

Introduction to the Constructor Knowledge Labs (CKL)

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About CKL

Constructor Knowledge Labs (CKL) is a non-profit research institute focused on advancing applied and interdisciplinary research in computer science, artificial intelligence, and related fields, in close collaboration with Constructor University.

It conducts research projects, supports young scientists through involvement in research, and develops practical AI-driven solutions in partnership with academia and industry.

Research Areas



1. Knowledge Generation and Processing

Formal modeling and composition of scientific knowledge aligned with cognition for next-gen AI. Combining symbolic reasoning, statistical learning, and simulation enables scientific inference. Graph-based and semantic knowledge representation structures that enable cross-domain inference and support the formalization of knowledge within the unified Constructor Knowledge Model. Generative models assist in writing, hypothesis generation, and education. Digital twins mediate human–AI knowledge co-production, supporting its evolution and refinement. Adaptive control, machine perception, and learning systems enabling autonomy in dynamic environments.

2. Applied AI & Software Engineering

We deploy existing AI algorithms, Constructor knowledge models, and digital twins to solve practical problems using active agentic approaches across domains. Our methodology lowers technical barriers for scientists and educators through adaptive learning and advanced analytics, with AI-driven avatars and agentic interfaces central to education, personalized medicine, and the real-world application of scientific discoveries. We focus on applied tasks involving digital twins of different directions like personal or medical ones, and systems, integrating data processing methods into knowledge twin operations.

3. Computational Methods, Including Quantum

Supporting scientists is the primary objective, and computational methods serve as both a testbed and an example of large-scale scientific activity to better understand scientific needs and to adapt knowledge models and research platform features accordingly. Computational methods underpin key activities in fields such as computational biology, materials science, and quantum physics, enabling advanced simulation, optimization, and data analysis for complex research problems. Efficient frameworks and representation models are essential for knowledge management, with graph-based and semantic models, such as the Constructor Knowledge Model, providing structured knowledge organization and cross-domain inference. Integrating diverse computational approaches, including those from quantum computing, allows refinement of core algorithms and knowledge models, ensuring they address real scientific challenges. Optimizing the use of local and distributed computational resources is necessary for supporting the training and deployment of tailored AI models within scientific workflows.

4. Metapresence & Virtual, Augmented Reality

Metapresence technologies enable seamless collaboration among scientists, educators, students, and autonomous agents. AI-driven avatars foster novel communication paradigms that accelerate research, knowledge creation, and education. The research targets the design of virtual communication environments across complexity scales. These environments employ formal communication-protocol models adapted to human–human, human–AI, and AI–AI autonomous interaction, supporting modes from text dialogs to immersive collective spaces. A unified layer represents humans via autonomous digital knowledge twins and incorporates non-human AI avatars. Customizable sensory and sensor integrations refine user experience. Core algorithms ensure efficient acquisition, storage, and processing of heterogeneous data.

5. Neuroscience & Neuro Psychology

Investigations into the neural foundations of learning and memory guide refined AI-driven tools and interventions. Implementation of assistive technologies with real-time neural feedback and insights for cognitive enhancement in education. Neuro-inspired computing draws on biological processes to create efficient AI algorithms and hardware. Understanding, modeling and controlling of brain disabilities related to educational and cognitions processes. Algorithmic optimization focuses on effectively leveraging insights into how humans create, store, and apply knowledge to achieve complex creative, scientific, cognitive and learning goals.

6. Learning Science & Cognitive Psychology

This research direction explores how to design and support collective human behavior in professional contexts such as science, research, and education. It examines the cognitive and social mechanisms behind effective collaboration, shared knowledge building, and collective problem-solving. Key learning activities and practices include inquiry-based learning, collaborative argumentation, reflective discussion, formative assessment, and knowledge mapping. Learning science also investigates how digital tools, instructional designs, and scaffolding strategies influence learners' engagement, conceptual change, and metacognitive development within these collaborative environments, informing evidence-based interventions that support both individual understanding and collective intelligence.

7. Robotics & Autonomous Machines

Human–robot collaboration increases laboratory productivity, as well as robotic systems contributing to scientific experimentation, automation in educational labs, and remote access to research equipment. STEM-oriented educational robotics for hands-on learning in hybrid or distributed settings. Adaptation of dynamic external environment control approaches inside knowledge model and adaptive learning environment. Supports knowledge production through physical experimentation and learning-by-doing paradigms.

8. Organization & Decision, Operations Research

Developing alternative approaches for maintaining and managing of research projects, as well as scientific and research organizations, including governance structures. Efficiency is addressed through direct knowledge of personal and team communication patterns, informed by analysis of digital twins. Methods emphasize adaptability to the current state of projects, research activities, organizational structures, and operational processes. Empirical studies assess AI's impact on research, teams, and methods.

Team of World-Leading Scientists and Innovators



Prof. Dr. Alexander Tormasov
Chief Research Officer,
Professor of Computer Science;
250+ Patents Worldwide



Prof. Dr. Andrey Ustyuzhanin
Chief Science Officer, Professor
of Computer Science (Software,
Data and Technology)



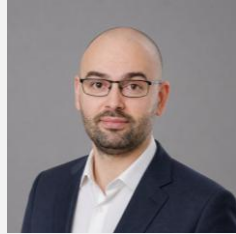
Prof. Dr. Isak Frumin
Head of Observatory of Higher
Education Innovations School
of Business



Prof. Dr. Giancarlo Succi
Dean of CS in Constructor
University, Professor in University
of Bologna, CS & Engineering



Ilya Shimchik
Team Principal at Constructor
Racing, Constructor Labs



Prof. Dr. Petr Popov
Associate Professor of Applied
Mathematics and Computational
Biology, School of Science



Sari Sadiya, PhD
Principal Investigator,
Constructor Labs



Our Industrial Projects

Semantic Flow AI

I. Problem:

- Reasoning in text, code, and diagrams is not represented explicitly.
- Existing systems lack traceable, auditable rationales.
- Domain-specific reasoning patterns are not reusable or transferable.
- Validation and explainability remain external and manual.

III. Impact:

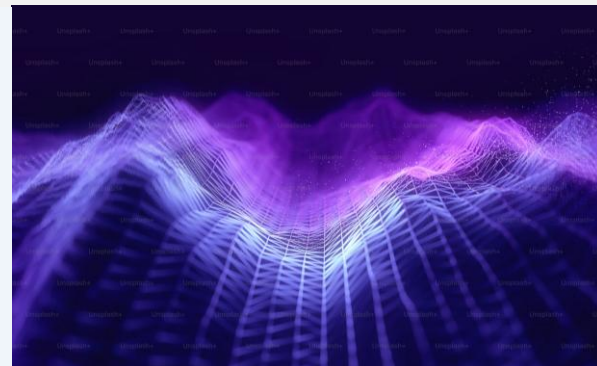
- **Researchers & educators:** Faster creation of knowledge materials; verifiable reasoning.
- **Organizations:** Improved training pipelines; reduced review and QA costs.
- **AI ecosystem:** New benchmarks for explainability, rationality scoring, and human–AI co-reasoning.

II. Solution:

- **3-year research initiative to build a Semantic Flow Engine.**
- Learns, represents, and transfers domain-specific reasoning patterns.
- Produces auditable, explainable outputs across text, code, and diagrams.

Core innovations:

- **Semantic Flow Modeling:** Machine-actionable graphs of concepts, reasoning steps, and rationales.
- **Rationale-centric generation:** Traceable logic with built-in self-tests for validation.
- **Cross-domain flow transfer:** Reuse of reasoning patterns across related problem spaces.



IV. Industrial Directions

- Knowledge-intensive systems requiring auditable and explainable reasoning.
- Education, training, and expert-support platforms.
- AI systems operating across text, code, and diagrammatic reasoning with validation and auditing requirements.

Knowledge Discovery

I. Problem:

Scientific knowledge is largely unstructured and static, while existing LLM- and RAG-based approaches do not represent how concepts and expertise evolve over time. This limits systematic analysis, reproducibility, and the identification of knowledge gaps across domains.

III. Impact:

Expected impact across stakeholders:

- **Researchers:** Faster literature review, discovery of knowledge gaps, and reproducible cross-domain insights.
- **Institutions:** Competence-aware collaboration mapping and support for strategic hiring decisions.
- **AI systems:** Benchmarks and foundations for question answering, hypothesis generation, and forecasting grounded in temporal knowledge representations.

II. Solution:

Knowledge Discovery is a 3-year research initiative led by PI Andrey Ustyuzhanin, focused on building temporal, semantically grounded cognitive maps of scientific knowledge and researcher competences.

The project introduces **Temporal Knowledge Hypergraphs (TKH)** and **Temporal Competence Hypergraphs (TCH)** to model the evolution of concepts, methods, and expertise across time, domains, and research communities.

Core innovations include:

- **Semantic structuring:** Transformation of unstructured data (papers, code, dialogue) into machine-actionable, interpretable graphs.
- **Time-aware representations:** Explicit modeling of how concepts, methods, and hypotheses evolve over time.
- **Competence mapping:** Linking scientific outputs (TKH) to researcher profiles (TCH) to support automated expertise search and team formation.
- **Task-aware reasoning:** Explainable, traceable, user-specific reasoning beyond black-box LLM behavior.



IV. Industrial Directions

The solution applies to research-intensive organizations and institutions that manage large volumes of evolving scientific knowledge and expertise. It supports applications such as research analytics, expertise discovery, team formation, and AI-assisted scientific reasoning in domains where explainability, temporal context, and reproducibility are critical.

Using Wearables for “Construct” for Bi-directional Collaboration

I. Problem:

- User signal extraction existed only in Proctor — used for monitoring, not for learning personalization or Construct enrichment
- Available devices (wearables) not integrated into Construct alongside existing product data;
- Challenges with deployment across jurisdictions, data availability and privacy constraints.

Goal:

- use available devices to enrich Construct for two purposes: (1) scientific recommendations to improve software quality; (2) increase user attachment and retention.

III. Impact:

- Context-aware personalization;
- Bi-directional feedback loop: sensing user state and sending signals back to via their devices.
- Validated multi-source data fusion under privacy and robustness constraints;
- Scalability up to 300m users

II. Solution:

- Enrichment of product capabilities (Learn, Assess, Schedule, Groups) by integrating wearable data into the construct;
- Personalisation: selection of highest-value signals for user context modelling, adapted to the individual and to their available devices;
- Verified fusion and policy algorithms for context-aware event generation and additional feedback opportunities;
- Support for explainability, privacy, autonomy, robustness, and edge–cloud optimization.

The project includes 2 research streams:

- **Stream 1:** Personalization from existing C>T product data fusion.
- **Stream 2:** Personalization from wearables + product data fusion (focus/energy, circadian, stress, readiness).



IV. Industrial Directions:

- Digital collaboration platforms.
- Learning, assessment, scheduling, and group coordination systems.
- Productivity environments leveraging wearable-based personalization;
- Research platform

Emerging Demands and Innovative Practices in Use of AI in Higher Education and Science

I. Problem:

EdTech companies face challenges in anticipating industry trends amid rapidly evolving AI technologies and educational practices.

Traditional market research fails to capture demand-side signals, such as emerging practices and weak signals from innovators, hindering effective product development.

III. Impact:

- **Researchers:** Access to global evidence on AI adoption, early practices, and emerging models.
- **Institutions:** Strategic insights for digital transformation and platform redesign.
- **CT Products:** Data-driven recommendations for product positioning, new opportunities, and infrastructure trends.
- **Global Reputation:** Strengthening CU's international research profile and networks.

II. Solution:

- **Cross-Country Monitoring:** Systematic tracking of AI adoption in universities and research institutions through an expert network.
- **Infrastructure Evolution Mapping:** Analysis of how education and research platforms are integrating AI and undergoing digital transformation.
- **Innovators & Trends Identification:** Detect early adopters – universities, labs, communities – shaping AI-enabled practices.
- **Scalable Text Analytics:** Use of automated transparent NLP and multilingual scraping to create structured corpora.



IV. Industrial Directions

Results target the EdTech sector, with direct application in higher education and scientific research institutions globally, including universities and research groups adopting AI tools.

Code

I. Problem:

The integration of open-source components in complex software systems remains largely manual and difficult to scale. Teams face persistent challenges in discovering compatible components, aligning interfaces and protocols, and validating integrations across heterogeneous environments. These constraints slow down deployment, limit reproducibility, and increase the risk of failure in production and regulated settings.

III. Impact:

Expected impact across stakeholders:

- Developers & IT teams: Reduced manual integration effort and faster, more reliable deployments.
- Startups & SMEs: Ability to scale software systems without requiring deep in-house integration expertise.
- Enterprises: Improved maintainability, compliance, and operational reliability, particularly in regulated environments such as the EU.

II. Solution:

A 3-year research and development initiative by Constructor Knowledge Labs, led by Prof. Dr. Giancarlo Succi and Prof. Dr. Alexander Tormasov, designed to automate the integration of open-source components in complex software ecosystems.

At its core is AFSI (Autonomous Framework for Software Integration) – an AI-powered framework that applies LLM-driven agents to automate critical integration tasks.

Key capabilities include:

AI-driven automation: Intelligent agents for component discovery, interface matching, protocol translation, and validation.

End-to-end workflow: A continuous pipeline from scientific papers → code generation → execution → reproducibility reports → cross-study meta-analysis.

Scalable deployment: Auto-generated scripts and APIs enabling seamless integration into real-world systems and production environments.



IV. Industrial Directions

The solution is applied in software-intensive organizations that build and operate systems composed of multiple open-source components, such as enterprise platforms, data-driven applications, and research software infrastructures. It is particularly relevant for teams managing frequent integration changes, cross-project reuse, and reproducibility requirements, including regulated and compliance-driven environments.

AI-agents for Life Science Industry

I. Problem:

- Wet-lab protein engineering and characterization, generates large volumes of complex biophysical assay data that are difficult to interpret rapidly and consistently.
- Researchers spend significant time on repetitive analysis, experimental planning, and integration of heterogeneous datasets.
- Current workflows lack a continuous feedback loop between:
 - experimental instruments,
 - computational bioinformatics models,
 - and scientific decision-making.

III. Impact:

- Accelerates life science research cycles.
- Reduces manual data interpretation workload for scientists.
- Enables continuous human-AI collaboration in wet-lab environments.
- Improves experiment prioritization through autonomous in silico experiments.
- Increases reproducibility, transparency, and scalability of research workflows.

II. Solution:

An autonomous AI-assisted research framework that combines:

- LLM-based AI Agents for reasoning, orchestration, and transparent decision support.
- MCP-enabled modular tools for standardized interaction with instruments, datasets, and models.
- Virtual Experiment Engine with Advanced Bioinformatics models for in silico simulations and predictions.



IV. Industrial Directions

Near-Term Applications

- Protein thermostabilization
- Enzyme engineering
- Antibody design
- High-throughput ligand screening

AI-Scientist (MIND-MATTER for ARIA)

I. Problem:

- Reconfigurable Nonlinear Processing Units (RNPUs) self-learn in matter, but their transport mechanism is unknown.
- Competing transport theories (e.g., VRH, SCLC) cannot be discriminated by existing methods.
- Manual experimentation cannot cover the full parameter space due to slow pace, and no AI autonomously runs the end-to-end scientific loop.

III. Impact:

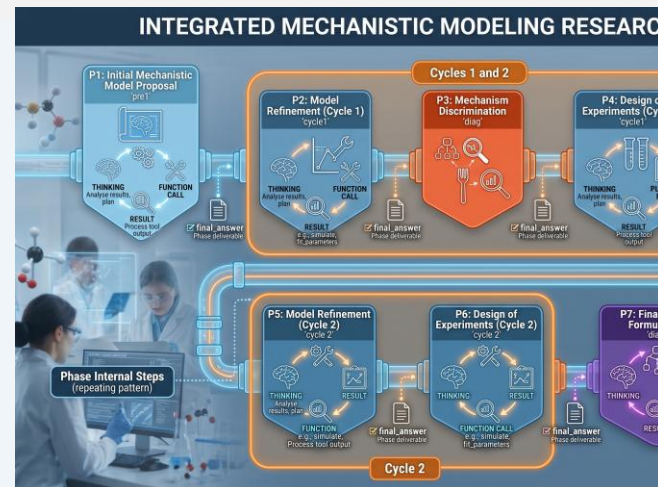
- **ARIA & funders:** Proof that AI can autonomously advance materials research — a model for self-driving labs.
- **CKL:** Leadership in knowledge-aware AI; 3 US patents, 2 Q1 publications, reusable MCP architecture.
- **The Field:** Design principles for scalable, low-energy neuromorphic computing — AI **discovering theory**, not just optimizing.

II. Solution:

- **A 9-month, CKL × U Twente (BRAINS Lab) initiative funded by ARIA's AI-Scientist Programme.**
- Closes the AI discovery loop: hypothesis → experiment → inference, with human-in-the-loop gates.
- Built on Model Context Protocol (MCP) servers, each scientific capability packaged as an AI-accessible tool.

Core innovations:

- **MCP-based scientific toolchain:** Simulation, DoE, inference, and literature tools — composable for any LLM agent.
- **Bayesian optimal design:** Selects experiments that maximize information gain between rival theories.
- **Auditable orchestration:** Full audit log of AI vs human decisions across the loop.



IV. Industrial Directions

- Neuromorphic hardware and low-energy AI computing.
- Materials science R&D and semiconductor industries.
- Self-driving lab platforms for autonomous scientific discovery.

Let's Connect

Scan the codes to follow our work and stay in touch.



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constructorlabs.org



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LinkedIn



Website