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Science Identity as a Pathway to Literacy: Reconceptualizing Science Education Through Dialogical Self Theory

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ABSTRACT

Despite decades of reform, science education continues to fall short of its aim to cultivate scientifically literate individuals capable of evidence-informed decision-making. However, dominant models of scientific literacy often understate the role of identity—particularly how learners navigate epistemic and affective tensions when making decisions. Drawing on classical identity traditions in developmental and social-cognitive psychology, Dialogical Self Theory (DST), and the Conceptual Profile Model (CPM), I propose the Science Identity as a Pathway to Literacy (SIPL) framework, which positions identity development as central to achieving scientific literacy. SIPL highlights two core developmental processes: (1) developing awareness of the dialogical self and (2) building the capacity to adopt meta-positions. Together these processes help learners coordinate conflicting I-positions and conceptual profiles when engaging with science and in decision-making more broadly. By reconceptualizing literacy as an emergent dialogical competence rather than the mere accumulation of knowledge and practices, SIPL foregrounds internal negotiation, conceptual flexibility, and epistemic agency as essential outcomes of science education. This framing aligns with emerging policy perspectives, including the draft PISA 2025 Science Framework, which recognizes science identity as an important dimension of scientific literacy.

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Introduction

For more than a quarter century, science education has aspired to cultivate scientifically literate individuals capable of evidence-informed decision making (National Research Council, 1996; NGSS Lead States, 2013a). Yet persistent concerns about scientific literacy—visible in international assessments and in everyday public discourse—suggest that these aims remain only partly realized (OECD, 2023a). I argue that the shortfall is conceptual: dominant accounts have treated the learner largely as a decontextualized knower, separating the "objective" from the "subjective" and presuming that identity and affect either do not shape decisions or will recede in the face of compelling

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evidence. In practice, however, decisions are identity-saturated, value-laden, and dialogically negotiated. The core claim of this paper is that literacy often fails at the point of decision, where identity-conditioned activation filters which evidence becomes usable.

Traditional literacy models lack a mechanism for interpreting identity–evidence conflicts. To address this gap, I draw on Dialogical Self Theory (DST) and the Conceptual Profile Model (CPM) to reconceptualize scientific literacy as fundamentally identity-mediated. DST foregrounds a multiplicity of I-positions that can enter into tension during reasoning (Hermans, 1996, 2001; Hermans & Hermans-Konopka, 2010). CPM highlights the coexistence of diverse conceptual stances across contexts and how learners shift among them (Mortimer & El-Hani, 2014). Together, these frameworks illuminate why learners can demonstrate scientific knowledge yet default to counter-evidential choices when competing identities or conceptual profiles are activated.

Building on this synthesis, I propose the Science Identity as a Pathway to Literacy (SIPL): a theoretical model that positions identity development—not merely knowledge and practices—as central to achieving scientific literacy. SIPL emphasizes two developmental processes: (1) awareness of the dialogical self and (2) capacity to adopt meta-positions. These processes enable learners to notice, name, and coordinate competing I-positions and conceptual profiles when engaging with science and with decision making more broadly. To ground the need for this reconceptualization, I next frame the limitations of prevailing goals of science education and dominant accounts of decision making.

Despite strong curricular emphasis on conceptual understanding, many students demonstrate a persistent gap between knowing scientific ideas and using them in real contexts. For instance, a Swedish study of teenagers deciding about influenza vaccination found that students drew primarily on risk, solidarity, family/friends, and media repertoires rather than on school science as an interpretative resource (Lundström et al., 2012). Similar patterns of non-acceptance of evolution—often tied to affective, cultural, and religious commitments—are well documented (Allmon, 2011; Miller et al., 2006). These patterns persist despite recent standards placing the Nature of Science (NOS) at the center of science learning, with explicit learning outcomes across K–12 (NGSS Lead States, 2013b, Appendix H).

What, then, is the proper goal of science education? A useful starting point is the broader societal role of education. Historically an elite institution, education today is far more democratized and compulsory, aimed at both individual development and social flourishing. From this perspective, the goal of science education in pluralistic democracies is to develop scientifically literate, responsible decision makers rather than to inculcate predetermined beliefs.

Smith and Siegel (2004) characterize scientific literacy in terms of two complementary aims: (1) knowledge of science content and (2) understanding of science. They elaborate understanding *via* four criteria—connectedness (linking and organizing ideas), sensemaking (plausibility/meaning), application (transfer to contexts of use), and justification (reasons that warrant claims). On the contested question "understanding vs. belief," Smith and Siegel argue that knowledge and understanding—not belief—should be the educational aims; while belief often accompanies understanding, it need not be the instructional end point (Smith & Siegel, 2004).

These two aims capture much of the learning process emphasized in contemporary reforms—developing conceptual knowledge and engaging in disciplinary practices. Yet they underspecifiy the resources learners need to make responsible decisions when identities, values, and emotions are implicated. Smith and Siegel acknowledge that some non-acceptance reflects deeply held convictions outside science, and thus beyond the reach of science instruction alone (Smith & Siegel, 2004, p. 579). My contention is that if such individual factors shape science learning, they will also shape decision making—precisely where scientific literacy is supposed to matter. Hence, either the field must (a) incorporate the role of identity, affect, and positioning into its goals and pedagogies, or (b) revisit those goals. Moving beyond tacit positivist assumptions that the "subjective" is irrelevant, I argue for a framework that accounts for how individuals make decisions in real contexts and how identity conditions evidence use.

Decision-making research provides further insight into why scientific literacy often fails at the point of application. Jonassen (2012) characterizes decisions as moderately ill-structured problems: the decision maker evaluates among plausible options and commits to a course of action. In short, decisions are a pervasive form of problem solving, and understanding how people decide is foundational to designing for responsible and effective decision making. Descriptive accounts highlight that real-world decisions are shaped by bounded rationality, affect, time pressure, and contextual constraints rather than purely normative calculations (Kahneman, 2011; Klein, 1998).

These realities matter for science education. If the goal is to develop scientifically literate, responsible decision makers, then instruction cannot address decision making by focusing only on the rational-analytic side of the ledger. A growing body of work shows that decisions about science are often identity-protective: individuals selectively attend to, interpret, and credit evidence in ways that sustain group commitments and self-positions (Kahan, 2017; Kahan et al., 2011). From this perspective, an "evidence-informed" decision is more—not less—rational when it incorporates information about how identity, affect, and positioning are shaping the choice. I therefore argue that learners need opportunities to (a) become aware of the internal plurality of perspectives they bring to problems and (b) adopt meta-positions from which they can notice, name, and coordinate those perspectives. This argument motivates my turn to Dialogical Self Theory and the Conceptual Profile Model as foundations for the SIPL framework.

Finally, this reconceptualization aligns with emerging policy frameworks. The draft PISA 2025 Science Framework explicitly includes science identity as a component of scientific literacy (OECD, 2023b), indicating a global shift toward recognizing how identity mediates learners' engagement with evidence.

Identity and the Dialogical Self

To understand how identity shapes scientific reasoning and decision making, it is necessary to locate the dialogical self within the broader developmental and social-cognitive traditions that have long theorized identity formation.

Classic identity theorists offer important foundations for this work. Erikson's (1968) account of adolescence as a period of intensified identity exploration highlights that young people increasingly confront tensions between competing roles, values, and

expectations. Because these tensions become particularly salient in early adolescence, the period when students begin to articulate commitments and face value-laden choices, a focus on identity—rather than solely on knowledge—becomes essential for understanding scientific reasoning in middle school contexts.

Marcia's (1966) identity-status model extends this developmental lens by showing that individuals differ meaningfully in how they explore and commit to identity-defining ideas. These differences underscore that identity is not fixed at the group level but varies across individuals, even within shared cultural contexts. For science education, this highlights that learners' engagement with scientific ideas depends not only on conceptual mastery but also on where they are in their identity trajectories—whether they are actively exploring, committed, or avoiding identity work altogether.

Berzonsky's (1990) identity-processing styles further illuminate how individuals approach information. Students with informational processing styles tend to examine evidence actively; those with normative styles rely more on established beliefs and authorities; and those with diffuse-avoidant styles delay or deflect commitment. These patterns map directly onto how learners filter and evaluate scientific evidence, providing an interpretive bridge between classical identity theories and the dialogical mechanisms emphasized in DST.

Together, these developmental and social-cognitive perspectives clarify that identity both shapes and is shaped by how individuals make sense of the world. Dialogical Self Theory (DST) builds on and extends these foundations by explaining *how* multiple identity commitments interact dynamically during reasoning. DST addresses the further question of whether "internal" factors are meaningfully distinct from "external" forces such as social expectations and cultural norms. By dissolving the dualism between self and society, DST provides a framework for understanding identity as both socially embedded and internally dialogical.

Dialogical Self Theory (DST) conceptualizes the self as a multivoiced, socially situated system—a "society of mind" populated by I-positions (e.g., I as a dutiful child, I as a curious scientist, I as a community member) that speak, respond, and negotiate with one another (Hermans, 2001; Hermans & Hermans-Konopka, 2010). These positions can be internal (voices experienced as inside the self) or external (voices of significant others, groups, or institutions that are internalized and can "speak" within the self). In this sense, identity is neither purely private nor purely public: the self is extended—formed in, through, and as part of sociohistorical relations (Hermans & Gieser, 2012).

This non-dualistic view has two important implications for education. First, micro–macro mutuality: transformations within persons and changes in the broader social world are reciprocally linked. Globalization, for example, multiplies contacts and perspectives, often expanding one's repertoire of I-positions while also generating uncertainty; such uncertainty can elicit counter-movements toward stability (e.g., renewed orthodoxy or fundamentalism), which in turn reshape public discourse and institutions (Hermans & Hermans-Konopka, 2010). Second, increasing complexity: as social life becomes more plural and dynamic, the self likewise becomes more polyphonic, with positions that can align, compete, or dominate one another depending on context.

DST's distinctive contribution, relative to classical identity theories, thus lies in its account of *how* multiple identity commitments interact during reasoning. Whereas

Erikson, Marcia, and Berzonsky describe developmental trajectories and processing tendencies, DST provides a mechanism—internal dialogue—through which tensions among positions are negotiated in real time. This dialogical mechanism is central for understanding how identity-conditioned activation shapes scientific judgment.

Taken together, DST supports analyzing learners as positioned and positioning agents whose decisions emerge from dialogues within the self and with the social voices they inhabit. This lens prepares the ground for the next two subsections: (a) Dominance and Social Power, which addresses how some positions gain authority over others; and (b) Promoter Positions, which explains how meta-level positions can reorganize the field of voices and enable more reflective, evidence-informed decision making.

Dominance and Social Power

If the self is inclusive of society, it is also inclusive of the complex phenomena that organize social life—hierarchies, power differentials, authority, and resistance. Meanings, interpretations, and definitions are formed through ongoing participation in these relations. In Dialogical Self Theory (DST), such dynamics are not only "out there" in the social world; they are also reproduced within the self's "society of mind," where multiple I-positions interact in patterns of coalition, opposition, centration, and dominance (Hermans, 2001; Hermans & Hermans-Konopka, 2010). Thus, the self is socially constructed and socially constructing: it reflects broader power dynamics and, through action, contributes to them.

Everyday dialogue makes this visible. Conversations typically involve asymmetries of voice—who speaks first, for how long, with what vocabulary, and authority. Analogously, the inner conversation can tilt toward certain I-positions that dominate the field (e.g., I as the obedient child, I as the orthodox believer, I as the gatekeeping expert), while others are marginalized. When dominance becomes pronounced, the inner dialogue becomes monologic: alternative positions are preempted or silenced, and counterarguments fail to gain uptake (Bakhtin, 1981; Hermans & Gieser, 2012). In DST terms, counterpositions may still arise, but they are repeatedly dismissed by the dominant position, narrowing what can be considered or felt.

Silencing is not merely intrapsychic; it is sociohistorically patterned. Voices associated with institutional authority (e.g., particular languages, expert discourses, or cultural scripts) often carry symbolic power that amplifies their claim to be heard (Bourdieu, 1991). In postcolonial school settings, for instance, an English-dominant position can acquire heightened legitimacy even among multilingual learners, reorganizing their inner conversation about what counts as "educated" speech. Such macro-level asymmetries can translate into testimonial disadvantages or epistemic exclusion for other voices (Fricker, 2007), with downstream effects on what evidence is noticed, trusted, or treated as actionable.

These dynamics have direct implications for science education. Students may possess knowledge and analytic skill yet still block evidence when a dominant identity position stakes the terms of acceptability (e.g., identity-protective cognition; Kahan, 2017). From a DST standpoint, the challenge is not simply to add more facts but to rebalance the dialogical field so that marginalized positions can speak and dominant ones can be examined rather than obeyed. This requires capacities that reorganize the system of

positions—precisely the role of promoter positions and meta-positions, which I develop next as mechanisms for enabling more reflective, evidence-informed decision making.

Ability to Adopt Promoter Positions

Viewing identity through a dialogical lens foregrounds a multiplicity of positions and an extended self that reaches beyond bodily boundaries to include significant others, groups, symbols, ideas, and objects. In Dialogical Self Theory (DST), these take the form of internal I-positions (e.g., I-as-student, I-as-researcher, I-as-brother) and external or other-in-the-self positions (e.g., my teacher, my rival, my hero) that can be voiced within the self. The extended self engages in both internal dialogues (among I-positions) and external dialogues (with people and institutions), each continually informing the other. When particular positions are silenced internally, external participation often narrows as well—dialogue can become monologic, with one position setting the terms of what counts as sayable, thinkable, or credible.

Genuine dialogue, by contrast, presupposes openness to uncertainty. One cannot truly enter dialogue—internally or interpersonally—without accepting that the exchange may lead to multiple possible outcomes. During such exchanges, some positions may gain relative prominence for a time, not because they permanently overpower others, but because they resonate, solve problems, or are integrated into a shared understanding. Think of a research meeting in which diverse hypotheses, methods, and interpretations are weighed: ideas are taken up, revised, or set aside as participants co-construct meaning. This collective engagement with uncertainty is learned rather than automatic; it develops through practice, reflection, and regulation of one's positioning.

DST names a family of capacities that make such movement possible: promoter positions. Promoter positions are positions within the self (or internalized positions of significant others) that generate development, organize movement among positions, and open space for integration in the face of threat or ambiguity (Hermans & Gieser, 2012; Hermans & Hermans-Konopka, 2010). They differ from, yet coordinate with, meta-positions: whereas a meta-position provides a reflective vantage point ("seeing the field" of positions), a promoter position provides motivational direction and forward momentum ("moving the field"). Functionally, promoter positions (a) anchor valued commitments while inviting new perspectives, (b) bridge otherwise competing I-positions, and (c) sustain tolerance of ambiguity long enough for evidence and counterarguments to be seriously entertained.

These mechanisms are directly relevant for science education. When value-laden issues (e.g., climate, public health) activate identity-protective tendencies, students may possess the requisite knowledge and analytic skill yet still block evidence. Cultivating promoter positions such as I-as-inquirer, I-as-critical thinker, I-as-systems-aware citizen, or I-as-steward can rebalance the dialogical field, preventing monologization and keeping multiple positions in conversation with the data. Instructionally, such cultivation can be supported through explicit role taking, reflective writing from contrasting I-positions, structured counterpositioning in discussion, and norms of metapositioning (e.g., pausing to articulate "who in me is speaking now?"). Promoter positions thus function as cognitive-emotional scaffolds for reflective, identity-aware decision making.

I next turn from identity's polyphony to conceptual polyphony—how learners hold and shift among multiple conceptual profiles—to complete the theoretical foundation for the SIPL model.

A Conceptual Profile Derived from the Dialogical Self

If the dialogical self is constituted by multiple internal and external positions in ongoing negotiation, then its engagement with knowledge—especially scientific knowledge—must be equally multivoiced and dynamic. The Conceptual Profile Model (CPM) provides a powerful lens for this epistemic plurality. Rather than treating learning as the replacement of "incorrect" conceptions with "correct" scientific ones, CPM posits that individuals simultaneously maintain multiple conceptual zones—historically, culturally, and experientially grounded stances that can be mobilized as contexts change (e.g., for matter: realist, substantialist/empirical, rational–classical, and rational–modern zones). From this perspective, learning involves developing awareness of these zones rather than erasing them (Mortimer, 1995; Mortimer & El-Hani, 2014; see also Yürük, 2003, 2005 for domain examples).

This CPM view dovetails with DST: just as I-positions can align, compete, or dominate in the self's inner conversation, conceptual zones can be activated, coordinated, or suppressed in discourse and activity. In classroom practice, the resulting conceptual polyphony is observable in the shifting voices and registers of talk (authoritative/dialogic; everyday/scientific) through which meaning is negotiated (Mortimer & Scott, 2003). Rather than signaling inconsistency, such shifts often reflect dialogical responsiveness—the capacity to move among epistemic registers while staying anchored in identity and purpose (Mortimer & El-Hani, 2014; Mortimer & Scott, 2003).

I develop this linkage in three steps. First, I outline the Conceptual Profile Model as a theory of heterogeneous conceptual zones. Second, I specify how activation of a zone depends on social, affective, and epistemic conditions (e.g., discourse norms, perceived stakes, identity commitments). Third, I propose how learners build understanding by metapositioning among zones and promoting integrative positions—mechanisms that parallel the DST constructs developed earlier and prepare the ground for the SIPL framework.

The Conceptual Profile Model (CPM): Conceptual Multiplicity as a Resource

The Conceptual Profile Model (CPM), developed by Eduardo Mortimer (1995), builds on sociocultural, epistemological, and constructivist perspectives to offer a nonlinear account of how individuals understand scientific ideas. In contrast to the assumption that learning science is a one-way process of replacing "incorrect" conceptions with "correct" ones, CPM—drawing on Bachelard's historical–epistemological insights, Vygotsky's mediated learning, and dialogical views of meaning—argues that people operate with multiple ways of knowing, each rooted in cultural experience and disciplinary practice (Bachelard, 1984/1938; Mortimer & El-Hani, 2014; Vygotsky, 1978).

CPM describes conceptual zones (or registers) that coexist within the same learner and are selectively activated by purpose and context. For the topic of matter, for example, profiles often include everyday/common-sense or substantialist understandings,

empirical descriptions, rationalist–classical accounts, and rationalist–modern (e.g., quantum/molecular) perspectives (Mortimer, 1995; Mortimer & El-Hani, 2014). Crucially, CPM is nonreductionist: everyday conceptions are not mere errors to be eradicated but cognitive resources with local explanatory power and affective salience. A caloric-like model of heat as a "flow" from hot to cold, for instance, can be pragmatically potent when teaching a child not to touch a hot surface, even though a kinetic account better explains thermal phenomena in formal science.

Against replacement views in traditional conceptual-change accounts, CPM emphasizes differentiation and coordination. Even expert scientists layer their profiles, shifting zones as needed (Mortimer & El-Hani, 2014). Learning, therefore, is not suppressing alternatives but developing conceptual consciousness—recognizing when a conception is useful, where its limits lie, and how to shift among zones as situations demand. This stance allows students to retain common-sense resources for everyday navigation while also deploying more sophisticated scientific reasoning in disciplinary contexts. Instructionally, the teacher's task is less to correct students than to expand and coordinate their repertoire of conceptual voices and to scaffold purposeful shifting across zones (Mortimer & Scott, 2003).

From this perspective, a conceptual profile functions as a cognitive interface linking the learner's sociocultural identity with disciplinary knowledge. Each zone carries not only epistemic assumptions (what counts as knowing) but also ontological commitments (what kinds of entities are taken to exist), often embedded in personal and cultural narratives. Consequently, teaching for "conceptual change" becomes teaching for epistemic fluency and ontological flexibility: learners learn to navigate, coordinate, and deliberately reposition among zones. In this sense, the conceptual profile is the epistemic counterpart of the dialogical self's polyphony—not a fixed map of "misconceptions vs. truths," but a fluid configuration through which meaning is made.

Activation of a Conceptual Profile: When Identity Meets Knowledge

While the Conceptual Profile Model (CPM) emphasizes the coexistence of multiple conceptual zones, it is the activation of particular zones that determines how a learner engages with a problem—especially under uncertainty, value conflict, or socio-scientific stakes. Mortimer (1995) argues that students do not operate from a single, stable conception; rather, they shift among zones as contexts, purposes, discourse norms, and emotions change. A learner might rely on empirical reasoning when measuring mass in a chemistry lab yet casually invoke a realist/substantialist notion of matter when chatting about "air as nothing." Such shifts are not flaws in reasoning but signs of contextual responsiveness, where different ways of knowing serve different purposes (Mortimer & El-Hani, 2014; Mortimer & Scott, 2003).

Activation dynamics parallel those of the dialogical self. Just as particular I-positions gain or lose salience depending on social setting and affect, conceptual zones wax and wane with changes in task demands, discourse, identity commitments, and affective states. Activation is thus cognitive, affective, and cultural. For example, identity-protective pressures can privilege zones that harmonize with group commitments (Kahan, 2017), while control–value appraisals (e.g., perceived value of the task, sense of control) shape which epistemic resources feel "available" in the moment (Pekrun, 2006). Within DST,

promoter positions can help maintain coherence while learners engage with less familiar scientific ideas, providing enough motivational stability to explore and coordinate zones rather than defaulting to monologic dominance.

In this view, activating a conceptual zone is not merely retrieving knowledge; it is positioning the self in relation to knowledge: Who in me is speaking? Which conceptual voice is being authorized now, and why? This framing suggests concrete levers for instruction. Discourse structures that foreground argumentation and evidence (Berland & Reiser, 2009; Osborne et al., 2004), explicit metapositioning prompts (e.g., "state the view you're using and its limits"), and reflective writing from contrasting positions can broaden what gets activated and sustain dialogical openness long enough for students to weigh data against identity-laden commitments (Sadler, 2004; Sinatra and Pintrich, 2003).

Figure 1 visualizes this process: identity positions, prior knowledge, and new information interact dialogically to shape and activate zones within the conceptual profile. Learning, from this perspective, is not linear replacement but navigation, uncertainty resolution, and integration within an evolving conceptual landscape.

How Do Learners Learn? A Dialogical Account Integrating DST and CPM

Bringing the Conceptual Profile Model (CPM) and Dialogical Self Theory (DST) into conversation yields a view of learning that is neither strictly cognitive nor purely social, but fundamentally dialogical. Learning involves the dynamic activation and coordination of both conceptual zones and identity positions. Just as students shift among everyday/empirical and rational–scientific understandings depending on context (Mortimer, 1995; Mortimer & El-Hani, 2014), they also shift among I-positions—I-as-curious learner, I-as-skeptic, I-as-outsider-to-science—in response to social and affective cues (Hermans & Hermans-Konopka, 2010). These movements are patterned, not random: they are shaped by learners' interpretations of the situation, the degree of uncertainty they experience, and the motivational clarity afforded by promoter positions within the self.

On this account, meaningful learning is not merely adopting currently "correct" ideas; it is the development of metaconceptual awareness and metapositioning—the growing capacity to recognize, evaluate, and coordinate both conceptual zones and identity positions across contexts. The learner becomes someone who can ask: Which conceptual voice am I using now—and why? Which part of me is aligning with or resisting this idea? What are the limits of this view? Such reflexive work presupposes seeing the self as polyphonic, understanding conceptual knowledge as plural rather than linear, and tolerating ambiguity as inherent to scientific inquiry. Here promoter positions scaffold the work: they stabilize motivation and openness long enough to keep multiple positions in play, while meta-positions provide the vantage point from which connections and limits can be articulated (Hermans & Hermans-Konopka, 2010; Mortimer & El-Hani, 2014; Sinatra & Pintrich, 2003).

If learning proceeds this way, classroom goals must shift accordingly. Rather than eliminating "misconceptions" or standardizing student thinking, teachers design environments that legitimize multiplicity and invite identity work. Practically, this means: (a) position mapping and reflective prompts (e.g., "Who in me is speaking?") to surface I-positions; (b) two-voices/two-zones writing and structured argumentation to compare

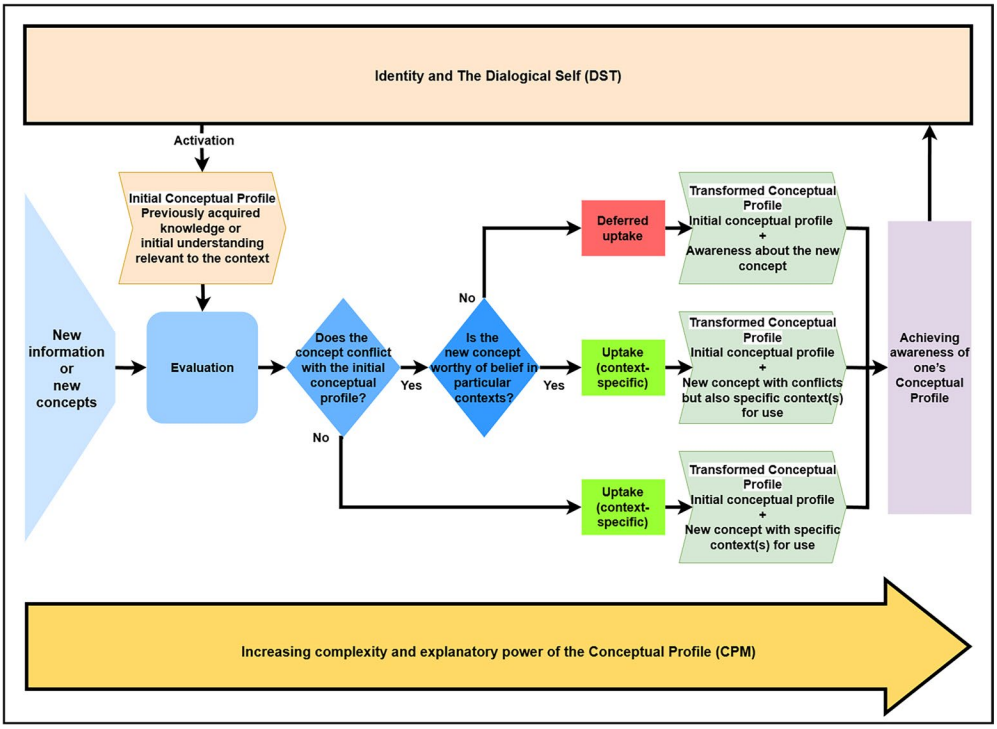

Figure 1. Dialogical activation of conceptual profile zones during learning.
Note. Figure created by the author. The diagram illustrates how identity positions, prior knowledge, and new information interact dialogically to shape the activation and coordination of conceptual zones (adapted from Mortimer, 1995; Mortimer & Scott, 2003; Hermans, 2001).

conceptual zones and state their limits; (c) metapositioning routines (e.g., pausing to name the zone in use before evaluating evidence); and (d) socio-scientific tasks that make identity-evidence tensions discussable (Mortimer & Scott, 2003; Osborne et al., 2004; Sadler, 2004). In doing so, learners build more integrated, flexible science identities and become not merely knowers of science but agents of meaning making—precisely the developmental capacities (awareness of the dialogical self and capacity to adopt meta-positions) that the SIPL framework treats as pathways to scientific literacy.

Toward a Dialogical Understanding of Scientific Literacy

If learners engage with science through a dynamic interplay of identity positions and context-sensitive conceptual understandings, then scientific literacy cannot be reduced to accumulating knowledge or mastering skills. As argued above, learning is dialogical: students shift among conceptual zones (CPM) and I-positions (DST) in response to context, affect, and purpose (Hermans & Hermans-Konopka, 2010; Mortimer, 1995; Mortimer & El-Hani, 2014). This perspective challenges models of literacy that treat rational-analytic engagement as the normative endpoint of instruction. Instead, the pathway to scientific literacy runs through identity, specifically through students' growing awareness of their dialogical selves and their capacity to metaposition and coordinate multiple conceptual voices. Building on this premise, the subsections that

follow (a) redefine scientific literacy beyond knowledge and belief, (b) clarify science identity as the mediating construct, and (c) explain how decision making in science is simultaneously cognitive and identity-saturated.

Redefining Scientific Literacy: Beyond Knowledge and Belief

Scientific literacy has often been framed as content mastery plus the ability to apply knowledge in civic and personal decisions. Smith and Siegel (2004) offer a two-pronged operationalization: (1) fostering knowledge of scientific content and (2) fostering understanding of science's claims and processes. They further articulate four criteria of understanding—connectedness, sensemaking, application, and justification. These remain important benchmarks for science education.

However, as science increasingly intersects with social, political, and ethical life, these epistemic goals are necessary but insufficient. Students may meet the criteria of understanding yet decline to act on or endorse that understanding when it conflicts with deeply held beliefs or identity affiliations. For example, students who can explain the scientific basis of vaccination may nevertheless reject its relevance or legitimacy due to familial, cultural, or group commitments (Lundström et al., 2012); more broadly, identity-protective cognition can lead individuals to discount evidence that threatens salient identities (Kahan, 2017). The assumption that understanding naturally translates into action may underestimate the identity tensions and affective investments shaping real-world decision making. Taken together, these limitations point to the need for a more explicit account of what scientific literacy entails.

A dialogical account repositions scientific literacy as an emergent competence that is co-constructed through internal negotiation within the self. Scientific literacy is not only what one knows or believes; it is the capacity to navigate uncertainty, evidence, and identity through reflective engagement. Practically, this entails developing (a) metaconceptual awareness of multiple conceptual zones, (b) metapositioning and identity coordination among I-positions, and (c) epistemic agency to bring evidence to bear even amid identity pressure. In short, scientific literacy is developmental rather than a fixed endpoint—something to be cultivated through dialogically rich pedagogy rather than merely taught as a stable body of facts.

What Is Science Identity?

In this paper, I use science identity as a construct that links learners' sense of self with their engagement in scientific thinking, practices, and decision making. I use science identity to mean how individuals see themselves—and are seen by others—in relation to science (as learners, doers, users, or critics). In a foundational formulation, Carlone and Johnson (2007) describe science identity as comprising recognition (being seen/seeing oneself as a "science person"), competence (knowledge), and performance (enacting practices). Subsequent work has extended this frame to include dimensions such as interest, belonging, and agency, and has shown that identity predicts persistence and engagement in STEM (e.g., Godwin et al., 2016; Hazari et al., 2010; Stets et al., 2017).

Crucially, such frameworks can understate the internal complexity of identity work. Students do not possess a single, stable "science identity"; rather, they navigate multiple,

sometimes competing I-positions—I-as-science learner, I-as-religious believer, I-as-community-first citizen, I-as-outsider to science. From a Dialogical Self Theory perspective, science identity is not a fixed trait but a process of positioning, counter-positioning, and repositioning in response to experience and reflection. In this paper I argue that two developmental capacities are pivotal for science-identity growth in ways that support scientific literacy:

1. Capacity to adopt meta-positions: the ability to step back from conflicting positions and evaluate them from a reflective vantage point.
2. Awareness of the dialogical self: noticing how internal identity positions and conceptual zones (CPM) shape one's engagement with scientific problems and with evidence.

Together, these capacities help learners participate in scientific discourse as agents, not passive recipients—able to coordinate who is "speaking" in them with which conceptual voice they are using, and to align that dialogue with evidence and purpose. When students develop this identity awareness, they become more capable of engaging with science in personally meaningful and socially responsible ways, preparing the ground for the decision making account that follows.

Dialogical Self and Scientific Decision Making

Here I make explicit how core dialogical mechanisms—such as I-positions, meta-positions, and promoter positions—shape scientific decision making. Scientific decision making is often modeled as a purely rational, evidence-based process. In practice, however, real-world choices—about climate change, biotechnology, voting, public health, and more—rarely rest on evidence alone. Individuals also draw on emotions, values, community norms, and prior experience. Dialogical Self Theory (DST) explains how these influences are instantiated within the person as multiple I-positions, each with its own voice, perspective, affective investment, and relative power (Hermans & Hermans-Konopka, 2010). Depending on context, some positions collaborate, some conflict, and others fall silent or are suppressed.

When students encounter a decision point, they do more than apply scientific facts; they also weigh the identity-laden value attached to the positions that are activated. A student deciding whether to accept evolution, acknowledge anthropogenic climate change, wear a mask, or get vaccinated may experience tension between I-as-science student (supporting evidence use) and I-as-member of my faith-based community (resisting particular conclusions). In such moments, decision making becomes a dialogical negotiation among internal voices rather than a strictly analytic process. Here meta-positions become pivotal: they enable learners to observe the inner dialogue, assess the relevance and strength of competing positions, and make decisions that are both reflective and integrated. Coupled with promoter positions, meta-positions help maintain openness to evidence long enough to coordinate identity commitments with data rather than defaulting to monologic dominance. These are evidence-informed decisions in a fuller sense: learners consider not only external information but also how their internal positioning is shaping what "counts" as evidence (Jonassen, 2012;

Kahan, 2017). Such moments illustrate why decision making is both cognitive and identity-saturated—a central premise of SIPL.

Taken together, these insights invite a reconstruction of scientific literacy. Knowledge and understanding are necessary but insufficient predictors of scientifically informed behavior. A dialogical account requires that we attend to how learners coordinate multiple conceptual zones and identity positions, especially when those positions are in tension. This view leads directly to the Science Identity as a Pathway to Literacy (SIPL) model, which formalizes the role of identity development in achieving scientific literacy through the twin processes of awareness of the dialogical self and the capacity to adopt meta-positions.

Science Identity as a Pathway to Literacy (SIPL): A Theoretical Model

The preceding sections support the claim that scientific literacy should be understood not merely as a cognitive attainment but as an identity-mediated competence that is assembled through internal dialogues and shaped by context. Existing frameworks in science education foreground knowledge, understanding, and sometimes belief, but often understate the identity work learners must do to engage authentically with science and to make evidence-informed decisions. In response, I propose Science Identity as a Pathway to Literacy (SIPL) model—a theoretical synthesis that aims to explain how learners become scientifically literate through the development and coordination of science identity. Figure 2 provides a schematic overview of SIPL, illustrating how identity positions and conceptual zones are coordinated through meta- and promoter positions.

SIPL is a conceptual framework, not a curriculum or a measurement instrument. It offers a lens on the psychological and epistemological processes that underlie identity development for science learning. Grounded in Dialogical Self Theory (DST) and the Conceptual Profile Model (CPM), SIPL posits that scientific literacy emerges when learners develop two core competencies:

1. awareness of the dialogical self and
2. capacity to adopt meta-positions.

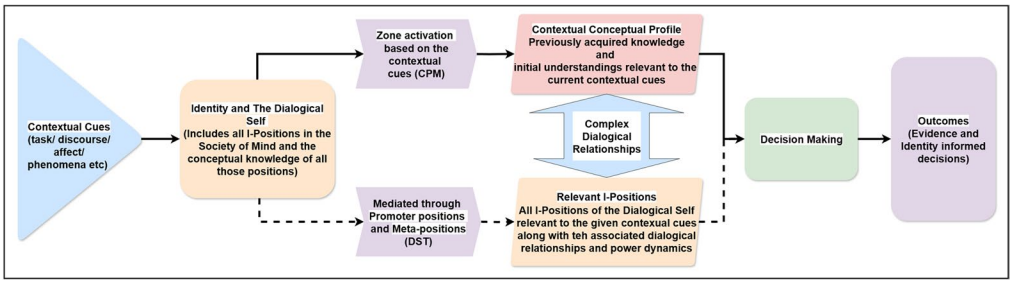

Figure 2. SIPL: Identity–concept coordination toward scientific literacy.
Note. Figure created by the author; the schematic shows I-positions (DST) and conceptual zones (CPM) as interacting layers; task, discourse, and affect cue zone activation, while meta-positions and promoter positions regulate movement and integration.

Together, these capacities enable learners to navigate internal conflicts, coordinate competing identity positions with conceptual zones, and make decisions that are both evidence-informed and personally meaningful (Hermans & Hermans-Konopka, 2010; Mortimer, 1995; Mortimer & El-Hani, 2014).

Theoretical Synthesis

DST conceptualizes the self as a society of I-positions (e.g., I-as-science student, I-as-community member) that negotiate, sometimes dominate or silence one another. Meta-positions and promoter positions help support movement, reflection, and integration within this field. CPM, in parallel, models conceptual multiplicity: learners hold coexisting conceptual zones (e.g., everyday, empirical, rational–classical, rational–modern) that are activated and coordinated by task, discourse, affect, and identity. SIPL integrates these traditions as a model of identity–concept coordination: evidence use and decision making depend on how identity positions and conceptual zones are noticed, named, and orchestrated in context.

Core processes in SIPL

1. Awareness of the dialogical self.
   Learners become conscious of the plurality of I-positions and conceptual zones that coexist within them and of how these voices shape engagement with evidence. Rather than attempting to eliminate culturally derived conceptions, learners learn to examine, contextualize, and interrogate them: What is this view's use, limit, and status here? What identity concerns are at stake? This awareness builds on Mortimer's idea of conceptual profile consciousness to include identity and affect, supporting epistemic flexibility, metacognitive control, and the reflective construction of science identity. Awareness also encompasses recognition of which I-positions are becoming salient in a moment, why they are activated, and how they shape what counts as "evidence" for the learner.
2. Capacity to adopt meta-positions.
   A meta-position is a higher-order standpoint from which the learner observes and evaluates tensions among positions (e.g., I-as-believer vs. I-as-science learner) and among conceptual zones. Meta-positions do not erase conflict; they create space for reflection, weighing of reasons, and temporary or provisional synthesis. In DST, promoter positions often energize this movement, providing motivational clarity ("why engaging with this inquiry matters to me/us") while meta-positions supply the reflective vantage point ("how these voices and concepts relate"). In SIPL, metapositioning is essential for regulating epistemic conflict and for sustaining openness to counterevidence in ways that make revision or integration possible. Metapositioning also includes the ability to ask reflective questions such as:

- *Who in me is responding to this idea?*
- *Which conceptual zone am I using right now, and why?*
- *How are my identity commitments affecting what I accept or resist?*

- These reflective acts help prevent monologic dominance by allowing multiple positions and conceptual zones to remain in productive dialogue.

Propositions (for empirical elaboration)

- P1. Zone activation is identity conditioned. The likelihood that a given conceptual zone will be activated in a task is influenced by the currently salient I-positions and their affective valence.
- P2. Metapositioning predicts evidence use under identity threat. When identity-protective pressures are high, learners with stronger metapositioning capacity may show greater uptake of counterattitudinal evidence than those with weaker capacity.
- P3. Promoter positions mediate coherence. The presence of promoter positions (e.g., I-as-inquirer, I-as-steward) may increase the coordination of competing positions/zones and may reduce monologic dominance.
- P4. Dialogical awareness fosters transfer. Growth in dialogical self-awareness may predict contextual transfer of scientific reasoning across settings (classroom → community).
- P5. Identity–concept coordination may predict literacy. The coordinated use of identity positions and conceptual zones may uniquely predict scientific literacy outcomes beyond knowledge/understanding alone.

Scope and uses

SIPL offers one explanation for why students who understand scientific ideas may nevertheless resist or disengage: literacy falters when dominant positions silence alternatives or when learners lack metapositioning to coordinate identity with evidence. The model complements, not replaces, content-focused accounts of literacy by adding an essential developmental layer that foregrounds identity, dialogue, and epistemic agency. Although conceptual, SIPL invites empirical work. Examples include:

- qualitative studies tracing position/zone activation in discourse;
- longitudinal designs on growth in dialogical awareness;
- mixed-methods studies examining how metapositioning moderates the relation between identity threat and evidence use;
- intervention studies exploring whether metapositioning routines support more flexible engagement with scientific evidence.

SIPL thus calls for a shift in science education—from concept-focused instruction to identity formation and dialogical reflection. If scientific literacy is not only what students know but who they are becoming in relation to science, then teachers, researchers, and designers must cultivate metapositioning and dialogical self-awareness as central aims of instruction. Taken together, these propositions highlight how SIPL reframes literacy as a developmental, dialogical process. The next section considers how this framework can inform pedagogical design, instructional practices, and future research directions.

Educational Implications and Future Directions

The Science Identity as a Pathway to Literacy (SIPL) model invites a shift in how science education is conceptualized, designed, and studied. It foregrounds the identity-based, dialogical processes by which students engage with science—not only as a canon of ideas and practices, but as a field of meaning making that intersects with values, communities, and lived histories. If scientific literacy is built not solely through acquiring concepts but through negotiating internal identity positions and epistemic commitments, then science education must respond with pedagogies, assessments, and research that are sensitive to these dialogical dimensions.

Design Principles for Teaching and Curriculum

1. Legitimate multiplicity. Treat diverse conceptual zones and I-positions as resources, not obstacles. Make room for "everyday" and disciplinary voices to coexist and be coordinated, rather than attempting to erase one with the other (Mortimer & El-Hani, 2014).
2. Surface identity work. Build position-mapping and short reflective prompts into lessons (e.g., Who-in-me is speaking right now? Which identity cares most about this claim?).
3. Cultivate meta- and promoter positions. Normalize brief metapositioning pauses during inquiry (naming the conceptual zone in use; articulating its limits) and design role taking tasks that seed promoter positions like I-as-inquirer or I-as-steward.
4. Structure discourse for evidence. Use routines from argumentation research—explicit claims, warrants, and counterarguments—to keep multiple positions in dialogue with data (Berland & Reiser, 2009; Osborne et al., 2004).
5. Identity-aware evidence audits. When decisions carry value stakes (socio-scientific issues), add a quick "identity audit": students list which I-positions are active, how each weighs the same evidence, and what would count as change-enabling evidence for each position.
6. Affect and control–value cues. Attend to task value and perceived control; design entries that reduce avoidance emotions and increase curiosity and relevance (Pekrun, 2006).

Assessment implications

- From correctness to coordination. Complement concept inventories with process evidence: (a) zone-switching explanations ("state the view you used, why it fits, and its limits"), (b) metaposition logs (short, time-stamped reflections), and (c) position↔evidence matrices that show how evidence is weighed across identities.
- Rubrics for dialogical competence. Assess (1) metaconceptual awareness (naming zones/limits), (2) metapositioning (articulating relations among positions), (3) tolerance of ambiguity, and (4) evidence uptake under identity tension.
- Portfolio artifacts. Collect brief identity-reflection memos alongside lab reports and argumentation artifacts to trace the identity–concept coordination central to SIPL.

- Ethical guardrails. Keep identity reflection invitational (opt out respected), nongraded for disclosure content, and protected by clear norms around privacy and care.

Research agenda (operationalizing SIPL)

- Testing the propositions.
  - P1 (zone activation is identity conditioned): microanalysis of discourse + experience sampling of salient I-positions during tasks.
  - P2 (metapositioning → evidence use under identity threat): randomized prompts that scaffold metapositioning during SSI debates; outcomes = counterattitudinal evidence uptake.
  - P3 (promoter positions mediate coherence): longitudinal coding of reflective journals to see whether emergent promoter positions predict sustained coordination.
  - P4 (dialogical awareness → transfer): follow learners from classroom to community action; measure cross-context use of evidence.
  - P5 (identity–concept coordination predicts literacy): mixed models including knowledge/understanding plus coordination indices to predict performance on applied decisions.
- Methods & measures. Multimodal classroom data (video + artifacts), short metapositioning prompts embedded in tasks, think-alouds for zone activation, and validated identity instruments where appropriate (paired with qualitative identity-mapping to capture polyphony).
- Design-based research. Iteratively refine identity-aware discourse routines and evidence audits; examine feasibility and teacher learning.

Reframing "evidence-informed" decisions

Students' decisions are shaped by identities and emotions as well as analysis. In a SIPL frame, taking identity into account is not a retreat from rationality; it expands rational deliberation by enlarging the evidential set to include how active I-positions are weighing the same data. Teaching "evidence-informed decision making" therefore includes helping students treat their own positioning as data—naming which voices are speaking, how those voices evaluate the evidence, and what additional evidence could move them. Paradoxically, acknowledging identity can increase rationality by preventing unexamined, identity-protective filters from implicitly shaping the choice (Jonassen, 2012; Kahan, 2017).

Open questions and cautions

- How do we affirm diverse identities without reifying or essentializing them?
- What forms of productive internal conflict catalyze growth, and when does conflict become harmful?
- How should we assess literacy when coordination (not mere correctness) is central?
- What teacher supports/professional development best cultivate the facilitation skills and ethical sensitivity this work requires?

- How do we ensure identity work does not obscure structural constraints (e.g., inequities in recognition, language power)?

SIPL does not diminish the importance of content knowledge and scientific practices; it complements them by illuminating the identity work required for meaningful engagement. As education grapples with polarization, science mistrust, and competing narratives of truth, identity-aware, dialogically grounded approaches to literacy are increasingly urgent. Recognizing that how students think is entangled with who they are becoming, SIPL offers a pathway to cultivating not only competent learners but reflective, responsible science thinkers and decision makers.

Conclusion

Scientific literacy in the twenty first century cannot be secured by concept delivery alone. I reframe literacy as a dialogical competence—the capacity to coordinate identity positions and conceptual zones in ways that keep evidence genuinely in play when choices are value-laden and socially consequential. By integrating Dialogical Self Theory (DST) with the Conceptual Profile Model (CPM), the SIPL framework proposes two developmental levers—awareness of the dialogical self and capacity to adopt meta-positions—that help learners notice which voices are speaking "in them," name the conceptual registers they are using, and sustain openness to counterevidence in ways that make revision or integration possible.

For practice, this reframing invites identity-aware pedagogies that legitimize multiplicity and teach metapositioning as routinely as we teach claims and warrants. For assessment, it shifts emphasis from correctness alone to coordination and evidence uptake under identity tension. For research, it offers testable propositions about how identity may condition conceptual activation, how promoter and meta-positions may mediate coherence, and how dialogical awareness may support transfer. In polarized, information-saturated contexts, cultivating these capacities is not ancillary; it is increasingly central to forming reflective, responsible science thinkers and decision makers—the very aim that motivates science education.

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Author contributions

All conceptualization, analysis, and final content decisions are my own.

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