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Beyond the Learner–Machine Loop: Systemic Triangulation, Agency and Social Productivity of the Algorithmic Self

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Abstract: The entry of artificial intelligence (AI) into education is not merely an instrumental innovation but an ontological transformation that redefines regimes of truth, criteria for validating knowledge and processes of subjectivation. Engagement thus risks being captured by the extractive logics of digital platforms, while the encounter between subject and algorithm may produce algorithmic homologation: a flattening of identity and cognitive trajectories onto standardised, statistically probable patterns. The study aims to extend the model of Algorithmic Triangulation, previously formalised as I = f(P, E, T), into a Systemic Triangulation that integrates the dimension of social productivity. A theoretical-conceptual design is adopted, combining critical-hermeneutic analysis of the literature, conceptual model building and heuristic formalisation in the tradition of Lewin's field theory. The resulting model treats technology as a trigonometric vertex rather than an additive variable, introduces social productivity as an orienting pole that opens the teacher–student dyad to community and territory, and extends triangulation to the group level, where technology becomes a shared relational environment of co-regulation. Four design criteria for Systemic Social Triangulation Laboratories are derived. Systemic Triangulation is proposed as a regulative criterion for an engaging education that protects semantic depth and epistemic agency at both individual and collective levels.

Keywords: algorithmic self; systemic triangulation; algorithmic homologation; social productivity; engaging education

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1. Introduction

The entry of artificial intelligence (AI) into educational contexts cannot be read as the mere addition of new instruments to the teaching repertoire. It is, rather, an ontological and cultural transformation redefining regimes of truth, criteria for the validation of knowledge and forms of contemporary subjectivation (Paparella & Mancarella, 2025). Within the infosphere, truth tends to lose its stable and documentary character and to become a computational construct, selected by logics that are often opaque, feeding an epistemology without precedent (Floridi, 2009). The datafication of schooling (Williamson, 2017) and the wider economy of behavioural extraction that underlies many digital platforms (Zuboff, 2019) make this transformation especially pressing for educational research.

Engagement is one of the constructs most exposed to this transformation. Educational research has long described it as a multidimensional construct, articulated in behavioural, emotional and cognitive components (Fredricks et al.,

EDIZIONI UNIVERSITARIE ROMANE
editoria scientifica dal 1952

2004), to which an agentic dimension, the learner's intentional and constructive contribution to the flow of instruction, has been added (Reeve & Tseng, 2011). In platform environments, however, engagement is frequently operationalised as time on task, clicks, streaks and the capture of attention: indicators that optimise retention rather than learning. For this reason, the concept of engagement needs to be *re-pedagogised* as a multidimensional and situated construct, able to withdraw from the extractive logics of the digital and to sustain an authentically *engaging education*.

The most urgent challenge, however, is not only epistemological but anthropological. It concerns the risk that the encounter between subject and platform produces an *algorithmic homologation*, that is, a progressive flattening of identity and cognitive trajectories onto standardised patterns, optimised for computational legibility rather than for the fecundity of thought (Paparella & Mancarella, 2025). This risk arises from a dynamic already described as a parabolic curve that rises from the dream of omnipotence and falls back into suspicion: human beings entrust the algorithm with ever greater tasks and responsibilities, only to lose the very experiential continuity, memory as identity, that no electronic memory can replace (Paparella & Mancarella, 2026). If the Algorithmic Self, the dimension of personal identity that is constituted and reconfigured in the continuous relational flow with digital technologies (Mancarella, 2026), finds no relational anchor that preserves its singularity, its very condition of possibility may turn into the cause of its dissolution into a double that cannot be distinguished from the system that observes it. Here the fate of contemporary subjectivity is decided: either the human being instructs the algorithm, or the algorithm instructs the human being.

One of the main vectors of homologation is the semantic impoverishment of language, namely the decline of the connotative attitude in favour of a merely denotative and functional communication (Paparella & Mancarella, 2025). The speed of digital flows and the use of simplified codes reduce the space for complexity, turning the word into a flat signal deprived of layers of meaning (Verdiani, 2020). This dynamic configures a form of *proletarianisation* of knowledge, understood as the growing delegation of cognitive functions to the machine and the consequent erosion of the symbolic and reflective dimension of experience (Stiegler, 2010). Such delegation weakens epistemic agency, the capacity of the subject to exercise reflective control over the acquisition, interpretation and validation of knowledge (Fricker, 2007). Without semantic depth, the attribution of meaning loses its creativity and bends to statistical stereotypy: it is precisely in this slippage, from singular connotation to statistical recurrence, that algorithmic homologation finds its most fertile ground, and it is the same slippage that leads many systems to *correlate* where the human being should *interpret* (Paparella & Mancarella, 2026).

Countering homologation also requires the deconstruction of a dyadic reductionism that confines teacher and student within an isolated pair (Mancarella, 2026). Dialogical philosophy has shown that the I–Thou relation is constitutive of the person (Buber, 1937); yet, when the educational encounter does not open itself to the world, it risks becoming what Fromm (1956) called an *égoïsme à deux*. A dyad deprived of social productivity is as vulnerable to homologation as the isolated individual facing the machine.

The current debate tends to oscillate between techno-centric enthusiasm and defensive resistance (Mancarella, 2026). Existing frameworks for AI in education

mostly address either individual competences or system-level governance, while models that explicitly link individual agency, technological mediation and the social outcomes of learning remain scarce. This paper addresses this gap by taking up the paradigm of Algorithmic Triangulation previously formalised by the author (Mancarella, 2026) and extending it into what we call *Systemic Triangulation*. Three research questions guide the work: (RQ1) how can triangulation be reformulated so that technology does not slide into a dominant position? (RQ2) what does the integration of social productivity add to the model? (RQ3) which design criteria follow for learning environments that operate at the level of the group? In answering them, the contribution addresses engagement as a matter of design, agency and social-affective relations rather than of attention capture.

2. Materials and Methods

The study adopts a theoretical-conceptual design. Its aim is not to test hypotheses on empirical data but to build, justify and formalise a conceptual model from which testable propositions and design criteria can be derived. It proceeded in three moves.

The first move consisted of a critical-hermeneutic analysis of a purposive corpus. The core of the corpus is formed by the author's previous studies on denotative rigour and semantic depth (Paparella & Mancarella, 2025), on the fragility of algorithms and algorethics (Paparella & Mancarella, 2026) and on Algorithmic Triangulation (Mancarella, 2026). Around this core, sources were selected from philosophy of information and technology, political philosophy, developmental and social psychology, cognitive neuroscience and the pedagogy of experience. Inclusion was guided by three criteria: relevance to at least one of the focal constructs (Algorithmic Self, algorithmic homologation, engagement); theoretical generativity, that is, the capacity of a source to add a new relation to the model; and complementarity with respect to the existing formalisation. The analysis is therefore interpretive and does not claim the exhaustiveness of a systematic review.

The second move was conceptual model building by theoretical integration. Lewin's topological psychology (Lewin, 1936) provides the structural matrix of the model; Arendt's (1958) account of action in the public space and Erikson's (1963) notion of generativity provide the foundations of the new social pole; Vygotsky's (1978) socio-cultural theory and research on embodied simulation (Rizzolatti & Sinigaglia, 2006) ground its extension to the group level.

The third move was heuristic formalisation. Following Lewin, functional notation is used not to measure quantities but to make explicit the structure of relations among constructs: dependence, interdependence and non-separability. The formulas below are therefore structural statements, not metric models. The study did not involve human participants or the collection of personal data, so ethical approval was not required. The illustrative scenario reported in Section 3.4 is a design hypothesis and not a report of empirical findings.

3. Results

3.1. From Algorithmic to Systemic Triangulation

Lewin's field theory states that behaviour (B) is a function of the interaction between the person (P) and the psychological environment (E), the life space as perceived by the subject (Lewin, 1936):

$$B = f(P, E) \quad (1)$$

In a previous study (Mancarella, 2026) this relation was extended to intercept the complexity of the digital transition, defining the Algorithmic Self (I) as an interdependent function of person, environment and technology (T):

$$I = f(P, E, T) \quad (2)$$

The theoretical innovation does not lie in the mere addition of a third term. Technology is treated as a *trigonometric vertex* and not as an additive variable. In geodesy, a trigonometric point allows a position to be determined through its angular relations with other known points, preventing spatial deformation of the map; in the same way, technology dynamically redefines the reciprocal position of the other two vertices and is in turn defined by them. Formally, the model excludes any additive decomposition:

$$I \neq g(P) + h(E) + k(T) \quad (3)$$

Here $g(P)$, $h(E)$ and $k(T)$ denote any functions expressing the isolated contribution of each vertex taken by itself: $g(P)$ the share of the Algorithmic Self attributable to the person alone, $h(E)$ the share attributable to the environment alone, and $k(T)$ the share attributable to technology alone. Expression (3) states that, whatever functions g, h and k are chosen, the Algorithmic Self cannot be obtained as the sum of three independent effects. Thus f is not additively separable: it contains interaction terms, so that the effect of T on I varies with the values of P and E. The same AI tool, used by a student who pursues a question of their own and verifies the answers in a real context, expands thought; used by a student without a guiding intention, in a context that requires no verification, it produces cognitive delegation. The tool is identical, but its educational effect is not, and no value of technology in itself can be isolated and added to the others.

It is this relational rather than hierarchical structure that, at the theoretical level, prevents technology from sliding into a dominant position and thus prevents the drift towards homologation (RQ1). The point is consistent with a classic principle of cybernetics: the security of a self-regulating system derives from its confrontation with error and with external reality, and the denser this confrontation, the wider the range of possible regulations (Paparella, 1978). Triangulation is therefore a reading of what has been called systemic ecology and anthropological resilience against algorithmic fragility: conceiving the algorithm as a relational node, rather than as a self-referential system, is a condition both for trustworthy AI and for a non-homologated Algorithmic Self (Bateson, 1972; Paparella & Mancarella, 2026).

The present contribution grafts onto this structure the dimension of social productivity (S), which we define as the capacity of the educational relation and of digital interaction to converge towards the co-construction of value for the

community and the territory. S is not a fourth additive variable but an orienting condition under which the whole field is organised:

$$I_S = f(P, E, T \mid S) \quad (4)$$

In expression (4) the vertical bar reads "given", as in conditional notation: P, E and T remain the interacting variables of the field, while S fixes the frame within which they interact; the subscript in I_S denotes the configuration that the Algorithmic Self assumes when the field is oriented towards social productivity. Writing $I = f(P, E, T, S)$ would turn S into one more ingredient, to be added or removed like a dose. Placed after the bar, S instead changes the meaning of every vertex: the person's intention becomes an intention to contribute, the environment becomes a territory to which value is returned, and technology becomes a support for co-construction within the group. S is thus the direction of the field rather than one of its forces.

This passage is not a terminological expansion but a reconfiguration of the model. Acting as a third pole that opens the teacher–student dyad to the world, social productivity works as a catalyst: it turns a potentially self-referential or merely adaptive relation between subject and technology into an open and generative process (RQ2). Its theoretical anchor lies in Arendt's (1958) political philosophy, according to which human action acquires its reality and meaning only when it unfolds in the public space, understood as a place of visibility, sharing and common responsibility. Removing the Algorithmic Self from the isolation of the feed and of profiling means repositioning it as a social actor within the community system. The quality of educational practices with digital technologies is then measured not only by technical literacy or individual agency but by the capacity of the whole system to trigger a dynamic of diffuse generativity (Erikson, 1963) that leaves a tangible trace in its social context and expands the substantive freedoms, or capabilities, of those involved (Sen, 1999). Figure 1 represents the resulting model.

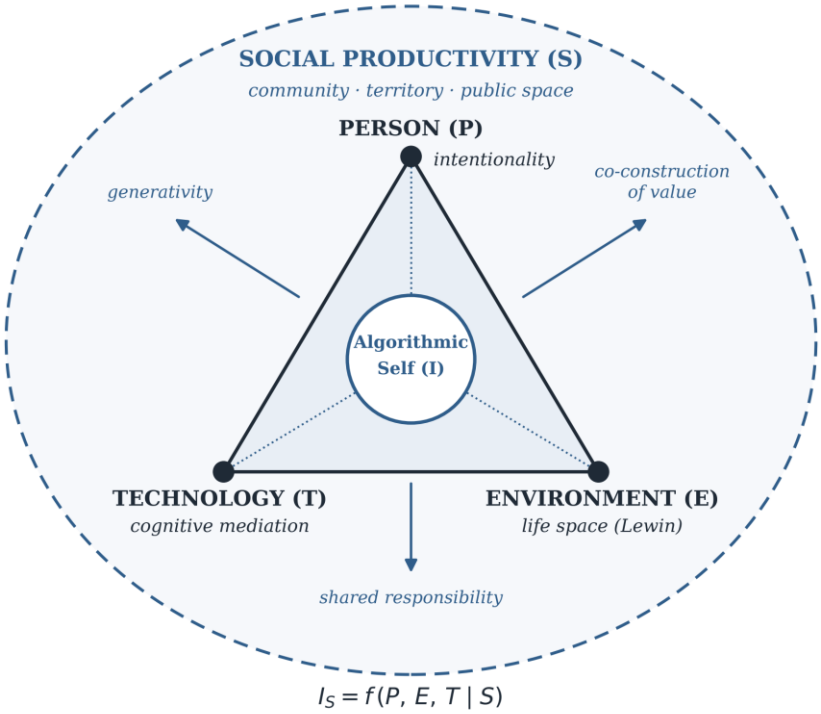


Figure 1. The Systemic Triangulation model. The Algorithmic Self (I) is the trigonometric point defined by its relations with Person (P), Environment (E) and Technology (T); social productivity (S) orients the whole field towards community, territory and public space.

3.2. The three vertices reconsidered

Each vertex keeps the function identified in the original model but acquires a further orientation towards the social pole.

- The **vertex of the Person** is the pole of intentionality and reflective thought (Dewey, 1933). Without this subjective anchorage, the trigonometric point of identity would slide towards uncritical homologation, flattening onto trajectories drawn by statistical probability.
- The **vertex of Technology** acts as a cognitive mediator that expands human capacities rather than replacing them: an AI treated as a cognitive ally and not as a substitute for subjectivity (Mancarella, 2023; Paparella & Mancarella, 2026). This implies transparent design and affordances conceived as facilitations, not as prescriptive invitations to interact.
- The **vertex of the Environment**, understood as life space, provides the ethical and historical coordinates that prevent digital identity from dissolving into liquid modernity (Bauman, 2000). Where the algorithm decontextualises data to make them processable, triangulation performs the inverse movement, relocating knowledge in its environmental, cultural and social roots; it is also the place where personal and collective memory, and therefore identity, are kept.

EDIZIONI UNIVERSITARIE ROMANE
editoria scientifica dal 1952

3.3. The social dimension: triangulation at the level of the group

If triangulation prevents homologation at the individual level, it displays its most original potential when applied to the social dimension of learning. Authentic engagement is never an isolated property of the single learner; it emerges in the network of intersubjective relations within which knowledge is built (Vygotsky, 1978). Applied to the class group, Systemic Triangulation redefines the technological vertex not as an interface between an individual and a machine but as a *shared relational environment* in which several subjectivities mirror and co-regulate one another. For a learner *i* within a group, the model becomes:

$$I_i = f(P_i, E, T, \{P_j\}_{j \neq i} \mid S) \quad (5)$$

Here the index *i* denotes any student in the group and P_i that student's person, while E and T carry no index because environment and technology are shared by the whole group. The braces denote a set: $\{P_j\}_{j \neq i}$ is the set of all the other members of the group. Each Algorithmic Self is thus defined also by its relations with peers. When every student questions the AI alone, parallel closed loops tend to return similar, statistically probable answers; when a hypothesis suggested by the AI is proposed by one student, contested by another on the basis of field observation and reformulated by a third, it becomes an object of mutual correction rather than of individual consumption. This co-regulation has a neurocognitive foundation in the mechanisms of motor and empathic resonance described by research on mirror neurons (Rizzolatti & Sinigaglia, 2006). Hence a caution: AI-mediated social learning becomes poorer when algorithmic interaction replaces, instead of enhancing, the embodied experience of the relation between peers.

On this point, algorethics, an ethical and operative framework that guides every phase of the algorithmic process through verification, revision and critical evaluation (Benanti, 2018; Paparella & Mancarella, 2026), offers a design criterion that can be transferred to the collective level. Any technological device introduced into the class group should be evaluated not for its capacity to optimise individual engagement but for its capacity to increase, rather than replace, the density of relations among peers. In this way the model prevents, at the collective scale, the same homologation that threatens the single Algorithmic Self.

Authentic engagement is achieved when didactic innovation widens the real possibilities of choice and action of all actors, teachers included. Teacher agency emerges as the capacity to keep the educational relation open through critical mediation (Priestley et al., 2015), transforming innovation from a bureaucratic obligation (Fullan, 2007) into an opportunity for reflective professional development (Schön, 1983). Table 1 summarises the differences between the two versions of the model.

Table 1. Algorithmic Triangulation and Systemic Triangulation compared.

Dimension	Algorithmic Triangulation (Mancarella, 2026)	Systemic Triangulation (present study)
Formal structure	I = f(P, E, T)	I_S = f(P, E, T | S); group level: I_i = f(P_i, E, T, {P_j} | S)
Unit of analysis	Individual learner	Individual learner and class group
Role of technology	Cognitive mediator between person and environment	Trigonometric vertex and shared relational environment of co-regulation
Main risk addressed	Individual homologation and cognitive delegation	Individual and collective homologation; closed dyads (*égoïsme à deux*)
Orientation of learning	Expansion of individual capabilities	Co-construction of value for community and territory (generativity)
Evaluation criterion	Pertinence of AI output to context	Pertinence to context and increased density of peer relations

3.4. Systemic Social Triangulation Laboratories

To translate the theory into practice, the model is operationalised in *Systemic Social Triangulation Laboratories*: learning environments in which AI supports the co-construction of meaning among peers, and not only between an individual and a machine. They develop the algorithmic triangulation laboratories previously proposed (Mancarella, 2026) and rest on four criteria (RQ3), summarised in Table 2.

1. *Experiential dimension*: learning takes shape in shared action and in direct confrontation with the environment (Dewey, 1938).
2. *Contextual verification*: evaluation shifts from the formal correctness of the AI output to its pertinence with respect to the social and cultural constraints of the group and of the territory (Lave & Wenger, 1991), favouring the transfer of competences (Paparella, 2011).
3. *Semantic literacy*: shared narration and symbolic language regain centrality, countering the functionalist reduction of knowledge (Bruner, 1996) and the decline of connotation (Paparella & Mancarella, 2025).
4. *Algorethic transparency*: no device enters the laboratory without a transparent design that makes the criteria by which the AI processes students' interactions readable to the students themselves (Paparella & Mancarella, 2026).

Table 2. Design criteria of the Systemic Social Triangulation Laboratories, with guiding questions and proposed indicators.

Criterion	Theoretical anchor	Guiding design question	Proposed observable indicators
Experiential dimension	Dewey (1938)	Does the AI output return to shared action in a real environment?	Proportion of tasks closed by field activity; artefacts produced for real recipients
Contextual verification	Lave & Wenger (1991); Paparella (2011)	Is the output judged by its pertinence to local constraints rather than by formal correctness alone?	Documented checks against local sources and stakeholders; revisions justified by context
Semantic literacy	Bruner (1996); Paparella & Mancarella (2025)	Does the activity enlarge the connotative and narrative repertoire of the group?	Lexical diversity of student texts; presence of metaphor, argument and narrative
Algorethic transparency	Benanti (2018); Paparella & Mancarella (2026)	Can students explain how the tool processes their interactions?	Student explanations of tool logic; explicit rules on data use agreed by the class

Note: indicators are proposals for future empirical validation and are not reported results.

An illustrative scenario follows. An upper-secondary class investigates the use of water in local agriculture. Small groups use a generative AI system to formulate hypotheses and draft questions (T); the hypotheses are checked against field observations, interviews with farmers and municipal data (E); each student keeps a reflective log and a short narrative of the inquiry (P); the class then presents a shared proposal to the municipal council (S). The AI never closes the process: its outputs are starting points that must pass through the environment, the group and the public space before they become knowledge.

4. Discussion

With regard to RQ1, the analysis shows that the dominance of technology is not only a matter of regulation but also of structure. As expression (3) shows, a technology modelled as a trigonometric vertex rather than as an additive factor cannot grow in weight without limit: an AI output has no educational value until it is related to an intention and to a context. This structural reading complements the algorethic perspective (Benanti, 2018; Paparella & Mancarella, 2026): principles of transparency and verification find in triangulation a pedagogical form in which they can be practised, and not only declared.

With regard to RQ2, social productivity changes the direction in which engagement is evaluated. The multidimensional models of engagement (Fredricks et al., 2004) and the notion of agentic engagement (Reeve & Tseng, 2011) describe the learner's involvement; Systemic Triangulation adds an orientation, asking *for whom* and *towards what* the learner is engaged. This shift offers an answer to critiques of datafication (Williamson, 2017; Zuboff, 2019): where platform metrics measure the capture of attention, the systemic model measures the density of relations and the value returned to the community. It also resonates with Biesta's (2013) warning against a risk-free education: homologation can be read as an attempt to eliminate the risk of education by making the learner predictable, whereas Systemic Triangulation keeps open the space in which subjects can appear in their singularity before others.

With regard to RQ3, the four criteria convert the model into choices that teachers can make and observe. They also imply a change in teacher education: alongside technical skills, teachers need philosophical, ethical and relational competences to mediate between students, tools and territory (Paparella & Mancarella, 2025; Priestley et al., 2015).

The study has limitations. First, it is conceptual: the model has not yet been tested empirically and its propositions should be treated as hypotheses. Second, the formalisation is heuristic and structural; it does not specify the form of the function *f*, nor does it provide metrics for its terms. Third, the corpus was selected purposively and is rooted mainly in the European and Italian pedagogical tradition, which may limit transferability to other contexts. Future design-based research could implement the laboratories in schools and universities, combining social network analysis of peer relations, measures of the lexical and semantic richness of student texts and qualitative analysis of reflective logs.

5. Conclusions

Systemic Triangulation offers a regulative criterion for educational action in the age of AI. It restores semantic depth and epistemic stability to the individual Algorithmic Self and extends the same protection to the collective level of social learning, where the risk of homologation appears on a wider and less visible scale. Education cannot limit itself to teaching the use of tools; it must reflect on the conditions that make thinking and acting possible in a mediated world. Only through a conscious triangulation of person, environment and technology, applied both to individuals and to groups and supported by a shared algorethics that turns computational fragility into an occasion for learning (Paparella & Mancarella, 2026), can education reaffirm its fundamental task: to accompany the co-evolution of subject, community and digital environment, preserving autonomy, meaning and the living fabric of relations that no algorithm can rebuild on its own.

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