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EDITORIAL ANALYSIS

The Mpemba Effect and India's Research Institutions — From Observation to Simulation

THE HINDU

8 January 2026

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SCIENCE & TECH

GS PAPERS

GS3

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The Hindu 8 January 2026 GS3

TH The Hindu | MAINS RELEVANCE: GS Paper 3

INTERVIEW ANGLE

"What does India's research institution ecosystem look like? What does the JNCASR Mpemba Effect breakthrough reveal about the quality of India's basic science funding?"

WHY IN NEWS

Researchers from JNCASR, Bengaluru, created the first computational simulation of the Mpemba Effect — demonstrating how hot water can freeze faster than cold water — a 57-year-old puzzle in physics that began with a Tanzanian schoolboy's observation about ice cream.

THE VALUE OF ANOMALOUS SCIENCE

The history of science is littered with phenomena that "shouldn't work" according to prevailing theory — and then upend entire fields when taken seriously. The photoelectric effect (which launched quantum mechanics), the discovery of non-Newtonian fluids, the anomalous precession of Mercury's orbit — all were observations that seemed wrong, were initially dismissed, and eventually forced theoretical revisions.

The Mpemba Effect belongs in this tradition. That a Tanzanian high school student's ice cream observation in 1969 led, 57 years later, to the first rigorous computational simulation by Indian researchers at JNCASR is a story worth understanding on multiple levels.

WHAT THE JNCASR SIMULATION ACTUALLY DEMONSTRATES

The simulation does **not** prove that hot water always freezes faster than cold water. What it demonstrates is more subtle and more scientifically interesting: it identifies the **specific thermodynamic conditions** under which an anomalous acceleration toward freezing occurs in hotter systems.

The key mechanism involves **entropy** — the measure of disorder in a system. Under normal conditions, a hotter body loses heat gradually and its entropy drops slowly. Under specific conditions involving the geometry and composition of the system, a hotter body can lose entropy *faster* than a cooler one — effectively reaching the ordered low-energy state of ice sooner.

This is a contribution to **non-equilibrium thermodynamics** — the study of systems that are far from thermal equilibrium. This is a frontier area of physics relevant not just to freezing water, but to:

How living cells maintain order against entropy

How quantum systems lose coherence

How energy-efficient processes can be designed in industrial and chemical contexts

The fact that Indian researchers produced this breakthrough is not coincidental. India's basic science institutes — JNCASR, IISc, TIFR, IMSc, HRI — have been quietly producing world-class research for decades in areas that don't generate the visibility of space launches or vaccine campaigns.

THE BASIC SCIENCE FUNDING PROBLEM

Despite this quality of output, Indian basic science faces a structural funding crisis. Research and Development expenditure in India stands at approximately **0.64–0.65% of GDP** — compared to 2.2% in China, 3.5% in Japan, 4.8% in Israel, and 2.8% in Germany. India's stated target of reaching 2% of GDP in R&D spending has been a recurring goal in successive Science and Technology Policy documents but has never been achieved.

The consequences are visible:

Brain drain: India produces world-class PhD graduates, but many of the best go to the US, UK, or Europe for postdoctoral positions and stay permanently, because funding availability and institutional infrastructure abroad is vastly superior.

Underfunded labs: Even premier institutions like JNCASR operate with equipment budgets that are a fraction of what leading global institutions spend.

Short-term bias: Government-funded research is increasingly evaluated on near-term "impact" metrics — patents, commercialisation — rather than on the quality and originality of fundamental inquiry. This creates pressure to pursue applied research over basic science.

JNCASR AS A MODEL — AND ITS LIMITS

JNCASR has produced remarkable science despite these constraints. Its model — a small, focused, autonomous institution with flexibility in hiring and research selection — partly explains its output relative to size. India has several such institutions: TIFR (Tata Institute of Fundamental Research), IMSc Chennai

(Institute of Mathematical Sciences), HRI Allahabad (Harish-Chandra Research Institute), IISc Bengaluru.

What these institutions share is **autonomy from bureaucratic constraints** and **concentration of interdisciplinary talent**. What they lack is **scale and funding**.

The Mpemba breakthrough should prompt a policy question: if India's basic science institutions can produce a simulation that solves a 57-year international puzzle with current funding, what could they do with 3× the resources?

THE CITIZEN SCIENCE LESSON

Erasto Mpemba was not a scientist. He was a student who made ice cream and noticed something strange. His observation was taken seriously — first by a curious teacher, then by a university physicist who published it. The science that eventually emerged began with a citizen observer whose anomalous finding was not dismissed.

India's science ecosystem could benefit from this model — encouraging curiosity-driven observation from non-expert sources, creating low-barrier mechanisms for students and practitioners to report anomalies, and building institutions that take unexpected findings seriously rather than filtering input through credentialist gatekeeping.

UPSC RELEVANCE

Prelims: JNCASR; DST; Mpemba Effect; entropy; non-equilibrium thermodynamics; India R&D spending (~0.64% GDP); TIFR; IISc; IMSc; HRI.

Mains GS-3: India's basic science research ecosystem — institutional strengths and funding gaps; science policy; R&D spending targets; brain drain; role of autonomous research institutions; importance of curiosity-driven basic research vs applied research focus.

📌 FACTS CORNER — KNOWLEDGEPEDIA

INDIA'S R&D SPENDING:

India's R&D as % of GDP: ~0.64–0.65% (one of the lowest among major economies)

Target: 2% of GDP (aspirational, repeatedly stated, not achieved)

China: ~2.2%; USA: ~3.4%; Japan: ~3.5%; Israel: ~4.8%; Germany: ~2.8%

GERD: Gross Expenditure on Research and Development — standard metric

KEY INDIAN BASIC SCIENCE INSTITUTIONS:

JNCASR: Bengaluru; DST; interdisciplinary; Mpemba simulation (2026)

TIFR: Mumbai; Department of Atomic Energy; mathematics, physics, biology

IISc: Bengaluru; deemed university; engineering and science research

IMSc: Chennai (Institute of Mathematical Sciences); mathematics, physics, biology

HRI: Allahabad (Harish-Chandra Research Institute); mathematics, theoretical physics

IUCAA: Pune; Inter-University Centre for Astronomy and Astrophysics; under UGC

SCIENCE AND TECHNOLOGY POLICY:

Science, Technology and Innovation Policy 2020 (STIP 2020) — India's current S&T framework

National Science Foundation equivalent in India: SERB (Science and Engineering Research Board) under DST

Anusandhan National Research Foundation (ANRF) — proposed to replace SERB; modelled on US NSF

MPEMBA EFFECT FACTS:

Observer: Erasto Mpemba; year: 1969; context: ice cream making in Tanzania

Published with: Dr Denis Osborne (physicist)

JNCASR breakthrough: first computational simulation; thermodynamic entropy mechanism

Application areas: industrial cooling, quantum systems, non-equilibrium thermodynamics

Sources: The Hindu, JNCASR, DST

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