

## Communication Under Heterogeneous Expectations: Enabling Actionable Collaboration in Innovation and Experimentation Labs\*

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### Abstract

Labs have become a central organisational form for transformative innovation, yet their internal functioning remains poorly understood. Existing work documents structural typologies and outcome contributions, but the communicative micro-processes that let heterogeneous actors act jointly under divergent expectations are still under-theorised and under-researched. This paper develops a communication-theoretical account of how labs become and remain actionable. Drawing on Luhmann's modern systems theory, Chesbrough's open innovation framework and the boundary spanning literature, we analyse sixteen semi-structured expert interviews with science, citizen and business stakeholders from five German labs. The material comprises 1,396 codings, analysed through MAXQDA-supported qualitative content analysis combined with code-relations analysis. Six deductive dimensions and one inductive dimension structure the data. The central contribution is the Lab Membrane Model (LMM), which reconceptualises the lab boundary as a selectively permeable communicative space. The membrane realises three operative functions – filter, translator and amplifier – sustained by an inner architecture of four condensations and a personal deep layer. The LMM concretises Luhmann's systems theory empirically, sharpens the coupled process of open innovation, and is operationalised for practitioners through the LabKompass diagnostic suite and the LabPuls monitoring app, which give lab leaders concrete, repeatable tools to diagnose imbalances, protect critical roles and steer their own reproduction.

**Keywords:** labs; communication; heterogeneous expectations; Lab Membrane Model

### Introduction

The notion of the “lab” has migrated from the natural sciences into a wide range of social, political and managerial discourses. Living labs, urban labs, social labs, fab labs, policy labs and corporate labs are increasingly framed as organisational forms in which experimental and participatory collaboration is arranged across disciplinary, sectoral and institutional boundaries (Chesbrough, 2003; Gassmann and Enkel, 2006; Leminen et al., 2012; Schneidewind and Singer-Brodowski, 2014; Voytenko et al., 2016; Hassan, 2014; Mazzucato, 2018). Yet the proliferation of the term has outpaced its conceptual clarification: labs differ widely in goals, governance, methods and outcomes, and the social mechanisms that make a lab actionable are still only partly understood (Gryszkiewicz et al., 2016; Eder and Beermann, 2020; Mulgan, 2014). We use “lab” as an umbrella for this entire family of formats.

Two strands dominate the existing literature. The first develops typologies of structural and functional features and proposes ideal-typical configurations (Leminen et al., 2012; Gryszkiewicz et al., 2016); the second investigates the contributions of labs to innovation outcomes, sustainability transitions or user integration (Almirall and Wareham, 2011; Schöpke et al., 2018; Voytenko et al., 2016). Both leave open how the joint capacity to act emerges in daily lab practice, and how heterogeneous expectations from science, business and civic life are communicatively coordinated such that actionable collaboration becomes possible. This gap is both

theoretical and empirical: a frame that reconstructs labs as communicatively constituted social systems is rare, and qualitative research tracing how heterogeneous expectations are articulated, negotiated and stabilised inside lab settings is scarce (Gryszkiewicz et al., 2016; Schöpke et al., 2018; Voytenko et al., 2016).

The paper therefore asks: how is actionable collaboration enabled communicatively in labs under conditions of heterogeneous expectations? We unfold this into three sub-questions: (1) What role do divergent expectations play in communicative processes inside labs? (2) How are these expectations communicatively negotiated and coordinated? (3) How can these processes be conceptualised, in systems-theoretic terms, as social system formation? To address them we combine three theoretical frames – Luhmann’s modern systems theory as the leading lens, Chesbrough’s open innovation as a process frame, and boundary spanning as an actor-level frame – with sixteen guideline-based expert interviews from five German labs, analysed via MAXQDA-supported qualitative content analysis (Mayring, 2015) and code-relations analysis. Six deductive dimensions were complemented by one inductive dimension on personal attributes; the material yields 1,396 codings whose distributional and relational profile grounds the Lab Membrane Model (LMM).

The contribution is threefold. First, it advances a Luhmannian, communication-theoretical account that understands the lab not as a method kit or participation format but as an autopoietic social system that reproduces itself through communication. Second, it develops the LMM as a theoretically integrated and empirically grounded model in which the lab boundary becomes a communicative work-space realising three operative functions (filter, translator, amplifier) carried by four core condensations and a personal deep layer. Third, it sketches the LMM’s practical operationalisation via the LabKompass diagnostic suite and the LabPuls app. The remaining sections develop the theoretical frame (2), methodology (3), findings (4), the integrative model and LMM (5), discussion (6), operationalisation (7) and conclusion (8).

## Theoretical Framework

Three lenses inform the analysis: open innovation, modern systems theory in the Luhmannian tradition, and boundary spanning. They are treated not as additive layers but as complementary observational positions on the same phenomenon: a process model of how knowledge crosses organisational boundaries, a model of how communicative operations constitute social systems, and an actor-level model of communicative translation between heterogeneous logics. To keep the terminology used throughout the paper explicit, Table 1 defines the central concepts before they are applied to the empirical material.

**Table 1. Key terms used in the analysis.**

| <b>Term</b>                              | <b>Definition</b>                                                                                                                                                                                          |
|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Communication</b>                     | The basic operation of social systems: a three-fold selection of information, utterance and understanding that produces further communication (Luhmann, 1984).                                             |
| <b>Autopoiesis</b>                       | The self-reproduction of a system’s operations out of its own operations, through which the system produces itself as a unity.                                                                             |
| <b>Operational closure</b>               | A system cannot import operations from its environment, only be irritated by it; closure is the precondition for environmental openness.                                                                   |
| <b>Structural coupling</b>               | Recurrent, stabilised interfaces through which co-evolving systems filter environmental noise into operationally usable irritations.                                                                       |
| <b>Expectations</b>                      | The medium through which heterogeneous actors coordinate; cognitive expectations are revised when disappointed, normative expectations are maintained against disappointment.                              |
| <b>Resonance</b>                         | The conditions under which environmental events provoke communicative reactions inside the system (Luhmann, 1986).                                                                                         |
| <b>Open innovation / coupled process</b> | Innovation as a distributed process in which knowledge crosses organisational boundaries; the coupled process denotes mutual co-creation across the boundary (Chesbrough, 2003; Gassmann and Enkel, 2006). |
| <b>Boundary spanning</b>                 | The communicative work of actors who collect, translate and transfer information across an organisational boundary (Tushman, 1977; Williams, 2002).                                                        |

| Term                       | Definition                                                                                                                                     |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Lab membrane</b>        | The selectively permeable communicative boundary of the lab, realising three operative functions: filter, translator and amplifier.            |
| <b>Filter</b>              | The membrane function that screens external impulses for fit and realises the lab's operational closure.                                       |
| <b>Translator</b>          | The membrane function that reformulates information from one logic into another (e.g. scientific into business language).                      |
| <b>Amplifier</b>           | The membrane function that produces resonance, making lab outputs connectable in the environment.                                              |
| <b>Condensation</b>        | An empirically observed cluster of co-occurring communications forming a load-bearing node of the lab's inner architecture.                    |
| <b>Personal deep layer</b> | The cross-cutting layer in which the membrane functions are carried by specific persons; both a condition of reproduction and a vulnerability. |

*Source: own representation.*

### ***Labs as open innovation spaces***

Open innovation reconceptualises innovation as a distributed, networked process in which valuable knowledge crosses the boundaries of single organisations (Chesbrough, 2003). Three process logics are distinguished: outside-in, inside-out and the coupled process of mutual co-creation across the boundary (Gassmann and Enkel, 2006). Labs are paradigmatic instantiations of the coupled process because they organise sustained, structured interaction between heterogeneous actors rather than discrete transactions. The lab literature has produced numerous typologies: living labs as user-driven co-creation in real-life settings (Leminen et al., 2012; Almirall and Wareham, 2011), urban living labs combining sustainability transitions with city-based experimentation (Voytenko et al., 2016), social and policy labs experimenting with collective problem solving (Hassan, 2014), and fab labs offering accessible prototyping infrastructure (Gryszkiewicz et al., 2016). Recent work condenses this diversity into morphological tableaux of carrier structure, openness, target setting and funding logic (Eder and Beermann, 2020). What this work captures less well is the communicative work that makes the coupled process possible: open innovation describes which knowledge moves across the boundary but remains largely silent on how heterogeneous expectations are kept compatible during that movement. This is the gap that systems theory and boundary spanning seek to fill.

### ***Modern systems theory: communication, expectations, structural coupling***

Following Luhmann (1984, 1995, 1997), social systems are constituted not by actors or institutions but by communication: a three-fold selection of information, utterance and understanding that produces further communication. Only this recursive linking keeps a social system in operation. A central consequence is operational closure: a system cannot import operations from its environment, only be irritated by it. Yet operational closure is the condition for environmental openness, because the system's own operations select what counts as a relevant impulse from outside.

Four concepts are central. Autopoiesis: a social system reproduces its own operations from its own operations and thereby produces itself as a unity (Luhmann, 1984). Structural coupling: systems co-evolve by stabilising recurrent interfaces that filter environmental noise into operationally usable irritations (Luhmann, 1990). Expectations: social systems stabilise themselves by building expectation structures and expectations about expectations, which condense into roles, programmes and values; they operate in cognitive (revisable on disappointment) and normative (maintained against disappointment) modes and are the central currency by which heterogeneous actors coordinate without sharing substantive worldviews (Luhmann, 1984). Resonance: the conditions under which environmental events provoke communicative reactions in the system (Luhmann, 1986). On this basis labs can be analysed at three levels of social system: interaction (co-presence in which expectations are articulated and negotiated), organisation (a decision-based system stabilising membership, roles and procedures) and societal function systems (science, economy, politics, civil society) with which the lab is structurally coupled.

### ***Boundary spanning at the lab's edge***

The boundary spanning literature complements systems theory by focusing on the actors who do the communicative work at organisational boundaries. Tushman (1977) and Tushman and Scanlan (1981) defined boundary spanners as individuals who collect, translate and transfer external information across the boundary;

Aldrich and Herker (1977) emphasised the dual function of outward representation and inward information processing; Williams (2002) extended the concept towards reticulist and inter-personal competences; and more recent work describes boundary spanning as a relational and emotional practice vulnerable to burnout (van Meerkerk and Edelenbos, 2018). In labs, boundary spanning is omnipresent because lab work is, by definition, work across boundaries. Yet the literature has described boundary spanners primarily as actors, not as the personal carriers of operative functions performed by the lab as a system – an opening our analysis takes up by treating boundary spanning not only as an activity but as a personal deep layer of the lab’s communicative operations.

### ***Synthesis: an integrative theoretical frame***

Synthesising the three lenses yields an integrative frame in which six deductive main categories structure the empirical analysis: (1) internal communication processes; (2) expectation management; (3) innovation enablement; (4) lab organisation; (5) external communication and network integration; (6) self-organisation and self-regulation. Each is anchored in at least two of the three theoretical frames and is empirically open enough to accommodate inductive sub-coding. Figure 1 summarises the frame, enriched with the empirical findings of Section 4.

### **Methodology**

The study is grounded epistemologically in operative constructivism (Luhmann, 1990) and methodologically in qualitative social research (Mayring, 2015; Helfferich, 2011). Operative constructivism treats observation as a system-internal operation that always carries the form of a distinction, which is congenial to a study asking how labs observe and stabilise their own communicative reality. The design combines guideline-based expert interviews, qualitative content analysis and code-relations analysis.

### ***Sample and field access***

Five German labs were selected by theoretical sampling along the morphological tableau (open, transdisciplinary, semi-structured labs with users as co-actors): the urban innovation hub (UIH!) in Heilbronn, the INSPIRE Lab at the University Medical Centre Mannheim (UMM), the Creative Space for Technical Innovations (CSTI) at HAW Hamburg, the FZI Living Lab smartEnergy in Karlsruhe and the Fab Lab Siegen. For each lab, three stakeholder perspectives were included: science (lab leadership and researchers), citizens (private participants or person-side intermediaries) and business (cooperating organisations or start-ups), with a second business interview at the Fab Lab Siegen, giving a final sample of sixteen interviews. Sampling sought diversity along thematic focus, institutional embedding and lab maturity.

### ***Data collection***

Three perspective-specific interview guides were developed, all anchored in the same conceptual base: communication as the central operation of social systems. Interviews lasted between 28 and 83 minutes (mean approximately 53) and were conducted between May and September 2024 in face-to-face, hybrid or video-conferenced format. All were recorded with informed consent, transcribed verbatim, anonymised and stored under a documented data-protection regime in line with the European GDPR.

### ***Data Analysis***

Analysis followed Mayring’s (2015) summative qualitative content analysis, supported by MAXQDA. The deductive code system reflected the six main categories from Section 2; sub-categories were refined inductively across three coding passes. After the second pass, a seventh main category (personal attributes / personhood) emerged inductively (54 codings) and was added as an autonomous dimension because it cut across the deductive categories without being absorbed by any of them. Beyond conventional content analysis, a code-relations analysis using the MAXQDA Code Relations Browser made co-occurrences of codes within the same coded segments visible, allowing us to identify communicative condensations and to ground the lab’s inner architecture as a relational structure rather than a list of categories.

### ***Quality criteria and ethics***

Quality was assessed against the criteria of qualitative research: intersubjective traceability via documented coding rules and audit trails, rule-governed analysis via the Mayring procedure, theoretical embedding via the integrative frame, and reflexive disclosure of the principal investigator’s long-standing engagement with a Heilbronn-area lab, flagged in the limitations.

## **Findings**

The material yields 1,396 codings across seven main dimensions and twenty-five sub-categories. Internal communication (385 codings) is the largest dimension, followed by lab organisation (291), innovation enablement (233), external communication and network integration (163), self-organisation and self-regulation (152), expectation management (118) and personal attributes (54). The strongest sub-categories are structuring communication (4.2; 206 codings), self-regulation mechanisms (6.2; 117) and external feedback to the lab (5.2; 94). This distribution is itself a finding: lab practice is communicatively dense, and the load concentrates on a small number of structural and regulatory operations. Full sub-category statistics and exemplary interview passages are documented in the underlying dissertation (Vogel, 2026).

### ***Internal communication processes***

Internal communication has the highest coding density of any dimension, covering formal versus informal communication (79 codings), audience orientation (85), communication channels (97), transparency and openness (117) and internal feedback (7). The density of structuring sub-categories alongside the weakness of internal feedback indicates that the labs stabilise the conditions of their own communication primarily through frame-setting rather than systematic reflexive loops. This confirms that labs reproduce themselves as autopoietic systems through communication, and that the coupled process is internally prepared by deliberate audience orientation and channel choice.

### ***Expectation management***

Expectation management aggregates target formation and alignment (43 codings), the formation of expectation structures (66) and the management of disappointment (9). Two findings stand out. First, the formation of expectation structures is empirically dense: labs invest substantial communicative effort in stabilising mutual readability. Second, the management of disappointment is striking by its low density: when expectations are not met, the labs tend to under-communicate the failure rather than treat it as productive material for adjustment. We read this asymmetry as a filter weakness of second order: the membrane is well prepared to install expectations but less prepared to process their disappointment. This confirms Luhmann's observation that expectations are the principal stabilising medium of social systems and extends Borup et al.'s (2006) sociology of expectations into the lab context.

### ***Innovation enablement***

Innovation enablement covers innovation drivers (117 codings), innovation barriers (45), feedback loops and learning (36) and innovation grade / research focus (35). Innovation drivers couple strongly with the formation of expectation structures (2.2) and structuring communication (4.2), supporting the open-innovation reading of labs as paradigmatic implementations of the coupled process: the lab actively organises mutual irritation between knowledge import and export and translates it into structured expectations that orient further work. Barriers cluster around regulatory and data-protection issues, multi-year third-actor delays and technical underperformance.

### ***Lab organisation***

Lab organisation consists of hierarchies and role distribution (48 codings), framework conditions and structuring communication (206) and sustainability and long-term orientation (37). The dominance of structuring communication – the single largest sub-category in the study – is the most important quantitative signal of the material. It is the operative ground on which everything else stands: routines, procedures, formats, agreements and resource allocations are not framing decorations but the recursive operations through which the lab as an organisation re-produces its anchorability. In Luhmannian terms, structuring communication realises the structural layer of lab autopoiesis and makes any further communication connectable.

### ***External communication and network integration***

This dimension covers interaction with external actors (53 codings), external feedback to the lab (94) and cooperation and network building (16). External feedback is empirically strong, but cooperation and network building are comparatively thin: networks tend to be sustained through repeated interaction rather than discussed as objects of communication. External feedback realises Luhmann's structural coupling: the operation through which the lab translates environmental irritations into internal adjustments. The strong code-relation between external feedback (5.2) and self-regulation (6.2; 16 co-codings) provides empirical evidence that structural coupling is a coupled process realised communicatively.

### ***Self-organisation and self-regulation***

This dimension consists of decision-making (20 codings), self-regulation mechanisms (117) and the emergence of new ideas and structures (15). Self-regulation mechanisms – the second-largest sub-category overall – signal that labs continuously observe and adjust their own operations through running update routines, anchor formats (weekly stand-ups, steering circles, recurring outreach formats) and personal vigilance. Self-regulation realises the self-reference layer of lab autopoiesis (Luhmann, 1984) and provides the operative anchor for emergent novelty: the labs produced follow-up formats (“uih\! 2.0”), steering-circle architectures and multi-year repeat constellations that were not planned *ex ante* but emerged from the recursive interplay of structuring communication, external feedback and personal trajectories.

### ***The inductive seventh dimension: personal attributes***

The seventh main category emerged inductively after the second coding pass and aggregates 54 codings across all sixteen interviews, with four sub-themes: professional role and self-conception (14 codings), depth of experience and routine formation (8), motivation and self-interest (15) and personal translation and contact competences (17). Personal attributes are not a psychological but a communication-theoretical category: persons are the second-order ascription units through which lab communication creates trust, recognisability and continuity (Luhmann, 1995). Personal translation and contact competences couple directly with boundary spanning, while motivation reveals a vulnerability of lab reproduction: in each lab one or two key persons carry a disproportionate share of the membrane work, making the lab structurally susceptible to membrane erosion when these persons leave or burn out.

### ***Cross-perspective synthesis***

Across all dimensions, the three stakeholder perspectives produce complementary readings: science describes the lab as an organising structure in which expectations are explicitly negotiated; citizens experience it as an accessible offer amplified by lab guides and multipliers; and business treats it as a learning system sustained via steering circles and follow-up projects. Four stakeholder-specific asymmetries emerge: internal feedback is thin from the citizen and business perspectives; disappointment management is implicit on the citizen side; external feedback on the business side is market-mediated rather than organisationally anchored; and formal decision processes are thin on the citizen side. A fifth, cross-cutting asymmetry runs through all of them: dosed external communication, regulatory delays, third-actor friction and technical underperformance act as external filter structures that shape what the lab can communicate to its environment.

### **From the Integrative Model to the Lab Membrane Model (LMM)**

The integrative model in Figure 1 condenses the three theoretical perspectives, three Luhmannian analysis levels and three stakeholder positions into a single visual. Around a lab core defined by communication and expectations, three concentric layers represent interaction, organisation and the surrounding function systems; a dashed boundary marks the membrane through which boundary spanners filter, frame and translate. The empirical findings of Section 4 are placed onto this model as quantitative anchors and stakeholder-specific coding emphases.

## THEORETICAL PERSPECTIVES

### GUIDING PERSPECTIVE

#### Modern Systems Theory

Niklas Luhmann (1984)

### PROCESS PERSPECTIVE

#### Open Innovation

Chesbrough 2003; Gassmann & Enkel 2006

### ACTOR PERSPECTIVE

#### Boundary Spanning

Tushman & Scanlan 1981; Williams 2002

## FOUR CONDENSATIONS

1

**Condensation 4.2** – Framework conditions and structuring communication  
*Membrane filter*

2

**Condensation 6.2** – Mechanisms of self-regulation  
*Membrane translator*

3

**Condensation 5.2** – External feedback to the lab  
*Membrane translator*

4

**Condensation 7** – Personal attributes / personhood  
*Inductive cross-layer*

F

**Filter** – secure connectivity  
*selects communicatively relevant impulses*

T

**Translator** – Science ↔ Economy  
↔ Citizens  
*Coupled Process realised communicatively*

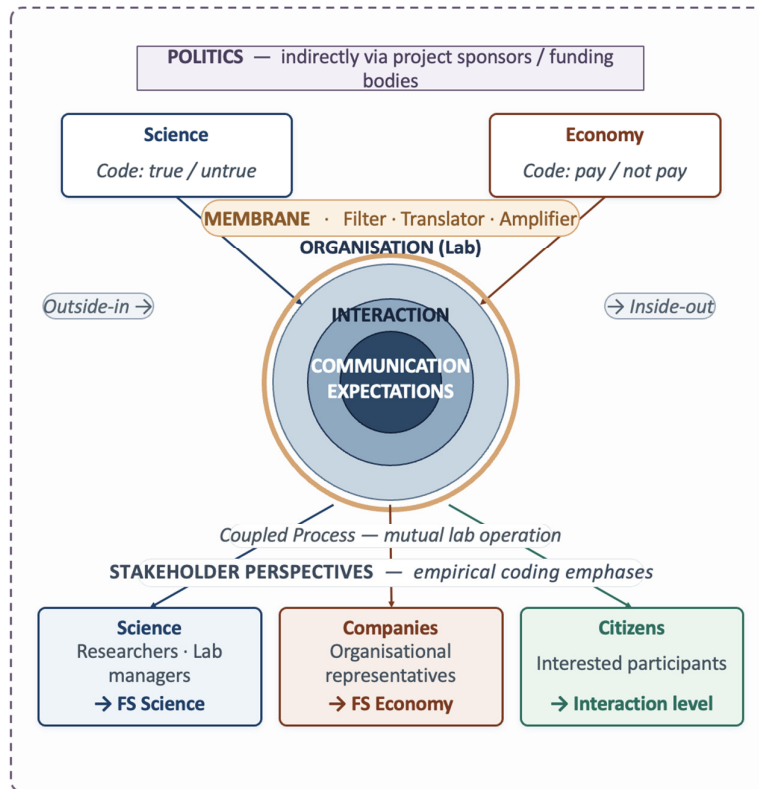


**Figure 1. Integrative model with empirical findings: anchoring the three theoretical perspectives, three analysis levels and three stakeholder positions in the empirical evidence. Source: own representation.**

At three places the integrative model invites deeper specification: the membrane remains a metaphor rather than an operative work-space; the inductive seventh dimension is not theoretically anchored; and the empirical code-relations are visible as anchors but not as a structural inner architecture. The Lab Membrane Model (LMM, Figure 2) addresses these openings by transforming the metaphor into an operative tripartite (filter, translator, amplifier), anchoring the personal deep layer as a cross-cutting carrier of all three functions, and integrating the four code-relations condensations as the inner architecture of the lab core.

### *The membrane as an operative work-space: filter, translator, amplifier*

Three operative functions of the membrane can be reconstructed across the seven dimensions. The filter function realises the operative closure of the lab. It is most visible in structuring communication (4.2; 206 codings) and in stakeholders' accounts of strategic gating: external requests are screened for fit before entering the lab, intellectual property considerations dose what is shared with whom, and reputational protection guides what becomes visible. A second, external filter structure runs across the membrane: data-protection delays, regulatory hurdles, third-actor friction and technical underperformance become operatively effective through it. Theoretically, the filter function corresponds to what Luhmann (1984) describes as communicative connectivity, in which only operations the system selects as connectable can become further communications.

The translator function realises what boundary spanning means in the strict sense: the reformulation of information from one logic into another, audience-oriented framing, and mediation between heterogeneous practice communities (Williams, 2002). It is the empirically richest finding across all perspectives: lab leaders describe dedicated translation roles toward industrial counterparts; lab guides and intermediaries call themselves "the bridge" between civil society and the lab; project managers anchor the translator at the operative daily-doing level and emphasise bidirectional re-translation of lab outputs into firm-specific language. The translator function is the communicative realisation of the coupled process (Gassmann and Enkel, 2006), modelled here not as an arrow between boxes but as a recursive operation of the membrane.

The amplifier function realises a hitherto under-described operation: the communicative production of resonance through which lab outputs become connectable in the environment and external impulses trigger internal variation.

Reputational resonance becomes tangible in business accounts of the lab as a “lighthouse” that binds partners through visibility; multiplier-supported resonance becomes tangible in citizen accounts of “AI ambassadors” who, via local press, mobilise hundreds of participants from a complete cross-section of society. The amplifier function builds on Luhmann’s (1986) concept of resonance and explains why labs, despite operative closure, depend on environmental resonance for their own reproduction: without amplification, labs produce communication but no connectable effect.

The three functions operate simultaneously and recursively. Filter without translator makes the lab autistic; translator without filter makes it overloaded; amplifier without filter and translator produces resonance into the void. Only their joint operation enables the structural coupling between lab and environment. This is empirically anchored in a key passage in which a citizen-side intermediary describes joint question development with stakeholders: the question filters (what is relevant), translates (what it means for the next practical step) and amplifies (what becomes jointly visible) in one and the same micro-operation, constituting the empirical reference case for the LMM.

### ***The personal deep layer***

The inductive seventh dimension is anchored in the LMM as the personal deep layer of the membrane, as a theoretical consequence of three observations. First, in the code-relations matrix the seventh dimension couples with all three membrane functions: with innovation drivers (3.1) and thus the amplifier, with the formation of expectation structures (2.2) and thus the translator, and with structuring communication (4.2) and thus the filter. Second, personal carriership is visible across all three perspectives: scientists describe enthusiasm, persistence and curiosity (filter side); citizens describe friendliness, patience and intelligibility (amplifier side); and business actors describe reliability, speed and solution orientation (translator side). Third, the personal deep layer is a communication-theoretical, not psychological, description: persons are the second-order ascription units through which lab communication acquires visibility, trust and recognisability (Luhmann, 1995).

This anchoring makes the vulnerability of lab reproduction theoretically describable: when membrane functions are personally carried, the loss of one or two key boundary spanners is not a personnel reshuffle but a membrane erosion. Two interview passages – a burnout reflection by a fab-lab manager and a replaceability reflection by a start-up founder – operationalise this empirically. The integrative model makes the insight invisible because it models boundary spanning only as an activity; the LMM holds both readings together, treating boundary spanning as an activity that is operatively performed via personal deep layers.

### ***The inner architecture of the lab core: four condensations***

The code-relations analysis identifies four condensations in which lab communication empirically clusters, documented as the inner architecture of the lab core. Structuring communication (4.2; 206 codings) is the central hub at which operative and structuring operations converge: the structural layer of lab autopoiesis (Luhmann, 1984). Self-regulation (6.2; 117 codings) is the layer through which the lab observes, adjusts and stabilises its own operations: the self-reference layer. External feedback (5.2; 94 codings) is the bridge between membrane and core through which environmental irritations are processed: structural coupling (Luhmann, 1990). The personal deep layer (54 codings) is a cross-structure anchoring the other three nodes in personal carriership: the second-order ascription layer (Luhmann, 1995).

These four condensations operate in a recursive reproductive dynamic. Structuring communication frames self-regulation by providing the routines, formats and rules within which adjustment becomes possible; self-regulation processes external feedback by translating environmental irritation into internal adaptation; external feedback is personally mediated by boundary spanners; and personal mediation in turn stabilises structuring communication by securing its connectivity. The dynamic is not a logical circle but an empirically grounded reproductive loop that carries the lab as a communicative system.

## The Lab Membrane Model (LMM)

*Theoretical condensation of empirical findings · inner architecture of the lab core and operation of the membrane*

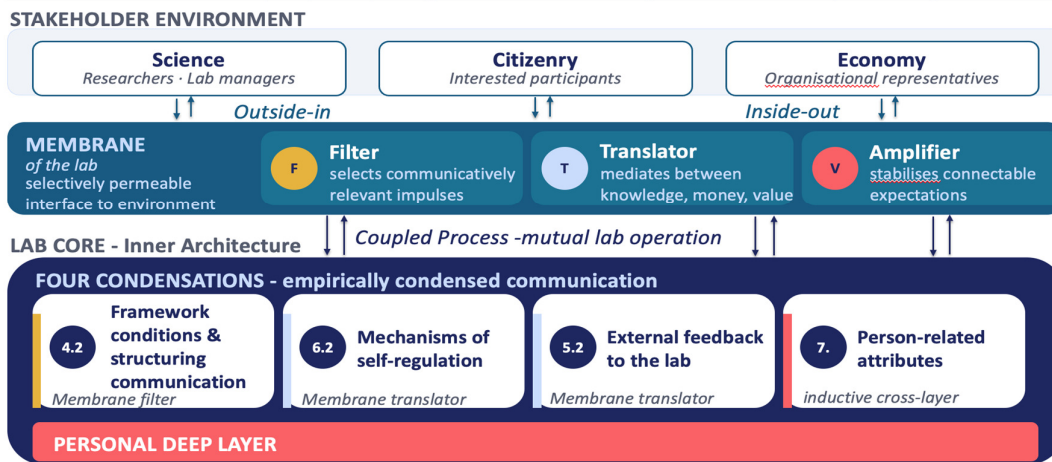


**Figure 2. The Lab Membrane Model (LMM): operative membrane functions (filter, translator, amplifier), four condensations of the inner lab architecture, and the personal deep layer as cross-cutting carrier. Source: own representation based on MAXQDA-supported content analysis.**

### *Five core findings condensed in the LMM*

Reading the seven dimensions through the LMM yields five core findings. First, the lab is a communicative system with a differentiated membrane architecture; the high coding densities in dimensions 1, 4, 5 and 6 evidence that lab practice is carried by communicative operations, not by structures, persons or resources as standing entities. Second, expectation structures are the communicative working axis of actionable collaboration: the empirical triangle between expectation structures (2.2), structuring communication (4.2) and innovation drivers (3.1) shows that expectations are formed, transferred into routines and translated into action-guiding practice. Third, the personal deep layer is at once a reproductive condition and a vulnerability indicator. Fourth, lab reproduction shows asymmetries read here as developmental opportunities: filter weaknesses around disappointment management, citizen-side gaps in formal decision processes and business-side externalities of feedback are addressable points of intervention, not deficits. Fifth, the three stakeholder perspectives are complementary, not contradictory: the lab is precisely the translation space in which the scientific, life-world and processual readings of practice become connectable.

## Discussion

The LMM extends each of its three theoretical reference frames. Towards systems theory, it offers an empirical concretisation of communication-theoretical concepts that are otherwise hard to operationalise: autopoiesis becomes visible in the dominance of structuring communication (4.2); structural coupling in the code-relation between external feedback (5.2) and self-regulation (6.2); resonance in the amplifier function; cognitive versus normative expectations in the asymmetry between expectation formation (2.2) and disappointment management (2.3); and the second-order person-concept in the personal deep layer. None of these concretisations replaces Luhmann's apparatus; each makes it operationally accessible.

Towards open innovation, the LMM sharpens the coupled process (Gassmann and Enkel, 2006). Where the standard reading depicts it as a bidirectional arrow between organisation and environment, the LMM shows it to be a recursive communicative operation of the membrane integrating filter, translator and amplifier in a single micro-operation, reframing labs as the prototypical implementation of the coupled process. Towards boundary spanning, the LMM extends Williams' (2002) and van Meerkerk and Edelenbos' (2018) work by anchoring it as a personal deep layer of the membrane: boundary spanning remains an activity but is operatively performed via persons, whose loss becomes describable as membrane erosion.

Methodologically, the paper shows the value of combining qualitative content analysis with code-relations analysis: content analysis stabilises the deductive frame and accommodates the inductive seventh dimension, while code-relations analysis makes visible which categories operatively couple and can be read as a model of communicative reproduction.

The LMM also yields actionable implications for lab governance, in four developmental logics. (1) Membrane balancing: a filter-dominated lab becomes inwards-turning, a translator-dominated lab overloaded, and an amplifier-dominated lab loudly visible but substantively thin; the LabKompass operationalises this balance via a three-axis self-diagnostic. (2) Condensation strengthening: the four core nodes (4.2, 6.2, 5.2, 7) and their recursive connections must be safeguarded, with weakly populated nodes treated as actionable opportunities. (3) Personal de-risking: tandems, structured handovers and mentoring reduce membrane erosion when key boundary spanners leave or burn out. (4) Disappointment cultivation: turning under-communicated disappointments into productive material for adjustment requires explicit communicative formats.

## **Practical Operationalisation: LabKompass and LabPuls**

The LMM is operationalised in two complementary application layers designed to deliver direct, usable value to the labs themselves: the LabKompass, a diagnostic suite that translates the model into three structured self-assessment instruments, and the LabPuls app, a longitudinal infrastructure that turns diagnostic snapshots into continuous reproductive observation. Rather than offering generic recommendations, both layers convert each model element into a concrete decision the lab can act on – where to invest scarce coordination effort, which roles to protect, and whether a given intervention has actually worked.

### ***The LabKompass***

The Membrane Diagnostic operationalises the three membrane functions in three to five Likert-style items each – for example, “In our lab it is clearly defined which topics are processed formally and which informally” (filter), “We can flexibly translate between scientific, lay and business language” (translator) and “Our lab generates traceable public resonance” (amplifier). It yields an aggregated three-axis profile that shows the lab in a single picture whether it is filter-, translator- or amplifier-dominant or balanced. The benefit is targeted action: a filter-dominant lab learns that it should invest in outward translation and visibility before its next funding round, while an amplifier-dominant lab learns that it is over-promising relative to its delivery capacity and can re-balance before reputational damage occurs.

The Condensation Diagnostic operationalises the four core nodes (4.2, 6.2, 5.2, 7) as reproductive conditions and shows the lab which of its load-bearing communicative routines are under-developed, so that scarce coordination time is directed to the weakest node rather than spread evenly across all of them. The Personal Deep Diagnostic maps the personal carriers of the membrane functions and identifies single-point-of-failure roles. Its direct benefit is risk reduction: the lab sees, by name and function, where the loss of one person would erode the membrane, and can install tandems, documented handovers and knowledge transfer before that person leaves or burns out – turning an invisible structural vulnerability into a manageable staffing decision.

### ***The LabPuls App***

The LabPuls app turns these one-off diagnoses into a continuous management instrument with four functions, each tied to a concrete payoff for the lab. A quarterly self-diagnostic produces longitudinal membrane profiles, so the lab can see whether an intervention actually moved the targeted axis. A perspective-integration function triangulates the lab’s self-assessment with science, citizen and business stakeholders, exposing blind spots where the lab over-rates its own translator or amplifier performance. A cross-lab benchmarking function aggregates anonymised comparisons, letting a lab judge its profile against peers rather than in isolation. A reproduction-monitoring function surfaces early-warning signals of membrane erosion – for example a rising concentration of boundary work on a single person – early enough for leadership to act. The app is currently a conceptual implementation; technical realisation, validation and field evaluation are set out as a follow-up research agenda.

## **Conclusion, Limitations and Outlook**

This paper has developed a communication-theoretical account of how labs become and remain actionable under conditions of heterogeneous expectations. Building on Luhmann’s modern systems theory, Chesbrough’s open innovation framework and the boundary spanning literature, and drawing on sixteen expert interviews from five German labs (1,396 codings), we have proposed the Lab Membrane Model (LMM), which reconceptualises the lab boundary as a selectively permeable communicative work-space realising three operative functions (filter, translator, amplifier) carried by an inner architecture of four condensations and a personal deep layer.

The model answers the three sub-questions. Heterogeneous expectations operate as the principal stabilising medium of lab communication; they are explicitly formed via structuring communication and translated into action-guiding practice via innovation drivers, but their disappointment is communicatively under-thematised. They are negotiated and coordinated through four communicative mechanisms – communicative proximity,

clarity, resonance and variation spaces – jointly carried by the three membrane functions and the personal deep layer. Systems-theoretically, the lab is an autopoietic social system formed through the recursive interplay of structuring communication, self-regulation, external feedback and personal mediation, whose reproduction depends on the simultaneous operation of all three membrane functions.

Six limitations frame the contribution. First, the empirical base of sixteen interviews supports the depth achieved here but not quantitative generalisation; the LMM should be read as an empirically grounded set of hypotheses for future quantitative work to test. Second, the sample focuses on open, transdisciplinary labs with users as co-actors, so corporate or strictly internal R&D labs may follow different communicative logics. Third, the findings rest on participants' self-accounts, where ethnographic observation would add an external observer position. Fourth, the theoretical triangulation deliberately combines systems theory, open innovation and boundary spanning, so alternative frames remain possible. Fifth, the actor perspectives are limited to science, citizens and business, leaving politics, administration and media unrepresented as stand-alone perspectives. Sixth, the LabPuls app is a conceptual proposal awaiting technical realisation and evaluation. A seventh, sample-related limitation should be added: interviewees were active and embedded in their labs at the time of fieldwork, so voices from people who left, never engaged or whose initiatives failed are not represented – a survivor bias best addressed by future contrastive studies.

Three avenues for future research follow. First, the LMM should be tested in other lab families (corporate and international labs) to assess whether the three membrane functions hold across configurations. Second, the LabKompass items should be psychometrically validated and combined with the LabPuls app for cross-lab benchmarking at scale. Third, the personal deep layer warrants in-depth ethnographic studies of how key boundary spanners are recruited, sustained and, too often, burn out. Beyond labs, the LMM offers a generic communication-theoretical model for the boundary work of intermediary organisations – transfer offices, citizen-science projects and open-innovation platforms – wherever heterogeneous expectations need to be made jointly actionable.

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