

# The Emergence of Complexity Thinking and Its Influence on Educational Research

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*Abstract: The fast-paced and ever-changing modern world is witnessing the onset of a novel era of teaching methods, which often combine elements of traditional approaches such as reductionism and holism while providing prospects for fresh discourse, ideas, and outlooks. This paper aims to explain how perspectives on how education is understood have changed throughout time until complexity thinking emerged in more recent decades (Jacobson & Wilensky, 2022; Morin, 1992, 2011). In pursuit of this goal, the main characteristics of reductionism, holism, and systemic thinking are discussed, as well as how such transformations in perspectives have influenced the emergence of complexity thinking. As explained by Davis et al. (2015), complexity thinking started to spread among educational researchers not as a way of superimposing previous theories, but to present new points of view and possibilities instead. Complexity thinking in education is innovative as it goes against previous beliefs that learning occurs in linear ways, meaning that it recognizes and deals with conflict, uncertainty, and disharmony in learning processes. According to Jacobson and Wilensky (2022), educational researchers should continue to explore innovative pedagogies and technologies that embrace complexity, bringing crucial contributions to theories of teaching and learning.*

*Keywords: Complex Systems; Complexity Thinking; Educational Research.*

## Introduction

The fast-paced and ever-changing modern world is witnessing the onset of a novel era of teaching methods, which often combine elements of traditional approaches such as reductionism and holism while providing prospects for fresh discourse and outlooks, questioning the applicability of prevailing learning theories. This context allowed for complexity thinking to start spreading among educational researchers in more recent decades - not as a way of superimposing previous theories, but in order to present new perspectives and possibilities (Davis et al., 2015). Complexity thinking in education is innovative as it presents a transdisciplinary approach and goes against previous beliefs that learning occurs in linear ways, meaning that it recognizes and deals with contradiction, uncertainty, and disharmony in learning processes (Montuori, 2008). Additionally, it refuses the compartmentalization of knowledge, such as its division into separate and independent disciplines or subjects that leads to explanations of events disregarding their interdependency (Montuori, 2008). In short, complexity thinking in educational research suggests understanding education as a complex system that is irreducible, unpredictable, contextual, adaptative, and multifaceted (Davis et al., 2015).

Based on the readings of several scientific papers published by Jacobson (2020) and partners (Jacobson et al., 2019; Jacobson & Wilensky, 2022; Jacobson & Wilensky, 2006), as well as other authors relevant to the topic (Davis et al., 2015; Morin, 1992, 2011; Pereira et al., 2022; Uhl-Bien et al., 2007), similarities between their ideas on complexity thinking in education were identified. The argument of these authors is for educational researchers to increasingly consider education as a complex system and make use of the concepts and methods linked to this understanding. Davis et al. (2015) defined complex system as a system that learns and that is self-organized. Schuelka and Engsig (2019) added that “complex systems are open and nested, meaning that there is little to no boundary between elements and surroundings, between inputs and outputs, and elements within the system are complex systems within complex systems ever unfolding like a fractal” (p. 452). Jacobson and Wilensky (2022) argued that interpreting educational phenomena through complex systems’ lenses “has the potential to open new intellectual horizons, explanatory frameworks, and methodologies that are increasingly important in scientific and professional environments” (p. 505).

In order to explain complexity thinking, it is useful to provide some contextualization of its emergence to understand what it is based on and how it differs from previous approaches and brings innovative ideas to education. Therefore, this paper invites readers to travel back in time and examine the roots of complexity thinking, its links to educational research, and the relevance of these discussions to the contemporary educational scenario. That said, the following sections aim to provide a historical perspective and thorough examination of different approaches that have influenced educational theories, practices, and research. Reductionism, holism, and systemic thinking are discussed, as well as how such transformations in perspectives have affected the emergence of complexity thinking.

## **Brief Overview of the Historical Changes in Perspectives in Education**

For many centuries, the reductionist and dualistic understanding of human beings prevailed, influencing the sciences and knowledge of Western society, as argued by Soligo (2018). The reason/emotion, body/mind, and affection/cognition dichotomies are a few examples that made it difficult to understand individuals comprehensively (Soligo, 2018). Furthermore, it is notable that reason and cognition were historically privileged to the detriment of emotion and affectivity (Nogueira, 2016).

It was from Hegel, Marx, and Engels's ideas that dialectical and historical materialism emerged, affirming that subject and cultural objects interacted and continuously transformed each other (Tassoni, 2008). Marx's theory stated that "historical changes in society and material life produce changes in 'human nature' (consciousness and behaviour)" (Cole & Scribner, 2007, p. 10). According to dialectical and historical materialism, culture is a fundamental element for the constitution of a person, their conscience, and their development. The context, therefore, plays an active role in human psychological development and the person is not passive in this process. Instead, the person has active and vigorous participation in their own development (John-Steiner & Souberman, 2007).

This new way of understanding a person encompasses aspects of their culture, social, and historical conditions and, thus, makes it possible for psychology to find alternatives for the study of subjects in terms of the organization and functioning of the mind. Supported by Marxist ideas, sociocultural psychology emerged at the beginning of the 20<sup>th</sup> century, suggesting that any psychological phenomenon develops over time and reflects the social, economic, and cultural condition of a person (Bock, 2007). Davis et al. (2015) added that it was towards the second half of the 20<sup>th</sup> century that other significant changes started to be noticed concerning educational approaches, including a shift from mechanistic approaches of teaching and curriculum to more holistic and exploratory conceptions of learning.

It is important to highlight that one of the main representatives of sociocultural psychology who had central participation in the mentioned changes was Vygotsky (1896-1934). Vygotsky (2007) argued that tools were fundamental in the relationships between humans and nature/environment because it was by using tools that humans transformed both the environment and themselves, as a consequence of a dialectical relationship of constant interaction and mutual influence. Vygotsky (2007) argued that, in addition to the genetic aspects, biological conditions, and culture in which an individual is inserted, their subjectivity is highly important and responsible for bringing meaning to all lived experiences. Another important contribution of Vygotsky to understanding how learning occurs was the introduction of the concept of Zone of Proximal Development (ZPD), which takes into account the person's previous knowledge in the process of building new knowledge (Vygotsky, 2007). It concerns both learning in general as well as the acquisition of academic or school knowledge. These ideas were innovative and influenced the research and practice of both psychology and education.

### ***Holism***

Vygotsky went against the tendency of treating the parts separated from the whole and proposed a unifying and developmental understanding of phenomena. In other words, his ideas suggested the abandonment of the fragmentation of individuals – as in the reason/emotion, cognition/affection dichotomies – in favour of a holistic understanding of phenomena. Vygotsky believed that all human dimensions were inseparable (Almeida, 2007). This understanding of human beings and their development that does not focus on the parts and emphasizes the whole context instead is called holism (Nogueira, 2016).

Vygotsky believed that it is necessary to investigate the individual story of each person so that it is possible to build an in-depth understanding of their development (Oliveira & Rego, 2003). In saying that, Vygotsky acknowledged the existence of the parts (or single elements that contribute to a phenomenon) but disagreed that they existed in isolation (Nogueira, 2016). For example, it would not be possible to work on a person's cognitive development without the incorporation of the emotions felt throughout the process (Leite, 2018). Vygotsky suggested that all parts (or aspects of a person and their life) are equally important in the process of human development and, more than that, they are inseparable (Leite, 2018).

Vygotsky recognizes the importance of the individual (part) within a given society (whole). However, while acknowledging the existence and pertinence of single parts that contribute to a phenomenon, his theory prioritizes the context (whole). In that sense, Morin (1992), a renowned French sociologist and philosopher with important contributions to discussions on complexity thinking, stated that both holism and reductionism rely on the same principle of simplification despite presenting themselves as opposites to one another. According to Morin (1992), “holism is a partial, one-dimensional, and simplifying vision of the whole. It reduces all other system-related ideas to the idea of totality, whereas it should be a question of confluence” (p. 373). In addition, another similarity between reductionism and holism that is subject to question is the understanding that both development and learning happen in linear ways. While in some cases it tends to make sense to learn an easier task first and a more difficult one later, this linearity does not apply to certain situations. One example is when a child learns to walk without having crawled first. While crawling is a typical developmental milestone that many children go through, it is not a necessary precursor to walking. However, the ‘linear manual’ of how to walk associated with both reductionist and holistic approaches would assume that one way of learning it is ideal and expected (the one that crawling comes first) and the other way is abnormal, or even incorrect.

### *Systemic Thinking*

Systemic thinking was introduced in the 20<sup>th</sup> century based on the assumption that formal schooling discussions up to that moment had been too narrow (Davis et al., 2015). Teaching started “to be seen in terms of helping to develop an awareness of self, others, humanity, and the more-than-human world” (Davis et al., 2015, p. 4). This moment brought embryonic discourses that would be incorporated into complexity thinking later, which will be further discussed in the next section of this paper. However, at that point, systemic thinking was still linked to similar ideas as those of holism, as explained by Mariotti (2005):

Systemic thinking takes into account only harmony, the functional synthesis contained in the whole. But it does not consider that this synthesis takes place at the expense of repressions and antagonisms. A system is not just harmony. Systemic harmony rests on conflict and disharmony, which are also part of the system and remain latent in it. (p. 3)

Since the emergence of holism and systemic thinking, discussions and approaches in education did not witness much innovation up until recently. On the other hand, the world itself has experienced huge transformations in the last decades, especially with the creation and growth of the internet and all digital technologies that followed it. Markauskaite et al. (2022), Siemens (2004), and Silva (2013) mentioned that these technologies have enabled new ways for people to connect, communicate, interact, produce, think, and learn. These developments have brought about the need to reassess our points of view and seek new routes to better understand the current reality as well as the subjects that are both its products and producers. It is in this context that complexity thinking emerged.

### *Complexity Thinking*

A historical analysis of approaches that have influenced educational practice, theories, and research throughout the decades allows the identification of the transition from reductionism to holistic and systemic thinking to the emergence of complexity thinking. Generally, the need for new explanations arises when the existing explanations of phenomena no longer suffice to provide a satisfactory understanding. Complexity thinking emerged based on criticisms addressed to both linear and systemic perspectives when it comes to their inability to deal with randomness, disorder, uncertainty, and conflict, which exist and are inevitable in any living system or organization (Mariotti, 2005, p. 5). Mariotti (2005) explains that linear and systemic approaches isolate the part from the whole and prioritize one of them. Likewise, order, harmony of systems, and generalizations are characteristics of those approaches. On the other hand, complexity thinking encourages the integration of the parts and the whole and deals with conflicts and disharmony of the systems. It focuses on uncertainties and is opposed to generalizations or simplifications. When writing about Morin’s contributions to the complexity thinking, Montuori (2008) argued that:

Our present way of thinking, feeling, and being [...] is deeply problematic: it reduces, separates, and opposes. Morin points us beyond this way of thinking and toward a paradigm of complexity: toward

a way of thinking and being that does not mutilate life, but allows us to live it more fully by being more present to the complexities, paradoxes, tragedies, joys, failures, and successes. He points us toward a way of thinking that is not disembodied and abstract, but rich in feeling, intuition, and connection to the larger social and historical context. A thought that is holographic and contextual, showing us how we are embedded in time and space. But a thought that is also transformative, self-eco-re-organizing, by including all of who we are and indeed stretching our understanding of who we are and pointing us toward new possibilities. (p. 24)

It is relevant to mention that complexity thinking does not oppose linear (reductionist) and systemic (holistic) approaches but rather, represents complementarity and transactionality between them (Morin, 2011). Contrary to previous understandings, complexity thinking suggests that the whole or context is both inferior and superior to the parts or single elements that contribute to a phenomenon. To better understand this idea, one example is the so-called principle of *emergence*, which sees the whole as superior to the parts (Nogueira, 2016). Jacobson and Wilensky (2022) clarified that the term emergence is used “to describe how large-scale patterns arise from the multiple interactions of individuals, and these resultant patterns are called emergent phenomena” (p. 504). One way to explain this is by looking at a rug with a specific design. Despite being composed of several threads (parts), the final result of the addition of the parts overcomes the individual characteristics of each thread. Thus, it is not just about adding the threads randomly. The whole (rug) is more than the mere sum of the threads and contains elements that would be lost if the parts were dissociated. In Morin’s (2011) words,

it is necessary to replace a thought that isolates with a thought that distinguishes and unites. It is necessary to replace a disjunctive and reductive thinking with a thinking of the complex, in the original sense of the term *complexus*: what is woven together. (p. 89)

However, in other situations, the whole is inferior to the parts. To understand this, there is the example of a situation in which a group of people/students get together to discuss and find a solution to a certain problem. Each one brings their ideas and discusses alternatives, but at the same time, they leave aside countless aspects of their individuality, several of their characteristics and abilities that are particular to each one but apparently irrelevant to the task they perform together. In this case, the whole (group) is not capable of including the totality of the parts. The potential of each part is not fully explored; that is, many of their abilities and characteristics are virtualized. Mariotti (2005) names this as the *imposition* principle and explains that this virtualization and/or repression is necessary because if all the potentialities emerged in that situation, it would harm the functioning of that group. Thus, complexity thinking rejects that the parts are more important than the whole as advocated by reductionism just as it rejects that the whole is more important than the parts as suggested by holism.

Understanding an educational phenomenon as a complex system and interpreting it through a complexity thinking perspective means understanding it as a dynamic system. This perspective recognizes the presence of both emergence and imposition in a circular manner, with alternating predominance, revealing that the whole is at the same time greater and smaller than the addition of the parts (Morin, 2011). For Morin (2011), the mutilation of multidimensional phenomena obstructs the understanding that knowledge of the parts depends on knowledge of the whole and vice versa. Dichotomous and holistic thinking insist on the same mistake of seeking certainty and denying doubts, conflicts, non-linearity and the unpredictable complexity of phenomena.

To further illustrate the differences between complexity thinking and previous approaches, Table 1 was designed to include key ideas of the main educational perspectives addressed in this paper in a succinct and chronological way:

**Table 1**

*Different Perspectives in Education*

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<b>Reductionism</b>	Consolidated by Descartes; concerns the division of the whole into parts and the study of the parts as independent. Reductionism is related to linear thinking and the fragmentation of knowledge.
<b>Holism</b>	Appears after reductionism and presents itself as an opposition to it for prioritizing the whole, without dividing it into parts. Holism prioritizes the social aspects in human development, understanding that the whole overcomes the parts. Linear thinking is also present in this approach. A key representative of holism in education is Vygotsky.
<b>Systemic thinking</b>	Introduced in 1940 by Ludwig Von Bertalanffy, it presents holistic understanding of human development and linear learning structure. This approach considers the interconnectedness and interdependence of multiple components of the educational system and learning processes.
<b>Complexity thinking</b>	A more recent approach that understands learning processes as unpredictable and non-linear. Complexity thinking suggests that education is a complex adaptive system, where the behaviour and outcomes of the system emerge from the interactions of multiple components (a complex web). The key authors in this paper to understand this concept are Davis, Morin, and Jacobson.

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### **Complexity Thinking and Educational Research**

Educational methods and approaches that involve breaking down complex concepts into smaller pieces to aid learning or explain a situation have shown limited evidence that they are effective in developing critical thinking and contributing to a deeper and more comprehensive understanding of a topic or phenomenon (Zhao, 2022). To address this issue, Sawyer (2022) suggested that educational researchers embrace the multidimensions of phenomena and understand that knowledge must be contextualized and generated collaboratively. Different epistemologies are welcome in this scientific practice that is based on experimentation, trial and error, hypothesis testing, debate, and argumentation for a broader comprehension of what is being studied. This new moment allows the accommodation of new methodologies and approaches, and it is in this context that complexity thinking gains strength in educational research.

By embracing complexity thinking and looking at education as a complex system, educational researchers have the opportunity to investigate and explain educational phenomena in alternative ways with the potential to bring unprecedented contributions to both educational theory and practice. Complexity thinking is associated with the *ecosystemic* theoretical-epistemological perspective. Sutton (2022) clarified that the ecosystemic principle is similar to a web, meaning that “all aspects of our world are interdependent and are constantly impacting one another” (p. 5). That said, complexity thinking proposes that reality is a global, participatory, integrated, interactive, and complex unit. Research that is based on complexity thinking requires broad and deep understanding of the object studied, emphasizes the multidimensionality of phenomena, and values subjective aspects.

When looking at how knowledge is constructed, both sociocultural theory and complexity thinking recognize the existence of two fundamental dimensions: the social and the individual. Moraes and Valente (2008) stated that “all knowledge is always an individual and social construction that takes place in consensual spaces represented by a scientific community” (p. 25). Moraes and Valente (2008) explained that feelings, emotions, intuition, beliefs, desires, and imagination act inseparably from cognition in the processes of knowledge construction. This means that every mental operation can be seen as a complex system where both subjectivation and objectification are observed. Nevertheless, educational research informed by complexity thinking recognizes the significance of considering both the whole and the parts. It acknowledges that the relevance of each (the whole and the part) may vary depending on the circumstances, as suggested by the principles of emergence and imposition.

According to Jacobson and Wilensky (2022), educational researchers should continue to explore innovative pedagogies and technologies that are aligned with students’ realities and that can help them learn about complex system ideas and methods, bringing crucial contributions to theories of teaching and learning.

In terms of its methodological approaches, contemporary research that looks at an educational phenomenon as a complex system often incorporates computational techniques to identify “the ‘objective’ and ‘observable’ global structures and functions emerging in unpredictable dynamic ‘complex adaptive systems’ of the physical, biological and social, by means of the local interaction of its components” (Malaiana, 2015, p. 2). Malaiana (2015) explained that computer modelling and visualization approaches for studying educational complex systems are based on cellular automata (CA) or multi-agent simulation (MAS). One of the advantages associated with CA and MAS is that “the structures and functions of the systems overcome the human computing capabilities and emerge as ‘surprising’ or ‘counterintuitive’ computational outcomes” (Malaiana, 2015, p. 2). Although it is not the purpose of this paper to dive deep into the details of existing computational models to study complex systems, this discussion helps to underline the emerging ways of researching in education that facilitate the investigation of the small details of a learning environment – including the multiple aspects pertaining to its participants – to understand how they contribute to promoting effective learning. Jacobson and Wilensky (2022) argued that there is great potential for computational modelling to bring innovative and significant contributions to educational research. The authors inferred that it could enhance teaching and learning, in addition to contributing to theory review and development, possibly leading to policy initiatives (Jacobson & Wilensky, 2022).

Overall, complexity thinking provides a valuable lens for educational researchers to gain a more comprehensive understanding of educational phenomena, uncover unexpected outcomes, and contribute to the development of innovative ideas and approaches. It allows researchers to examine the multiple dimensions of phenomena, including their social, cultural, and cognitive aspects in addition to external or environmental ones. Complexity thinking recognizes that the behaviour of a system is not always predictable or linear and that subtle changes in one part of the system can have significant effects on other parts. As a result, researchers are prompted to look beyond simple cause-and-effect relationships. They are encouraged to examine the interactions between different parts of the system, which can be achieved with or without the support of computational modelling and other technologies. In doing so, researchers can identify patterns and relationships that may not have been visible before, leading to new insights into how educational systems work as well as new approaches to teaching and learning.

## Conclusion

The emergence of complexity thinking and its incorporation into educational research was driven by criticisms of the limitations of reductionist, holistic, and systemic perspectives, particularly in relation to their inability to deal with randomness, disorder, uncertainty, and conflict, which are present in any living system. Complexity thinking encourages the integration of the parts and the whole and deals with conflicts and disharmony within complex systems. It also rejects generalizations or simplifications, which indicates important differences from previous approaches. Complexity thinking suggests that any educational phenomenon should be seen as a complex system that is irreducible, unpredictable, contextual, adaptive, and multifaceted. This approach recognizes the dynamic nature of systems and the interconnectedness of their elements and focuses on understanding how these systems interact and adapt to changing circumstances.

The contributions of complexity thinking to educational research do not deny those of previous approaches such as reductionism, holism, and systemic thinking. Instead, it embraces and transcends their ideas. Educational research that adopts a complexity thinking perspective requires a new way of thinking that is holographic, contextual, and transformative. It highlights the complexities, paradoxes, antagonisms, and subjective aspects of the different elements and emergent behaviours of a system.

This paper does not aim to provide an exhaustive review of the topics presented, but rather, to promote reflections that are relevant to the improvement of current educational practices and research. The ideas presented above imply that embracing complexity thinking in educational research leads to the emergence of novel outlooks and methodologies, which can ultimately facilitate the development of existing theories on education and the practices associated with teaching and learning, as well as the creation of new ones.

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