview and connected paradigms can be seen in different sciences, say in psychology and physics, despite the fact that they have no direct interdependence. Scientific advances take place in a different historical period and are influenced by the overall tone and intellectual patterns of that period.

In the field of adult thinking research, Kallio (2015) says that almost all psychological theorisation can be traced to two theorists, Piaget and Perry. The first waves of model creation were based on Piaget's theory of formal thinking, while Perry's model of cognitive development paved the way to various new post-Piagetian models (in this book e.g., Chapters by 2, 3, 4, 11, and for the impact on moral reasoning theorisation, see Chapters 5, 6). For Piaget, formal operations represent the highest level of thinking that cannot be extended, while Perry and other neo-Piagetian scholars claimed that adult development is more complex phenomenon than assumed.

According to Kallio (2015), Perry redefined the study of adult cognition. The new line of research inquiry was first and foremost concerned with conceptual change (changing understandings of concepts and their meaning) as opposed to the Piagetian focus on operational-logical cognition. Perry was concerned with the development of epistemological assumptions in young adulthood, identity formation and moral development. Neo-Piagetian research called into question the basic assumption of linearity and the endpoint of development, and prioritised logical thinking as the highest level of intellectual operations. This led to the introduction of a new, *postformal stage of thought*[2]: a type of complex logical thinking that develops in adulthood through interaction and co-creation with other people who have contradicting ideas. Other features of postformal thinking include contextualism, value relativism, recognition and management of uncertainty, complex problem solving, tolerance of ambiguity, and dialectics. Several new models of the development of adult thinking emerged, most notably by Mascolo and Fischer (2015), Commons, Gane-McCalla, Barker and Li (2014), Basseches (1984), Labouvie-Vief (2015), Kegan (1982, 1994), Sinnott (2011, 2013) and Kallio (2015).

Kallio (2015) offers some interesting reflections on Piaget's paradigmatic choices. First, she points out that the theory of developmental stages specifically concerns cause-and-effect reasoning regarding physical reality, and thus cannot be a universal theory of all cognitive development. In devising a theory of development for causal thinking, Piaget has used methodology applicable to the natural sciences, which indicates the points of departure of his studies and therefore also has implications for the results. Second, Piaget only uses so-called

well-defined problems in his research settings, with no intermediate social or human variables in the testing situation that could enhance confusion in the reasoning process. Third, Piaget has a teleological assumption that the development of causal thinking has a final endpoint, and that this line of development does not allow any exceptions, different developmental routes, or other than deterministic changes. One premise of Piaget's theory is that there is a *telos* towards which causal thinking inevitably proceeds. Fourth, Kallio points out that Piaget fails to address many crucial dimensions of adult thinking; for instance, he excludes from consideration problems with foggy premises or complex interdependencies that do not get solved by means of logical reasoning.

Kallio's critique against Piaget's theory clearly rises from the context of the dynamic systems paradigm. Despite the complexity of the phenomena he addressed, Piaget's choices are grounded in the closed mechanistic view of the first systems paradigm, such as the assumption that the development of causal thinking has a final endpoint. Perry's approach, then, incorporates dimensions from both the second systems paradigm with its more self-regulatory and open-ended emphases, and the third paradigm with its focus on complexity, self-transformability, contradictions, meanings, multifaceted reality, and interaction between people. Perry's work represents a clear paradigm shift from Piaget.

The third systems paradigm warrants closer scrutiny here, not only because it can help us understand the functional dynamics of the current world, but also because it is the most complex and chronologically the latest and therefore less well known. Furthermore, this is the most interesting paradigm from the point of view of adult thinking, since the theory of postformal thought, especially as presented by Sinnott (1998), is explicitly grounded in the dynamic systems paradigm. The next section describes the key theories behind the third systems paradigm and then looks at how the paradigm ties in with Sinnott's theory of postformal thought.

Dynamic Systems Paradigm: Self-Organising and Self-Referential Systems

The Belgian Nobel laureate Prigogine (1917–2003) is possibly the single most important contributor to the dynamic systems paradigm. Prigogine was awarded the Nobel Prize in 1977 for his theory of dissipative structures. These are physical or chemical systems that appear to develop *order out of chaos*. Prigogine discovered new laws of nature that could connect the natural sciences to the human sciences, and he maintained that these laws were valid and applicable to social systems as well (Prigogine, 1976, pp. 120–126).

Another perspective on systems self-renewal was opened by Chilean biology professors Humberto Maturana (1928–) and Francisco Varela (1946–2001), who introduced the concept of autopoiesis to describe the self-generating, self-maintaining structure of living systems. As early as the 1980s, autopoiesis was recognised as part of the new emerging paradigm that addressed issues of self-organisation and spontaneous phenomena in physical, biological and social systems (Zeleny, 1980). The main contribution of Maturana's and Varela's research lies in their addressing the question of cognition and knowledge at cell level: they were not just biologists, but also cognition scientists. The most relevant theoretical expansion of autopoiesis in the field of sociology is attributable to Niklas Luhmann (1927–1998) and his theory of self-referential systems. Luhmann is recognised as one of the most important social theorists of the 20th century (Bechmann & Stehr, 2002).

Self-Organising Systems

Prigogine (1993) maintains that most systems in the world are liable to proceed to the state of far-from-equilibrium, and therefore are inherently capable of re-organising and transforming themselves. These self-organising systems share some features in common with open systems, including feedback loops and dependence on the environment, but they nonetheless function in a radically different way. Open systems are characterised as self-regulating and as having the ability to maintain stability via continuous feedback processes. Chaos is seen as an end and dispersion. In contrast to this view, Prigogine pointed out that rather than an end, chaos marks a new beginning. Indeed, new structures are created out of chaos. Even though this is by no means rare and most systems are self-organising, there are certain preconditions that must be met. Based on Prigogine's publications, Ståhle (1998) lists the following requirements for self-organising systems:

- *State of far from equilibrium:* Unstable, chaotic state of a system. In social systems this means tolerance to confusion, discrepancies and disharmony.

- *Production of entropy:* Information that cannot be used by the system. High entropy means greater disorder, wasted resources, lost information and uncertainty in the system. For a social system this means abundant communication and production of ideas, different angles of information without any certainty as to whether they will prove useful.

- *Iteration:* Frequent and sensitive feedback that provides the system with ultimate receptivity. In a social system this means active response to each other's ideas, opinions and reactions.

- *Momentums of bifurcation:* There are certain momentums in the system's life when genuine choices can be made. These choices are irreversible and cannot be predicted in advance. 'Bifurcation is a source of innovation and diversification, since it endows a system with a new solution' (Nicolis & Prigogine, 1989, p. 74).

Autopoiesis and Self-referential Systems

Maturana and Varela take a very different perspective from Prigogine. While Prigogine emphasises the creation of order out of chaos, the dramatic emergence of a new structure, Maturana and Varela highlight the role of continuity, maintenance and self-reference in the system's renewal.

Autopoiesis is based on the idea of self-reference, which means that 'what we see is always a reflection of what we are'. In the social realm, this means that whoever prescribes the borders or nature of a system must necessarily be part of the system. Information about a system can only be achieved from within: to understand the system we must be part of it, and being part of the system occurs via interaction and communication. Interaction, in turn, is not possible without self-reference: for instance, a person (or a group, organisation, etc.) who has no reference to it/herself/himself cannot be in authentic interaction with others. Thus the dynamics of an autopoietic system is described by the system's boundaries (i.e., to become aware of the system), self-reference (becoming aware of oneself), and interaction (restructuring and strengthening both of the previous) (Varela & Johnson, 1976, p. 31).

The autopoietic system has a special relationship with its environment (see Figure 12.1). On the one hand, it needs the environment to keep up its life, but on the other hand, in an operative sense, the system is autonomic. The environment is a *point of reference* for an autopoietic system, a kind of a mirror (Maturana & Varela, 1988, p. 75). It might even be described as a negative mirror, telling the system what it is *not*. The creation of a core identity is the main principle and ultimate goal of the system, be it an individual, group or organisation. All social systems are self-referential, because the system must always define itself in order to be able to exist (Varela & Johnson, 1976, pp. 26–31).
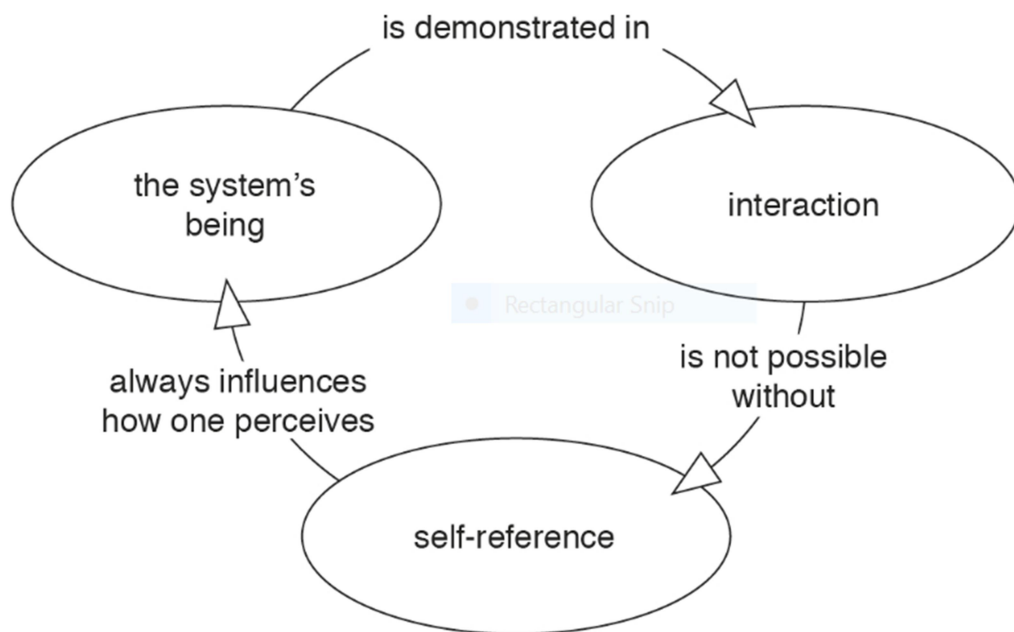

Figure 12.1. A system's autopoietic nature (Ståhle, 1998, p. 102). Printed with permission. Copyright by Faculty of Educational Sciences, University of Helsinki, Finland.

The work of Luhmann represents the most significant application of autopoiesis to a social context. Sociologist Knodt observes that Luhmann's 'Social Systems accomplishes in the social realm what Maturana and Varela have done for cognitive biology and Prigogine's work on non-equilibrium thermodynamics for physics' (Luhmann, 1995, p. xxii). Luhmann argues that the theory of autopoietic social systems requires a conceptual revolution within sociology, and also contains an understanding of communication as a particular mode of

autopoietic reproduction (Luhmann, 1989, pp. 174, 177–178). Luhmann stresses the immutable identity of the system, that is, the system's capacity to continuously renew its identifiable self, as well as the continuity or the process-like development of a system. Based on Luhmann's work it is possible to identify the following four vital antecedents for a system's self-renewal (Ståhle, 1998, p. 111):

–   *Self-reference* means that a system must be in connection with other systems and use them as a point of reference for itself. This is not a process of adaptation, but rather the use of another system as a mirror in order to create self-awareness and strengthen identity: to recognise similarities and differences between others and self, i.e., what it is and what it is not.

–   *Double contingency* means positive, mutual interdependence, balance of power and trust within the system. The people who make up the system are *of equal value* (however, there is no imperative to *have similar values*).

–   *Experiential quality of information.* The system's power of renewal lies in the exchange of information. However, it is important to make a distinction between data and information. The latter is closely linked with experience: the information exchanged *influences* the people who make up the system and always changes the state of the system, in one way or another. Luhmann describes information as an event more than a fact.

–   *Processing meanings.* Luhmann says that meanings are created collectively within the system through mutually created events. Meanings are the basic structural elements of a self-referential system and guide its functioning.

Next we proceed to reflect on how all this ties in with the development of adult thinking by exploring Sinnott's theory of postformal thought.

Theory of Postformal Thought

Sinnott sees the development of thinking as part of the holistic and complex process of human development. It is reflected in wisdom, interpersonal skills, concern for others, spirituality and an ability to deal with paradoxes. She describes how adult individuals construct their own identities and realities and how this has an impact on their cognitive

functions. Meaning and intention form a prominent part of adult life. However, Sinnott points out that we lack studies of higher-level intellectual operations that are required when adults make sense of life and process its meaning. For the holistic challenges of adult life, abstract, formal logics do not work without linkage with emotional, interpersonal and spiritual aspects. Problems in adult life are most often obscure, and problem-solving is therefore a multidimensional process involving a close interplay of cognitive, emotional and social processes. Our impact on the evolving systems in which we are involved is permanently transformative for ourselves and other systems. We are neither victims nor outsiders, but instead team members helping design it all. Thus, she says, there is a need not only for new paths of research, but also *for new theoretical paradigms*. She suggests the new physics theory, systems theories, complexity theory and self-regulating systems theories as prominent frameworks for research into modern adult thinking (Sinnott, 1998, pp. 14–33; 1981, p. 110).

Sinnott says that rather than just the individual's development and connection with the physical world, our research should be concerned with an individual's *interaction* with other developing individuals. This view of social interaction is far more complex than the framework applied in earlier behavioural sciences, she adds, and has implications for understanding social development, emotional growth and group dynamics, for instance (Sinnott, 1981, p. 301).

Sinnott elaborates the theoretical background of her thinking in great depth, and lays bare the false assumptions of current research. She describes with clarity and precision her new proposed path and argues that the development of adult thinking must be anchored to the elements that guide adult life, that is, meaning, identity and intention. These can be seen as the determinants of adult development to which cognitive operations are subordinate, and therefore adult thinking *must be studied in this context* rather than seeking to solve predefined problems. Her theorising is surprisingly identical with the three systems paradigms described earlier, and in contrast to most other behavioural scientists she explicitly states her theoretical grounds and anchors her theory to the third systems paradigm.

Sinnott (1998, pp. 23–52) summarises her view on the development of adult thinking and argues that postformal thinking

– is unique to major adult thought and thus exceeds Piaget's theory;

– includes various truth systems, multiple conflicting ideas and uncertainty as a driver;

– is higher-level thinking, although all other levels are also purposefully in use;

– is developed through interaction with other knowers, through social interactions, and co-created by people in those interactions;

– has an impact on one's view of self, the world, other persons, change over time, and our connections with one another over time;

– is complex cognition, a bridge between affect and cognition, between one person and other persons, and a way to make the demands and practical concerns of adult life meaningful;

– refers to knowledge as a subjective component being necessarily incomplete, because any logic we use is self-referential logic (the higher-level postformal system of self-referential truth decisions gives order to lower-level formal truth and logic systems).

The theory of postformal thought has been developed both on the basis of the general systems theory and the theories under the third paradigm, especially chaos and complexity theories and the theory of self-organising systems, and the views on self-renewing systems and postformal thought overlap in significant respects (Table 12.2).

Key characteristics of self-organizing and self-referential systems	Requirements of self-renewal of social systems	Assumptions of the theory of postformal thought (Sinnott 1998)
State of far from equilibrium	Tolerance to confusion, discrepancies and disharmony.	Uncertainty is a driver developed through interaction with other knowers. Disorder, potential, unstructuredness are necessary requirements (204).
Production of entropy	Abundant communication and production of ideas, different angles of information without any certainty as to whether they will prove to be useful.	Postformal thinking needs awareness that there are various truth systems, and that contradiction, subjectivity, and choice are inherent in all objective observations and solutions

(24).

Iteration	Active and frequent response to each other's ideas, opinions and reactions.	
Momentums of bifurcation	Momentums in the system's life when genuine choices can be made. Bifurcation is a source of innovation and diversification, since it endows a system with a new solution.	Chaos theory explains why development of thinking is not linear but often happens by leaps (108).
Self-reference	System must interact with other systems and use them as a point of reference for itself: reflection of existence, identity and boundaries.	The essential notion of self-reference is that we can never be completely free of the built-in limits of our system of knowing (32). Systems construct their own realities, and for this they need to interact with other systems (204).
Double contingency	Mutual interdependence, power balance, and trust within the system. Everyone is of equal value and positively dependent on each other.	
Experiential information	Exchange of information is the system's renewing power. Information must have influence on others and thus it always changes the state of the system.	Complex cognition is a bridge between affect and cognition, and between one person and other persons (52). Cognitive development is dependent on social-cognitive experience; the ideas of others challenge the reality of the knower (27, 28).
Processing meanings	Meanings are created collectively within the system through jointly created events.	Postformal thinking is about making sense of life (26). Making demands and practical concerns of adult life meaningful occurs by co-creation by people in

interactions (27).

Table 12.2

Comparison of the Characteristics of Self-renewing Systems and Postformal Thought (Page References to Sinnott (1998) in Parentheses)

Conclusions

In this chapter we have briefly discussed some dimensions of systems thinking and the development of systems theories. In addition, we have reflected on the links between systems theories and modern research into adult thinking. As we have seen, both organisational-level research and models of the learning organisation have widely adopted the premises of the open systems paradigm and modified their concept apparatuses for learning. By contrast, it seems that systems theories rarely serve as a generic starting point for learning research, although there are some individual studies that are clearly grounded in systems thinking. However, we have also shown that some models describing adult thinking have a clearly articulated link with systems theories. In particular, Sinnott's theory of postformal thought explicitly leans on the third systems paradigm.

Several interesting research questions that would shed light on the interconnections between thinking and learning still remain unanswered, including whether learning about systems sciences and systems theories can help develop our thinking. Sinnott presents a number of examples and case studies of the development of adult thinking as an empirical basis for her theory. However, the unit of analysis in these studies is always the *individual thinking process*, while the basic unit of analysis in systems research (Luhmann, 1995, p. 123; Ståhle, 1998) is *communication between individuals*. Even though Sinnott's premises and paradigm are clearly systemic, her empirical research still focuses on individuals.

In order to create cross-fertilisation between research on adult thinking and systems science, the next step would be to explore the individual thinking process in conjunction with the collective knowledge creation process. Systems theories would thus not just provide a

background for understanding the nature of adult thinking, but thinking could also be studied in the actual social (complex) context, within a system. On the other hand, the individual thinking perspective is completely absent in studies on the self-renewal of systems. A genuine merger of research perspectives might lead to the discovery that systems thinking can only be learned within the system, and not as an isolated piece of knowledge picked up from a textbook or teacher; and furthermore, that self-renewal might not take place in groups that do not have the capacity for formal or postformal thinking. This could surely add to our insight about the required pedagogical methods and collective learning processes or know-how of coping in innovation ecosystems. It seems that postformal or complex adult thought has opened up new understandings, but it still remains for future research to implement them in research settings and methodologies. We hope that this article provides inspiration for such efforts.

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[1] Expressed in terms of cognitive development psychology (Piaget, 1950/2002), single loop learning is about assimilation, a process in which new knowledge is added to existing knowledge, whereas double loop learning refers to accommodation, a process in which earlier knowledge structures are adjusted according to new experiences and new knowledge (cf. Chapters 2, 3).

[2] Researchers don't agree about the usage of the concept (see e.g., Kallio, 2011).