Physics International

Original Research Paper

The Rise of the Physical Sciences in "Stricto Sensu" The Developmental Approach and the History of Sciences

Georg W. Oesterdiekhoff

Department of Sociology, Institute for Technology, 76128 Karlsruhe, Germany

Email: Oesterdiekhoff@t-online.de

Abstract: J. Piaget dedicated several books and articles on the psychogenetic reconstruction of the history of sciences. A couple of disciples followed Piaget´s ideas and reconstructed the history of single disciplines or of some scientific developments in terms of developmental psychology. They found a striking similarity between childish psychological stages and the sciences in their premodern period. Correspondingly, they also found similarities between adolescent psychological stages and early modern sciences. Many data hint at the fact that psychological stage advancements respectively the emergence of the adolescent stage of formal operations during the 17th century was the cause to the rise of the physical sciences in stricto sensu. The research of Piaget and his followers, however, was not deep enough insofar as they were insecure whether the correspondencies related may concern the theories only or also the minds of the theoreticians (the scientists) themselves. Therefore, the main goal of this article is to demonstrate that the emergence of the formal operational stage took place in the minds of the scientists themselves. It is argued that the cognitive transformations within the minds of the scientists themselves were the origin of the scientific breakthroughs and the emergence of the new disciplines. The article presents the data according to them premodern peoples stood on pre- and concrete operational stages, as the ancient scientists did, too. Then it shows that premodern sciences substantially likewise root in these lower stages, as their adherence to magic and animism already evidence. Consequently, it is argued that the transformation from magical-animistic theories to the sciences in stricto sensu during the 17th century originates in the rise of the formal operations. The next step is to show how the formation of the disciplines such as physics, astronomy, chemistry and medicine and the accumulation of scientific knowledge already in the first generation directly followed the fresh establishment of the formal operational stage. The conclusion is that the relationship between psychological stage development and the history of sciences is closer and more direct than Piaget and his followers ever described.

Keywords: Psychological Stage Development, Scientific Revolution, Physics, Astronomy, Chemistry

Introduction

The first rise of the physical sciences in world history happened during the Hellenistic period especially between 300 and 50 B. C., being interrupted and mainly finished by the Roman conquest of the Eastern Mediterranean. It was not possible to maintain the scientific level, once reached by the great Greeks with their main protagonist Archimedes, during the succeeding time of the Roman Empire, for whichever reasons (Russo, 2005; Dijksterhuis, 1952; Pichot, 1995). The rebirth of the physical sciences with their early main representative Galileo Galilei after 1590 largely resorted to ancient achievements, as the scholars studied the ancient literature preserved in libraries over the millennia. A lot of knowledge gained and experiments conducted during the early modern period based on ancient predecessors, thus being not truly original

discoveries (Russo, 2005; Dijksterhuis, 1952). Especially during the 18th century, however, the European breakthroughs overhauled the Hellenistic achievements by far. Therefore, it is legitimate to judge that the physical sciences originated during the 17th and 18th centuries in Europe, leading to an explosion of knowledge never seen before in world history. Whatever ancient sciences in Europe or Asia may have contributed, the physical sciences born or reborn in Europe from 1590 onwards dwarfed the ancient predecessors (Galilei started the phase of conducting controlled experiments during the 1590ies). The uprise of the physical sciences is a phenomenon that one mainly refers to European developments unfolding from 1600 onwards. Scientific breakthroughs were bound to the Western culture from 1600 to 1900, but, from 1900 onwards, scientific culture became more and more a possession of the whole world.

The cognitive-developmental approach did the most to work out this latter position. Jean Piaget (1975, vol. 8-10; Piaget and Garcia, 1989) and many of his followers (e.g., Kälble, 1997; De Caprona, 1983; Strauss, 1988; Wenzel, 2013; Oesterdiekhoff, 2011; 2013a; 2015a) described that the origination of the physical sciences in early modern Europe is explainable only in terms of developmental psychology. This group of authors explained that the lower stages of reason and mind, known as typical characteristics of children, resemble the prescientific ideas of ancient and medieval cultures, peoples and intellectuals, while the features of the fourth stage of human development, the formal-operational stage, corresponds to the peculiarities of the physical sciences of the early modern period. The Piagetian-led authors showed these resemblances regarding the history of physics, mathematics, biology, chemistry, regarding the transformation from Aristotelian physics to the mechanical physics, regarding the evolution of the understanding of the concept of the physical law and regarding the evolution of concepts such as causality, chance, possibility, necessity and probability. This seems to evidence that deep-rooted psychological stage developments had been necessary in order to cause the uprise of the sciences. Moreover, such a description strenghtens the idea mentioned that special intellectual preconditions precede the rise of the sciences, thus being phenomena that are not in the mental reach of most ancient and premodern peoples and societies. Further, only this approach explains both the very nature and the origination of the physical sciences.

While some authors (e.g., De Caprona, 1983; Strauss, 1988) emphasize that only the new theories and not the cognitive structures of the scientists themselves, went through the transformation from concrete to formal operational stages, Piaget himself was insecure regarding this central point, swaying in different publications from one position to the other. The argumentation here supports the view that the evolution of the formal operational stage occurred in reason and mind of the scientists themselves and is by no means restricted to their theories only.

Psychological Stage Development and Piagetian Cross-Cultural Psychology

The proof of the prevalence of the lower psychological stages among premodern peoples and correspondingly, of the psychological advancement of peoples living in modern societies is the precondition to the identification of the far-reaching commonalities between the transformation from prescientific to scientific concepts and theories on the one side and the ontogenetic developments on the other side. Many founders and representatives of the human disciplines especially between 1840 and 1940 contributed to the theory according to it premodern peoples, both nature peoples and premodern civilizations, stood on psychological stages typical for children. Nearly every early child psychologist and psychoanalyst shared this idea and likewise many founders of sociology, ethnology, philology, linguistics, etc. It was nearly a commonsense idea in Western civilisation at that time. Ethnological literature described abundantly and precisely that premodern peoples think and act in patterns completely deviating from those forms that are common among modern peoples (Tylor, 1871; Frazer, 1994; Lévy-Bruhl, 1923; 1985; 1983). Many authors recognized that only developmental psychology might be able to explain these divergences (Allier, 1929; Elias, 1994; Schultze, 1900; Langer, 1988; Oesterdiekhoff 2015a; 2015b). Especially Werner (1948) and Piaget (1959a; 1959b; 1969; 1967) showed the resemblances between children and premodern adults in a convincing and comprehensive way.

Piaget´s developmental psychology was a milestone regarding this research industry. According to it, humans, during their first two decades of life, develop through four main stages. The first three stages, the sensorymotor, the preoperational and the concrete operational stage describe the human development during its first decade, whereas the fourth stage, the stage of formal operations, unfolds during the whole second decade, being divided in substage A and B, the latter one coming into existence after the age of 15 (Piaget, 1959a; 1959b; 1969; 1984; Piaget and Inhelder, 1969; 1973; 1975). It was shown that the formal operational stage is the prerequisite to scientific reasoning abilities (Piaget, 1975; Piaget and Inhelder, 1958).

Piagetian cross-cultural psychology, especially from 1950 onwards, conducted empirical research right across the five continents and numerous types of cultures. Some thousand experiments have been conducted regarding the development of the four stages. It was found that folk societies (R. Redfield), that is, premodern or traditional societies, or underprivileged social milieus in developing

nations, do not acquire the fourth stage of human development but remain staying on preoperational or concrete operational stages. This assignment concerns mental abilities in the whole range of world understanding such as logic, physics, social affairs, law understanding, politics, morals and religion. Only more educated people in developing nations and the mass of people in the developed nations establish the fourth stage of human development, whereby 30-50% of people in the most advanced nations manifest also substage B of formal operations (Dasen, 1977; Dasen and Berry, 1974; Luria, 1982; Mogdil and Mogdil, 1976, vol. 8; Hallpike, 1979; Oesterdiekhoff, 2009; 2011; 2012a; 2012b; 2013a; 2013b; 2016a; 2016b; 2016c; Piaget, 1974b; Flynn, 2007).

Against the knowledge of developmental psychology, differences between children and premodern or primitive adults are not describable. However, adults, even when staying on children´s stages, have more life experience and knowledge (only such forms of knowledge that does not depend on higher stages) than children have. Thus, both groups share their qualitative development (their stage structures) but differ in their quantitative development (knowledge and experience). However, stage structures override the role of life experience in shaping the human mind and psyche (Oesterdiekhoff, 2009; 2013b; 2016a; 2016b; 2016c).

Modern culture with all its peculiarities such as school curriculum, education, job requirements, etc. must affect human brain and mind from birth onwards to prompt the human mind to attain the higher stages. Humans living in cultures with face to face communication only, without specialized education and qualified jobs, have no chance to use the several sequential developmental windows in order to surmount the lower stages. Unused developmental windows lead to forms of arrested development, premodern adult humans are being caught in. The phenomenon of arrested development explains the far-reaching commonalities between (modern) children and premodern adults right across the whole range of world understanding and psychological phenomena (Allier, 1929; Flynn, 2007; Werner, 1948; Hallpike, 1979; Luria, 1982; Mogdil and Mogdil, 1976, vol. 8; Oesterdiekhoff, 2012b; 2013a; 2013b; 2016a; 2016b; 2016c; Scott *et al*., 1951).

For example, adult Pirãha Indians from Brazil cannot learn anymore to count 1, 2 and 3, to add 2+2 = 4, or to draw a straight line, not even after months of daily schooling because they stay so low on the preoperational stage that stimuli cannot provoke them to attain higher stages in order to be able to master these tasks (Everett, 2008; Oesterdiekhoff, 2016e, p. 76). Premodern people that stay on higher stages than the Pirãha do, being able to master the tasks mentioned, likewise remain caught in their low psychological structures. Ethnography or history have never documented that premodern people or single traditional milieus have ever surmounted their magical-animistic or mythical way of reasoning, that is, their childish mind. Thus, arrested development characterizes the psychological life of the whole premodern humankind (Oesterdiekhoff, 2011; 2013a; Allier, 1929; Werner, 1948).

Piagetian Psychology and the Rise of Sciences

Accordingly, the psychological analysis of the intellectual, philosophical and scientific milieus in premodern societies has to refer to this Piagetian research. The bell curve of intelligence distribution or psychological stage distribution within a single population teaches that premodern intellectuals and scientists must have stood on lower psychological stages than modern scientists. During their childhood and education they weren´t exposed to curricula and education modern scientists enjoy and benefit from. Therefore, they couldn´t use the sequential developmental windows to that rate as modern scientists do. They may have advanced psychologically more than their uneducated contemporaries but did not parallel educated persons living in the currently most advanced nations (Oesterdiekhoff, 2013a; 2016d).

Therefore, nearly every premodern scientist adhered to magical-animistic schemes as modern children do by the end of the first decade of life and shared the popular superstitions as the belief in witches and sorcerers, ghosts and gods. Scientists believed in providence and destiny, paradise and hell and they all shared theological views, mostly being the intellectual foundations of their research. Premodern intellectuals have mostly been theologians (Thorndike, 1923-1946; 1905/2003; Kieckhefer, 1995; Kiesewetter, 2005; Luck, 1990).

Basically, these premodern intellectual manifestations are shared by (modern) children only during their first decade. Magic, animism, belief in ghosts, witches and sorcerers are strong in the mind of preschool children. These phenomena almost totally vanish in modern children with ten years roughly. One hundred years of child research has shown that these phenomena root in the basic patterns of the child´s psyche. The formal-operational stage eradicates them. Therefore, it is evident that magic, animism and superstition as prevailing patterns in the minds of premodern intellectuals proves of their lack of formal operational stage structures (Piaget, 1959b; 1969; Oesterdiekhoff, 2012a; 2013a; Rosengren *et al*., 2000; Ellwanger, 1980).

Modern scientists from the 17th century onwards started the abolishment of this magical-animistic stage of mind in favor for the mechanical and rational worldview (Cassirer, 1920; Meyenn, 1990; Dijksterhuis, 1956; Gloy, 1995). While the scientists of the early modern period still manifested transitional phases, consisting of both childish and formal operational structures, the

scientists of the 19th century predominantly eliminated the rests of the childish stage. Thus, the intellectual growth in scientists from the premodern to the modern period manifests the transformation from the childish stages to the adolescent stage of formal operations.

Correspondingly, not only the origination of the physical sciences during the 17th century is explainable in terms of psychological stage development but also the history of philosophy generally and the rise of the early modern philosophy specifically. It was shown that ancient metaphysics, the Ionian philosophy, further the philosophy of Plato and Aristotle and the medieval philosophy are describable in terms of developmental psychology. The elimination of ancient metaphysics and its replacement both by the critical theory of knowledge and by the mechanical philosophy during the 17th century reflects likewise the transformation from the childish to the adolescent stage of formal operations. Both the history of philosophy and the history of sciences reflect the transformation from the childish to the formal operational stage. The sciences in stricto sensu emerged during the same period as the early modern philosophy surmounted ancient metaphysics. The replacement of the magical-animistic and theological view by the mechanical view took place both in sciences and philosophy during the same generations, often created by the same protagonists (Oesterdiekhoff, 2000; 2016e; 2012a; 2013a; Fetz, 1982; Piaget, 1975, vol. 8-10, 1967; De Caprona, 1983; Kälble, 1997; Wenzel, 2013).

The transformation from concrete operational to formal operational structures among modern adolescents concerns the whole psychological life, the basic categories of logic and causality, the ability to perform combinatorial, systematic, hypothetico-deductive and reflective conclusions and the abilities to construct coherent theories basing on empirical research (Piaget, 1984; Piaget and Inhelder, 1969; 1973; 1975; 1958).

Piaget and Inhelder (1958) have abundantly demonstrated that only the rise of the formal operational stage enables modern adolescents to understand modern physics and mathematics, to conduct empirical research and to understand basic experiments in physics, chemistry and biology. Children on the concrete operational stage are still not capable to understand the basic experiments of the physical sciences and therefore to study these disciplines. The experiments Piaget and Inhelder (1958) applied are mostly those that the sciences invented for the first time during the early modern times. Therefore, the authors themselves hinted at the parallels between the ontogenetic and historical developments.

The historical parallels do not only concern the transformation from the magical-animistic to the mechanical view but also the other patterns mentioned. The scientists of the early modern period developed higher elaborated categories of causality and logic and for the first time systematic theories built on empirical experiments. As modern adolescents understand that only systematic experiments lead to scientific discoveries, as the scientists of the early modern period understood that not philosophical considerations but only controlled experiments discriminate wrong from explanatory hypotheses. As modern adolescents are capable to discriminate illusionary from appropriate theories, as the new scientists were capable to formulate systematic theories. As modern adolescents are capable to understand the laws of chance and probability, as the new scientists discovered the previously unknown laws of statistics and probability (Piaget and Inhelder, 1958; 1975; Piaget, 1987; Hacking, 1975). As the adolescents start to discriminate physical from moral laws, as the early modern scientists introduced this discrimination for the first time in history, while children and premodern scientists do not understand this discrimination (Piaget, 1983; 1969; Zilsel, 1976; Gloy, 1995; Störig, 2004; Oesterdiekhoff, 2012a; 2013a).

Piaget (1975, vol. 8) reconstructed the history of mathematics in terms of developmental pyschology, likewise the history of physics (1975, vol. 9) and the history of biology, psychology and sociology (1975, vol. 10). Piaget and Garcia (1989) applied developmental psychology to the reconstruction of physics, Aristotelian philosophy, geometry and algebra. All this research shows that the rise of the adolescent stage of formal operations is the cause to the rise of sciences in stricto sensu and the accumulation of scientific knowledge after 1600.

Foundations of the Rise of Sciences

From the Magical-Animistic to the Mechanical Worldview

Especially the books of Piaget (1959b; 1969; 1983) about the worldview and the physics of children, first published in 1922, 1926 and 1927, are crucial to understand the prescientific worldview and the following evolution of sciences. These books deliver a deeper and more comprehensive analysis about the prescientific mind, including its physics and worldview, as Piaget´s books on the rise of the sciences. Piaget shows there that children initially understand every object and thing as alive and conscious. Children initially don´t discriminate matter and life, body and soul, object and subject, physis and psyche, incident and action, physics and biology. They assume every object and every movement are ruled by intention, will, or psyche. Children´s animism is an inevitable part of their psychological developmental stage, of their nature and psyche, independent of socialisation and culture. Only children of the modern culture go through several stages leading to weaker forms of animism and finally to its eradication. With ten years roughly animism is going to be replaced by the

empirical-causal explanations and the mechanical worldview with its discriminations between soul and matter, etc. (Piaget 1959b; Kälble, 1997; Werner, 1948; Bühler, 1930; Hyde, 1990).

Therefore, the child sees the whole cosmos or world as a living being or as a container consisting of living beings only. Stars, clouds, winds, rainfalls, sunshine, woods, waters, mountains, etc., are living beings, following intentions, ruled by a psyche and communicating with other beings. Therefore, children don´t recognize empirical causality and chance and avoid accepting mechanical explanations. Instead, all beings communicate and influence each other. This communication and influence have magical forms, which are unobservable, direct and intentional. Magic is the form of interdependence between the ingredients of the cosmos respectively the living beings. The power of magic makes the stars shining, the seasons or the rainfalls coming and disappearing, the nations growing and decreasing, etc. Thus, the beings may sometimes act individually and egocentrically but that is not their very nature and destiny. Instead, they all work together to make the cosmos running and to hold the world together. They do this because they are created for this reason and because they are forced to function in alignment with the whole cosmos. They have to obey to the cosmos and its creator. The harmony of the cosmos roots in the obedience of the beings to the common goal. The world soul, governing the cosmos, rules the single beings by sending them magical influences or orders. Thus, the cosmos functions in a way comparable to a factory ruled by its boss or to an army ruled by its general. Therefore, children´s worldview is animistic, magical and theological by definition (Piaget 1959b; 1969; 1983; Ellwanger, 1980; Hyde, 1990; Fetz, 1982; Kälble, 1997).

Ethnography and history have described that every premodern society has the same worldview. Ancient China and India, African cultures and pre-Columbian cultures in America, ancient and medieval Europe shared this worldview. Ancient and medieval metaphysics, the world religions of Eurasia and the philosophies of Plato and Aristotle manifest the animistic, magical and theological aspects of this children´s worldview. Plato (1957) and Aristotle (1995) confirm that the world soul steers the cosmos by sending magical influences down to the single elements, thereby producing harmony and beauty and enacting the law that governs the whole world. This worldview dominated Europe´s scientific elite still during the whole 16th century (Thorndike, 1923-1946; Cassirer, 1920; 1998; Hallpike, 2008, pp. 396-400; Oesterdiekhoff, 2012a, pp. 257-310; Thomas, 1997).

The physical sciences during the early 17th century came into being with the disappearance of this worldview. The two phenomena are directly and causally interconnected. Disappearance of this metaphysical worldview and rise of the physical sciences happened at the same time and in the minds of the same scientists. Moreover, the rise of the physical sciences implies the abolishment of the magical-animistic worldview. At the same moment as the scientists surmounted the childish worldview and the childish psychological stage they developed the physical sciences. The freshly grown formal operational stage eradicated the fairy tale worldview, the ancient metaphysics and established the physical sciences at the same time.

Every human being in modern society runs through the same stages as the scientists from about 1300 to 1700. As developmental psychology described, adolescents of the second decade of life, establishing the formal operational stage, surmount the magical-animistic worldview by the empirical-causal and mechanical one. With 13 or 15 years, the mechanical worldview has replaced the childish one. Adolescents now have the prerequisites to understand and to follow the scientific worldview. They believe now that the cosmos mainly consist of dead matter, ruled by natural laws and that it does not fulfill mysterious intentions and holy duties. From now on they understand experiments in physics and complex physical explanations (Piaget and Inhelder, 1958; Piaget, 1969; 1959b).

It is obvious that the adolescent´s evolution of the formal operational stage parallels the breakthroughs the scientists of the 17th century produced. The scientists of the early modern period surmounted the belief in magic, animism, world soul, providence, etc. They discriminated between biology and physics, life and matter, soul and things, psyche and physis. They understood that the greatest part of the cosmos is filled with dead matter and that life is constrained to plants, animals and humans only. They described that matter and objects only react to certain physical environments describable by physical laws. They compared the functionning of the cosmos with a clockwork where all parts have a special function that makes the system running, but without consciousness and will. They understood the cosmos generally and its single ingredients especially in terms of a machine or in terms of mechanics. The movements of stars and planets, of waters and clouds, the seasons of the year and all other natural phenomena were not longer understood in terms of soul but in terms of physical reactions to certain physical environments. The cosmos was not anymore a living being following intentions or holy duties but a machine obeying to physical laws (Shapin, 1998, p. 46, pp. 165-175; Dijksterhuis, 1956, p. 550; Koyré, 1998, p. 67, 50; de Solla Price, 1990; Gordon, 1988; Meyenn, 1990, p. 21). “Mechanics, as a science (in the modern sense of the world), did not occur before the seventeenth century” (Piaget and Garcia, 1989, p. 31).

This transformation started in astronomy with Johannes Kepler in his book *Epitome* at first and was accomplished with Newton in his *Philosophiae naturalis principia mathematica* published in 1687. Kepler was

the first to surmount animism and magic in astronomy and Newton was the scientist who completed the task to deliver a comprehensive mechanical theory of the universe (Koyré, 1998, p. 65; Shapin, 1998, p. 45; Gloy, 1995, p. 166; Oesterdiekhoff, 2012a, p. 301). The transformation took also place in all kinds of physics, chemistry, geology, meterology, etc. The scientists replaced the animistic theory of movement by the mechanical one, magical-animistic theories of fluids, bodies, etc. by causal-empirical ones. Especially Descartes (1980) developed a general theory of nature in terms of the machine model, constraining soul and mind to god and the human being only. Descartes described even the body of humans, animals and plants in terms of machines, being more materialistic and mechanistic than any philosopher before him (Gloy, 1995, p. 171; Shapin, 1998, pp. 67, 182). The understanding of the world in terms of a machine is the precondition for the new role of experiments in physics. Experiments try to figure out explanatory factors among a range of other factors belonging to a coherent system. Experiments make no sense in a magical-animistic worldview that does not regard natural elements as reacting unintentionally to certain environments. Galileo Galilei´s introduction of experiments in the natural sciences based on this new understanding, unknown and disrespected by the prior metaphysics of Plato and Aristotle (Gloy, 1995, p. 192).

During the 17th century the great scientists adhered to the mechanical philosophy and ridiculed the magical-animistic ideas of ancient metaphysics generally and of Plato and Aristotle specifically. The ideas of the new sciences prevailed in the educated classes everywhere across Europe.

Discovery of the "Thing"

On the lower stages of animistic thinking there is no object without a ruling psyche or internal motor (Piaget 1959b). Correspondingly, ethnography and history described that folk societies or premodern peoples regard stones, mountains and artefacts such as tables or swords, ships or houses as living beings (Lévy-Bruhl, 1983; 1985; Frazer, 1994; Oesterdiekhoff, 2013a, pp. 129-138). Even Aristotle understood the movements of stones, clouds, or projectiles as caused by their internal motors or intentions, as other intellectuals in ancient and medieval times did, too. The scientists of the 17th century, however, surmounted this idea, recognizing for the first time in history that there are things, which are dead objects only. Their research of fluids, movements, temperature, etc. proved of the fact that not internal and psychological factors caused the reactions of objects but only their relationship to a set of external conditions. As modern humans of the second decade recognize that the world mainly consists of "things" (Piaget 1959b), the scientists of the 17th century discovered the existence of "things" in chemistry, physics, mineralogy, geology, astronomy, etc.

Descartes (1980) drew the philosophical consequences of this discovery, thus creating the early modern philosophy, abolishing ancient metaphysics and revolutionizing the history of philosophy and sciences. His famous discrimination of res cogitans and res extensa bases on the new discovery that there are things. Res cogitans is constrained to the mind of god and humans; it does not imply the reactions of animals which are only machines. There is no other res cogitans in the world apart of the mind of god and humans. Everything else in the world is dead matter, including animals, plants, stars, waters, etc. Everything else is res extensa, matter defined only by mass, extension and position. There is no matter that does entail any magical or animistic qualities. Nature is the ensemble of extended matter and nothing else. Thus, Descartes surmounts Aristotle´s assumption that any matter includes its form, that is, its internal mover and goal. Descartes´ famous distinction defines in a radical way "things" and introduces the materialistic worldview, from now on basing the scientific worldview (Gloy, 1995, p. 176; Meyenn, 1990, pp. 182, 329; de Solla Price, 1990; Shapin, 1998, pp. 59-60; Oesterdiekhoff, 2012a, pp. 305-307).

Evolution of the Understanding of the Physical Law

Children and premodern scientists do not know about the existence of physical laws, while adolescents in modern societies and scientists from the 17th century onwards recognize their existence. Children have a precausal understanding of natural regularities. For example, the sun shines because it intends to shine (psychological aspect), it has to shine because it is its duty on behalf of god (moral aspect) and it really shines (the observable fact or the physical aspect). Thus, the precausal understanding of nature combines the psychological, the moral and the physical aspect. According to the children´s mind, every description of any natural phenomenon, incident or regularity has to refer to these three aspects. Any description not referring to the psychological and moral aspects is insufficient. This precausal understanding of nature, as exemplified with regard to the sunshine, characterizes the child´s understanding of any incident and regularity. It roots in the magical-animistic view and other patterns of the child´s psyche. The regular behavior of the sun and the planets, of waters and winds, of seasons and movements, etc., do not come from physical laws but from moral laws. The holy nature and god have enacted the laws according to them the natural phenomena have to function and have to play their part. The harmony of the cosmos, the physical regularities and the behavior of the elements follow from their intentional law obedience. They want obey to the holy laws in order to avoid god´s punishment. On the whole, children understand physical regularities in terms of human relations respectively in terms of legislation, jurisprudence, authority and

obedience. They understand physical regularities in terms of moral laws (Piaget 1959b; 1969, pp. 237-306, 1983, pp. 191-258).

"We can distinguish three periods in the evolution of law in the child. Each of these is characterized by the peculiar relationship in which generality and necessity stand to one another. During the first, generality is non-existent; as to necessity, it is purely moral, physical determinism not having been separated from the idea of social obligation. During the second period, these two types of necessity are differentiated and generality comes into being. During the third period, generality is established and physical determinism is accompanied by logical necessity, which is the last term in the evolution from moral necessity." (Piaget 1969, p. 273).

The adolescents of the second decade, in consequence of the emergence of the formal operational stage, surmount this fairy tale worldview and establish the true understanding of physical laws, from now on discriminating physical from moral laws, the world of physics from the world of humans. With their abolishment of precausality, magic and animism, they understand that physical laws only describe regularities, not manifesting any psychological or moral aspects (Piaget and Inhelder, 1958; 1969).

The whole premodern world, including Africa, Asia, ancient and medieval Europe, nature peoples and civilizations, shared the children´s understanding of physical regularities. They all understood "physical laws" in terms of moral laws. They all believed that the physical regularities originate in the intentional law obedience of the elements to the divine orders and to the holy cosmos. The medieval name in Europe for this law understanding, encompassing human society and nature alike, is "ordo". The Russian name is "Prawda", the Persian name "Rita", the Greek name "Logos" or "Dike", the Chinese name "Tao" or "Li", the Egyptian name "Maat", etc. (Oesterdiekhoff, 2009, p. 257). Ancient philosophy, including Plato and Aristotle, shared this law concept (Needham, 1979, pp. 286, 276, 290; Lévy-Bruhl, 1923).

The Spanish philosopher Suarez is said to be the first scientist to understand and formulate the concept of physical law in 1612 (Needham, 1979, p. 260-270; Zilsel, 1976, p. 66-70). The modern common sense understanding of the physical law, manifested in the average modern mind with roughly 13 years, originated for the first time in history in the minds of the great scientists during the 17th century. The evolution of the mechanical view of the universe, of the empirical-causal explanations, of the concept of the physical law and of the abolishment of magic and animism are interconnected phenomena (Oesterdiekhoff, 2013a, pp. 313-315).

Evolution of the Scientific Disciplines

Evolution of Physics (Theory of Movement)

The transformation from metaphysics to physics and the following explosive accumulation of physical knowledge appeared during the 17th century. Piaget and Garcia (1989) dedicated a complete monograph to this evolution of physics, describing it in terms of developmental psychology, likewise De Caprona (1983), Strauss (1988; Piaget, 1967; 1975, vol. 9). I want confine the description related to the theory of movement, central to the development of physics during the 17th century. The transformation from the magical-animistic to the mechanical theory of movement took place twice in history, during the short period of Hellenism and again during the 17th century. Both transformations started from Aristotle´s theory of movement. "In one particular case, that of the evolution of physics from Aristotle until just before Newton, we have been able to establish a correspondence – indeed a very direct one – between the four historical periods (the two Aristotelian driving forces, the recourse to a single driving force, the discovery of the impetus and that of acceleration) and the four stages in psychological development. In particular, we observe a striking construction and generalization, at about seven or eight years of age, of the idea of élan, in surprising analogy with Buridan´s concepts. In this case, the parallelism in the evolution of concepts in history and in psychological development concerns the content of the successive forms of the concept" (Piaget and Garcia, 1989, p. 26). Already Kurt Lewin (1981, p. 239) compared Aristotle´s physics to that of children and primitives. A. Koyré and T. Kuhn mentioned that Piaget´s description of these similarities had helped them to understand both children and Aristotle.

Like children explains Aristotle (1995, vol. 6) every movement as made by an internal power accompanied by an external supporter. For example, both children and Aristotle understand movements of trees and clouds in the wind differently as modern adults do. Modern adults do not assume an internal motor working within trees and clouds, causing their movements in the wind. They explain such movements solely by the wind, affecting clouds and trees. Children and Aristotle explain otherwise. They explain the interaction between clouds (or trees) and winds by the original and autonomous movements of the clouds (or trees), which make winds by their movements that additionally enhance them. The internal movement of the cloud (or tree) creates the winds, which again promote the cloud´s (or tree´s) movement. Waves in the waters go up and down by their own force, making wind by that, which again support the waves. Thus, the internal motor or causer is central and the environment magically supports it. Both object and environment have some kind of will or intention and are magically intertwined. "Every movement is supposed by

the child to contain an element of spontaneity. An internal motor is necessary if the object is to be moved by an external motor. If dead leaves ´move with the wind´, it is because they are ´alive´, even if driven by the wind" (Piaget, 1969, p. 50).

This relation also concerns the description of artefacts such as projectiles. Children and Aristotle have the same understanding of the flight of arrows, down to single details involved. A projectile, thrown by a human being into the air, flies due to its own will and force. The surrounding air immediately supports this flight, it rushes intentionally aside to give room to the projectile, it flies back to the tail of the arrow, then it makes a 180 degree turn again in order to be able to push the arrow from the back. Thus, the wind obeys to the arrow and it is its duty to help the arrow intentionally. The wind knows its duties and is able to assist. Every movement of the wind is caused by its will and commitment. Arrow and wind deliberately co-operate to make the flight possible. On the whole, the movements of trees, clouds, waves and artefacts are produced by an internal and an external mover or causer. Antiperistasis is Aristotle´s name for this kind of double causation. "… it will suffice to say that the explanations given by our children of the third and fourth stages bear a close (or distant) resemblance to the famous explanations of projectiles which Aristotle has discussed in his "Physics". The first of these explanations is that of antiperistasis, which Aristotle seems to accept in some passages while he rejects in others." (Piaget, 1969, p. 23).

Further, children and Aristotle believe that the projectile flies horizontally and falls down vertically with a 90 degree angle. Both assume that every object has its "natural place" to land and to stay (Piaget and Garcia, 1989, pp. 45, 67-69; Piaget, 1969, pp. 61-64; Piaget, 1975, vol. 9, 67). Older children, roughly with 12 years of age, run through a stage where they renounce on the concept of antiperistasis, establishing the medieval concept of élan. "When, finally, the fifth stage is reached, the child declares that the impetus (l´élan) is sufficient to explain the advance of the match and that the air hinders rather than helps the movement." (Piaget, 1969, p. 22) The adolescents, with 13 years, establish then the objective explanation the scientists of the 17th century reached in consequence of Galileo Galilei. From now on they are able to understand the law of inertia, discovered in the early modern period.

Evolution of Astronomy

Children of the first decade of life understand sun and moon, stars and planets, as living beings or as persons. They are believed to watch at humans and control their behavior on behalf of parents and god. Their movements originate in their will and power comparable to animals and humans when they walk. The regularity of their movements and their work, e.g., the daily alternation of sun and moon, day and night, comes from their law obedience to the rules of the cosmos and god. They draw their circles because this is their function and their role the holy order imposed upon them. "In a word, sun and moon move of their own free will, but their advance is controlled for moral reasons by God or by man." (Piaget, 1969, p. 75) With ten or twelve years, children of modern societies surmount the magical-animistic view of the heavenly bodies in favor for the mechanical explanation (Piaget, 1969; 1959b).

Every premodern culture, without any exception, had the same understanding of stars and planets. Nature peoples and ancient civilizations adored the heavenly bodies as gods, brought sacrifices to them and asked them for help. Ancient people felt controlled by sun and moon and spoke to them, believing they would know everything happening in the world. Astrology implies the belief the stars would cause the human being´s destiny (Oesterdiekhoff, 2007).

Even Aristotle still believed that the stars are gods that intentionally follow their perfect circles to manifest the divine harmony of the cosmos. The astronomers of the ancient world up to the 16th century adored the sun as god, as Copernikus and the young Kepler did, too. In his early work *Mysterium Cosmographicum* Johannes Kepler still described the planets as living beings and as gods that follow "reasonable circles". In his later work *Epitome* he was one of the first or even the first astronomer who surmounted the magical-animistic interpretation of heavenly bodies, explaining a theory of the heaven solely in mechanical terms. Isaac Newton in his *Philosophiae naturalis principia mathematica* of 1687 completed the mechanical theory of the heavenly movements. He showed that the law of inertia and the law of gravitation completely explain the movements of the heavenly bodies (Cohen, 1994; pp. 167-264; Gloy, 1995, pp. 162-198; Dijksterhuis, 1956; Koyré, 1998, pp. 70-87).

The 17th century originated the scientific theory of the heaven and the universe. It created astronomy as a true and great science and it created with Newton the next to Einstein greatest scientist in history. The knowledge in astronomy exploded and gained standards never seen before. This breakthrough mainly based on the replacement of the magical-animistic view of the heaven by the empirical-causal or mechanical one. The transformation from the childish psychological stage to the adolescent stage of formal operations in the mind of the scientists during the 17th century made astronomy a true science and enabled its explosive accumulation of knowledge. Thus, developmental psychology explains the main trajectories and transformations in astronomy (Oesterdiekhoff, 2012a, pp. 298-303).

Evolution of Chemistry

Alchemy preceded chemistry which came into being as late as the 17th century. Alchemy was the general

theory of the chemical elements during antiquity and medieval times in Europe and Asia. It mainly consists of a magical and animistic theory of chemical substances, fluids and minerals. The alchemist spoke to fire, gas, water, stone, etc and promised them to help to reach other states or to make them perfect. The alchemist helped the elements reach higher states by prompting their metamorphosis. He understood them as living beings striving for better conditions or as beings that react to the alchemist´s intentions willingly or not. Therefore, the alchemist distinguished them with regard to their female or male status and treated them with regard to their sex. On the other hand, the alchemist hoped the chemical elements could help him to find the key to eternal youth or power, to make gold or accomplish other magical goals. He believed that appropriate charms and prayers, adorations and rites could provoke the chemical elements to fulfill his wishes. This magical-animistic understanding of the chemical elements prevailed by 1600 or 1650 in Europe (Jung, 1981; Gebelein, 2000).

The chemistry as a true science started with the replacement of the magical-animistic theory by the mechanical or empirical-causal one. Only the understanding of the chemical elements as dead matter, reacting to certain environments passively and regularly, created chemistry as a true science. This basic understanding was accompanied by the introduction of controlled experiments, destined to find the causing factors among a couple of others in affecting certain transformations. The chemists of the early modern period found some basic elements, later on the period system of elements and the first chemical regularities. R. Boyle in 1661 formulated the programme that the chemistry has to be built on the search for the elements. The chemists found the laws of air pressure and understood chemical reactions of gas, alcohol, porcelain and explosives. Van Helmont introduced the name “gas” (Störig, 2004, vol. 1, p. 269). Galilei, Torricelli and von Guericke discovered the atmospheric pressure by experiments, thereby inventing barometer, air pump and thermometer. They discovered the secrets of temperature, surmounting the formerly believed opposition of heat and coldness as two distinct phenomena. Children go and scientists went through the same stages regarding the discrimination of heat and temperature (Wiser, 1988, pp. 28-48).

According to Störig (2004, vol. 1, p. 339) and Cohen (1994), any knowledge of chemistry before 1600 was almost missing. The chemical knowledge exploded during the 17th and 18th centuries. That implies that during the same period during which alchemy was replaced by chemistry the knowledge accumulated and grew above the beforehand given minimum. Chemistry developed as a true science with knowledge respectable in that moment at that scientists replaced magic and animism by empirical-causal explanations. On the whole, the cognitive transformation from the childish psychological stage to the adolescent stage of formal operations is the only cause to the evolution of chemistry and the accumulation of knowledge related (Oesterdiekhoff, 2013a, pp. 318-320). It is not by chance that Piaget and Inhelder (1958) showed that only adolescents on the formal operational stage are capable to understand chemistry and experiments in chemistry. What they described in their book on the adolescent´s understanding of chemistry, took place for the first time in history in the minds of the chemists 300 or 350 years ago.

Evolution of Medicine, Biology and Geology

Medicine was preceded by shamanism or magical treatment. The cunning man, the magical doctor, was more requested in Europe during the 16th century than the educated medical doctor (Thomas, 1997). The Europeans preferred at that time magical treatments, not empirical ones. Of course, even among nature peoples and ancient civilizations empirical treatments were already applied. Magic never defined medicine alone. However, magical treatments were more often applied and played a greater part than empirical treatments, both among nature peoples and medieval civilizations (Evans-Pritchard, 1937; Lévy-Bruhl, 1923; Lindberg, 2000; Thorndike, 1923-1946).

Medicine became a natural science in consequence of the recognition that the body functions in analogy to a machine, described by Descartes (1980). The ban to open the body for the research of the organs was abolished in the early modern times and the scientists discovered the human body as a complex and coherent organism, where different organs overtake different functions. They discovered the functions of blood circulation, of lungs, of digestion, etc. and found the causes to a couple of illnesses. Scientific treatments replaced common sense and magical treatments such as blood-letting, thus enhancing health care enormously. The 18th century was the first one with great visible successes of medicine, not being anymore a field for charlatans only (Lindberg, 2000).

Biology remained a descriptive science up to the 18th century because the scientists were unable to surmount magical beliefs and artificialistic assumptions, according to them living beings must be made by a creator. The children´s belief in the magical creation of beings, as described by Piaget (1959b), continued in modern sciences and philosophy very late. Only the replacement of the artificialistic belief, manifested in the book of Genesis in the scripture, by the evolutionary theory of Darwin and Wallace, introduced the type of explanations that transformed biology in a true science. Formal operational thought is the main cause to the rise of evolutionary theory; therefore, developmental psychology explains the evolution of biology as a true science (Oesterdiekhoff, 2013a, pp: 598-599).

Geology went through stages very similar to those biology experienced. The early modern scientists, caught in the cage of the machine model, weren´t able to understand nature in terms of evolution. They understood the earth as made in that form it was visible in their times. Machines are programms, running always the same way, created by the maker, by god. Thus, neither biosphere nor earth could have gone through stages. Therefore, scientists replaced artificialism by the evolutionary model regarding the history of the earth very late (Störig, 2004, vol. 1, pp. 246-248).

Theory of the Scientific Revolution

The scrutiny of the scientific developments during the early modern period refutes the idea of some relativists (Shapin, 1998) that there wasn´t any scientific revolution during that time or anywhere else in history. Nowadays voices are widespread according to them every culture may be able to create sciences or even has always created sciences, e.g., when inventing arrow and bow, shipping and housebuilding, farming and cattle breeding (Cole and Scribner, 1974). Other authors deny any qualitative difference between ancient sciences in Mesopotamia or China or medieval Europe on the one side and European sciences after 1600 on the other side, thus denying both the existence of any scientific revolution at all and the uniqueness of the European sciences in the period 1600-1900, or the uniqueness of modern sciences altogether. However, the scrutiny of the developments in each of the single disciplines reveals that the premodern sciences have to be discriminated from the physical sciences in stricto sensu coming into existence only after 1600 in Europe, apart from some Hellenistic exceptions and predecessors. The physical sciences had their great successes only after 1600 and only in the Western world and not anywhere else and not anytime else in history.

Henceforth, there really was a scientific revolution. Popper, Kuhn and Feyerabend discussed whether there was a change in worldview, methodology or in the role of experiments that caused the scientific revolution (Zilsel, 1976; Russell, 2004; Piaget and Garcia, 1989, pp. 257-263). Some other authors saw deeper, assuming that the early modern scientists established higher stages, surmounting the primitive magical-animistic worldview (Cassirer, 1920; 1998; Nestle, 1975; Elias, 1983; Lévy-Bruhl, 1985; Thorndike, 1923-1946). However, a true understanding of the scientific revolution is only reached upon the foundations of the developmental approach. Every description of the scientific revolution remains as long superficial as it does not refer to the psychological development from concrete operational to formal operational stages.

Every aspect defining the prescientific modes of thought prevailing in Europe by 1600 roughly belongs to the characteristics of the childish psychological structures below the formal operational stage. Magic, animism and artificialism are the main characteristics of children´s mind and worldview (Piaget, 1959b; 1969; Bühler and Bilz, 1977; Bühler, 1930; Ellwanger, 1980; Hyde, 1990; Diekmann, 1995; Rosengren *et al*., 2000; Werner, 1948); they are the main foundations of the premodern sciences, too (Brunschvicq, 1922; Campbell, 1960; DeGroot, 1910; Kieckhefer, 1995; Kiesewetter, 2005; Luck, 1990; Sawicki, 2003; Schultze, 1900; Seeck, 1975; Theiler, 1925; Thorndike, 1905, 1923-1946; Tylor, 1871). Developmental psychology described that the mechanical worldview is possible only on the formal operational stage and appears after the breakdown of the childish fairy tale worldview (Piaget, 1959b; 1969; Hyde, 1990; Rosengren *et al*., 2000). The same transition took place in Europe´s philosophy, sciences and worldview during the 17th century (Dijksterhuis, 1956; Meyenn, 1990; Einstein and Infeld, 1991; de Solla Price, 1990; Gordon, 1988).

Children have the same categories of causality, chance, probability, necessity and possibility as premodern intellectuals have. These categories go through the concrete and formal operational stages as every other psychological phenomenon does. The scientists of the early modern period were the first to develop these categories on the formal operational stage level (Piaget, 1969, 1987; Piaget and Inhelder, 1975; 1958; Lewin, 1981). Only this period of time discovered the laws of probability and statistics, possible only on substage B of formal operations (Piaget and Inhelder, 1958; Hacking, 1975).

Only adolescents of the formal operational stage, not children on the concrete operational stage, are able to understand and to perform physical experiments where one causal factor has to be isolated from a couple of correlative factors in order to find the appropriate explanation. Only the formal operational stage enables humans to combinatorial and systematic thinking abilities in order to perform experiments in statistics, physics and chemistry. That what Piaget (1980; 1976; Piaget and Inhelder, 1958) showed regarding a wide range of physical experiments, with solutions possible only on the formal operational stage, strongly resembles to the physical experiments the scientists of the early modern period conducted for the first time. Piaget and Inhelder (1958, p. 320) themselves remarked the far-reaching similarities between the physical experiments of the early modern period and those that only the adolescents understand and perform, not the younger children. Thus, both the lack of physical experiments in medieval sciences and the introduction of them after 1590, with Galilei as their inventor, are explainable in terms of developmental psychology (Lewin, 1981; Brunschvicq, 1922; Oesterdiekhoff, 2013a, pp. 320-328).

On the whole, it is not the one or other aspect of the child´s psyche that accounts to the premodern worldview, or the one or other aspect of the adolescent´s psyche that accounts to the modern scientist´s intellect. Instead, every aspect of the child´s psyche explains the foundations and boundaries of the premodern sciences and every aspect of the adolescent´s formal operational stage causes and carries the early modern sciences. Thus, the childish psychological stage carries the premodern sciences and the formal operational stage originates the natural sciences in stricto sensu coming into existence after 1600. Moreover, there is only one cause to the rise of the natural or physical sciences in stricto sensu. The origination of the formal operational stage is the only cause to the emergence of the physical sciences. It has not the status of a precondition or of an accompanying factor only; it really is the only factor to the rise of the physical sciences, as the scrutiny of the single disciplines above already revealed.

This phenomenon is linked to the fact documented that the accumulation of knowledge started at the same moment at that the transition from concrete to formal operational stage took place. The apparent rise of the formal operational stage was not only a precondition enabling the scientists in a row of some generations eventually to gain scientific knowledge, to find physical laws, or to conduct successfully physical experiments. Instead the fresh emergence of the formal operational stage immediately caused scientific breakthroughs and knowledge accumulation. The first generation of scientists on the formal operational stage, with Galilei, Torricelli, von Guericke, Boyle, Bayle, Newton, etc., generated masses of scientific data and a huge bulk of knowledge. Psychological stage advancement and the first gathering of scientific knowledge coincided and it coincided often in the same protagonists. The physical sciences (or how you want to call the preceding forms) from 1000 to 1400 did not originate much scientific knowledge in comparison to the knowledge explosion from 1600 to 1700, as the sciences in stricto sensu advanced. This again proves that the rise of the formal operational stage is the single cause to the rise of sciences (Oesterdiekhoff, 2013a, p. 321). Conversely, as the (premodern) sciences were performed on the concrete operational stage only, they did procur only scanty knowledge. Accumulation of scientific knowledge in the time 1600-1900 outperformed the whole scientific knowledge won over the millennia beforehand.

Piaget, however, is insecure how to understand exactly the interrelationship between psychological stage development and the rise of sciences. Sometimes he describes that there was a direct relationship between the two phenomena. In such cases, he directly refers the emergence of sciences to the psychological stage advancements within the brains and minds of the scientists themselves. “Our point of departure is that there is *continuity* in the development of the cognitive system, from the child to the average adult (one not educated in science) to the scientist… From Aristotelian and medieval physics (with their surprising similarities, both in method and in content, to the thought of children and adolescents) to the most highly developed branches of contemporary science (whose levels of abstraction are beyond the capacities of children and average adults) there exist mechanisms of action with strikingly common properties.” Piaget and Garcia (1989, pp. 263-264) The contention of continuity in the row child – uneducated adult – scientist implies the contention that psychological stage development concerns directly the mental transition from uneducated adult to scientist or from medieval to early modern scientist. The continuity is then not constrained to theory transitions but encompasses mind and psyche, as the formulation clearly indicates. Many more of Piaget´s statements likewise confirm that he refers the similarities between ontogenetic and historical phenomena to the psychological structures themselves, thus not leaving any room for any further differentiations (Oesterdiekhoff, 2013a, pp. 320-324). For example, he writes that the psyche and intelligence of the scientists themselves changed and advanced during the early modern times and later on and not only their theories (Piaget, 1975, vol. 10, p. 295).

However, there are remarks of a different character, showing Piaget´s insecurity how far he can draw the parallels between ontogenesis and history. Sometimes he writes that medieval scientists had thinking abilities on the formal operational stage level, as modern scientists have, but do not reveal them in their theories which stay on the lower stages. Accordingly, he makes then a difference between psyche and mind on the one side and theoretical content on the other side. Ancient and medieval scientific theories were childlike, but not the scientists themselves (Piaget, 1967; Piaget and Garcia, 1989, p. 28). Some of his disciples (McCloskey and Kargon, 1988; Wiser, 1988; De Caprona, 1983; Damerow, 1988) followed this idea, thus manifesting great insecurity how far they should understand the correspondencies between historical and psychological phenomena. Therefore, they all did not understand the decisive point and the quintessence of the entire project.

The fact that all characeristics of the child´s psyche account to the features of the premodern scientists and that all characteristics of the formal operational stage define the early modern scientists, evidence that the resemblances related concern the psyche and mind of the scientists themselves and not only their theories. Moreover, developmental psychology does not know the phenomenon of any difference between psychological structure and outcoming content, theory, or performance. There is no theoretical and empirical room for any contention a formal operational individual or group could produce childish or concrete operational science or

theory. Developmental psychology has always shown the strong connection of psychological stage structure and content, performance and theory. It is just the quintessence of developmental psychology to show the dependency of theoretical content from stage structure (Piaget and Inhelder, 1969, 1973; Piaget, 1984). Therefore, it is against any good science to maintain magic and animism among medieval scientists could be combinable to their assumed higher stage structures. A further reason to this erroneous view is that neither Piaget nor his disciples had a good knowledge of the empirical results of Piagetian cross-cultural psychology. They simply did not know that this research industry had verified the non-development of the formal operational stage among premodern peoples (Oesterdiekhoff, 2016a; 2016b). Altogether, the origination of the formal operational stage in the brains and minds of the scientists themselves (and not only in their theories) is the single cause to the origination of sciences during the 17th century (Oesterdiekhoff, 2013a, p. 321).

Piaget is also insecure how to conceptualize the relation between stage development and progress of science after 1650. Frequently, he stated that the link of stage development and history proceeds up to 1650 but breaks apart later (Piaget and Garcia, 1989, p. 26). This would imply that the scientific progress after 1650 only has a quantitative character in terms of developmental psychology, that is, it does not root anymore in further stage advancements.

Piaget (1975, vol. 10, p. 295), however, contrary to his restraining remarks mentioned, sometimes maintained that the psychological development of the scientists continued even after the early modern period. This is an apparent fact, considering that European peoples advanced their psychological stages even during the whole 20th century, stepwise from generation to generation. Both Piagetian psychology and intelligence research have evidenced this growth of intelligence and this stage advancement (Raven *et al*., 1993; Flynn, 2007; Oesterdiekhoff, 2009; 2011; 2012a; 2012b; 2013a; 2013b; 2014a; 2016c). It is practically impossible that the scientists did not participate at that growth of intelligence; they are not completely disconnected from the uprise of intelligence over the generations during some hundreds of years.

Indeed, the sciences of the past generations provide more elaborated cognitive structures than the sciences of the 17th or 18th centuries. They are more differentiated and more decentered than their predecessors of the early modern times. Correspondingly, the scientists of the earlier periods manifest more cognitively limited views regarding all questions of science, life, politics and morals than their successors (Oesterdiekhoff, 2013a, pp. 321-325; Russell, 2004). On the whole, the spiral of the from generation to generation growing intelligence of scientists did not stop around 1650 but has been continuing to present days.

The explanation to the phenomena of the lower stages of premodern peoples and scientists and of the rising stages of modern peoples and scientists, roots in the basic facts of developmental psychology. The above-mentioned phenomena of developmental window and arrested development deliver the key to the understanding of the whole phenomenon. As mentioned, adult Pirãha cannot learn anymore to draw a straight line or to enumerate 1, 2 and 3, while their children can learn it when exposed to some training. Correspondingly, adult primitives living in their premodern societies do not surmount childlike psychological stages, even not later in their lifetimes when being 50 or 70 years old, as the whole ethnological literature evidences (Everett, 2008; Scott *et al*., 1951; Allier, 1929; Werner, 1948; Oesterdiekhoff, 2016c; 2013a).

The growth of intelligence identifiable in Greek society from Homer to Aristotle comes from educational improvements, from small steps of more demanding cognitive stimuli that affect following new generations in their childhood. Aristotle, socialised in a more primitive culture and by weaker educational facilities than available in today´s most advanced nations, could not surmount later in his life certain stages in consequence of arrested development and closed developmental windows. Even his lifelong occupation with science and philosophy could not counteract his comparable "socialisation deficits" mentioned of course. This connection of premodern culture, education and socialisation on the one side and used developmental window on the other side concerns the psychological development of any scientist of the premodern world (Oesterdiekhoff, 2016d).

The increasing screwdriver or spiral effect of better socialisation and advanced cognitive growth in early childhood enabled early modern scientists to surmount the cognitive cages medieval philosophers were caught in. The next generations of scientists were exposed to even still better education and could benefit from the former achievements. For example, some schools in Birmingham of the early 18th century taught already Newtonian physics (Jacob, 1997), thus imposing cognitive stimuli on young brains, pupils of the 16th century had not available. This further climbing spiral effect of better socialisation conditions and accelerating cognitive growth in early childhood has been continuing during the succession of centuries up to now, especially during the 20th century (Raven *et al*., 1993; Flynn, 2007; Oesterdiekhoff, 2011; 2013a; 2012a). The screwdriver or spiral development of socialisation and psychological stage development explains, among many other things, the growth of intelligence and of sciences from 1600 up to now.

These historical results match ideas Piaget himself developed regarding the foundations of his genetic

epistemology. He said that four factors influence psychological development, search for equilibrium, brain development, social and physical stimuli coming from the environment. Brain development bases the unfolding of the four stages but the higher stages can only be achieved when environmental stimuli may affect strongly enough. Therefore, in case enviromental stimuli are as weak as they are in premodern societies it is expectable that adult humans do not surmount the lower stages. That is what Piaget, Hallpike and Oesterdiekhoff actually evidenced. This theoretical model, basing on socialisation theory and developmental psychology alike, is necessary to understand the lack of sciences in premodern societies and the rise of sciences in the early modern times. Intellectuals of the Middle Ages were not exposed to curricula and socialisation factors that were able to arouse the formal operations. The scientists of the early modern period, exchanging their ideas, forced each other to advance by competition, cooperation and discussion.

Conclusion

Piaget and his followers such as Garcia, DeCaprona, Strauss, Fetz, Wiser and Kälble successfully applied the cognitive-developmental approach to the study of the history of sciences. However, they did not sufficiently work out the depth and the scope of the similarities. Those similarities are not confined to the theories only but encompass moreover the psychological structures within mind and brain of the scientists themselves. This consideration enormously strengthens the relevance of the whole approach and defines its quintessence more precisely.

Piaget and his followers missed in linking the research regarding the history of sciences with the results of Piagetian cross-cultural psychology and its revolutionary notions regarding the non-development of the adolescent stage of formal operations in premodern peoples. The premodern scientists shared with their non-scientific contemporaries the same psychological stages and cognitive structures. Therefore, premodern scientists did not make systematic experiments to test theories and manifested magical and animistic ideas and all those further characteristics typical for stages below the formal operational stage. The sciences of the 17th century, however, manifested structures typical for the formal operational stage. The invention of “thing”, “causality” and “law”, the establishment of the mechanical worldview and the eradication of magic and animism reveal the establishment of the new psychological stage. At the same time the new disciplines created masses of knowledge and technologies never seen beforehand. Therefore, the evolution of this scientific knowledge has to be referred to the psychological stage advancements within the minds of the scientists themselves.

The new approach is superior to considerations made by Popper, Kuhn, Lakatos, Toulmin and Feyerabend, who tried to explain the rise of sciences in terms of changing methodologies or worldviews. It is also superior to simple supply-and-demand approaches or those, who only assume a rise of rationality without basing this on a developmental approach, as Bachelard or Cassirer had tried to.

More, it is necessary to reconstruct the whole history of humankind against the new theory, called structural-genetic theory programme. It is possible to reconstruct the history of law, politics, religion, morals, economy, literature, lore, etc. in terms of developmental psychology. It has been shown that the lower psychological stages explain the main structures of the domains mentioned during the premodern times, while the higher psychological stages explain their evolutionary modifications during the last centuries. Especially, it could be described that the rise of the modern, industrial society is explainable only in terms of developmental psychology, that is, as a manifestation of psychological development. Obviously, the modern sciences are a main causer to the emergence of the modern, industrial society. Moreover, the psychological advancement also concerns the rise of democracy, humanism, Enlightenment and economy, not only that of the sciences, as parts and causers of modern society (Oesterdiekhoff, 2011; 2000; 2013a; 2013b; 2014a; 2014b; 2014c; 2015a; Radding, 1985; LePan, 1989). Thus, the formal operational stage is the main reference point both to the rise of sciences and to the rise of the modern, industrial civilization.

Acknowledgement

The article was created without any funds.

Ethics

I am the only author of this article and alone responsible for the content.

References

Allier, R., 1929. The Mind of the Savage. 1st Edn., Harcourt, Brace and Company, London.

Aristotle, 1995. Philosophische Schriften. 1st Edn., Wissenschaftliche Buchgesellschaft, Darmstadt.

Brunschvicq, L., 1922. *L´éxperience humaine et la causalité physique*. 1st Edn., Alcan, Paris, pp: 625.

Bühler, C. and J. Bilz, 1977. *Das Märchen und die Phantasie des Kindes*. 1st Edn., Springer Verlag, Berlin, Germany.

Bühler, K., 1930. Mental Development of the Child. Harcourt, New York.

Campbell, J., 1960. The Masks of the God. 1st Edn., Penguin Books, New York.

Cassirer, E., 1920. Geschichte der Philosophie und Wissenschaft der neueren Zeit. 1st Edn., Bruno Cassirer, Berlin.

Cassirer, E., 1998. Philosophie der symbolischen Formen. Bd. 1: Die Sprache, Bd. 2: Das mythische Denken, Bd. 3: Phänomenologie der Erkenntnis. Wissenschaftliche Buchgesellschaft, Darmstadt.

Cohen, I.B., 1994. Revolutionen in der Naturwissenschaft. Suhrkamp, Frankfurt am Main, pp: 715.

Cole, M. and S. Scribner, 1974. Culture and Thought. John Wiley and Sons, New York.

Damerow, P., 1988. Individual Development and Cultural Evolution of Arithmetical Thinking. In: Ontogeny, Phylogeny and Historical Development, S. Strauss (Ed.), Ablex Publishing Corporation, Norwood, New Jersey, pp: 125-152.

Dasen, P. and J. Berry, 1974. Culture and Cognition. 1st Edn., Readings in Cross-Cultural Psychology. London.

Dasen, P., 1977. Piagetian Psychology*:* Cross-Cultural Contributions. 1st Edn., Gardner Press, New York.

De Caprona, D., 1983. History of Science and Psychogenesis. Genf.

DeGroot, J.J., 1910. The Religion of the Chinese. 1st Edn., The Macmillan Company, New York.

Descartes, R., 1980. Meditationen über die erste Philosophie. Reclam, Stuttgart.

de Solla Price, D.J., 1990. Philosophical Mechanism and Mechanical Philosophy. Annali dell´Istituto e Museo, 5: 75-85.

Diekmann, H., 1995. Die symbolische Sprache der Märchen. In: Märchenforschung und Tiefenpsychologie. Wilhelm L., (Ed.), Wissenschaftliche Buchgesellschaft, Darmstadt, pp: 442-470.

Dijksterhuis, E.J., 1952. Archimedes und seine Bedeutung für die Geschichte der Wissenschaft. 1st Edn., Schünemann, Bremen, pp: 76.

Dijksterhuis, E.J., 1956. Die Mechanisierung des Weltbildes. 1st Edn., Berlin.

Einstein, A. and L. Infeld, 1991. Die Evolution der Physik. Weltbild Verlag, München.

Elias, N., 1983. Engagement und Distanzierung. 1st Edn., Suhrkamp, Frankfurt am Main.

Elias, N., 1994. The Civilizing Process. Williston, Vermont.

Ellwanger, W., 1980. Die Zauberwelt unserer Kinder. 1st Edn., Herder Verlag, Freiburg.

Evans-Pritchard, E.E., 1937. Witchcraft, Oracles and Magic among the Azand*e*. 1st Edn., University Press, Oxford.

Everett, D., 2008. Don´t sleep, there are Snakes. Life and Language in the Amazonian Jungle. 1st Edn., Pantheon, New York.

Fetz, R.L., 1982. Naturdenken beim Kind und bei Aristoteles: Grundfragen einer genetischen Ontologie. Tijdschrift Voor Filosofie, 44: 473-512.

Flynn, J., 2007. What is Intelligence? 1st Edn., Cambridge University Press, Cambridge.

Frazer, J.G., 1994. The Collected Works of J.G. Frazer. 1st Edn., Richmond Press, London.

Gebelein, H., 2000. Alchemie. München.

Gloy, K., 1995. Das Verständnis der Natur: Die Geschichte des wissenschaftlichen Denkens. 1st Edn., C.H. Beck, München.

Gordon, R.B., 1988. Who turned the mechanical idea into mechanical reality? Technol. Culture, 29: 744-778.

Hacking, I., 1975. The Emergence of Probability. 1st Edn., University Press, Cambridge.

Hallpike, C.R., 1979. Foundations of Primitive Thought. 1st Edn., Clarendon Press, Oxford.

Hallpike, C.R., 2008. How We Got Here: From Bows and Arrows to the Space Age. 1st Edn., Author House, Bloomington, Indiana, pp: 624.

Hyde, K., 1990. Religion in Childhood and Adolescence. 1st Edn., Religious Education Press, Birmingham, Alabama.

Jacob, M.C., 1997. Scientific Culture and the Making of the Industrial West. 1st Edn., Oxford University Press, New York, pp: 269.

Jung, C.G., 1981. Psychologie und Alchemie. Walter Verlag, Olten/Freiburg.

Kälble, K., 1997. Die Entwicklung der Kausalität im Kulturvergleich. 1st Edn., Westdeutscher Verlag, Opladen.

Kieckhefer, R., 1995. Magie im Mittelalter. 1st Edn., Dt. Taschenbuch-Verlag, München, pp: 263.

Kiesewetter, C., 2005. Die Geheimwissenschaften. 1st Edn., Marix Verlag, Wiesbaden.

Koyré, A., 1998. Leonardo, Galilei, Pascal. Die Anfänge der neuzeitlichen Naturwissenschaft. Fischer, Frankfurt am Main.

Langer, J., 1988. A Note on the Comparative Psychology of Mental Development. In: Ontogeny, Phylogeny and Historical Development, Sidney Strauss (Ed.), Norwood, New Jersey, pp: 68-85.

LePan, D., 1989. The Cognitive Revolution in Western Culture. 1st Edn., The Macmillan Press, London.

Lévy-Bruhl, L., 1923. Primitive Mentality. The Macmillan Press, New York.

Lévy-Bruhl, L., 1983. Primitive Mythology. The University of Queensland Press, St. Lucia, New York, London.

Lévy-Bruhl, L., 1985. How Natives Think. University Press, Princeton.

Lewin, K., 1981. Der Übergang von der Aristotelischen zur Galileischen Denkweise in Biologie und Psychologie. In: Kurt-Lewin-Gesamtausgabe, von C.F. Graumann, (Ed.), Stuttgart, Klett, pp: 233-278.

Lindberg, D.C., 2000. Die Anfänge des abendländischen Wissens. 1st Edn., DTV, München.

Luck, G., 1990. Magie und andere Geheimlehren der Antike. 1st Edn., Kröner Verlag, Stuttgart.

Luria, A.R., 1982. Cognitive Development: Its Cultural and Social Foundations. 1st Edn., Harvard University Press, Boston.

McCloskey, J. and R. Kargon, 1988. The Meaning and Use of Historical Models in the Study of Intuitive Physics. In: Ontogeny, Phylogeny and Historical Development, Strauss, S. (Ed.), Norwood, New Jersey, pp: 49-67.

Meyenn, K.V., 1990. Lust an der Erkenntnis: Triumph und Krise der Mechanik: Ein Lesebuch zur Geschichte der Physik. 1st Edn., Piper, München.

Mogdil, S. and C. Mogdil, 1976. Piagetian Research. Vol. 1-8. London: INFR.

Needham, J., 1979. Wissenschaftlicher Universalismus: Über Bedeutung und Besonderheit der Chinesischen Wissenschaft. 1st Edn., Suhrkamp, Frankfurt am Main, pp: 411.

Nestle, W., 1975. Vom Mythos zum Logos. Darmstadt.

Oesterdiekhoff, G.W., 2000. Zivilisation und Strukturgenese: Norbert Elias und Jean Piaget im Vergleich. 1st Edn., Suhrkamp, Frankfurt am Main, pp: 406.

Oesterdiekhoff, G.W., 2009. Mental Growth of Humankind in History. 1st Edn., BoD – Books on Demand, Norderstedt, ISBN-10; 3837093182, pp: 456.

Oesterdiekhoff, G.W., 2011. The Steps of Man Towards Civilization. 1st Edn., BoD – Books on Demand, Norderstedt Books on Demand, ISBN-10: 3842342888, pp: 236.

Oesterdiekhoff, G.W., 2012a. Die geistige Entwicklung der Menschheit. Weilerswist Velbrück.

Oesterdiekhoff, G.W., 2012b. Was Premodern Man a Child? The Quintessence of the Psychometric and Developmental Approaches. Intelligence. A Multidisciplinary J., 40: 470-478.

Oesterdiekhoff, G.W., 2013a. Die Entwicklung der Menschheit von der Kindheitsphase zur Erwachsenenreife. 1st Edn., Springer-Verlag, Wiesbaden, pp: 626.

Oesterdiekhoff, G.W., 2013b. The Role of Piagetian Cross-Cultural Psychology to Humanities and Social Sciences. Am. J. Psychol., 126: 477-492.

Oesterdiekhoff, G.W., 2014. The Rise of Modern, Industrial Society. The Cognitive-Developmental Approach as Key to Disclose the most Fascinating Riddle in History. Mankind Qu., 54: 262-312.

Oesterdiekhoff, G.W., 2014b. The role of developmental psychology to understanding history, culture and social change. J. Soc. Sci., 10: 185-195.

Oesterdiekhoff, G.W., 2015a. Denkschrift Zur Gründung eines Max-Planck-Instituts für Human-Wissenschaften. 1st Edn., LIT Verlag Münster, Berlin, pp: 268.

Oesterdiekhoff, G.W., 2015b. The nature of premodern mind. Tylor, Frazer, Lévy-Bruhl, Evans-Pritchard, Piaget and Beyond. Anthropos, 110: 15-25.

Oesterdiekhoff, G.W., 2016a. Cognitive Modules or Evolutionary Stages? The Discussion about the Relationship between Developmental and Cross-Cultural Psychology. Human Evolution, 31: 69-83.

Oesterdiekhoff, G.W., 2016b. Is a Forgotten Subject Central to the Future Development of Sciences? Jean Piaget on the Interrelationship between Ontogeny and History. Personality Individual Differences, 98: 118-126.

Oesterdiekhoff, G.W., 2016c. Child and Ancient Man. How to Define their Commonalities and Differences. Am. J. Psychol., 129: 297-314.

Oesterdiekhoff, G.W., 2016d. Progress in mind and Consciousness: Psychological stage development and the history of philosophy. Eur. J. Philosophical Res., 6: 91-105.

Oesterdiekhoff, G.W., 2016e. Developmental psychology as answer to the question: Can the human disciplines achieve foundations comparable to biology in consequence of Darwin, or to physics in consequence of Newton and Einstein? Eur. J. Psychol. Stud., 8: 68-107.

Piaget, J. and B. Inhelder, 1969. The Psychology of the Child. 1st Edn., Basic Books, New York.

Piaget, J. and B. Inhelder, 1973. Die Entwicklung der elementaren logischen Strukturen. Düsseldorf: Schwann Verlag, Zwei Bände.

Piaget, J. and B. Inhelder, 1975. The Origin of the Idea of Chance in Children. W.W. Norton, New York.

Piaget, J. and B. Inhelder, 1958. The Growth of Logical Thinking from Childhood to Adolescence. 1st Edn., Psychology Press, New York, ISBN-10: 041521002X, pp: 356.

Piaget, J. and R. Garcia, 1989. Psychogenesis and the History of Sciences. Columbia University Press, New York.

Piaget, J., 1959a. Judgment and Reasoning in the Child. Littlefield, Adams and Co, New York.

Piaget, J., 1959b. The Child's Conception of the World. Littlefield, Adams, New York.

Piaget, J., 1967. Die historische Entwicklung und die Psychogenese des Impetusbegriffs. In: Piaget und die Folgen, Bd. 7 von Kindlers Lexikon der Psychologie des 20. Jahrhunderts, Steiner, R. (Ed), München Kindler, pp: 66-73.

Piaget, J., 1969. The Child's Conception of Physical Causality. 1st Edn., Adams and Co, Totowa, New Jersey Littlefied.

Piaget, J., 1974a. Die Bildung des Zeitbegriffs beim Kinde. Suhrkamp, Frankfurt am Main, pp: 396.

Piaget, J., 1974b. Need and Significance of Cross-Cultural Studies in Genetic Psychology. In: Culture and Cognition, Dasen, P. and J. Berry (Eds.), London, pp: 299-310.

Piaget, J., 1975. Gesammelte Werke. Ten volumes. Stuttgart, Germany: Klett Verlag (vol. 8-10: Original: Piaget, J. (1950): Introduction à l´épistémologie génétique. Vol. 1: La pensée mathématique, vol. 2: La pensée physique, vol. 3: La pensée biologique, la pensée psychologique, la pensée sociologique. Paris: Presses universitaires de France).

Piaget, J., 1976. The Grasp of Consciousness. Harvard University Press, Boston, Mass.

Piaget, J., 1980. Experiments in Contradiction. University of Chicago Press, Chicago.

Piaget, J., 1983. Sprechen und Denken des Kindes. Ullstein, Frankfurt.

Piaget, J., 1984. Die Psychologie der Intelligenz. Walter, Stuttgart.

Piaget, J., 1987. Possibility and Necessity. Two vols. University of Minnesota, Minneapolis.

Pichot, A., 1995. Die Geburt der Wissenschaft: Von den Babyloniern zu den frühen Griechen. 1st Edn., Wissenschaftliche Buchgesellschaft, Darmstadt.

Radding, C.M., 1985. A World Made by Man: Cognition and Society 400-1200. 1st Edn., University of North Carolina, Chapel Hill.

Raven, J., J.C. Raven and J.H. Court, 1993. Manual for Raven´s Progressive Matrices and Vocabulary Scales. Oxford Psychologists Press, Oxford.

Rosengren, K.S., C.N. Johnson and P.L. Harris, 2000. Imagining the Impossible. 1st Edn., Cambridge University Press, Cambridge, pp: 418.

Russell, B., 2004. Philosophie des Abendlandes. 1st Edn., Piper, München.

Russo, L., 2005. Die vergessene Revolution oder die Wiedergeburt des antiken Wissens. 1st Edn., Springer Verlag, Berlin.

Sawicki, D., 2003. Magie. 1st Edn., Fischer, Frankfurt am Main.

Schultze, F., 1900. Psychologie der Naturvölker. 1st Edn., Von Veit and Comp, Leipzig.

Scott, J.P., E. Fredericson and J.L. Fuller, 1951. Experimental Exploration of the Critical Period Hypothesis. Personality, 1: 162-183.

Seeck, G.A., 1975. Die Naturphilosophie des Aristoteles. 1st Edn., Wissenschaftliche Buchgesellschaft, Darmstadt, pp: 426.

Shapin, S., 1998. Die wissenschaftliche Revolution. Fischer Digital, Frankfurt am Main.

Störig, H.J., 2004. Kleine Weltgeschichte der Wissenschaft. Zwei Bände. 1st Edn., Parkland Verlag, Köln.

Strauss, S., 1988. Ontogeny, Phylogeny and Historical Development. 1st Edn., Ablex Publishing Corporation, Norwood, New Jersey.

Theiler, W., 1925. Zur Geschichte der teleologischen Naturbetrachtung bis auf Aristoteles. 1st Edn., Leipzig, Zürich, pp: 104.

Thomas, K., 1997. Religion and the Decline of Magic: Studies in Popular Beliefs in Sixteenth and Seventeenth-Century England. 1st Edn., Penguin Books Limited, London, pp: 880.

Thorndike, L., 1905/2003. The Place of Magic in the Intellectual History of Europe. 1st Edn., Forgotten Books, London.

Thorndike, L., 1923-1946. The History of Magic and Experimental Science in Europe. 6 vols. New York.

Tylor, E., 1871. Primitive Culture. 1st Edn., Harper and Row, New York, pp: 539.

Wenzel, U., 2013. Vom Ursprung zum Prozeß: Zur Rekonstruktion des Aristotelischen Kausalitätsverständnisses und seiner Wandlungen bis zur Neuzeit. 1st Edn., Springer-Verlag, pp: 261.

Werner, H., 1948. Comparative Psychology of Mental Development. 1st Edn., Follet, New York.

Wiser, M., 1988. The Differentiation of Heat and Temperature: History of Science and Novice-Expert Shift In: Ontogeny, Phylogeny and Historical Development, Strauss, S. (Ed.), Ablex Publishing Corporation, Norwood, New Jersey, pp: 28-48.

Zilsel, E., 1976. Die sozialen Ursprünge der neuzeitlichen Naturwissenschaften. 1st Edn., Suhrkamp, Frankfurt am Main.