Obutchénie
Revista de Didática e Psicologia Pedagógica

DOI: http://doi.org/10.14393/OBv10.e2026-20

Knowledge mobilization in science education. An agentive activity characterization

Movilizar conocimientos en el aprendizaje de las ciencias. Una caracterización desde la actividad agencial

Mobilizar conhecimento em ciência. Uma caracterização a partir da atividade agencial

José Manuel Ruvalcaba Cervantes[1]

ABSTRACT
In science learning, the term mobilizing knowledge refers to applying what has been learned in new situations, contexts and problems. It is usually assumed that mobilizing learning is an intuitive activity that transforms implicit knowledge and ideas into explicit ideas through language. This paper reviews the classic conception of knowledge mobility. It communicates some limitations of this approach, such as reducing learning, confusing the term with transfer or generalization and presenting mobility as an intuitive act. The purpose is to propose knowledge mobility in science learning as an agentive activity that requires self-regulation and control of the mental actions that make up mobility. Based on Igor M. Arievitch's theory of agential activity, the mental actions necessary to actively engage in knowledge mobility are characterized. This position explains how knowledge mobility is an emergent activity that becomes efficient with the control and orientation of the activity itself. The explanation here presented is reflexive and theoretical through the dialogue between empirical references of science teaching and the theory of agential activity.

Keywords: Knowledge mobility; Agentive activity; Science learning.

RESUMEN
En el aprendizaje de las ciencias se emplea el término movilizar conocimientos para aludir a la aplicación de lo aprendido en nuevas situaciones, contextos y problemas. Por lo regular, se asume que movilizar los aprendizajes es una actividad intuitiva que consiste en transformar los conocimientos e ideas implícitas en ideas explícitas por medio del lenguaje. En este escrito se realiza una revisión de la concepción clásica de movilidad de conocimientos y se comunican algunas limitaciones de este enfoque, como reducir el aprendizaje,

[1] IxM SECIHTI-CINVESTAV Monterrey, México. Orcid: https://orcid.org/0000-0002-5046-1572; E-mail: jruvalcabac@cinvestav.mx.

DOI: http://doi.org/10.14393/OBv10.e2026-20

confundir el término con transferencia o generalización y presentar la movilidad como un acto intuitivo. El propósito es proponer la movilidad de conocimientos en el aprendizaje de las ciencias como una actividad agencial que exige auto regulación y control de las acciones mentales que integran la movilidad. Con base en la teoría de la actividad agencial de Igor M. Arievitch, se caracterizan las acciones mentales necesarias para comprometerse activamente en la movilidad de conocimientos. Desde esta postura se expone cómo la movilidad de conocimientos es una actividad emergente que deviene eficiente con el control y orientación de la actividad misma. La explicación que se expone es de naturaleza reflexiva y teórica por medio del diálogo entre referentes empíricos de la didáctica de las ciencias con la teoría de la actividad agencial.

Palavras-chave: Movilizar conocimientos; Actividad agencial; Aprendizaje de las ciencias.

RESUMO
Na aprendizagem de ciências, o termo mobilização de conhecimento é utilizado para se referir à aplicação do que foi aprendido em novas situações, contextos e problemas. Geralmente assume-se que a aprendizagem mobilizadora é uma atividade intuitiva que consiste em transformar conhecimentos e ideias implícitas em ideias explícitas através da linguagem. Este artigo revisa a concepção clássica de mobilidade do conhecimento e comunica algumas limitações desta abordagem, como reduzir a aprendizagem, confundir o termo com transferência ou generalização e apresentar a mobilidade como um ato intuitivo. O objetivo é propor a mobilidade do conhecimento na aprendizagem de ciências como uma atividade agencial que requer autorregulação e controle das ações mentais que compõem a mobilidade. Com base na teoria da atividade agencial de Igor M. Arievitch, são caracterizadas as ações mentais necessárias para se engajar ativamente na mobilidade do conhecimento. A partir desta posição, explica-se como a mobilidade do conhecimento é uma atividade emergente que se torna eficiente com o controle e orientação da própria atividade. A explicação apresentada é de natureza reflexiva e teórica através do diálogo entre referências empíricas do ensino de ciências com a teoria da atividade agencial.

Palabras clave: Mobilizar conhecimento; Atividade agencial; Aprendizagem científica.

1 Introduction

In science education, it is common to use the terms mobilising knowledge and mobilising learning to indicate students' abilities to apply their learning in new situations and problems (POZO, 2001, 2011, 2017), to refer to the transfer of what has been learned to new contexts for interpreting natural phenomena and facts, or to use new knowledge to construct new problems and learning questions.

Mobilising knowledge is an essential activity for manifesting learning in science education (CLEMENT, 1994, 2003, 2022). The term mobilising knowledge, and its

DOI: http://doi.org/10.14393/OBv10.e2026-20

variants such as knowledge mobility or moving learning, are so rooted in teaching and academic discourse that we have paid little attention to it, mainly because there is a tacit, implicit consensus about its general sense and meaning.

The idea of mobilising knowledge is a physical metaphor that refers to a change of position—in this case, of abstract entities: learning. Mobilising knowledge means shifting a set of items of knowledge from one point to another. It implies a medium through which knowledge is transferred and a force that modifies the state or position of the knowledge entities (RUVALCABA CERVANTES, 2020). In other words, **mobilising knowledge is manifested through speech and demands active engagement**.

More precisely, mobilising knowledge is the voluntary mental activity by which an agent sets in motion their internalised knowledge—tacit or implicit—, makes it emerge, and externalises it in a representational system (speech, drawings, diagrams) to operate with it, transform it, and solve a cognitive or learning task. Throughout this paper, "knowledge mobility" designates a system of activity—with structure and functionality—made up of a set of mental actions, and not an isolated action or a mere function. It is worth distinguishing two planes: what is internalised is knowledge of a tacit and embodied nature, whereas the representation is what emerges outward during the activity. Strictly speaking, there are no internal representations that are externalised; rather, internalised knowledge is represented when mobilised (ARIEVITCH, 2017).

Some conceptions refer to the mobility of scientific knowledge as a cognitive process necessary for formulating investigable questions in the classroom (CHAMIZO, 2017; CHAMIZO; RÍOS-LÓPEZ, 2017), or as a process of evocation that denotes understanding (BROUSSEAU, 2007). However, the allusions to mobility are brief and prove inadequate for understanding this mental activity. The view of knowledge mobility understood exclusively as the activity of verbalising knowledge to make explicit what has been learned (POZO, 2001, 2011, 2017; MIŠČEVIĆ, 1992, 2007, 2022) is the one that most clearly sets out the elements for defining and understanding this mental activity. From this standpoint, mobilising knowledge means establishing a connection between internal and external representations of knowledge. A similar account of the term is developed by Clement (2003, 2009, 2022) in his comparative work between novices and experts. Clement distinguishes experts from novices by the verbalisation

DOI: http://doi.org/10.14393/OBv10.e2026-20

and explicit communication of acquired and consolidated knowledge when they mobilise knowledge in new problems or learning situations. However, there are different levels for verbalising what has been learned, depending on the representational format. Pérez et al. (2023), in their work on teaching to address epistemological obstacles in learning evolution, show how iconic representations convey knowledge that the oral format cannot convey, thereby complementing each other. For their part, Gallegos-Cázares et al. (2022) and Gómez Galindo (2026) highlight the relevance of multirepresentation and multimodality for communicating and consolidating learning.

Mobilising knowledge is a speech activity, but it is not reduced to mere verbalisation. Otherwise, it would suffice to teach learners to communicate and speak precisely to dissolve the differences between novices and experts that Clement observes. It would be enough to teach students to use different representational formats to communicate more ideas. It is necessary to understand and appreciate active engagement in mobility per se.

By active engagement in the context of knowledge mobility, I mean that the student is an agent who becomes intentionally, consciously, and deliberately involved in mental actions that allow them to explore, reflect, evaluate, understand, and control the mobilising activity. By understanding and appreciating active engagement in mobility, I want to highlight the need to examine how internalised knowledge relates to external representations and vice versa, without reducing the matter to the classic problem of mental dualism (ARIEVITCH, 2017). This entails describing the system of activity through which knowledge mobility is manifested. Nevertheless, the literature leaves a gap in the description of this mechanism and is limited to representation-centred views.

Like any other mental activity, the system of knowledge mobility is composed of a set of actions with structure and functionality. I assume that describing the actions—their structure and functionality—that make up knowledge mobility will allow us to have the system of activity that characterises the manifestation of knowledge mobility as a verbal activity. Therefore, the objective of this paper is to characterise knowledge mobility by setting out the mental actions that constitute this system of activity.

DOI: http://doi.org/10.14393/OBv10.e2026-20

The paper is divided into four sections. The first sets out what is understood, by tacit consensus, as knowledge mobility, following the classic works in the psychology of learning (KARMILOFF-SMITH, 1992; POZO, 2001, 2011, 2017) and in cognitive philosophy (MIŠČEVIĆ, 1992, 2022). The second sets out the limitations and problems related to the classic conceptions of knowledge mobility. The third part presents the proposal of the mental actions that describe and characterise the system of activity of knowledge mobility and its manifestation through language, emphasising the relationship between control and active engagement when mobilising knowledge. The fourth presents the conclusions to project possible avenues for reflection arising from this paper.

2 Mobilising knowledge: an activity of verbalisation

In the classic conception, knowledge mobility is manifested through verbal expression when learning is made explicit (MIŠČEVIĆ, 1992, 2022; POZO, 2001, 2011), thereby inscribing it in the dynamic relationships between internal and external representations of knowledge. This means that mobilising knowledge is externalising previously learned representations. From this view, it is a mental activity that is manifested exclusively through language. The activity of mobilising fosters the acquisition, development and refinement of knowledge.

Mobilising learning is an activity in which implicit ideas and knowledge, of a tacit nature, are made explicit and verbalised (CLEMENT, 1994, 2003, 2009, 2022) with some purpose or function. The activity of mobilising operates with learned and internalised knowledge, organised as internal representations (POZO, 2001, 2011, 2017). When verbalising to construct external representations, a greater level of awareness is required to complete the process of making explicit (KARMILOFF-SMITH, 1992). It is regularly thought that, intuitively and spontaneously, implicit knowledge becomes explicit and verbalised representations (GENDLER, 2010; MIŠČEVIĆ, 2007, 2022; NERSESSIAN, 2010; POZO, 2001, 2017). Thus, intuition is the mechanism by which useful conclusions are conjectured and inferred to verbalize and make knowledge explicit.

2.1 Knowledge mobility, representational levels and modelling

The idea of mobility is progressive, from the unconscious implicit to the explicit

DOI: http://doi.org/10.14393/OBv10.e2026-20

and conscious. A couple of structured conceptions are those studied by Pozo (2001, 2011, 2017)—a view proper to the cognitive psychology of learning—and Miščević (1992, 2007, 2022)—a naturalistic account based on modelling.

Pozo, following Karmiloff-Smith's (1992) theory of representational redescription, uses the idea of mobilising the results of learning to various situations. Although he does not define what mobilising knowledge is, he provides elements that allow us to glimpse mobility as dynamic, linked to the transfer of learning outcomes to other situations (POZO, 2001, 2011, 2017). In this conception, mobilising is the process of changing unconscious knowledge structures into explicit, conscious verbalisation. He sets out progressive levels of representational explicitation in which processes of retrieval and transfer are involved: implicit (I), explicit non-conscious (E1), explicit conscious and non-verbalised (E2), and explicit conscious and verbalised (E3).

At the implicit level (I), one operates with internal representations used to carry out procedures, wich are not available for cognitive tasks of verbalisation. They are representations of an embodied nature. The E1 level operates with symbolic representations available in memory, but they are not conscious; they have cognitive value when they are retrieved and related by the explicit representations E2 and E3. At the explicit level E2, the internal representations are conscious; however, they are not expressed in linguistic formats but are mobilised through diagrams. The E2 level operates with internal representations that, when decomposed into their constituent parts, are used in cognitive tasks of constructing external representations (diagrams). At the E3 level, a person can report linguistically on the external representation, its components, and the transformations applied to it.

The theory of representational redescription entails modifying, reconstructing and restructuring knowledge. An implicit representation of a fact of the world will be redescribed and re-represented with a different structure at the E3 level than at the lower levels. However, the transformation of knowledge is not mobilising but rather a redescription of the representation (KARMILOFF-SMITH, 1992), which is why Pozo's characterisation of mobility is incomplete. This is set out later as a problem of reductionism.

DOI: http://doi.org/10.14393/OBv10.e2026-20

For his part, Miščević (2000, 2007, 2022) explains mobility from a naturalistic, modelling-based perspective, in which intuition serves as the explanatory mechanism. Intuition is the "response that produces a phenomenologically immediate belief, accompanied by a feeling of obviousness and certainty" (MIŠČEVIĆ, 2000, p. 88) and, consequently, it will only be possible to recognise the results of intuition, but not its underlying process (MIŠČEVIĆ, 2007).

Following Miščević, knowledge mobility in science learning involves three intuitive cognitive states: accumulation of examples, bound insight and universal insight. Accumulating examples involves associating contents with various cases, creating an intuitive context close to the experiences in which intuitions arise. This cognitive state is relational and generates expectations about the behaviour of the facts of the world, which constitute bound insight. The implicit expectations are transformed into propositional contents through judgments of apparent truth (universal insight).

Miščević (2000, 2007) argues that tacit knowledge becomes propositional and explicit when structured representations are consciously applied to concrete problems. Representations make it easier to make truths explicit as modal judgments. However, Miščević's proposal, like Pozo's, is incomplete because it lacks a clear model for how internal representations are translated into external representations. Miščević (2007, 2022) acknowledges the elusive character of intuitive mechanisms.

Here, it is necessary to pause and make some remarks about the classic view of mobility:

1. Mobilising learning is a spontaneous activity proper to the representation-centred learning process.
2. Mobilising knowledge is an activity that consists of generalising and transferring knowledge.
3. Mobilising learning effectively is the product of the accumulation of intuitive experiences provided by trial-and-error practice.

The previous remarks, derived from the classic conception, present knowledge mobility as an activity with spontaneous and intuitive properties that, although it has structure and function, lacks didactic implications and fails to

DOI: http://doi.org/10.14393/OBv10.e2026-20

transcend the discourse that confuses mobility with other cognitive activities, such as generalising, transferring, and applying knowledge. (LOBATO; HOHENSSE, 2021). It is possible to mobilise knowledge without transferring, generalising or applying it to new situations, but it is not possible to transfer, generalise and apply knowledge without first mobilising learning.

Confining mobility to the classic conception requires understanding it as the dynamic integration of intuitive (implicit and unconscious) and explicit representations; that is, mobilisation occurs spontaneously during learning. However, mobility as an activity can be trained and enhanced by developing the skills needed to execute the actions that make up mobility. Like any other mental process, to enhance the cognitive use of mobility, it is necessary to transcend the mentalism exclusive to the spontaneous relationship between internal and external representations by studying the action and the system of activity that constitute it.

3 The problem with knowledge mobility

There are two problems with the classic conception of knowledge mobilisation. On the one hand, there is limited clarity in characterising mobility. We believe we understand it and use the term as a catch-all. This problem is reflected in remarks 1 and 2 of the previous section. 'Knowledge mobility' is used in teaching and academic discourse to refer to the transfer and application of learning in contexts different from those of teaching; however, it is often confused with generalising what has been learned. On the other hand, the problem of understanding it as a spontaneous and intuitive activity, which is reflected in statements 1 and 3. Mobilising what has been learned occurs automatically; that is, it is an intuitive, involuntary and unreflective intellectual activity, even when it is not intentionally fostered and developed in the classroom.

3.1 The reductionism of learning

By describing knowledge mobility as the activity of externalising internal representations of an implicit nature through language, one forgets that representations emerge in learning situations mediated by the natural, social and cultural environment (ARIEVITCH, 2017). The classic explanation is mentalist and incomplete. The

DOI: http://doi.org/10.14393/OBv10.e2026-20

mechanism of mobility focuses on the content of the representation (mentalism), neglecting the actions involved in mobility. The progression and evolutionary complexity of representations are set out, from unconscious, non-verbalised thought to external, conscious and verbalised representation.

The problem consists of reducing learning to mentalism, without considering the natural relationship between representations and the actions performed with them. Kuhn (1989) explains that the duality of activities associated with different degrees of metacognition, such as mobility, requires associating conscious reflection and deliberate control, rather than merely representational content.

Based on studies of differences in scientific thinking among scientists, lay adults, and children, Kuhn (1989) develops a conceptual framework in which scientists' thinking consists of associative and controlled processes linking theory and scientific evidence. The substantial difference in scientific thinking between experts and laypeople goes beyond verbalising the discrepancies between theories and evidence. The expert establishes explicit criteria for evaluating evidence and scientific theory as distinct entities, without falling into prejudice. Kuhn highlights that these subjects tend to focus on the variation, or lack thereof, in the evidence they evaluate, and from there they begin to elaborate causal inferences. Another substantial difference is control over variables. When children and laypeople focus on the effects of one variable, they lose control over the others. In short, the differences among scientists, laypeople and children are explained by the actions performed with scientific theories and evidence, and the control one has over such actions.

Another problem when reducing the meaning of learning in science—by explaining knowledge mobility as a mere process of making unconscious and non-verbalised representations explicit—is restricting the mobility of learning to the individual processing of information. Currently, there are learning models that extend the application of what has been learned to collective knowledge systems and social systems of activity (LOBATO; HOHENSSE, 2021), highlighting the sociocultural character of learning. Here we reflect in two ways:

1. Although knowledge mobility does not have as its object the practices of social systems of activity, as in collective learning models (LOBATO;

DOI: http://doi.org/10.14393/OBv10.e2026-20

HOHENSSE, 2021), the exchange of social senses and meanings of knowledge is indeed proper to it. Mobilising knowledge is part of the complexity that characterises the internalisation, negotiation, production, and learning of science in spaces shaped by historical and sociocultural factors.

2. Knowledge mobility, in dealing with representations that are products of cultural and social history, requires mediation to achieve the internalisation of human knowledge (ARIEVITCH, 2017). Mobility makes us participants in culture before we are participants in its transformation and evolution.

This requirement of mediation is not incidental but constitutive of the activity of mobilising knowledge. From the historical-cultural and dialectical-materialist tradition (VYGOTSKY, 2010; DAVYDOV, 1986; TALIZINA, 2008; STETSENKO, 2016), knowledge is not a private mental entity that the subject simply externalises, but rather a product and a means of human activity situated historically and culturally. The representations that are mobilised do not pre-exist apart from the social practices that generate them: they emerge, develop and acquire meaning in the course of collective activities mediated by semiotic and material tools (ARIEVITCH, 2017; STETSENKO, 2016). To state that knowledge mobility requires mediation means, then, that the mental actions that make it up have their origin in shared forms of acting with others, which are progressively internalised (SOLOVIEVA, 2019; TALIZINA, 2008). Mobilising school scientific knowledge is, in this sense, appropriating culturally constructed ways of operating with knowledge, rather than an individual transfer of representational contents; the social and the cultural are not the setting in which mobility occurs, but its constitutive condition.

3.1.1 Mobility, transfer and generalisation of school scientific knowledge

The relationship between mobility and other intellectual actions and activities for completing tasks suggests the need to distinguish the function of knowledge mobility from the transfer of learning and generalisation. In transfer of learning, the purpose is to transform the organisational structure of the class (BARNETT; CECI, 2002; LOBATO; HOHENSSE, 2021). Barnett and Ceci (2002) show that transfer is disciplinary in nature, of interest to teachers and educational policies, and has little to do with knowledge domains and mental actions.

Transfer of knowledge is a view in which semantic relationships of content are constructed; it is through similarity and resemblance between learning situations that correlations can be established (LOBATO; HOHENSSE, 2021). The changes between two educational experiences are superficial (LOBATO; HOHENSSE, 2021; PERKINS, 2009), so that learning is distributed across various learning situations. This is evidenced in works where multimodal representation enables a more complex and enriched scientific understanding of topics such as climate change (ZONA-LÓPEZ et al., 2023) and supports self-regulation and the overcoming of epistemological obstacles in learning about evolution (PÉREZ et al., 2023).

For its part, generalising knowledge is a mental activity of a different nature from transfer (DAVYDOV, 1986; TALIZINA, 2008; VYGOTSKY, 2010). The object of generalising knowledge is to construct progressive relationships between knowledge and the objects it represents, such that the essence of knowledge is internalised (DAVYDOV, 1986). That is, generalising knowledge is a verbal act of thought that reflects how the facts of the world are assumed as reality, independently of the sensation and perception (VYGOTSKY, 2010) of such facts of the world.

In short, mobilising knowledge is distinguished from the terms generalising and transferring knowledge by its functionality. The transfer of learning refers to the construction of semantic relationships between learning situations, where knowledge is the object of social interaction. Generalising, at its different levels of achievement, seeks to establish relationships between what has been learned and the represented object. While transfer requires superficial and contextual similarities, generalising means constructing logical relationships between the representation and the represented object, such that, in the end, they become rules or laws that represent reality. The mobility of scientific knowledge is an activity that emerges in learning situations whose object is the transfer, generalisation, application or progression of learning. That is, mobilising knowledge is an

DOI: http://doi.org/10.14393/OBv10.e2026-20

emergent activity with the function of endowing learning with a dynamic character to fulfil different cognitive tasks.

3.2 The problems with intuition

Intuitive thought is the source of the heuristics of rational thought when different cognitive tasks are performed (GENDLER, 2010; MIŠČEVIĆ, 2007, 2022; NERSESSIAN, 2002, 2010). Intuitions are implicit ideas and actions to which we attribute a self-justified, self-evident and true character. It is not known how an implicit idea is made explicit, but we do know that intuitive thought is nourished by experiences, by practice and by the development of a skill (CLEMENT, 1994, 2003, 2009, 2022; GENDLER, 2010; MIŠČEVIĆ, 2007; NERSESSIAN, 2002, 2010; RUVALCABA CERVANTES et al., 2021). The same occurs with verbalised ideas. It has been reported that the conclusions verbalised by teachers and students when solving physics problems, for example, do not necessarily derive from the mental process of modelling but rather from the act of stating and asserting prior knowledge (ASIKAINEN; HIRVONEN, 2014; RUVALCABA CERVANTES; RUIZ; QUINTERO, 2022).

Assuming intuition as the explanatory mechanism of knowledge mobility shows that we lack an explanatory model or characterisation of the actions through which teachers and students mobilise knowledge. Considering that mobilising is an emergent activity with various functions in completing cognitive tasks, it is necessary to understand that it is a system of activity involving structured actions, and that it cannot be assumed to unfold automatically. On the contrary, it is a non-automatic response (ARIEVITCH, 2017).

What is meant is that intuition, as an explanatory mechanism, is a solution that accounts for knowledge mobility as an automatic and spontaneous cognitive process. If this were so, it would suffice to increase the number of experiences of teachers and students with the content across various learning situations. Nevertheless, many of the initial conceptions and prior knowledge, close to intuitive thought, remain after didactic interventions (VOSNIADOU, 2014). Learning situations with multiple representations contribute to generalising and transferring the content of learning (TALIZINA, 2008), but not mental actions and activities (ARIEVITCH, 2017; DAVYDOV, 1986; GALPERIN; ENGENESS, 2023).

DOI: http://doi.org/10.14393/OBv10.e2026-20

Hence, the confusion with mobility, and the reduction of knowledge mobility to content, leaving aside the representation-action interaction.

The assumption of intuition as an explanatory mechanism reduces the understanding of the mobility of learning exclusively to the content of representations, as a magical cognition which, as the positions of Miščević (2000, 2007, 2022) and Pozo (2011, 2017) assert, provide the student with the sensation of being new ideas at the moment of making them explicit and, therefore, allow relearning about the facts of the world.

4 Actions that make up knowledge mobility

The purpose here is to characterise the mobility of school scientific knowledge in terms of agentive activity (ARIEVITCH, 2017). In this approach, the unit of analysis is the intellectual activity, composed of cognitive actions, the content of the representations involved in the actions, and the natural and cultural environments surrounding the activity. Therefore, to characterise means to set out the actions that make up mobility, understanding that these actions are not automatic responses to the stimuli provided by a learning situation. On the contrary, mobilising knowledge is an activity that calls for orientation and control over one's own ideas and how one uses them. The actions that make up knowledge mobility are specific and require a refined control that grows and becomes more ordered as one experiences them.

Before characterising the actions that make up knowledge mobility, it is necessary to set out how these mental actions are oriented, to identify the contexts in which knowledge mobility emerges.

4.1 Orientation, control and active engagement in mobilising knowledge

Mobility occurs spontaneously during learning; nevertheless, it becomes effective only when the agent deliberately orients to and controls it, transforming it from an intuitive act into a reflective, directed intellectual activity.

Knowledge mobility integrates the action and the representation that emerge from it. Although it is spontaneous, it is not a magical mental process (ARIEVITCH, 2017); it requires orientation, control and active engagement. The orientation and

DOI: http://doi.org/10.14393/OBv10.e2026-20

control of the activity of *mobilising knowledge* have structure and function, and are integrated by active engagement (ARIEVITCH, 2017; GALPERIN et al., 2023).

Orientation of the actions. Knowledge mobility is carried out to issue conclusions, develop scientific explanations, argue, construct an investigable question, appraise prior knowledge, conjecture hypotheses, design school experiments, construct and analyse the validity of scientific evidence, and test theories and the possible reality of the facts of the world. For knowledge to move toward achieving the task, the activity and its actions need to be oriented, and guided toward the goal (successfully executing the task). Consequently, the function of orienting knowledge mobility is a double mediation. On the one hand, orientation guides knowledge mobility, guides the agent's thoughts and acts and their interactions with the task and the emergent representations. On the other hand, orientation mediates the interaction between the agent and the task, thereby favouring self-regulation and integrating mental actions (the described parameters) into a complex mental activity: mobilising knowledge.

Orientation has structure (ARIEVITCH, 2017; SOLOVIEVA, 2019): goal, direction, condition of the action, mediating evaluation, orienting schema, monitoring and correction.

a) Goal: it is associated with the motivations and purposes the student or teacher assigns to mobility, ranging from solving a problem to evaluating the validity of conclusions and/or solutions. It establishes the why and what of mobilising knowledge.
b) Condition of the action: according to Arievitch (2017), the development of actions entails recognising and evaluating the scenario in which the agent will act. Prior to knowledge mobility, the student or teacher recognises, in the context of the task, the resources available to successfully carry out the actions that make up knowledge mobility. The awareness of the possible opportunities, constraints and obstacles to performing the mobility actions is deployed.
c) Orienting schema: it consists of the plan and the action decisions. It is an action guide that integrates the conditions, goals and control of the action. It is a mediator of the interaction between the agent and the

DOI: http://doi.org/10.14393/OBv10.e2026-20

action. That is, the orienting schema is the guide, the step-by-step, that helps the student to direct and control their knowledge-mobility actions in accordance with the action conditions and goals.

d) Direction: it manifests the sense and order in which the actions (parameters) for mobilising knowledge are executed. It is the expression of the orienting schema, such that the orienting schema (the guide for mobilising knowledge) is present to keep the activity carried out at the conscious level. The parameters do not represent a defined linear sequence.

e) Mediating evaluation: the mediating evaluation is a process of constant comparison between the desired mobility parameters (goal, orienting schema and direction of the action) and the actions carried out. The mediating evaluation is a cycle of reflection for iterating ideas about the mobility actions. Each time ideas are iterated, the control, achievement, and effectiveness of the actions used to mobilise knowledge are evaluated.

f) Monitoring and correction: in accordance with the results of the mediating evaluation, the effectiveness of mobility and the emergent representations are monitored and corrected. If necessary, the mobility parameters' actions are corrected. The orienting schema is relevant here to correct actions and avoid errors in knowledge mobility. In this regard, the work of Pérez et al. (2023) effectively illustrates students' use of graphic schemas to solve problems in evolution—and to avoid epistemological obstacles in learning.

Control and regulation of the actions. The structure of orientation fosters reflection processes that translate into self-regulation and control of knowledge-mobility actions. This involves levels of mobility depending on the level of control achieved. There is no linear control but rather control of the set of actions. The levels of mobility concern the acquisition, development, and maturation of mobility control. Therefore, control has properties: it is progressive, it requires normative mediation, and it implies agency.

DOI: http://doi.org/10.14393/OBv10.e2026-20

a) Progressive control. This means that the mobility actions are more controlled and self-regulated as one moves from the mere activity of mobilising toward the construction of orienting schemas, to the supervision and correction of actions during execution, until reaching a fluid and coordinated action. Such a transition does not occur through the accumulation of experiences and the self-adjustment of action through trial and error, but rather through an intentional and normative mediation that helps one orient oneself in action. This means that knowledge mobility needs to be a collective activity guided by teachers to foster the development and maturation of awareness and perception of its dynamic structure. It is through collective action in the student-teacher interaction that one learns to develop the ability to self-adjust and correct the mental actions necessary for mobilising scientific knowledge.
b) Normative mediation. Mobility requires mediating tools so that the mobility actions acquire meaning and progressive control. The orienting schemas guide and help agents mobilise knowledge, but from the agentive activity approach, a mediator is not only a semiotic instrument (ARIEVITCH, 2017); it is more than a guide or a representation of how to mobilise knowledge step by step. A mediation entails starting from a series of actions carried out together with others (classmates or teachers), with the purpose of learning to mobilise knowledge and giving meaning to that schema. It is these meanings given to the schema for mobilising knowledge that are internalised as knowledge-mobility actions.
c) Agency. When the agent learns—through mediation in interaction with others—that mobilising knowledge is an activity with structure, directed and intentional —the agent will also recognise that structure as their own when orienting their knowledge mobility. Agency implies that the individual can recognise the situations, purposes, and contexts in which they need to mobilise knowledge in a controlled way.

DOI: http://doi.org/10.14393/OBv10.e2026-20

Active engagement. Orientation and control do not operate on their own; they require the agent to become intentionally, consciously and deliberately involved in the mental actions that make up mobility. Active engagement requires the student or teacher to become involved in actions with specific purposes (ARIEVITCH, 2017) of exploring, reflecting, evaluating, understanding and controlling their own mobilising activity, rather than merely stating what they already know. It is what transforms a sequence of oriented and controlled actions into a genuine activity of mobilising knowledge; without active engagement, orientation remains an external guide and control a mechanical correction (SOLOVIEVA, 2019). Therefore, together with orientation—the structure of mobility—and control—the regulation of mobility—, active engagement is the condition that integrates the parameters into the system of activity of knowledge mobility.

According to Arievitch (2017, p. 40), "from the agentive activity perspective, psychological processes are not separate 'objects,' but rather emergent properties of the agent's interaction with the external world." This implies defending here knowledge mobility in terms of actions, of the acts of an agent (student or teacher) on and with knowledge. The following are proposed: parameters of actions that, together, constitute the system of activity for knowledge mobility in science learning. The parameters set out here are the product of empirical work (RUVALCABA CERVANTES, 2020; 2025; RUVALCABA CERVANTES; QUINTERO, 2022; RUVALCABA CERVANTES et al., 2021) and theoretical reflections (RUVALCABA CERVANTES, 2024; RUVALCABA CERVANTES et al., 2021) in which systems of activity for mobilising knowledge are examined, when carrying out free-fall thought experiments and transforming climate fiction into school climate problems.

4.2 Parameters of the actions of knowledge mobility

The parameters set out below are not speculative; they are the product of a qualitative analysis of think-aloud reports and retrospective interviews with physics teachers who were solving free-fall thought experiments (RUVALCABA CERVANTES, 2020; RUVALCABA CERVANTES et al., 2021). The expressions that externalised the teachers' actions were organised into data-grounded categories and were refined by constant comparison until the parameters described here were configured. Subsequently, the characterisation was contrasted and broadened in another domain and with other agents—biology teachers who transformed climate fiction into school scientific problems (RUVALCABA CERVANTES, 2024, 2025). In this way, the proposal articulates empirical evidence within a theoretical reflection: the data delimit the actions that are observed when mobilising knowledge, and the agentive activity approach (ARIEVITCH, 2017) provides the unit of analysis and the concepts—orientation, control and active engagement—that make them intelligible as a system of activity.

They are set out as parameters or indicators of actions, since each intellectual action manifests nuances proper to the function (arguing, asking, explaining, conjecturing or testing hypotheses, generalizing, transferring or applying learning) of knowledge mobility, of the discipline, of the scientific content being mobilized, of the task or learning situation, and of the experience and control the student/teacher has over the activity. This means that the parameters do not specify universal regularities of mental activity, given that the mental actions are related to "the levels of the situated interactions between the active agent and the environment" (ARIEVITCH, 2017, p. 41). The parameters do not indicate consecutive, causal actions when mobilising knowledge. The actions occur in a simultaneous and varied order. The parameters reveal actions that, together, evidence the emergence of knowledge mobility. It is necessary to emphasise that (1) the actions are expressed in an integrated way to denote knowledge mobility and (2) mobility is manifested integrated with other mental activities. The term 'parameters' is retained—rather than 'steps' or 'stages'—to emphasise that they do not constitute a linear sequence or universal regularities, but rather actions whose nuances and emergence depend on the task and context.

The parameters do not describe individual cognitive operations isolated from the social and cultural world. The agentive activity approach is sustained by the dialectical-materialist view (DAVYDOV, 1986; TALIZINA, 2008; SOLOVIEVA, 2019; STETSENKO, 2016; VYGOTSKY, 2010), so that the mental actions that make up mobility have their origin in collective, culturally mediated activities and are internalised from shared forms of acting with others (SOLOVIEVA, 2019). For this reason, each parameter must be read in a double sense: as the action of an agent

DOI: http://doi.org/10.14393/OBv10.e2026-20

and as the appropriation of a historically and culturally constructed way of operating with knowledge. The reference domains that emerge when knowledge is mobilised are laden with the history of their learning and the practices in which they were constructed; the integration of elements obeys models, laws, and scientific criteria that are cultural products. Orientation, control, and active engagement are integrated through the normative mediation of the mobility of scientific knowledge, which occurs only in interaction with others or with semiotic and cultural tools (SOLOVIEVA, 2019; STETSENKO, 2016; VYGOTSKY, 2010). Consequently, the social and the cultural do not externally surround knowledge mobility, they constitute it, since it is in the mediated collective activity that these actions are formed, acquire meaning and become progressively conscious and controlled. Mobility emerges as an activity in the learning situations or tasks that require dynamising knowledge and changing its position; representations, for their part, emerge from the interaction between the agent and their environment and do not pre-exist as internal entities that are later externalised (ARIEVITCH, 2017; STETSENKO, 2016).

The parameters relate to the orientation described in section 4.1: the seven parameters are the constituent actions with which one mobilises, whereas orientation is the structure that regulates them. Orientation operates as a double mediation: it guides the agent's thoughts toward the goal and, at the same time, favours control and self-regulates the integration of the parameters into the activity of ‘*mobilising knowledge’*.

1. *Emergence of reference domains.* Underlying the activity of mobilising learning is the assumption of a set of internalised referents. The different systems of representation and activity emerge through the mediation of learning situations, the cognitive tasks to be carried out, or any other cultural, material or symbolic tool that calls for mobilising knowledge. It is important to stress that the reference domains are more than representational contents; they involve cultural history, the dialectical interaction between culture and agent in learning processes, and the activities and actions performed with the reference representations.

DOI: http://doi.org/10.14393/OBv10.e2026-20

2. *Operability with the reference domains*. With the systems of representation and activity that emerge, in accordance with what the student has available and considers necessary to begin and complete the assigned task, actions are operationalised to suppress, inhibit, and suspend the emergent representations and actions. Simultaneously, the emergent representations and actions are filtered, and the information that the student or teacher considers indispensable for beginning, developing, completing, and evaluating the task is abstracted. As greater control and awareness for mobilising knowledge is achieved, the agent makes explicit the criteria used to filter and abstract information from the reference action and representational systems. For example, it has been reported (CLEMENT, 2022; VOSNIADOU, 2014) how experts, unlike novices, inhibit and suspend the initial internal representations they activate, and abstract the information required to solve problems about gravity. Likewise, physics teachers (RUVALCABA CERVANTES; QUINTERO, 2022) draw on diverse sources and abstract the elements needed to conduct free-fall thought experiments.
3. *Integrating elements and actions.* The elements that are abstracted from the referents are integrated in accordance with criteria imposed by the task and the agent. Integrating the elements is an action manifested in making explicit constraints and variables and in determining the conditions of validity for the integrated information. This is reflected, for example, in works in which teachers establish variables to carry out thought experiments (RUVALCABA CERVANTES, 2020), and in tasks in which students determine relationships between the known and the unknown to construct questions (CHAMIZO; RÍOS-LÓPEZ, 2017), or those in which students use tools (e.g., mind maps) to monitor and self-regulate epistemological obstacles when learning (for example, PÉREZ et al., 2023). It is necessary to consider that the organization of the integrated elements obeys both internalised school scientific models, laws and principles, and the interpretations and perceptions of the facts of the world per se (ARIEVITCH, 2017; CLEMENT, 1994, 2003, 2009; REINER; GILBERT, 2000; RUVALCABA CERVANTES; QUINTERO, 2022). The arrangement depends on the control the student or teacher has over mobility, such that greater control of the activity implies integrating learning around a nuclear term, variable, action or

DOI: http://doi.org/10.14393/OBv10.e2026-20

concept. This is manifested, for instance, in the control of variables when experts monitor each variable's behaviour while solving problems (KUHN, 1989), conduct experiments (REINER; GILBERT, 2000) or construct investigable questions (CHAMIZO; RÍOS-LÓPEZ, 2017).

4. *Mental simulation.* When integrating reference elements, a representation emerges that, tentatively, responds to the needs of the assigned task. From the newly adjusted or constructed representation, possible consequences of relating certain reference fragments are denoted. It is then that the agent becomes actively engaged; that is, they intentionally direct their mental actions and thoughts toward conjecturing hypotheses, causal relationships and explanations. Their actions will serve to visualise the viability of the emergent representation in the mind. In this regard, empirical work based on think-aloud and retrospective interviews provides evidence of reflective thinking, language use, the generation of mental images, and the monitoring of self-regulation processes when working with great dilemmas (CLEMENT, 2003, 2022; RUVALCABA CERVANTES, 2020, 2025). Simulating in the mind is an action that helps the agent explain, in a controlled way, and make explicit internally what underlies the situation posed in the task to be solved. That is, simulating in the mind helps explain to oneself what could occur or is occurring in the world that is the object of attention in the assigned task.
5. *Monitoring (vigilance).* When making explicit to oneself the knowledge being mobilised, one evaluates it to monitor its integration (in the emergent representation) and to recognise the relationships between the mobilised knowledge. The agent doubts the pertinence of the established relationships in order to a) explore other possibilities of integrating the mobilised knowledge (for example, retrieving and introducing other knowledge or new referents), b) evaluate the consequences of how the knowledge was integrated and draw a conclusion, c) identify other possible consequences and the criteria that support them and integrate them into the initial arrangement. Monitoring is not a final action but a self-regulation that accompanies the whole activity: the agent compares the emergent representation with the goal and the task's criteria, detects inconsistencies, and decides whether to iterate the action, retrieve new

DOI: http://doi.org/10.14393/OBv10.e2026-20

referents, or sustain the conclusion. In empirical works, this controlled scepticism distinguishes the expert from the novice, since the former tests the variation of the evidence before concluding (KUHN, 1989; RUVALCABA CERVANTES, 2020, 2025).

6. *Externalising the representation.* When the agent integrates and evaluates the mobilised knowledge in an emergent representation, they communicate it. The format of the external representation is coherent and appropriate to the task; it may be written, oral, iconic, or a flowchart, mind map, or any other format pertinent to the task's demands. The choice of format is essential because, when externalising, the agent makes their representation an object of revision, their own and others'. Different formats make explicit different relationships (GÓMEZ GALINDO, 2026)—a diagram can communicate dependencies that oral discourse does not state—, so that the external representation is multimodal and is adjusted to the discipline and the demand of the task (CLEMENT, 2003, 2009; GALLEGOS-CÁZARES et al., 2022; GÓMEZ GALINDO, 2026; PÉREZ et al., 2023). Externalising is the point at which the individual activity becomes social and is made available for the teacher's and peers' mediation.
7. *Evaluation.* At all times, the agent—student/teacher monitors, self-regulates and controls their activity of mobilising knowledge and each of the actions that constitute it. Nevertheless, externalising and communicating the representation favours visualising consequences and conclusions that have not yet been foreseen. The evaluation of the externalised emergent representation is carried out by contrasting it with the assigned task and its criteria, and by assessing its internal consistency. The evaluation prompts the agent to realise that they have completed knowledge mobility, to recognise the need to restart the mobility activity, or to iterate on an action. This evaluation makes it possible to close or reopen the cycle: confronted with the task and with peers, it can reveal unforeseen consequences that require restarting mobility or iterating an action; it is also the moment at which normative mediation becomes decisive so that the agent recognises actions they do not yet master (TALIZINA, 2008; RUVALCABA CERVANTES, 2025; RUVALCABA CERVANTES et al., 2021).

DOI: http://doi.org/10.14393/OBv10.e2026-20

Finally, it is worth distinguishing between monitoring (vigilance) and evaluating, parameters that could be confused. Monitoring is the self-regulatory doubt that accompanies the process, whereas evaluation compares the plan with the execution; monitoring adjusts the action in progress, and evaluation judges the consistency of the externalised final product with the task.

To emphasise, the mobility of scientific knowledge is characterised by a complex activity composed of actions—described as parameters—that an agent consciously and intentionally carries out to complete tasks and satisfy the cognitive demands they entail.

4.3 The parameters in a situated task: the free-fall thought experiment

To illustrate how these parameters are materialised in a concrete situation, an example will be given with a task involving secondary-school physics teachers documented in empirical works (RUVALCABA CERVANTES, 2020; RUVALCABA CERVANTES et al., 2021). The task consisted of conducting a free-fall thought experiment, in which one is asked to imagine what would happen to an object—an apple—that falls through a tunnel crossing the Earth from one side to the other. When faced with the task, the teacher does not respond automatically. First, a reference domain emerges: the narrated situation activates knowledge of gravity, the fall of bodies, and the centre of mass, together with the learning history and prior experiences associated with those concepts, like didactic knowledge (RUVALCABA CERVANTES; QUINTERO, 2022). Next, the agent operates with that domain by filtering and abstracting the elements they consider pertinent—the gravitational force, the mass of the object, the absence of air resistance—and inhibiting those they judge irrelevant. When integrating those elements, they make explicit constraints and conditions of validity (for example, assuming a frictionless tunnel and an Earth of uniform density) and organise the knowledge around a nuclear concept, gravity.

On that experimental arrangement, the agent carries out a mental simulation: they imagine the behaviour of the object as it falls through the tunnel and conjecture its consequences, anticipating that the apple would accelerate toward the centre and oscillate from one end to the other until coming to rest at the Earth's centre of gravity.

Here, active engagement is observed, since the agent intentionally directs their actions to test the viability of their representation. When monitoring, they doubt the established relationships, introduce new referents and evaluate unforeseen consequences. When externalising the representation—orally, in the documented cases—they communicate it in a format coherent with the task. When evaluating, the result is contrasted with the task criteria (conjecturing the behaviour of the falling apple along the tunnel) and with the model's internal consistency, which allows teachers to recognise whether mobility has concluded or needs to be iterated.

Empirical work also shows that when this process lacks deliberate orientation and control, teachers tend to state the knowledge they possess without exploring the consequences of the imagined experiment (RUVALCABA CERVANTES, 2020; RUVALCABA CERVANTES et al., 2022; RUVALCABA CERVANTES; QUINTERO, 2022). For example, they do not explore how gravity would continue to act on the apple once it passes the centre of the Earth. This contrast confirms that effective mobility is not spontaneous, but rather an activity that requires mediation, orientation and active engagement.

Although the thought experiment was carried out by the teachers in individual interviews, mobility is an activity of a sociocultural nature: the teachers propose the experimental scenario and conjecture aloud, discuss the constraints and correct themselves in a self-regulated way, such that the emergent representations are projections outward of the semiotic tools and senses of internalised mental actions proper to school scientific culture (RUVALCABA CERVANTES; QUINTERO, 2022). The collective dimension is the condition in which mental actions are constituted, as internalised knowledge is mobilised through the mediation of symbolic and material tools and social interaction (DAVYDOV, 1986; SOLOVIEVA, 2019; STETSENKO, 2016; VYGOTSKY, 2010). In this sense, providing guiding tools to mobilize knowledge to the agents materializes the sociocultural nature of this activity (RUVALCABA CERVANTES, 2025).

It might be objected that the proposed mobility parameters reduce knowledge mobility to a manifestation of working and long-term memory, serving to make information explicit and to serve complementary representational purposes (NERSESSIAN, 2002, 2010; POZO, 2001, 2011, 2017). If it were

DOI: http://doi.org/10.14393/OBv10.e2026-20

exclusively so, it would suffice to train knowledge mobility with mnemonic techniques to retrieve, make explicit and communicate knowledge. The mobility parameters set out require conceiving mental actions together with their orientation (ARIEVITCH, 2017; RUVALCABA CERVANTES, 2025). Such orientation was set out in section 4.1, where it was explained how the mental actions that constitute the mobility of school scientific knowledge are oriented.

To conclude, knowledge mobility in science education implies that the agent (student/teacher) learns to: a) know and apply the parameters that allow them to mobilise knowledge in a conscious and regulated way; b) construct orienting schemas that give meaning and control to knowledge mobility; c) develop actions and skills for the control, supervision and correction of mobility.

5 Final considerations

The aim of this text is to characterise the mental actions that constitute the activity of mobilising school scientific knowledge. These actions were set out in section four. The mobility parameters begin by describing what is imagined, retrieving information from memory, seeking relationships among elements of the initial emergent representations, fixing an expectation or hypothesis, testing it by varying the task's circumstances, and evaluating the result. When mobilising scientific knowledge, one operates with theoretical, experiential and common-sense knowledge through actions of thought in various situations, from imaginary ones to those located in real learning contexts.

The scope of the proposal is to discuss the characteristics of knowledge mobility to recognise it when it manifests and to provide elements to foster it explicitly and effectively. That is, to have an initial orienting schema for teaching and learning to mobilise scientific knowledge.

To broaden these reflections, it is worth placing the teacher at the centre of the mobilising activity. If mobilising scientific knowledge is a mediated activity learned through interaction with others, the teacher is not a transmitter of information but one who orients, models, and regulates mobility actions until the students make them their own. Their role consists of constructing and sharing orienting schemas, making the

DOI: http://doi.org/10.14393/OBv10.e2026-20

activity's structure visible, and progressively ceding that regulation to students as they develop agency over their own mental actions (RUVALCABA CERVANTES, 2025).

This role entails concrete challenges. The first is of an epistemological and disciplinary nature: fostering knowledge mobility requires of the teacher a solid and integrated content knowledge, since only thus can they anticipate the consequences of a scenario, evaluate the pertinence of the relationships the students propose, and guide the correction of errors. Empirical research warns that limitations in teachers' content knowledge restrict the transformation and exploration of learning scenarios (McCONNELL; PARKER; EBERHARDT, 2013; RUVALCABA CERVANTES, 2025). A second challenge is didactic: designing tasks and mediations—thought experiments, investigable questions, multiple representations—that call for mobilising knowledge in a conscious, not merely intuitive, way. A third challenge is the management of the collective activity: sustaining an interaction in the classroom in which mobility is exercised, discussed, and regulated among peers, so that normative mediation becomes cultural appropriation rather than a mere following of steps.

Recognising these challenges opens avenues for future research: how do levels of mobility control develop and mature throughout schooling? Which orienting schemas prove most effective within the discipline and for the scientific content? And how can knowledge mobility be evaluated without reducing it to the mere verbalisation of what has been learned? These questions confirm that characterising knowledge mobility as an agentive activity is a starting point for teaching and learning to mobilise scientific knowledge in an explicit, regulated and situated way.

6 References

ARIEVITCH, I. M. *Beyond the brain:* An agentive activity perspective on mind, development, and learning. New York: Springer, 2017.

ASIKAINEN, M. A.; HIRVONEN, P. E. Probing pre-and in-service physics teachers' knowledge using the double-slit thought experiment. *Science & Education*, v. 23, p. 1811-1833, 2014. DOI: http://doi.org/10.1007/s11191-014-9710-1.

DOI: http://doi.org/10.14393/OBv10.e2026-20

BARNETT, S. M.; CECI, S. J. When and where do we apply what we learn?: A taxonomy for far transfer. *Psychological bulletin*, v. 128, n. 4, p. 612-637, 2002.

BROUSSEAU, G. *Iniciación al estudio de la teoría de las situaciones didácticas*. Buenos Aires: Libros del Zorzal, 2007.

CHAMIZO, J. *Habilidades de pensamiento científico. Los diagramas heurísticos*. México: UNAM, 2017. Disponível em: http://www.joseantoniochamizo.com/pdf/educacion/libros/014_Habilidades_pensamiento_cientifico.pdf. ISBN: 978-607-02-9893-6.

CHAMIZO, J. A.; RÍOS-LÓPEZ, G. Diseño y evaluación de una estrategia didáctica para enseñar a preguntar. *Revista Científica*, v. 28, p. 33-41, 2017. DOI: http://doi.org/10.14483/udistrital.jour.RC.2017.28.a3.

CLEMENT, J. Imagistic Simulation and Physical Intuition in Expert Problem Solving. In: RAM, A.; EISELT, K. (ed.). *Proceedings of the Sixteenth Annual Conference of the Cognitive Science Society.* Routledge, 1994. p. 201-206. DOI: http://doi.org/10.4324/9781315789354.

CLEMENT, J. Imagistic simulation in scientific model construction. *Proceedings of the Annual Meeting of the Cognitive Science Society,* v. 25, n. 25, 2003.

CLEMENT, J. The role of imagistic simulation in scientific thought experiments. *Topics in Cognitive Science,* v. 1, n. 4, p. 686-710, 2009. DOI: http://doi.org/10.1111/j.1756-8765.2009.01031.x.

CLEMENT, J. Multiple Levels of Heuristic Reasoning Processes in Scientific Model Construction. *Frontiers in Psychology,* v. 13, 750713, 2022. DOI: http://doi.org/10.3389/fpsyg.2022.750713.

DAVYDOV, V. V. *Tipos de generalización en la enseñanza.* La Habana: Editorial Pueblo y Educación, 1986.

GALLEGOS-CÁZARES, L.; FLORES-CAMACHO, F.; CALDERÓN-CANALES, E. Elementary School Children's Explanations of Day and Night. *Science & Education,* v. 31, p. 35-54, 2022. DOI: http://doi.org/10.1007/s11191-021-00230-1.

GALPERIN, P. Y.; ENGENESS, I.; THOMAS, G. *Psychological Significance and Difference Between Tools Use by Humans and Animals:* PY Galperin's Dissertation. Springer Nature, 2023. DOI: http://doi.org/10.1007/978-3-031-14929-0.

PÉREZ, G.; GÓMEZ GALINDO, A. A.; GALLI, L. M. G. Multimodalidad y regulación metacognitiva en el aprendizaje de la evolución. *Enseñanza de las Ciencias. Revista de investigación y experiencias didácticas,* v. 41, n. 1, p. 5-24, 2023.

GENDLER, T. *Intuition, Imagination, and Philosophical Methodology.* Oxford University Press, 2010.

DOI: http://doi.org/10.14393/OBv10.e2026-20

GÓMEZ GALINDO, A. A. Precursor Models in Early Science Education: a multimodal perspective. *Mediterranean Journal of Education,* v. 6, n. 2, p. 39-48, 2026.

KARMILOFF-SMITH, A. *Beyond modularity: A developmental perspective on cognitive science.* Cambridge: MIT Press, 1992.

KUHN, D. Children and adults as intuitive scientists. *Psychological Review,* v. 96, n. 4, p. 674-689, 1989. DOI: http://doi.org/10.1037/0033-295X.96.4.674.

LOBATO, J.; HOHENSEE, C. Current Conceptualizations of the Transfer of Learning and Their Use in STEM Education Research. In: HOHENSEE, C.; LOBATO, J. (org.). *Transfer of Learning.* Springer, Cham, 2021. DOI: http://doi.org/10.1007/978-3-030-65632-4_1.

MCCONNELL, T. J.; PARKER, J. M.; EBERHARDT, J. Assessing Teachers' Science Content Knowledge: A Strategy for Assessing Depth of Understanding. *Journal of Science Teacher Education,* v. 24, n. 4, p. 717-743, 2013. DOI: http://doi.org/10.1007/s10972-013-9342-3.

MIŠČEVIĆ, N. Mental models and thought experiments. International Studies in the Philosophy of Science, v. 6, n. 3, p. 215-226, 1992. DOI: https://doi.org/10.1080/02698599208573432.

MISCEVIC, N. Intuition as a second window. *The Southern Journal of Philosophy*, v. 38, n. 5, p. 87-112, 2000.

MIŠČEVIĆ, N. Modelling intuitions and thought experiments. *Croatian Journal of Philosophy,* v. 7, n. 20, p. 181-214, 2007.

MISCEVIC, N. *Thought Experiments.* Cham: Springer, 2022. DOI: https://doi.org/10.1007/978-3-030-81082-5.

NERSESSIAN, N. J. The cognitive basis of model-based reasoning in science. In: CARRUTHERS, P.; STICH, S.; SIEGAL, M. (org.). *The Cognitive Basis of Science.* Cambridge University Press, 2002. p. 133-153. DOI: http://doi.org/10.1017/CBO9780511613517.008.

NERSESSIAN, N. J. *Creating Scientific Concepts.* MIT Press, 2010.

PÉREZ, G. M.; GÓMEZ GALINDO, A. A.; GONZÁLEZ GALLI, L. Multimodalidad y regulación metacognitiva en el aprendizaje de la evolución. *Enseñanza de las ciencias:* revista de investigación y experiencias didácticas, v. 41, n. 1, 2023. DOI: https://doi.org/10.5565/rev/ensciencias.5641.

PERKINS, D.. *Making learning whole:* How seven principles of teaching can transform education. San Francisco: John Wiley & Sons, 2009.

POZO MUNICIO, J. I. *Humana mente: el mundo, la conciencia y la carne*. Madrid: Ediciones Morata, 2001.

POZO MUNICIO, J. I. *Aprendices y maestros: la psicología cognitiva del aprendizaje.* Madrid: Alianza editorial, 2011.

POZO MUNICIO, J. I. *Psicología del Aprendizaje Humano: Adquisición de conocimiento y cambio personal.* Madrid: Ediciones Morata, 2017.

REINER, M.; GILBERT, J. Epistemological resources for thought experimentation in science learning**.** *International Journal of Science Education,* v. 22, n. 5, p. 489-506, 2000. DOI: http://doi.org/10.1080/095006900289741.

RUVALCABA CERVANTES, J. M. *Experimentos pensados y movilidad de conocimientos: un estudio con profesores de física del nivel secundario.* 2020. Tese (Doutorado) - CINVESTAV, México, 2020.

RUVALCABA CERVANTES, J. M.; QUINTERO, R. Z. Conocimiento docente: ¿modelar la caída libre o un modelo teórico? *Revista de Enseñanza de la Física,* v. 34, p. 283-288, 2022.

RUVALCABA CERVANTES; GÓMEZ GALINDO, A. A.; QUINTERO, R. Z. Conocimiento de contenido de profesores: el experimento pensado de caída libre de Galileo. *Enseñanza de las ciencias: revista de investigación y experiencias didácticas,* v. 40, n. 1, p. 5-24, 2021. DOI: http://doi.org/10.5565/rev/ensciencias.3357.

RUVALCABA CERVANTES, J. M.; RUIZ, H. L. G.; QUINTERO, R. Z. Imaginación científica escolar: actividad social y cognitiva. *Síncronía,* n. 81, p. 487-500, 2022. DOI: http://doi.org/10.32870/sincronia.axxvi.n81.24a22.

RUVALCABA CERVANTES, J. M. Transformar la ficción: una actividad mental para modelar y aprender sobre cambio climático. *Síncronía,* n. 86, p. 671-696, 2024. DOI: http://doi.org/10.32870/sincronia.axxviii.n86.36.24b.

RUVALCABA CERVANTES, J. M. Agentive Activity to Transform Cli-Fi into School Science Problems About Climate Change. *Australian Journal of Environmental Education,* v. 41, p. 420-435, 2025. DOI: http://doi.org/10.1017/aee.2025.10073.

SOLOVIEVA, Y. Las aportaciones de la teoría de la actividad para la enseñanza. *Educando para Educar,* n. 37, p. 13-24, 2019.

STETSENKO, A. *The Transformative Mind: Expanding Vygotsky's Approach to Development and Education.* Cambridge: Cambridge University Press, 2016.

TALIZINA, N. Mecanismos psicológicos de la generalización. *Acta Neurológica Colombiana*, v. 24, n. 2 supl 1, p. S76-S88, 2008.

DOI: http://doi.org/10.14393/OBv10.e2026-20

VOSNIADOU, S. Examining cognitive development from a conceptual change point of view: The framework theory approach. *European Journal of Developmental Psychology*, v. 11, n. 6, p. 645-661, 2014. DOI: http://doi.org/10.1080/17405629.2014.921153.

VYGOTSKY, L. *Pensamiento y lenguaje*. Barcelona: Paidós, 2010.

ZONA-LÓPEZ, J. R.; RUIZ-ORTEGA, F. J.; MÁRQUEZ-BARGALLÓ, C. Modelos de explicación sociocientífica sobre el cambio climático desde una perspectiva multimodal. *Educación y Humanismo*, v. 25, n. 44, 2023. DOI: http://doi.org/10.17081/eduhum.25.44.5747.

Received: September/2024

Approved: March/2025