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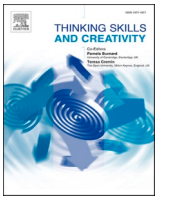

A conceptual proposal and operational definitions of the cognitive processes of complex thinking

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ABSTRACT

In the last decade studies on the notion of complex thinking have proliferated and there are several authors who propose the need of promoting it through educational systems; However, there is a lack of operational conceptualization allowing the development of instruments, tasks or evaluation systems for observation or measurement, especially from the conceptual perspectives developed by Edgar Morin and Mathew Lipman, considered the most relevant and referenced notions in the educational field. In this sense, this study aims to develop a conceptual model with the operational definitions of skills and/or cognitive processes of complex thinking. To accomplish this, the main proposed conceptualizations and the approach to their processes from the cognitive sciences were reviewed. Therefore, a new conceptualization for complex thinking is proposed through a process of synthesis and conjugation of different conceptual perspectives.

1. Introduction

There are multiple studies regarding the educational context which propose the need to develop complex thinking at all levels of training, from basic or primary through university education (Álvarez, Pérez, & Lara, 2019; Bustamante, Ayllón, & Escanés, 2018; Colina, 2020; Degener & Berner, 2017; Estrada, 2018; Gomero, 2019; Servín, 2020; Viguri, 2019; Yang, 2018). One of the most frequent argument suggests that science in the midst of its rationalization must understand that there are elements that cannot be isolated, reduced, simplified, but rather understood as systems that interact with each other and with the environment. This requires transforming education from a less reductive, less fragmented way of thinking to one that is more flexible, more critical, more creative, more humane and, at the same time, complementary (Martínez & Vicuña, 2017; Roger & Regalado, 2018). Nevertheless, there is no system or instruments that enable the evaluation of complex thought from the conceptual perspectives proposed by Edgar Morin (1990; 1999) and/or Mathew Lipman (1997), who have developed the most important definitions in this regard.

To have an evaluation system which allows the analysis of higher order cognitive aspects, such as complex thinking, can be extremely useful for any educational system. Particularly if we consider that evaluation systems determine the practices in the teaching-learning processes (Dziob, Kwiatkowski, & Sokolowska, 2018; López-Pastor & Sonlleva, 2019; Otero-Saborido & Vázquez-Ramos, 2019; Subheesh & Sethy, 2020). In this context, the present study aims to elaborate a conceptual model with the operational definitions of the cognitive processes of complex thinking, which would serve for the further design and development of instruments, tasks or an assessment system that allows the observation and/or measurement of complex thinking skills in university

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students. Specifically, it would be used for a subsequent empirical study that would involve the application of an assessment system to characterize complex thinking skills in undergraduate Arts students and also to be able to compare those skills with students from other careers. To this end, this article was structured by considering: the conceptualization of complex thinking from a review of the main notions proposed; an approach to the cognitive processes of complex thinking from the cognitive sciences; and the proposal of a conceptual model with the operational definitions of the processes or cognitive abilities of complex thinking.

1.1. Complex thinking conceptualization

The notion of complex thinking was coined by Morin (1990) and refers to the ability of thought to pursue multidimensional knowledge, which integrates the simplifying modes of cognition and rejects reductionist, unidimensional and blinding consequences. It is the process of thought that allows us to face complexity understood as the union between unity and multiplicity (Unitas Multiplex), this implies that we cannot understand the whole (or the multiple) without knowing the parts (or the unity) and neither can we know the parts without knowing the whole, since every phenomenon is circumscribed in an interdependent, interactive and inter-retroactive fabric between the object of knowledge and its context. Likewise, all knowledge is part of a system and, simultaneously, each system interacts or is interrelated to other systems. It also entails the recognition of the principle of incompleteness and uncertainty. Recognizing a reality that is: conflictive/harmonic; peaceful/aggressive; fair/unfair; equitable/inequitable, i.e., that carries within it the contradiction, the dialectic; the dialogic, understood as a means of dialectic-conflictive communication between different forms.

Lipman (1997) suggests that understanding complexity requires a type of thinking that integrates algorithmic and heuristic thinking, as well as procedural thinking with the noun. The heuristic thinking would allow to reformulate complex problems and to simplify them for their easy resolution; the one that, in turn, can be submitted to a more precise, ordered and logical procedure, from the tools used by the algorithmic thinking, "they can be useful as error mechanisms reducers, because if they are used correctly they can produce justifiable conclusions"(p.65). For Lipman heuristics is linked to creative thinking and the algorithmic to critical thinking. On the other hand, procedural thinking is methodological and it would have reduced content; and substantive thinking is related to content and it would have limited method.

Following this line, Lipman (1997) proposes a model (see Fig. 1) that serves as a guiding axis, as it allows us to approach the cognitive processes that underlie complex thinking. This model presents more cognitive characteristics than other conceptualizations developed by other authors. It is circumscribed to the reasoning theories proposed by Sternberg: According to Lipman, complex thinking is higher order thinking and takes as reference the concept of “higher order thinking” proposed by Resnick (1987); In turn, Resnick takes as a reference the theory of components of human intelligence suggested by Sternberg (1980), Sternberg and Gardner (1983) The componential theory, in turn, is situated within the theory of analogical reasoning and the unified theory of reasoning proposed by Sternberg himself (1986).

For Lipman, complex thinking emerges from the fusion between critical and creative thinking. He argues that "there is no such thing as totally pure critical or creative thinking; it is precisely higher-order thinking that leads to criticism and creativity" (p.222). There is no creative thinking that does not have critical judgments, just as there is no critical thinking sidelined from creative judgments. Complex thinking is based on both rationality and creativity. It combines the declarative with the procedural. It produces multiple solutions. In contrast to lower-order thinking, complex (higher-order) thinking is not reduced to the algorithmic; it is expansive, it requires tolerance of uncertainty, it is self-critical, and, synchronously coordinates various problem-solving skills. It is multiple and dialogical. It implies the use of multiple criteria, meta-criteria or mega-criteria and the self-regulation of the thinking process (metacognition).

When comparing Morin and Lipman proposed notions on complex thinking, some parallels or convergences can be distinguished:

> Among the main convergent aspects are thoughts that: overcome a simple, reductive and fragmentary thought; explore the logical, multilogical and dialogical possibilities; recognize uncertainty and ambiguity; imply approaching knowledge from

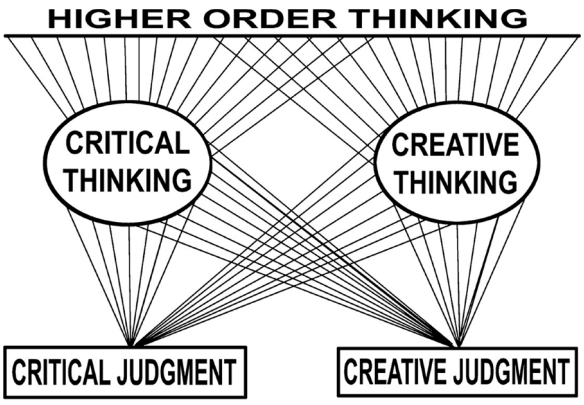

Fig. 1. Complex thinking or higher order thinking scheme.
Source: Lipman (1997)

> multidimensional aspects; utilize interdisciplinary, multidisciplinary or transdisciplinary methods; and examine in a critical or self-critical way their own procedures and methodologies, self-regulating their thought processes (metacognition). (Silva, 2020, p.251)

According to Lipman, metacognition would play a key role in the cognitive processes of complex thinking.

> Complex thinking is one that is aware of its own assumptions and implications, as well as the reasons and the evidence on which its conclusions are based. Complex thinking examines its methodology, its procedures, its own perspective and point of view. Complex thinking is ready to identify the factors that lead to bias, prejudice, and self-deception. It involves thinking about the procedures themselves in the same way that it involves thinking about the subject. (Lipman, 1997, p.67).

What we call complex thinking here includes resource-rich, metacognitive, self-correcting thinking and all those modes of thinking that involve reflection on the methodology itself and on the content they deal with (Lipman, 1997, p.68).

Given to these metacognitive features, it has been postulated that complex thinking is circumscribed in a higher level of competences, locating it as a metacompetence (Silva, 2020). Moreover, Tarricone (2011) sets the relationship between metacognition, critical thinking and complex thinking. She argues that metacognition would be based on critical thinking since it would involve the monitoring and control of inferences through reasoning, knowledge, and regulation of cognition, which is at a higher level of reflection. Under this perspective, intentional critical thinking would turn into complex thinking.

> Metacognition relies on critical thinking which involves monitoring and the control of inferences through reasoning, and knowledge of cognition and regulation of cognition. It is important to note that critical thinking may not always be metacognitive; to be metacognitive, it must be purposeful and deliberate re¯ection. Both metacognition and critical thinking rely upon an internal dialectic for the critiquing of prior knowledge and the understanding of new knowledge. Internal dialectic or internal verbalisation is stimulated in collaborative situations where beliefs, judgments, prior knowledge and understandings, and the interpretation of new information are challenged and supported. This occurs in complex problem solving and relies upon a higher level of re¯ection which brings into play advanced understanding of self. This purposeful, critical thinking becomes complex thinking, or higherorder thinking, which involves a focus on awareness of issues such as selfdeception, bias and prejudice which can affect problem solving. Higherorder thinking is a combination of critical and creative thinking and is considered to be complex thinking. (Tarricone, 2011, p.42)

1.2. The cognitive processes of complex thinking from cognitive sciences

The aforementioned suggests that there are three main cognitive processes involved in complex thinking: critical thinking, creative thinking, and metacognition. The complementarity and interdependence of these cognitive processes would make complex thinking possible. An evidence that could support this idea comes from the cognitive sciences. A relationship between creative or divergent thinking and metacognition has been found metacognition (Ellamil, Dobson, Beeman, & Christoff, 2012; Fox & Christoff, 2014; Preiss, Ibaceta, Ortiz, Carvacho, & Grau, 2019; Sanz de Acedo Lizarraga & Sanz de Acedo Baquedano, 2013; Van de Kamp, Admiraal, van Drie, & Rijlaarsdam, 2015). Preiss et al. (2019) claim that metacognition predicts creativity. Zhang, Bohemia, and McCardle (2019) postulate that people with a high level of metacognition are able to solve problems more creatively. Fox and Christoff (2014) propose that creative evaluation depends on metacognition, since the optimal creative process would rely on metacognitive evaluation. Furthermore, they argue that the default network, which is considered a traditional metacognitive brain region, is also involved in creative processes and divergent thinking. They refer to a study where a simultaneous recruitment of metacognitive brain and network regions in predetermined mode was found during the creative assessment process: "Three metacognitive regions—RLPFC, RMPFC, and the anterior insula—were specifically identified as being part of metacognitive creative evaluation" (p.304). Other research indicates that the frontal regions of the cerebral cortex (frontal cortex or frontal lobes) play an important role in metacognition (Allen et al., 2017; Fleming, Huijgen, & Dolan, 2012; Hulbig, 2020). Imaging studies have identified that the prefrontal cortex (PFC) is specifically involved in metacognitive aspects such as self-regulation, judgment, planning, and conscious behavior (Hulbig, 2020).

This is connected to the findings of Beaty et al. (2018; 2020), who argue that the Default mode network interferes with the processes of divergent thinking and creative thinking alongside the Salience and Executive Control networks. It also links to another study where they found that creativity involves the left dorsolateral prefrontal cortex (DLPFC) and the right lower frontal gyrus (IFG) (Chen, Beaty, & Qiu, 2020). Beaty et al. (2018) postulate that in high creativity there is a dynamic coupling between these three neural networks (default, salience and executive), suggesting that this coupling may be a reliable neural marker and predictor of creative ability.

> Specifically, we found that the regions showing the greatest number of significantly correlated functional connections corresponded to the hubs of three largescale brain networks: default (posterior cingulate cortex), executive (right dorsolateral prefrontal cortex), and salience (left anterior insula). These regions showed increased functional connectivity in a recent fMRI study of divergent thinking (Beaty et al., 2018, p.1090).

Default network activity is associated with spontaneous and self-generated thinking, mental wandering, mental simulation, social cognition, autobiographical retrieval, and episodic future thinking. The salience network works to identify candidate ideas (potentially useful information generated through the default network). The executive network comprises the lateral and anteroinferior prefrontal parietal regions, and it associated with cognitive processes that require externally directed attention, working memory, and high-order processing, such as the evaluation, elaboration, or revision of ideas (Beaty, Benedek, Silvia, & Schacter, 2016). The coupling of these neural networks is a relevant finding because it is an unusual feature, as these networks usually work separately; generally, the default network is activated when the brain is at rest, rambling or imagining and is deactivated in a state of cognitive attention and/or when

the executive system is activated (Beaty et al., 2018).

These findings are consistent with other studies that have established relationships between: critical and creative thinking; critical thinking and metacognition; creative thinking and metacognition. Regarding the relationship between critical and creative thinking, some studies propose a complementary relationship between these two types of thoughts (Silva, 2019), other authors found that there is a significant correlation between critical and creative thinking skills measured in both adolescent students and adults (Fatmawati, Zubaidah, Mahanal, & Sutopo, 2019; Saremi & Bahdori, 2015; Sıburıan, Corebıma, & Saptasarı, 2019). Through structural equation models, Tsai (2019) found that the relationship between critical thinking and creative thinking in Chinese university students was positive and strong (r = .77).

Several studies have established significant and/or strong correlations between critical thinking and metacognition (Barzegarbafrouee, Farzin, & Zare, 2019; Amin, Corebima, Zubaidah, & Mahanal, 2020; Arslan, 2018; Correa, Ossa, & Sanhueza, 2019; Lukitasari, Hasan, & Murtafiah, 2019). Lukitasari et al. (2019) found a mean value (r) of 0.904, which means a strong correlation of critical thinking and metacognition skills. Amin et al. (2020) postulate that metacognitive skills have an 81.81 % contribution towards critical thinking abilities. Ku and Ho (2010) examined critical thinking processes in students and concluded that high achievers were characterized by the use of metacognitive strategies. Additionally, they demonstrated the importance of metacognitive knowledge regarding the effective regulation of critical thinking skills. Through structural equation models Arslan (2018) showed that metacognition was positively predicted by critical thinking. Miharja, Hindun, and Fauzi (2019) found that critical thinking and metacognitive skills have a strong correlation between them and with cognitive learning success, suggesting that these skills play an important role in predicting cognitive learning achievement.

Regarding the relationship between creative thinking and metacognition, there are studies that establish a strong correlation between creative thinking and metacognition, such as the study carried out by Suratno, Komaria, Yushardi, Dafik, and Wicaksono (2019) that found a correlation value of 0.873 between these skills. Chua and Kok (2017) found that individuals with high metacognition had a high degree of creativity. Jia, Li, and Cao (2019) found that people with an incremental creative mindset showed better performance in metacognitive monitoring of selection and assessment strategies than people with a significant creative mindset. The work of these authors is also important because it suggests an interaction between some creative thinking processes and metacognition. Pitts, Anderson, and Haney (2018) discovered that meta-cognition would moderate the ideation-production relationship in creativity. Kusuma, Kartono, and Zaenuri (2018) found that subjects with high metacognition showed high indicators in creative thinking skills, fluency, flexibility and elaboration.

All these findings suggest that there is evidence to establishing a close relationship between critical thinking, creative thinking and metacognition, which allows us to assume that this link may be associated with a higher cognitive process that underlies it, which we call complex thinking. From this perspective, we dare to postulate that complex thinking would be shaped by the interrelation and complementarity between critical thinking, creative thinking and metacognition.

2. Method

2.1. Literature search

A systematic search of published articles was carried out which included the review of the following databases: Web of Science, Scopus, ScienceDirect, Scielo and Latindex. Digitized books and doctoral theses were also reviewed online. Regarding the search and selection criteria, the terms "complex thinking", "critical thinking", "creative thinking" and "metacognition" were used in isolation and in conjunction with terms "definition", "education", "university education" and/or studies that related two or more of the aforementioned terms. Their presence was sought in: a) original articles, b) with search terms in title, abstract and/or keywords, c) published in English or Spanish, d) and without time limitations. Additionally, references from articles, books and doctoral theses were reviewed to identify other authors and/or articles that were important in this review process.

2.2. Inclusion and exclusion criteria

The literature search and selection was applied in accordance with the preferred report elements for systematic reviews and meta-analyzes (Moher, Liberati, Tetzlaff, Altman, & Group, 2010). Studies describing definitions or conceptualizations, models, relationships between different cognitive processes (complex, critical, creative thinking and meta-cognition) and relationships with associated assessment systems were included. Experimental studies that developed and proposed new conceptualizations or evaluation systems for some of the aforementioned cognitive processes were also included. The excluded articles corresponded to purely methodological studies (validation of instruments, tasks or evaluation systems, etc.), which lacked a development of conceptualizations, definitions or theoretical models associated with these cognitive processes.

2.3. Analysis

The Meta-synthesis methodology of the "theoretical construction" type was used, as it is an ideal systematic guide that allows the clarification of concepts, patterns and results for the refinement of existing knowledge and the emergence of new models and theories (Carrillo-González, Gómez-Ramírez, & Vargas-Rosero, 2007; Finfgeld, 2003). For the analysis of information, the intertextual reading and analysis method was used (Genette, 1989; Kristeva, 1988), which served to recapitulate the main ideas of the different texts and to synthesize the information that allowed to generate the proposed model.

3. Results

3.1. A conceptual model and operational definitions of the cognitive processes of complex thinking

Based on what has been previously developed, the following conceptual model is outlined and proposed, integrated by the different cognitive processes and skills linked to complex thinking (see Fig. 2).

This model is shaped by three main cognitive processes: critical thinking, creative thinking and metacognition; and the skills/indicators that result from each of these main processes. This model derives from Lipman's proposal, but with some variants, such as the inclusion of metacognition as one of the main cognitive processes of complex thinking. Although Lipman already emphasized the importance of metacognition, he had not included it among the main processes of his model. Our proposal includes it because it would be supported by several investigations developed from the cognitive sciences that establish that metacognition is a process independent of other processes, such as critical or creative thinking, however, it would be related or interrelated to these cognitive processes, as we previously reviewed. The inclusion of cognitive skills or sub-processes is proposed from the review, contrast and synthesis of the different conceptualizations related to the main processes, establishing similarity or relationship with Lipman and Morin's conceptual proposals. The definitions for each of the main cognitive processes are set out below.

3.1.1. Critical thinking

Lipman (1997) postulates that the products by which critical thinking is defined are judgments; understanding that a judgment is a determination of thought, speech, action or creation. Judgments are always judgments of relationships, connections, comparisons, similarities, and differences. 'Critical thinking is thought that 1) facilitates judgment because 2) it is based on criteria, 3) it is self-correcting and 4) it is context-sensitive' (174). It suggests criteria such as "inference, feasibility, induction and deduction" (p.205) and dialogic capacity as an important aspect in the evaluation of arguments. Furthermore, Goodwin Watson and Edward Glaser were pioneers in the conceptualization and evaluation of critical thinking. They postulated that critical thinking included the ability to recognize the existence of problems and the need to generate evidence in support of what is claimed to be true; to know the nature of valid inferences, abstractions and generalizations in which the weight or precision of different types of evidence are logically determined; such as the skills to use and apply previous knowledge and attitudes. In addition, "to test the conclusions and generalizations that are reached, to reconstruct the patterns of beliefs on the basis of a broader experience and to make precise judgments about specific things and qualities in everyday life" (Glaser, 1941, p. 6). Watson and Glaser (1980) have proposed the most widely used test to

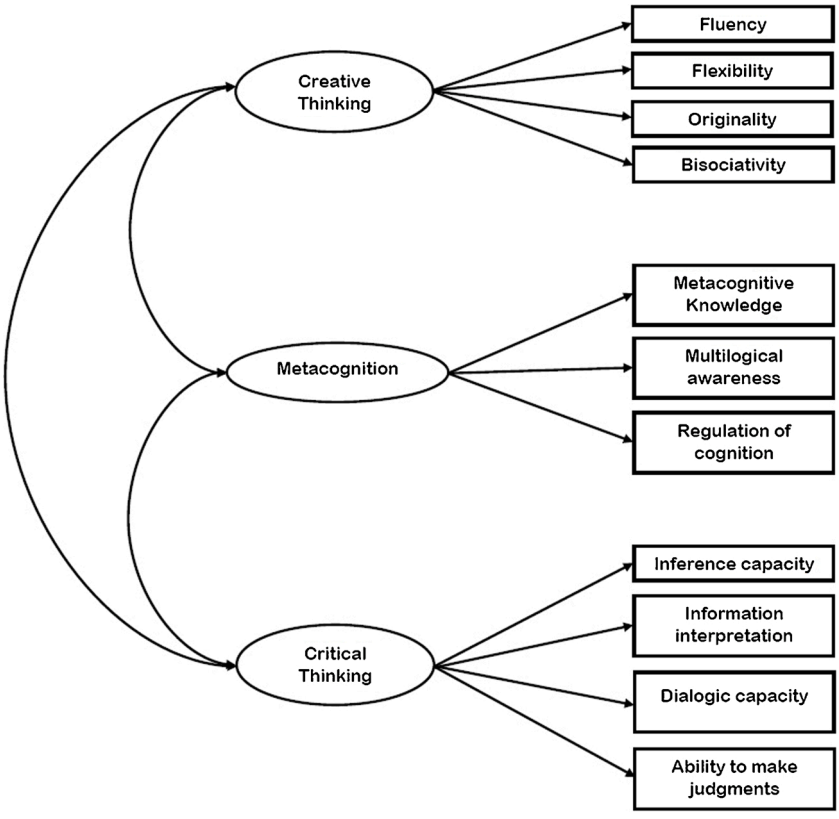

Fig. 2. Complex thinking cognitive processes model.
Source: Own elaboration

measure this competence, the Watson-Glaser Critical Thinking Appraisal Test, which assesses the following skills: inference, recognition of assumptions, deduction, interpretation of information and evaluation of arguments. Both Lipman and Watson & Glaser agree on the importance of making judgments about certain things, qualities or specific contexts and on the use of criteria, such as inference and deduction.

Recent studies have proposed some variants, extending the skills that compose it, such as: the ability to infer, analyze, synthesize, suppose, argue, evaluate, the process of conceptualizing, interpreting and applying information to solve a problem, making statements supported by evidence, making decisions, finding an answer to a certain question or reaching conclusions, and the capacity for dialogue (El Soufi & See, 2019; Shavelson, Zlatkin-Troitschanskaia, Beck, Schmidt, & Marino, 2019; Silva, 2019; Rahardjoni, Hasanah, & Nugraheni, 2020).

The definition we propose for critical thinking within this model of complex thought is as follows: ability to interpret and understand information from some text, discourse or fact and judge the proposed conclusions; ability to draw judgements or conclusions from certain facts, propositions or principles, whether general or particular, observed or assumed, and to discriminate between the degrees of truth or falseness of inferences drawn from certain data or given information; dialogical ability to distinguish and evaluate the strengths and weaknesses of opposing arguments or perspectives in order to arrive at consensual interpretations or better argued solutions to specific problems; and ability to make informed judgements on particular issues through the use of criteria

3.1.2. Creative thinking

Lipman (1997) proposes that creative thinking is "that thought that leads to judgment, oriented by context, self-transcendental and sensitive to criteria" (p. 265). One aspect that stands out is that it is governed by the context in which the research is carried out, so it would have more dynamic and evolutionary factors, such as the capacity for generation, extension, rupture and autonomous thinking. Among the criteria that guide it, he mentions originality, novelty, generativity, uniqueness, productivity, capacity for rupture, capacity for surprise, invention, liberating quality, spontaneity, imagination, inspiration, capacity for synthesis, flexibility, and fluidity. On the other hand, one of the pioneers in investigating creativity was Guilford (1950), for this author creative people are sensitive to problems, they are people who realize the need for change, apply new methods, realize the defects and deficiencies of things. Like Lipman, he emphasizes the role that judgments and criteria play in creativity, pointing out that the application of judgement and the use of criteria is crucial in order to elucidate what is valuable and satisfactory, especially in artistic production, and these would be criteria to go beyond the purely logical. He proposed that creativity is composed of three categories: redefinition, evaluation and divergent productions.

Other important authors who have investigated creative thinking have also formulated their theoretical proposals based on Guilford's postulates, using the same three categories, pointing out that creativity involves skills such as: evaluation (sensitivity to problems, inconsistencies and unnoticed elements); divergent production (fluidity, flexibility, originality, and elaboration); and redefinition (Torrance, 1962, 1981, 1988; Torrance, 1990); The Torrance Test (1966) the most widely used to assess creativity, is also based on this theory, with special emphasis on divergent thinking skills: fluency, flexibility, originality, and elaboration. Others have also pointed out that standard definitions for creative thinking revolve around the application of judgment and criteria, and postulate that divergent thinking skills are a potential predictor of creativity (Runco & Acar, 2012; Runco & Jaeger, 2012; Runco, 2017, 2018). Another aspect related to creative thinking is bisociation, referring to actions aimed at the analysis or integration of divergent points of view or the ability to establish associations between apparently dissimilar concepts, which can produce resistance, tension or synthesis (Koestler, 1969; Rodríguez, 2013) and related to the broad capabilities of conceptual expansion and conceptual combination (Benedek, Jurisch, Koschutnig, Fink, & Beaty, 2020).

The definition we propose for creative thinking within this complex thinking model is the following: ability to imagine and propose divergent results for specific situations or problems; ability to produce novel, unconventional responses, far from the established and usual answers (originality); ease of generating a large number of ideas or the ability to produce a large number of responses in a given field (fluency); ability to produce different ideas to change from one thinking approach to another and to use different problem-solving strategies (flexibility); and the ability to establish connections or associations between apparently dissimilar concepts, coming from different areas of knowledge and/or in opposition (bisociativity).

3.1.3. Metacognition

the American epistemologist and psychologist John Flavell (1976), who proposed the first definition of metacognition, developed extensive studies and provided the first classifications of the metacognitive process. He postulated that metacognition refers to one's knowledge of one's own cognitive processes and products or anything related to them, for example, the properties of information or data relevant to learning. Among other things, it also refers to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or the data they contain, generally in the service of a specific objective. This definition has remained almost unchanged by the most authors who have approached metacognition so far, who agree that it is classified in two main aspects: knowledge of cognition and regulation of cognition (Anderson, 2008; Brown, 1987; Ozturk, 2017; Tarricone, 2011).

For our model we have considered the definition proposed by Tarricone (2011) in her *Taxonomy of Metacognition* because it is the one that best fits the theoretical construct proposed for complex thinking, considering that the same author links her proposal of metacognition with the notion of complex thinking. From this author's perspective, metacognition refers to knowing and regulating the processes of cognition, including metacognitive experiences. We also propose to add a new component, extracted from the notion proposed by Lipman, which is the multilogical aspect that we will call "multilogical awareness" since the use of multiple perspectives and/or reasoning strategies serves to think, with precision and impartiality, contributing to the reanalysis, clarification or

demystification in metacognitive processes.

The definition we propose for metacognition within this complex thinking model is as follows: knowledge capacity that a subject has of their learning, their abilities, the use of their cognitive abilities, identifying their strengths and weaknesses; the knowledge they have about when, where and why to use the learning strategies; the knowledge about the transfer and adaptation of these strategies; the awareness of multiple perspectives or reasoning strategies applied in tasks and contexts; the activity of monitoring and evaluation of learning and performance in action, during the development of tasks; to regulate changes in cognitive behaviors aimed at establishing coherence with the objectives and demands of the task; the process of identifying weaknesses in learning and adjusting strategies to improve performance; and the regulation of feelings and judgments experienced in tasks and strategies used.

3.2. Operational definitions of skills/indicators

Based on the conceptualizations developed so far, the following operational definitions of the skills or indicators of complex thinking are proposed below (see Table 1).

4. Discussion and conclusions

The proposal of a conceptual model for complex thinking and operational definitions of its cognitive skills arises from the need to promote complex thinking in educational systems, especially at the university level, as has been proposed by several authors. As Edgar Morin would say, it would allow, students to develop thinking that dialogues with uncertainty, that links knowledge, that does not separate the object of study from its context, from its background, from its future, in order to understand the different aspects of a multidimensional reality and that is in tune with the new socio-cultural and scientific paradigm, the paradigm of complexity. In this sense, our proposal would be a first step in that direction.

It is also important to note that this model is configured from a new conceptualization, which emerges from the synthesis and conjugation of different conceptual perspectives, the result of which gives rise to the following definition of complex thinking: it refers to systemic thinking that arises from the fusion between critical thinking, creative thinking and metacognition, from which the

Table 1
Operational definitions of skills/indicators.

Main cognitive processes	Skills/indicators
Creative thinking	*Fluency:* it is the characteristic of creativity or the facility to generate a large number of ideas or the ability to produce a large number of responses in a given field, from verbal or figurative stimuli. *Flexibility:* it is the characteristic of creativity through which the process is transformed to reach the solution of the problem or its approach. It includes a transformation, a change, a rethinking or reinterpretation. In short, it is the constant ability to produce different ideas to move from one focus to thinking and using different problem-solving strategies. *Originality:* it is the characteristic that defines the idea, process or product as something unique or different. It refers to the ability to produce novel, unconventional responses, far from the established and habitual. *Bisociativity:* ability to establish connections or relationships between apparently dissimilar concepts, coming from different areas of knowledge and/or opposites; redefining concepts, structuring information or producing new logical alternatives to obtain novel ideas.
Metacognition	*Metacognitive knowledge:* ability to: know the characteristics and complexity of all the information included in a task, in its relation to the strategies, the proposed processes, to the general, abstract or epistemological knowledge related to a task and its context; know the monitoring and control strategies in their relation to the object of knowledge involved in specific tasks; know the application and transfer of strategies and their adaptation to the demands of the tasks. *Multilogical awareness:* it is the knowledge or awareness of the use of different strategies, forms of reasoning or logical systems (coming from different areas of knowledge) in the solution of a problem or artistic production; to examine the assumptions, perspectives, and conceptual structures that lie beneath the surface of a particular problem or task, considering different points of reference. *Regulation of cognition:* ability to: control and monitoring cognitive strategies or processes, supervising retrospectively or prospectively or making metacognitive judgments that provide feedback; observe their own beliefs, prejudices or states and their involvement in the cognitive processes in the development of the task or artistic production; to self-assess or reflect on their memory and cognitive abilities or characteristics, recognizing their cognitive strengths and weaknesses; to be aware of your own feelings, emotions, intuitions or passions and how it influences your confidence or sense of satisfaction and, in turn, your performance and achievement of results.
Critical thinking	*Inference capacity:* ability to extract judgments or conclusions from certain facts, propositions or principles, whether general or particular, observed or assumed. The inference arises from a mental evaluation between different expressions that, when related as abstractions, allow a logical implication to be drawn. From some hypotheses or arguments, it is possible to infer a conclusion. *Information interpretation:* ability to interpret and understand information from a text, speech or event and judge the proposals; or to elucidate the reasons that led a subject to act as he did, using broader contexts that include social norms, customs, or others, to give meaning to the action. *Dialogic capacity:* it is the process by which knowledge is built through dialogue or contradictions. It allows us to understand the interpretations of others and to look for arguments to refute, affirm or reformulate them. Communicative action and dialogue are key components in the construction of knowledge and the main instrument of social transformation. This process also focuses on assessing the strengths and weaknesses of opposing perspectives. And through this, we can arrive at consensual interpretations or better argued solutions. *Ability to make judgments:* ability to formulate judgments using criteria based on the evaluation of arguments. These judgments can be universal, particular, singular, affirmative, negative, categorical, hypothetical or disjunctive depending on the problem or object in question.

Source: Own elaboration

following skills/indicators are derived and integrated; fluency, flexibility, originality, bisociativity, metacognitive knowledge, multilogical awareness, regulation of cognition, inference capacity, information interpretation, dialogic capacity and ability to make judgments.

The choice and proposal of the skills/indicators for each of the main processes is a function of establishing coherence with the conceptualizations proposed by Morin and Lipman. Additionally, it was considered to select the most used skills/indicators in the different assessment systems related to the indicated cognitive processes and that have demonstrated sufficient empirical evidence of validity. The reduction of indicators is also aimed at obtaining a simplified model that avoids the overlapping of components. For example, multiple authors have proposed that the formulation of judgments is a component of critical thinking and also of creative thinking (Mumford, Giorgini, Gibson, & Mecca, 2013), which is in line with the conceptualizations developed by Lipman. In our proposal it was decided to place it in the set of critical thinking indicators, since the formulation of judgments is more predominant in this cognitive process by definition. However, we consider that all the indicators would be interrelated and circumscribed to the general construct of complex thinking, appealing to a relational structure of suprasumativity rather than the sum of the parts. Appealing, moreover, to the inherent systemic character at the structural level of our proposal.

Regarding the indicators selected for creative thinking, fluency, flexibility and originality were chosen. The elaboration criterion was omitted, as some studies have pointed out that this component is not related to the other criteria, it has shown a negative correlation with each of them. The "elaboration" could hinder the creative or divergent process by not allowing the subjects to produce a large number of ideas (Kudrowitz & Dippo, 2013). Furthermore, Jiménez, Artiles, Rodríguez, and García (2007) warn that, although the internal structure of divergent thinking and creativity would be defined by fluidity, originality, flexibility and elaboration; nevertheless, the components that best define the construct are those that present greater saturation in the factor, being better defined by the components of fluidity, originality and flexibility. On the other hand, many authors have opposed the use of scores that are fluently confused, specifically alluding to their confusing relationship (quality versus quantity) with originality (Clark, Griffing, & Johnson, 1989; Forthmann, Szardenings, & Holling, 2020; Silvia, 2008); however, other authors point out that both fluency and originality cannot be confused, since "people differ in their abilities to generate original responses compared to many responses, and these differences must be taken into account when designing training protocols" (Cotter, Ivcevic, & Moeller, 2020, p.8).

Another important component for measuring creativity, which has emerged with great interest in recent scientific literature, is bisociation or bi-association (Benedek et al., 2020). The choice of this indicator variable is due to the fact that it connects with theories of creativity that postulate that creative ideas arise from the recovery of remote associations that are combined in novel and appropriate ways (Benedek et al., 2020; Mednick, 1962). Just as skills or indicators of divergent thinking have been highlighted as potential predictors of creative thinking (Runco & Acar, 2012), bisociation represents a more restricted version of the generation of creative associations and implies qualitatively different cognitive mechanisms in achieving conceptual integrations. Furthermore, due to their relational characteristics, bissociative skills would play an important role in the linking of knowledge and in the ability to unite units to multiplicities, which are key aspects that complex thinking tries to promote.

With regard to the selected skill/indicators for critical thinking, two indicator variables used in the Watson and Glaser (1980) test were included, the ability to infer and interpret information, which have been included in other evaluation systems and are considered basic skills for critical thinking. The inclusion of the dialogical capacity and the formulation of judgments is due to the fact that these components are key in the conceptualizations developed by Morin and Lipman, respectively. Dialogic capacity would allow the assessment of argumentation in its interaction. The evaluation of different or opposing arguments is a strategy that allows establishing dialogue and/or contrasting information with the perspectives of other interlocutors (Remache-Bunci, 2019; Santiuste et al., 2001). The formulation of judgments has also been postulated by other authors, but it has not been included in systems of critical thinking assessments. This indicator would also allow the observation of the criteria used in the formulation.

Regarding the selected skills/indicators for metacognition, the most used and almost unchanged indicator variables since Flavell (1976) were included: metacognitive knowledge and cognition regulation. However, it was proposed to add a new variable, multilogical awareness, as mentioned above, since it would allow observing self-awareness about the use of multiple perspectives and/or reasoning strategies used in problem solving and/or retrospective analysis.

As a future task, the challenge is to be able to design and validate a complex thinking evaluation system and apply it to different students to observe, in an empirical way, its practical implications on learning processes in educational systems. It would serve to characterize the levels of development of the competences or cognitive processes involved and to be able to make decisions with greater knowledge in this regard, towards the configuration of an improved assessment system.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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