

# OntoMI: An ontology grounded in the theory of multiple intelligences for semantic classification of educational resources

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## Abstract

This article introduces OntoMI, a semantic ontology based on Howard Gardner's Theory of Multiple Intelligences, developed to formally represent and infer the cognitive dimensions evoked by educational texts. OntoMI provides an organized conceptual framework that enables the identification, classification and quantification of multiple intelligences in educational texts. It serves as the basis for a computerized model that processes texts, extracts elements and infers cognitive activations through semantic inferences. Based on these inferences, the system creates explainable cognitive profiles for each resource, which are represented as intelligence distribution vectors. This approach aims to enable the semantic classification and evaluation of content to support more comprehensive pedagogical analysis, personalized access to learning materials and adaptation to individual cognitive profiles.

## Keywords

Ontology, Multiple Intelligences, Educational Technology, Semantic Classification, Personalized Learning

## 1. Introdução

The uniqueness of human beings manifests itself in several dimensions – cognitive, affective, social and cultural – that have a direct impact on how individuals learn and interact with knowledge [1, 2, 3]. This diversity requires pedagogical approaches that not only recognize these differences, but operationalize them as central elements in the planning and delivery of instruction. The Theory of Multiple Intelligences (MI) proposed by Howard Gardner offers a conceptual framework for this, which assumes that human cognition manifests itself in different areas of competence, such as linguistic, logical-mathematical, musical, spatial, physical-kinesthetic, interpersonal, intrapersonal, naturalistic and existential intelligences [3].

Despite the growing demand for personalized education systems, most current approaches still rely on standardized teaching models that ignore the diversity of individuals' learning styles and processes. Even when some degree of customization is attempted, the appropriation of theory is usually limited and superficial, which restricts its application. In digital contexts, this limitation is exacerbated by the lack of models capable of representing, deriving and applying the principles of MI to the analysis or recommendation of instructional content in a structured, explainable and scalable way. This gap hinders the advancement of pedagogical practices that respond to cognitive plurality in light of MI, and complicates the identification, classification and use of materials based on the intelligences they elicit – especially on a large scale and with computerized support.

Against this background, the present work proposes the development of OntoMI, a semantic ontology based on the MI theory and aimed at the formal representation of the cognitive dimensions elicited by educational texts. The proposal addresses the following central research question: *How can textual*

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*educational resources be semantically classified to support personalized teaching while remaining faithful to the Theory of Multiple Intelligences?*

OntoMI attempts to fill this gap by providing an ontological infrastructure that enables the identification, classification and quantification of features of intelligences elicited through the semantic mapping of textual elements to ontological classes and properties. Its construction is based on the systematization of the pedagogical principles contained in Gardner's works and on a conceptual modeling oriented towards inference that allows educational materials to be interpreted according to the dominance of certain intelligences.

Therefore, this study aims to develop a formal semantic ontology based on Gardner's theory that is capable of representing, inferring and quantifying the cognitive dimensions evoked by educational textual content and that can be integrated into a computerized system. The specific aims of this study are: (OE1) to identify and systematize the pedagogical foundations of MI directly from Gardner's works; (OE2) to develop a semantic ontology that focuses on the representation of MI in educational contexts; and (OE3) to implement a computational model for classifying educational texts based on OntoMI.

The aim is to provide a conceptual and technical tool capable of matching educational content with students' cognitive profiles and supporting pedagogical curation and personalized teaching from an explainable, semantically structured perspective coherent with the principles of the theory.

## 2. Related work

Several studies have used ontologies as the basis for adaptive educational systems and have investigated their ability to formally represent knowledge and allow conclusions to be drawn about content and learning profiles. One example is the work of Vasiliki Demertzi and Konstantinos Demertzis [4], who propose an adaptive teaching system based on ontological matching that enables personalized content recommendations according to the mapping between students and teaching materials. Although it contributes to personalized learning, their proposal takes an ontology-centric approach that focuses on the scope of the study and does not involve cognitive concepts.

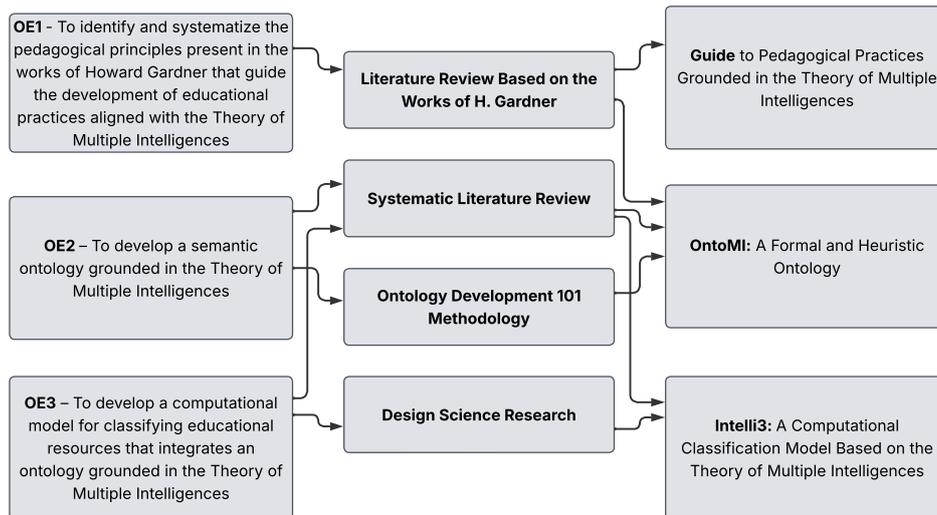
Similarly, Monika Rani et al. [5] presented the OPAESFH system, which combines ontologies with inference techniques based on Fuzzy Petri Nets (FPN) and Hidden Markov Models (HMM) to adapt instruction to student characteristics. Despite its technical sophistication, the model does not integrate a conceptual structure based on cognitive theories and is limited to predefined learning profile categories.

The work of Pornpit Wongthongtham et al. [6] explicitly attempts to integrate MI theory into a fuzzy ontology aimed at the semantic annotation of educational content. The proposal highlights the potential of MI as a basis for intelligent recommender systems and personalized learning, but still lacks a structured ontological formalization of intelligences, especially one aimed at the detailed analysis of textual materials.

Against this background, this paper proposes OntoMI, a semantic ontology developed based on the original principles of the MI theory proposed by Howard Gardner. In contrast to the aforementioned approaches, OntoMI aims to formally represent and infer the MI evoked by textual educational content by providing an explainable conceptual and computational infrastructure capable of generating cognitive vectors expressing the distribution of intelligences activated by each resource. As such, the proposal brings advances in terms of theoretical fidelity to MI, semantic classification capability, and the development of educational systems more attuned to cognitive diversity.

## 3. Methodology

The methodological approach of this applied research is aimed at solving a practical problem related to personalized learning and the pedagogical curation of learning objects based on the MI theory. The investigation is structured in complementary phases that include a conceptual foundation, a review of the state of the art, and the development of computational artifacts. A summary of this methodological structure is presented in Figure 1.



**Figure 1:** Methodological model of research: objectives, methods and artifacts. Source: authors' elaboration.

The starting point was an in-depth analysis of the works of Howard Gardner, focusing on the epistemological and pedagogical assumptions of MI theory. This formed the basis not only for the systematization of the pedagogical criteria (OE1), but also for the conceptual support necessary for structuring the ontology (OE2). This first phase is characterized by an exploratory approach aimed at directly extracting the core elements of the theory in relation to pedagogical practices, avoiding secondary interpretations or purely instrumental uses. As a result of this phase, a guide to pedagogical practices based on MI has been developed, containing principles and guiding criteria for planning teaching and learning experiences adapted to the cognitive diversity of learners.

Subsequently, a systematic literature review (SLR) was conducted, following the methodological guidelines of Barbara A. Kitchenham, David Budgen, and Pearl Brereton [7], with the aim of critically capturing how MI is used in digital educational environments. The SLR identified recurring gaps in the computational application of theory, particularly in relation to the lack of semantic mechanisms, limited personalization strategies, and a lack of structures capable of deriving cognitive profiles from textual data. This mapping supported the conceptual and technical choices underlying the proposals described in OE2 and OE3.

On this basis, pedagogical and computational artifacts are being developed using methods appropriate to the nature of each phase of the research. In line with OE2, OntoMI has been developed – a formal and heuristic ontology created according to the *Ontology Development 101* methodology [8] and adapted for the semantic representation of text elements that evoke different intelligences. This ontology represents the main conceptual artifact of the research and enables the modeling of inferential relationships between theoretical concepts and the construction of cognitive vectors describing the profiles activated by educational content. It is validated by analyzing illustrative examples, checking semantic coherence, conceptual coverage, and computational applicability.

Finally, in response to OE3, the research culminates in the development of the computational model *Intelli3*, built using the *Design Science Research* (DSR) methodology [9], which focuses on the construction and evaluation of technological artifacts to solve practical problems. The system represents the main computational artifact of the study and is structured by a modular, multi-layered architecture that ensures flexibility, scalability and separation of functional responsibilities. This architecture was designed to operationalize MI at a computational scale.

A focus group composed of educators and MI specialists will be formed to validate the artifacts of the study and the data obtained during testing. The evaluation will follow a knowledge elicitation methodology based on the Delphi [10, 11] qualified consensus on the conceptual coherence, pedagogical applicability and appropriateness of the conclusions drawn by the system.

## 4. The OntoMI ontology

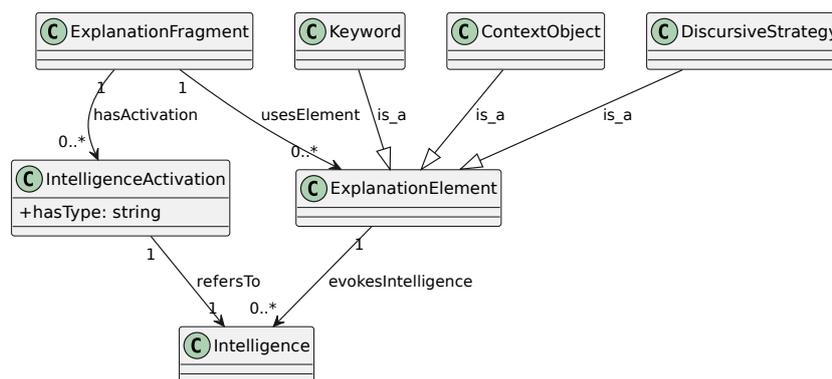
OntoMI is a formal and heuristic semantic ontology that was developed to conceptualize and infer in a structured way the MI elicited by educational content expressed in natural language. The ontology is based on the principles of MI theory, as proposed by Howard Gardner [2? ], and aims to translate human cognitive diversity into an ontological architecture capable of supporting explainable mechanisms for analyzing and classifying textual educational resources.

The construction of OntoMI followed the principles of the *Ontology Development 101* methodology [8], which was adapted to the educational domain with a focus on the semantic representation of cognitive properties. This methodology was selected because of its simplicity and step-by-step orientation, which makes it particularly suitable for the creation of initial ontological artifacts and for maintaining clarity in scope definition. The process comprised: (i) a clear specification of the domain and goals of the ontology; (ii) the identification and organization of recurring terms and concepts in pedagogical discourse; (iii) the definition of semantic categories related to the intelligences proposed by Gardner; and (iv) the modeling of classes, properties, and axioms that enable the derivation of cognitive profiles from observable linguistic elements.

The conceptual structure of OntoMI is organized around three main types of elements extracted from texts. The first are keywords, which correspond to terms that represent concepts, content, or cognitive operations strongly associated with specific intelligences. The second are *ContextObjects*, which denote the central topics of the content and their disciplinary connections. Finally, there are the *DiscursiveStrategies*, referring to the ways in which the content is organized and presented, such as through narratives, descriptions, or comparisons.

Each of these elements, once identified in a text segment, is linked to one or more intelligences via the *evokesIntelligence* property. This relationship is not binary, but weighted: Each association can have a certain weight that reflects the intensity with which the element evokes a certain intelligence. The exact definition of this weighting is left to the person performing the inference, which allows for flexibility in the application of the model. However, for the purposes of this study, the weights are discussed and determined with a focus group.

Based on the co-occurrence and intensity of the elements, the OntoMI computational system generates instances of the class *IntelligenceActivation*, which formalizes the inference that a given text fragment cognitively activates one or more intelligences. Figure 2 depicts the conceptual model of OntoMI in UML and highlights its main classes and ontological relationships.



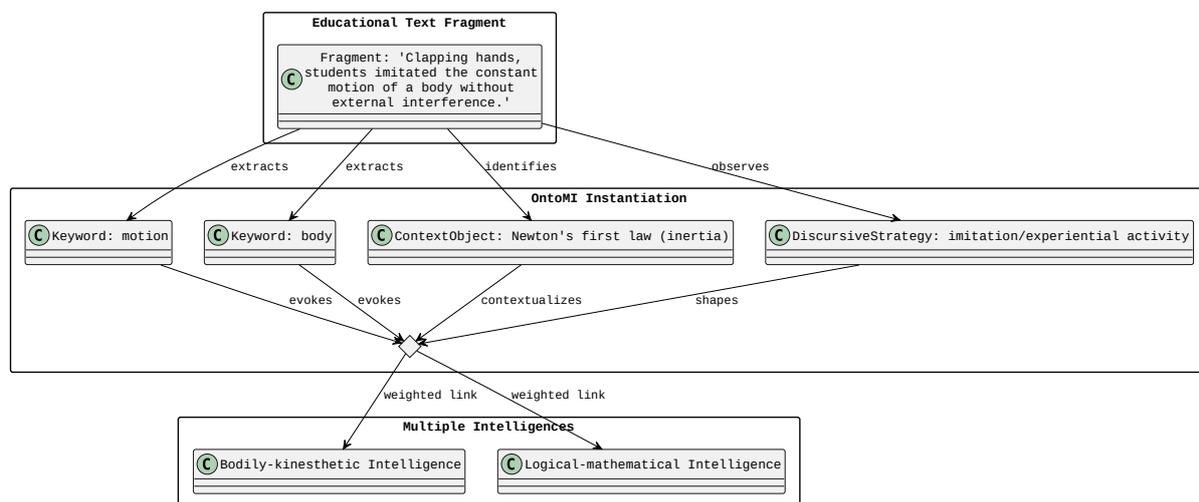
**Figure 2:** Conceptual model of OntoMI: UML structure of the inferential relationships between text fragments and multiple intelligences.

To summarize, a natural language educational content is broken down into explanatory fragments during processing, from which three main types of elements are identified: Keywords, Central Themes and Discursive Strategies. Each of these elements is assigned to a corresponding ontology class – *Keyword*, *ContextObject* or *DiscursiveStrategy*– associated with one or more of the MI proposed by Gardner via the property *evokesIntelligence*. This association is weighted by heuristic

values that indicate the intensity of the cognitive stimulation. The result of this process is the creation of instances of the class *IntelligenceActivation*, which formally and explainably represent which intelligences are activated by a particular text segment. This mechanism aims to convert content into interpretable semantic representations that can be used by computational systems focused on analysis.

OntoMI was developed to be integrated into computer systems for text analysis in education, such as the cognitive classifier *Intelli3* proposed here. The central function of ontology in this context is to provide a formal basis for systems to identify, classify and semantically quantify intelligences elicited by textual educational content. The integration between the ontology and computer models should enable the generation of explainable cognitive vectors – vector representations of the distribution of intelligences in a given resource that can be used in various pedagogical applications such as personalized instruction, curriculum analysis, and semantic indexing of learning objects.

To illustrate how OntoMI is instantiated in practice, consider the fragment “Clapping hands, students imitated the constant motion of a body without external interference.” In this example, the linguistic elements are mapped to *Keyword* (e.g., *motion*, *body*), a *ContextObject* (*Newton’s first law – inertia*), and a *DiscursiveStrategy* (*imitation/experiential activity*). These instances feed an *IntelligenceActivation*, which—via weighted links—evokes bodily-kinesthetic and logical-mathematical intelligences. The figure below summarizes this minimal instantiation and the corresponding inference flow.



**Figure 3:** Minimal OntoMI instantiation.

#### 4.1. Data collection

Data collection for the application and validation of OntoMI is carried out through the selection of educational materials in text form, which include textbooks, handouts, scientific articles and lesson plans from various subject areas (preferably in editable formats such as PDF, TXT, or HTML), transcripts of video lectures and other discursive resources available in public repositories, as well as learning objects and materials from freely accessible educational platforms, always considering usage licenses and public domain availability. These materials are organized, segmented, and, when necessary, manually annotated to ensure quality in the application of the ontology and in the creation of cognitive vectors.

#### 4.2. Ontology validation

The validation of OntoMI will be carried out in two complementary stages. The first consists of verifying the structural and semantic consistency of the ontology independently, following the criteria of *Ontology Development 101*, ensuring clarity of scope, coherence of relations, completeness, and

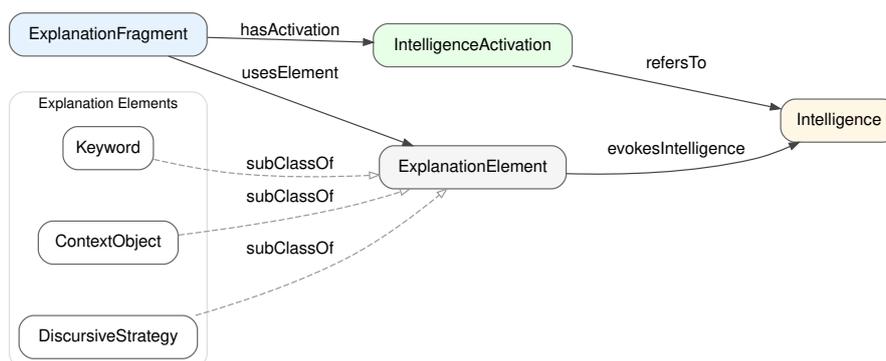
absence of ambiguities. The second stage involves applying OntoMI within the computational classifier, initially using large language models (LLM) to support the instantiation of textual fragments. This phase will be evaluated through proof-of-concept experiments and expert analysis in a focus group. In both stages, the evaluation will consider semantic adherence, conceptual coverage, explainability, and pedagogical applicability, verifying whether the ontology adequately represents multiple intelligences and supports reliable inference over educational texts.

Computational Model Validation: While the focus is on the ontology, the computational validation phase helps to demonstrate the practical applicability of OntoMI and its potential as a basis for educational systems that take cognitive diversity into account.

## 5. Considerations and next steps

The research has already made significant progress towards its specific objectives. OE1, which involved identifying and systematizing the pedagogical principles in Howard Gardner’s works, has been fully achieved. As a product of this phase, the Guide to Pedagogical Practices based on MI was developed, which summarizes criteria and strategies related to cognitive diversity and serves as a theoretical validation basis for the other project artifacts.

OE2, which focuses on the development of a semantic ontology based on MI, is at an advanced stage of implementation. The conceptual structure of OntoMI has been defined, including the modeling of key ontological classes, semantic properties, inference rules and heuristic weightings related to the activation of intelligence. Work is currently underway on the integration of inference elements into the formal OWL structure and preparations for practical use in the classification system (Figure 4).



**Figure 4:** OntoMI model: OWL structure of the inferential relationships between text fragments and multiple intelligences.

In parallel, OE3 — which proposes the development of a computational model for classifying educational resources based on OntoMI — has already defined its architecture, summarized in the following pipeline: input educational text → semantic segmentation → OntoMI instantiation → inference → cognitive vector. The *Intelli3* system parses textual resources, segments them into explanatory fragments, maps linguistic elements (keywords, context objects, discursive strategies) to OntoMI classes, and applies inference rules that generate `IntelligenceActivation` instances. These are aggregated into cognitive vectors that represent the distribution of intelligences across the text and enable similarity measures and personalized recommendations aligned with students’ profiles.

The integration between OE2 and OE3 is already planned, and the next steps of the research will focus on completing the operational ontology, developing semantic inference mechanisms, and functionally validating the *Intelli3* system with real educational materials. Still pending are the structured collection of natural language educational data and the selection of experts for the focus group, who will participate in the qualitative evaluation of both the ontology and the system results, including the weighting analysis of the guide. These activities will be carried out in parallel with testing and proof-of-concept validation.

## Declaration on Generative AI

During the preparation of this work, the author(s) used artificial intelligence tools to assist with translation and language editing. Specifically, ChatGPT was utilized to translate the manuscript into English, and InstaText.io was used to refine the grammar and phrasing. The author(s) reviewed and edited the final output and take(s) full responsibility for the content of the publication.

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