



FROM SCHOOL PROGRAM TO SCIENCE LESSON: DEVELOPING THE CULTURAL COMPETENCE OF BIOLOGY, CHEMISTRY AND PHYSICS TEACHERS IN A MULTILINGUAL SCHOOL

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ABSTRACT

In multi-ethnic, multilingual classrooms, science teachers must move students between the subculture of canonical science and the cultural repertoires they bring to the laboratory bench, and Target 4.7 of the Sustainable Development Goals makes that movement an explicit obligation of science education. How a school builds this capacity in its own biology, chemistry, and physics teachers is scarcely documented outside Anglophone and Southeast Asian settings. This study asks how a multi-ethnic secondary school converts a national infrastructure program into a working routine for developing its science teachers' cultural competence, and how far that routine reaches the science lesson itself. A single-case insider action research design was used in a state secondary school in Astana, Kazakhstan, with municipal experimental-site status. The authors analyzed seven categories of documentary evidence through qualitative content analysis with two independent coders. The routine runs through three stacked layers rather than by individual initiative: a regulatory layer that authorizes the work, an operational layer that distributes it across a nine-month thematic cycle, and a reflexive layer that converts it into evidence. Its instructional output is a subject-specific didactics cleared by the city Expert Council, in which four chemistry cases invert the concept-culture relation - equilibrium, catalysis, and collision theory become instruments for reading cultural situations - while the biology and geography examples follow the Ethnoscience direction. The evidence equally shows the limits: no record of any case reaching a lesson, nineteen of sixty-six student events carrying natural-science content, and monitoring instruments that measure school climate rather than science teaching. Schools pursuing SDG 4.7 through a whole-school route should install a lesson-facing instrument from the outset.

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INTRODUCTION

Science classrooms are demanding spaces for meeting the commitments education systems have made to cultural diversity. The teacher must move students between the subculture of canonical science and the everyday cultures they bring

to the laboratory bench, a movement Aikenhead (1996, 2001) called border crossing; where the classroom is multi-ethnic and multilingual, that movement is a continuous negotiation among several co-present cultural repertoires (Lee & Buxton, 2010; Charamba, 2020, 2023; Wong & Tian, 2025). Target 4.7 of the Sustainable Development Goals raises the stakes, requiring all learners to acquire the knowledge and skills needed

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to promote, among other things, an appreciation of cultural diversity and culture's contribution to sustainable development (Sterling, 2016; Pashby & Sund, 2020; Rose & Sayed, 2024) how teacher education systems answer that commitment varies widely, across national syllabi, science curricula and single programmes alike (Chisingui & Costa, 2020; Fiel'ardh et al., 2023; Hakim et al., 2025; Vidal & Kuckuck, 2025).

The professional capacity to conduct that negotiation is commonly labeled cultural competence (Cross et al., 1989; Atwater, 1993, 2010; Deardorff, 2006). Two decades of research in multicultural science education have established what it consists of and how teacher education might cultivate it (Atwater et al., 2014; Brown, 2017; Warren, 2017; Underwood & Mensah, 2018; Mensah & Chen, 2022), with comparable arguments for teacher development against the SDGs more broadly (Amin & Greenwood, 2018). Rather less is known about the school as the unit of provision. A growing whole-school literature argues that cross-cutting professional capacities are more durable when carried by an institutional program, a participation infrastructure and a monitoring routine than when left to individual initiative (Miled, 2019; Brown & Flood, 2020; Nguyen et al., 2021; Gericke & Torbjörnsson, 2022; Seiser et al., 2022). What such an arrangement delivers in practice is documented mainly for Anglophone and Nordic systems.

This article addresses that gap from a Central Asian, post-Soviet setting. Kazakhstan is a strategic site: its schools operate under a Kazakh-Russian bilingual reality overlaid by a trilingual policy introducing English into science instruction (Karabassova, 2020; Mehisto & Winter, 2022; Goodman et al., 2023), its urban schools enrol genuinely multi-ethnic cohorts, and the state is commissioning more than two hundred new schools under the national «Comfortable School» (Jaily Mektep) programme (Ministry of Education of the Republic of Kazakhstan, 2025) - an unusual opportunity to observe a national infrastructure programme becoming school-level professional routine. Evidence from the region remains scarce (Rollan & Somerton, 2019; Amirova et al., 2020; Frost & Kambatyrova, 2020; Silova, 2020; Sar-murzin et al., 2024).

The case examined here is a state secondary school in Astana holding municipal experimental-site status, selected purposively against four criteria rather than for convenience: a formally approved multi-year experimental program whose declared object is cultural competence, which makes the governance layer visible in do-

cuments rather than inferred; commissioning under the national program, so that its arrangements are comparable with the schools now opening; a multi-ethnic, bilingual cohort with a natural-science teaching cluster large enough to treat as a unit; and documentation complete enough for triangulation across seven independent record types. Among the schools holding experimental-site status in the city, it was the only one meeting all four at the time of the study.

A terminological clarification is required before proceeding. Post-Soviet scholarship works with «culturological competence» (Benin et al., 2013), a construct rooted in the philosophy of culture and oriented towards the teacher's general cultural erudition; Anglophone cultural competence developed out of service delivery to minority populations (Cross et al., 1989) and carries an explicit equity commitment (Sleeter, 2017; Brown & Boda, 2018; Miller et al., 2024). The two are not interchangeable: the school's documents use the culturological framing, the analysis reads it against the Anglophone construct, and the divergence is substantive rather than a translation choice.

The research problem follows from that gap: how a multi-ethnic secondary school converts a national infrastructure program into a working routine for developing the cultural competence of its biology, chemistry and physics teachers, and how far that routine reaches the science lesson itself.

The study's objectives follow from the problem. The first is to establish how the school's governance documents operationalize the cultural competence required of science teachers: how the work is authorized, who is assigned it, and at what cost. The second is to identify what the arrangement specifies for the science lesson, the didactic design it produces for chemistry, biology, physics, and geography, and what its instructional and monitoring routines measure about science teaching. The third is to position this case's pathway against the Ethnoscience pathway of Indonesian science education, and to state what a whole-school route must add to evidence change in science instruction.

Three research questions correspond to these objectives. RQ1: How is the cultural competence required of biology, chemistry, and physics teachers operationalized at the level of school governance? RQ2: What does the arrangement specify for the science lesson, and what do its instructional and monitoring routines actually measure about science teaching? RQ3: What does the case imply for science education elsewhere pursuing

SDG 4.7 through a whole-school route, and how does it compare with the Ethnoscience pathway developed in Indonesian science education?

A clarification of purpose is required, because three different studies could be built on this material: an examination of how a school governs the development of its science teachers' cultural competence, a measurement of that competence, or an evaluation of the program's effectiveness. This study is of the first kind. It does not measure teacher cultural competence, since no instrument in the corpus is designed to do so, as the analysis of the monitoring layer demonstrates; nor does it evaluate program effectiveness, which would require a comparison condition and lesson-level outcome measures the case does not provide. Where the corpus contains figures belonging to the second or third kind of study, they are reported as claims made by the school and excluded from every inference drawn here.

The comparison invoked in RQ3 is developed in full in the discussion. The Ethnoscience tradition published in this journal reconstructs scientific content within a single regional cultural frame - traditional food preparation, indigenous medicine, local craft, customary ecological practice (Parmin et al., 2017; Suastra & Jatmiko, 2017; Suprpto et al., 2021; Sumarni et al., 2021; Irfandi et al., 2023; Ardianti et al., 2023; Uslan et al., 2024; Nur Hikmah et al., 2025) - and has recently been extended towards the Sustainable Development Goals (Pada et al., 2025; Rosyidah et al., 2025; Erwinsyah et al., 2025; Nurkanti et al., 2026). The Kazakhstani case starts from a different problem: not how to bring one culture into science, but how to manage several at once.

The article thus contributes to science education on three counts. It documents multicultural science teacher development in a system under-represented in international research; it shows what a school's institutional artifacts specify for the science lesson, and which of those artifacts carry evidential weight about teaching; and it identifies what a whole-school approach to SDG 4.7 must add if it is to evidence change in science instruction rather than in school activity.

METHODS

The study uses a single-case design (Yin, 2018) within the insider action research tradition (Coghlan, 2019; Darwin & Barahona, 2018). Yin supplies the case logic: a contemporary phenomenon in its real-life setting, theoretical rather than statistical generalization, and triangulation across evidence types as the principal validity

strategy. Coghlan supplies the positional logic, since the research team is not external to the setting: the first author is the school's principal and a doctoral candidate at L. N. Gumilyov Eurasian National University, and the co-authors belong to the same university's doctoral school in pedagogy.

The unit of analysis is the school's governance arrangement for cultural competence: the set of institutional artifacts and routines through which the work is authorized, distributed, and documented. Teachers, student cohorts, events, and documents enter the analysis as they are represented within that arrangement rather than as units in their own right. The nine natural-science teachers are accordingly the population the arrangement addresses, not a sample of respondents; no data were elicited from them for this study.

Coghlan's insider action research cycle (constructing - planning action - taking action - evaluating action) was modified in two respects for the present study, and the modifications are reported here explicitly rather than assumed.

First, the authors decoupled the cycle from the intervention. In the canonical cycle, the researcher plans and takes the action under study. Here, the action - the school's experimental program was designed and enacted through the school's ordinary governance. At the same time, the research function was restricted to constructing and evaluating, because the alternative, a principal researching an intervention she simultaneously designs, compounds the insider bias the design is meant to control.

Second, an artifact-first analytical entry point replaced the participant-first entry typical of action research. Analysis began from the institutional artifacts the school produces in the ordinary course of its work - program document, annual plan, self-assessment sheet, participation registers, monitoring protocols - treating them as the primary evidence of what the school does, with participant accounts read against them rather than in their place. Artifacts are produced for administrative purposes independent of the research and are therefore less exposed to the reactivity that affects accounts elicited by an insider researcher from her own staff.

Selection of Sources and Cases. Stating the criteria for selecting the school does not account for the other selections the study makes, and the distinction that runs through them is between what was selected and what was taken whole. The school was purposively selected against the four criteria stated in the introduction and was the only experimental site in the city meeting all

four. The nine science teachers were not sampled: they are the school's entire natural-science cluster in 2024-2025, and the analysis treats the cluster as a unit. The authors also did not sample documentary sources; the seven categories in Table 1 are the complete set of record types the school produced for the program that year, each analyzed in full, and the authors classified all 3 teacher and 66 student events registered for the year rather than a selection. The student cohorts and the psychological instruments were selected neither by us nor for this study: the school's psychological service administers a fixed pack within its routine adaptation program, which is why the grades differ between instruments - Grade 5 for school motivation, Grades 5-11 for anxiety, Grade 10 for classroom climate, Grades 8-11 for the open questionnaire. They are therefore administrative data the study reads rather than research samples it drew, and this is a limitation rather than a design choice: no instrument in the pack is science-specific or was selected for its fit to the research question. The reflexive layer analysis and the limitations section state the consequences.

The case school is a state secondary school of the Astana City Akimat, commissioned under the national «Comfortable School» program. It holds municipal experimental-site status for 2025-2028 under an approved program entitled «The development of cultural competence among teachers, students and their parents as a condition for improving the quality of the educational process in a Comfortable School», comprising three sub-projects.

The evidence analyzed here comes from the 2024-2025 academic year, which precedes the formal award of experimental-site status. This

is deliberate and central to the interpretation: 2024-2025 was the preparatory year in which the school assembled and trialed the practices subsequently codified in the approved program. The case documents the formation of a governance arrangement rather than its mature operation, and all claims are bounded accordingly.

In 2024-2025 the school enrolled 1,383 students across grades 1-11. Two staffing figures appear in the corpus and are reported as they stand: the program self-assessment records 96 teachers as involved in the experimental program, while the staffing register lists 64 by subject; proportions here are calculated against the register, the only source identifying teachers by subject. Instruction is delivered in Kazakh and Russian, with English entering as an additional language of science instruction in selected upper-secondary classes under national trilingual policy (Karabassova, 2020; Mehisto & Winter, 2022). The natural-science cluster - the focal group - comprises nine teachers: three of biology, two of chemistry, two of physics, and two of geography, or 14% of the register; the school teaches no separate integrated-science subject, and widening the group to mathematics and informatics adds seven. Within the nine, five teach in Kazakh and four in Russian, so the bilingual condition examined reflects the cluster's composition, not only its classrooms. Two school psychologists coordinate diagnostic monitoring, and the student body draws on Kazakh, Russian, Uzbek, Uyghur, Korean and Tatar families.

Seven categories of evidence were assembled, all produced by the school in the ordinary course of its work (Table 1).

Table 1. Evidence base: Sources, Coverage and Analytical Use

No	Source	Coverage	Analytical use
1	Approved experimental program	2025 - 2028, with preparatory year 2024 - 2025	RQ1: regulatory layer, declared object, allocation of work
2	Annual thematic plan	Nine-month cycle, 2024 - 2025	RQ1, RQ2: operational layer; science content of each month
3	Implementation records	2024 - 2025	RQ2: what was actually delivered against plan
4	Self-assessment sheet, twelve indicators with SWOT component	2024 - 2025	RQ1, RQ2: reflexive layer; the cluster's own diagnosis
5	Participation registers, teachers and students	2024 - 2025; 3 teacher events, 66 student events	RQ2: participation infrastructure; what it records

6	Psycho-diagnostic monitoring	2024 - 2025; four standardized instruments plus one open questionnaire	RQ2: what the monitoring routine measures
7	Methodological guidelines on managing teachers' cultural competence, cleared by the city Expert Council	37 pp., December 2025; four-facet CQ training design and subject-specific cases	RQ2, RQ3: the instructional layer; what the arrangement specifies for the lesson

The psycho-diagnostic pack comprises an oral questionnaire administered to all first-graders; the Luskanova school motivation test ($n = 145$, grade 5); the Phillips school anxiety test ($n = 78$, grades 5-11); the Lutoshkin classroom climate scale (grade 10); and an anonymous open-format questionnaire ($n = 190$, grades 8-11). All four are instruments routinely used in Kazakhstani school psychological services and were administered by the school's two psychologists within the standard adaptation program for entry cohorts.

We analyzed documentary sources 1, 2, 4, and 7 through qualitative content analysis using Mayring's (2014) deductive category application. We derived an a priori coding frame from two sources: Atwater's (2010; Atwater et al., 2014) multicultural science education dimensions and Aikenhead's (1996) border-crossing categories. Two coders (the first and second authors) applied the frame independently. Inter-coder agreement on a 30% random sample of coded segments reached Cohen's $\kappa = 0.78$, acceptable for exploratory categorical coding; discrepancies were resolved in discussion and the reconciled coding used for analysis.

Sources 3 and 5 were analyzed quantitatively but descriptively. Each registered event was classified along three dimensions: organizational level (school, district, city, republican, international) as stated by the organizing body; presence of natural-science content, coded as present only where the event addressed biology, chemistry, physics, geography, ecology, robotics, or student research projects in those fields; and documented outcome. Both coders applied the science-content classification to the full register and resolved disagreements by reference to the event's own documentation. The authors report this classification in full because it produces one of the study's principal negative findings.

Source 6 was received as service-aggregated descriptive percentages; no re-analysis of raw responses was performed, and none is claimed. Source 7 was analyzed at the level of design: its cases were tabulated by scientific concept, cultural

situation, and student task, and the direction of the concept-culture relation was coded for each. The document reports its own diagnostic percentages, which the school presents as a claim and we report as such rather than using them as evidence, for the reasons given in the results.

Insider action research in one's own organization carries three well-documented risks: role duality, preunderstanding that obscures the taken-for-granted, and organizational politics (Darwin & Barahona, 2018; Coghlan, 2019). Four measures were taken. The intervention was decoupled from the research function. The school's psychological service collected and aggregated all psycho-diagnostic data, and its staff were not informed of the study's analytical categories. Two coders performed documentary coding independently, one of whom is external to the school. We verified factual records of competition participation and outcomes against documentation held by the city Methodological Center.

RESULTS AND DISCUSSION

The analysis is organized around the three governance layers that emerged from the coding - regulatory, operational, and reflexive - followed by the conceptual comparison with the Ethnoscience pathway and the implications that follow.

The Regulatory Layer: Authorization as a Precondition

Coding the experimental program against the multicultural science education frame identified three features that directly relate to science teacher development.

The program is anchored in a published national policy frame, the Concept of Educational Development of the Republic of Kazakhstan for 2023-2029, and is authorized by the city Methodological Center. That authorization turns a principal's preference into an instruction: it gives leadership the standing to ask science teachers to do work beyond their contracted teaching load and outside their subject preparation.

The multicultural science education literature argues consistently that institutional authorisation is a precondition of durable change rather than an administrative formality (Atwater et al., 2014; Sleeter, 2017; Brown & Boda, 2018; Miled, 2019), and the same dependency is reported for whole-school sustainability work (Gericke & Torbjörnsson, 2022; Seiser et al., 2022) and, from the leadership side, in this journal's own work on science teacher competency (Utaminingsih et al., 2024; Ardianto et al., 2026). The case adds a specification: in a centrally administered system, authorization must come from outside the school. The municipal experimental-site status, not the school's own declaration, made the work legible to teachers as a legitimate demand.

The program's declared object is triadic - teachers, students, and parents. In Banks's (2016) terms, this moves the work past the contributions level, where cultural diversity enters as supplementary content, toward the transformation level, where cultural perspective reorganizes the school's basic structure. The coding confirms the document's framing; whether it is realized in instruction is a separate question.

A voluntary interdisciplinary teacher group is assigned work within regular working

time, supported by a small premium fund. This low-cost design is consistent with the resource constraints reported across post-Soviet school systems (Amirova et al., 2020; Silova, 2020; Sarmurzin et al., 2024) and is the feature most readily transferable to other schools. It also imposes a ceiling: work that depends on voluntary participation within an existing workload cannot easily extend to sustained lesson-level redesign, and the evidence supports that ceiling.

Read against the terminological distinction drawn in the introduction, the program is culturological rather than equity-driven in the Anglophone sense. Its object is the general cultural formation of teachers, students and parents, and cohesion is its declared value. No document in the corpus frames the work in terms of structural disadvantage, differential attainment or the position of minority-language students relative to the majority. This genuinely diverges from the Anglophone construct (Sleeter, 2017; Brown & Boda, 2018; Kotluk & Aydin, 2021; Miller et al., 2024) and is not a translation artifact. Figure 1 presents the conceptual model of the three-layer governance arrangement, linking national policy, school-level sub-projects, and teacher and student outcomes.



Figure 1. Conceptual Model of the Three-Layer Governance Arrangement, Linking National Policy, School-Level Sub-Projects and Teacher and Student Outcomes

The Operational Layer: The Annual Cycle and What It Actually Carries

Implementation in 2024-2025 followed a nine-month thematic cycle, with each month

carrying a single guiding theme and a portfolio of three to five activities. Table 2 summarizes the cycle and highlights the science-education components carried by each month.

Table 2. Annual Thematic Cycle, 2024-2025: Themes, Activities and Natural-Science Content

Month	Theme	Documented activities	Natural-science content	Science-curriculum integration	Audiences
September	Acquaintance with cultures of the world	Program launch; family-culture exhibition stands; «tolerance tree»; teacher seminars on cultural features in learning and on managing multi-ethnic classes	<i>Indirect:</i> teacher seminars address multi-ethnic classroom management, including science lessons	Teacher-facing; no subject learning objective addressed	Criticality and tolerance; teacher participation in seminars
October	Dialogue and tolerance	Support campaign; world dance festival; thematic film day; teacher seminar on intercultural upbringing	None documented	-	Criticality and tolerance; tolerance survey results
November	Art and creativity	Pupils' art and craft exhibition; «masters of time»; traditions fair; folk-craft workshops	<i>Latent only:</i> craft workshops involve dyes and materials but no chemistry content is documented	Chemistry - properties of materials and dyes; potential not realised in the documentation	Flexibility of method; number of works produced
December	Kindness and friendship	Songs and sketches; seminar on emotional intelligence; lessons on helping; games of the peoples of the world	None documented	-	Reflectiveness; student satisfaction survey (threshold $\geq 80\%$)
January	Discoveries: culture and science	Student projects on cultural contributions to science; invited talk on culture's influence on science and technology; «lessons of discovery»; culture-and-science quests	<i>Direct:</i> the month's entire portfolio is organised around the culture-science relation	Biology, chemistry, physics - the cultural and historical context of scientific discovery	Mobility of knowledge and flexibility of method; number and quality of research works, competition placements («Eureka Academy» platform)
February	Languages and communication	«Language as a bridge»; multilingual book collection; teacher seminar on instruction in multilingual schools; language-identification game	<i>Direct for science instruction:</i> the teacher seminar addresses the multilingual classroom, the setting in which science terminology diverges across languages	All science subjects - scientific terminology across the languages of instruction	Mobility of knowledge; language proficiency levels, number of cross-cultural projects («Polylingua culturology» platform)
March	Women's cultural achievements	«Discover the great names»; poetry evening; national cuisine; «heroines' day» featuring women scientists	<i>Partial:</i> women scientists feature within a broader cultural portfolio	Biology, chemistry - contributions of women to the natural sciences	Mobility of knowledge; number of student presentations

April	Ecology and cultural traditions	Presentations on ecological traditions across cultures; tree planting and grounds clean-up; «cultural eco-market» of recycled-material objects	<i>Direct:</i> ecological content with a cultural frame; recycled-materials work carries chemistry and environmental science content, the curricular area in which science teachers most readily integrate cross-cutting themes (Punzalan, 2024)	Biology, chemistry, geography - ecology, recycling and environmental chemistry	Flexibility of method; number of projects realized
May	Culture as the basis of unity	Gala concert; year memory album; teachers' exchange of successful cases and methods; final exhibition of student projects	<i>Reflexive:</i> the teachers' exchange includes science-cluster practice	Cross-subject - reflection on science-cluster practice	Reflectiveness; cases contributed to the exchange, projects exhibited

Note. Natural-science content was coded as direct where the documented activity addresses biology, chemistry, physics, geography, or ecology content or the teaching of it; partial where such content appears within a broader portfolio; latent where the activity has evident science potential the documentation does not realize; none where no such content is documented. Two features of the school's documentation bear on the argument. The program establishes no mapping to the learning objectives of the national typical curriculum: the connections in column five are subject-level correspondences the authors established from the documented activities. The indicator system is organized by activity platform and the four components of culturological competence, not by month; the indicators in column six apply to each month's portfolio and are again matched by the authors. Neither absence is incidental - see the fourth finding.

Four organizational features of the cycle are analytically significant, and the fourth is negative. First, every month addresses at least two of the three audience categories, which prevents the theme from settling into an extracurricular sideline. Second, it alternates low-cost intra-school activity with higher-effort cross-school events, distributing organizational load and limiting the burnout risk the professional learning community literature identifies as the principal threat to sustained school-level programs (Voelkel & Chrispeels, 2017; Doğan & Adams, 2018). Third, three months - January, February, April - place the culture-science relation at the center of the portfolio rather than at its margin, and these are the months in which Aikenhead's (1996) border-crossing logic is operationalized. Fourth, and against

the interpretation offered in earlier accounts of this school's work, the cycle is a general cultural program within which science content is unevenly distributed, not a science program with cultural framing. Direct natural-science content appears in three of nine months, is partial in one, is latent but unrealized in one, and is absent in four; the teaching seminars addressed to the multi-ethnic classroom are subject-neutral, and the program declares no link to curricular learning objectives. This matters for transfer: the cycle does not, by itself, deliver science teacher development; it provides institutional occasions into which a science cluster must deliberately insert its work. Figure 2 presents the nine-month thematic cycle, with months marked as carrying direct natural-science content.



Figure 2. The Nine-Month Thematic Cycle, with Months Marked with Carrying Direct Natural-Science Content

The Participation Infrastructure: What the Registers Record

The school treats participation in external

professional competitions as a measurable program output. Table 3 reports the complete record for 2024-2025.

Table 3. Teacher Participation in External Professional Competitions, 2024-2025

Date	Event	Organizing body	Level	Participants (n)	Outcome
24 Dec 2024	«Festival of Pedagogical Ideas», republican competition, city stage	« A s t a n a Daryny» Centre for Gifted Children and Talented Youth	City	3	1 × second place; 1 × third place; 1 participant without award
14 Feb 2025	«STEM Olympiad», city olympiad	Methodological Centre, Astana City Akimat	City	3	No awards
17 Feb 2025	«Talented Teacher for Gifted Children», republican pedagogical olympiad, city stage	« A s t a n a Daryny» Centre	City	3	1 × third place; 2 participants without award
Total	3 events		all city-level	9 participations, 8 individual teachers	3 awards: one second, two third places

Note: One teacher participated in two events, giving nine participations by eight individuals. Checked against the school's staffing register, the eight include two natural-science teachers (physics; biology, first year of service), one informatics teacher, one mathematics teacher, one primary-class teacher, one arts and crafts teacher, one senior youth leader, and one name the register does not contain.

The record is modest, and the subject check makes it more so. Three city-level events involving eight of 64 registered teachers is a thin infrastructure beside the professional learning networks documented in the school improvement literature (Brown & Flood, 2020; Nguyen et al., 2021). Crucially, only two of the eight belong to the natural-science cluster: the register records the school's overall professional activity, not that of the focal group. It shows the cluster's external competitive participation in the preparatory year was close to negligible.

Even setting subject composition aside, participation records evidence engagement, not competence: nothing in them indicates what a participating teacher subsequently did differently in a laboratory session. This is a limitation of the instrument rather than the teachers, and it is why the study cannot claim that the program developed cultural competence in the measurable sense of Cross et al. (1989) and Deardorff (2006).

A second internal record qualifies that picture. The mentoring scheme comprised, in the year following the preparatory one, 28 pairs, six with science-cluster mentors: the cluster supplies 21% of mentoring capacity while holding 14% of the posts, the one indicator in the corpus on

which it stands above its share. Mentoring is lesson-adjacent, but the scheme records pairings, not observations.

That qualification aside, the arrangement lacks a proper lesson-facing instrument. The school's response to its own SWOT diagnosis included a structured peer-observation routine - biology, chemistry and physics teachers visiting one another's lessons twice per quarter against a protocol focused on multi-ethnic interaction during laboratory work, small-group inquiry and frontal explanation - and its indicator system for 2025-2028 adopts Lesson Study as its methodological basis. These are precisely the instruments the literature identifies as capable of registering instructional change (Vermunt et al., 2019; Elkommy & Elkhail, 2022). Their outputs for the preparatory year are not part of the present corpus, and the corresponding analysis is therefore reserved.

Student participation shows the same pattern at a larger scale. The 2024-2025 student register documents 66 events. Applying the science-content classification described in the methods, 19 of those events carry natural-science content (Table 4).

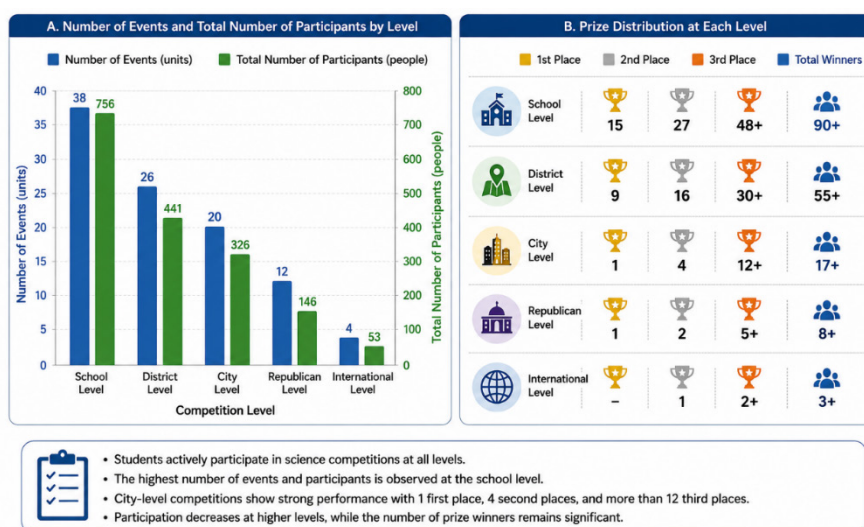
Table 4. Student Participation in Science-Related Competitions and Projects, 2024-2025

Event type	Events (n)	Participations (n)	Documented awards
STEM Olympiads (city stage and international final)	2	6	Invitation to international forum
Research and creative project competitions («Zerde», city and republican stages)	4	8	1 first, 1 second, 5 third places
Science project competitions, grades 8-11 (city and republican stages)	2	2	1 second-degree diploma; 1 advancing score
Robotics («Robotek Grand Tournament», city qualifier)	1	2	2 third places
Geography olympiad (district and city stages)	2	5	1 third place
Scientific conferences (Mustafa Shoqai; «Äbish readings»)	2	2	2 third places
Science-related essay competitions (intellectual property and AI; ecology; geology of Kazakhstan)	3	10	1 third place; 3 letters of commendation
School Science Week	1	330	Internal school event
Cosmonautics Day drawing and craft competition, grades 1-4	1	86	14 first, 20 second, 21 third places, 5 certificates
Total, science-related	19	451	-
Total, all documented events	66	-	-

Note. Events were classified as science-related where they address biology, chemistry, physics, geography, ecology, robotics, or student research in those fields; the remaining 47 concern mathematics, languages, history, literature, and artistic competition. Participations are counted per event. School Science Week and the Cosmonautics Day competition are internal mass events and are distinguished from external competition.

Two readings follow, and they pull in different directions. Each registered event is paired with a named responsible teacher, converting student participation into a documented professional outcome that feeds the annual performance review - a genuine mechanism linking student activity to teacher accountability. At the same time, science-related events make up under a third of

documented student activity, and external science participation outside the two mass internal events amounts to 35 participations across the year. A school presenting this register as evidence of a science-focused program would overstate what it shows. Distribution of student participation by event type, with science-related events distinguished from the remainder, is displayed in Figure 3..

**Figure 3.** Distribution of Student Participation by Event Type, with Science-Related Events Distinguished from the Remainder

The corpus contains one document that speaks directly to the science lesson: a 37-page set of methodological guidelines on managing teachers' cultural competence, authored within the school and cleared by the city Expert Council of the Astana Education Department (protocol No.2 of 24 December 2025), with a review by a candidate of psychological sciences. Two features of its provenance matter: it underwent external methodological scrutiny, unlike the internal planning documents analyzed, and it is dated to the first year of the authorized period rather than the preparatory year, which situates it as an output of the preparatory work rather than an instrument used during it. Its structure follows the four-facet model of cultural intelligence - motivational, cognitive, metacognitive, behavioral (Ang et al.,

2007) - as a staged professional development sequence grounded in sociocultural developmental theory and a values framework. The document is addressed to subject teachers rather than to the school in general: its scale of cultural competence, adapted from Cross et al. (1989), illustrates cultural blindness with a science teacher's own formulation, «it makes no difference to me, I only teach physics», and treats the disregard of a student's language or belief as a factor in lesson performance as the position to be worked on. The metacognitive stage becomes subject-specific: teachers must produce a lesson plan in their own subject. Worked examples cover chemistry, biology, geography, and mathematics, with the fullest elaboration in chemistry, in four cases (Table 5).

Table 5. Subject Cases in the School's Methodological Guidelines: Scientific Concept, Cultural Situation and Student Task

Case	Scientific concept	Cultural or social situation	Task set for students
1	Le Chatelier's principle; factors shifting equilibrium	A student under examination pressure whose internal equilibrium is disturbed	Describe the «reaction» restoring equilibrium: if «pressure» rises, how does the system reduce it - by raising the concentration of preparation or lowering the temperature through rest?
2	Catalysis and reaction rate	A misunderstanding between two classmates into which a third party intervenes	Identify who acts as positive catalyst and who as inhibitor; explain conflict resolution through lowering of activation energy; account for why the catalyst leaves the reaction unchanged
3	Collision theory: the conditions of an effective collision	Students of different cultural backgrounds in an international school forming a «bond»	Is concentration sufficient for an effective collision? (No - orientation and energy are also required.) What are «orientation» and «energy» in terms of cultural intelligence?
4	The industrial significance of chemical equilibrium	Fritz Haber, whose ammonia synthesis saved billions from famine and whose knowledge was then applied to chemical weapons	Complete a two-sided table, «the equilibrium of knowledge»: scientific achievement against moral responsibility. If a scientist's ethical values fall in concentration, in which direction does society's «equilibrium of safety» shift?
5	Ecological relationships; conservation of natural resources (biology)	The customary Kazakh code «Jeti Jargy» and steppe law on the protection of nature; «the traditional ecological culture of the Kazakhs» as a project theme	Build an ecological project that links a present-day conservation rule to the customary norm it echoes, and defend it
6	Local ecology and environmental change (geography)	The ecology of the home region	Study the ecology of the home region and carry the study into an environmental project

Note: Reconstructed from the methodological guidelines, section VII. Column headings follow the source table. Cases 1-4 are elaborated in full in the source; entries 5 and 6 are given there at the level of a lesson-design example, and the asymmetry is discussed below.

Analytically, the corpus contains both directions of the concept-culture relation, and the contrast matters for science education. In the four chemistry cases, the direction is inverted relative to the Ethnoscience pathway discussed: the scientific concept is the analytical instrument and the cultural or social situation is what gets explained - equilibrium describes composure under pressure, catalysis mediation, collision theory the conditions of intercultural contact. In the biology and geography entries, the direction is the familiar one: customary ecological norms and the ecology of the home region supply the material that scientific content then organizes (Parmin et al., 2017; Sumarni et al., 2021). That a single document holds both directions is itself a finding: the arrangement prescribes no single didactic logic to its science cluster, and the inverted variety, the less documented of the two, appears precisely where subject elaboration went furthest. The fourth chemistry case is of a different order again, placing a documented episode from the history of chemistry at the center of an explicitly moral judgment - the structure the socioscientific-issues literature identifies as the vehicle for values work in science classrooms (Annisa & Subiantoro, 2022; Atabey & Topçu, 2025). For SDG 4.7, which pairs sustainable development with a culture of

peace and global citizenship, that case is the most direct curricular realization in the corpus.

The limitation must be stated with the same clarity. The guidelines are a specification, not a record of use: the corpus contains no dated lesson plan built on any of the cases, no observation protocol recording one being taught, and no student work produced in response; nor does the document report how many teachers received it, and the elaborated cases are concentrated in chemistry, which two teachers in the cluster teach. What the arrangement has demonstrably produced is a didactic design of real conceptual ambition that passed external methodological review - and no evidence that it reached a lesson. That is precisely the gap a lesson-facing instrument would close.

The Reflexive Layer: What the Monitoring Instruments Measure

The 2024-2025 self-assessment sheet aggregates four standardized instruments and one open-format questionnaire administered by the school's psychological service as part of its routine adaptation program for entry cohorts. Selected indicators appear in Table 6.

Table 6. Selected Indicators from the 2024-2025 self-Assessment Sheet, Multi-Ethnic Cohorts

Indicator	Cohort and instrument	n	Result
Likes coming to school	Grade 1, oral questionnaire	full cohort	100%
School motivation: high	Grade 5, Luskanova	145	12%
School anxiety: high	Grades 5-11, Phillips	78	3%
Dominant emotion: tiredness / joy	Grades 8-11, anonymous questionnaire	190	38.4% / 26.3%
Likes studying at this school	Grades 8-11, anonymous questionnaire	190	72.5%
Classroom psychological climate: positive	Grade 10, Lutoshkin	full cohort	81%

Three patterns are visible. Entry-cohort adaptation indicators are uniformly high, suggesting a psychologically safe entry experience - a precondition the multicultural science education literature treats as before cultural competence work rather than as its product (Atwater, 2010; Borgerding, 2016). The senior-cohort climate is favorable but uneven: 72.5% report a positive orientation to the school while 38.4% name tiredness as their dominant in-school emotion, a combination the cluster has read as a signal to differentiate workload across the laboratory, theory, and problem-solving components of the lesson cycle. High anxiety at 3% is low against the instrument's norms.

The decisive observation concerns what these instruments can support. They measure affective school climate, not instructional practice, and none is science-specific: no instrument in the pack asks about the science classroom, samples science lessons, or distinguishes respondents by language of science instruction. The data establish a baseline for future work; they cannot be read as a program outcome. Reporting this openly is a finding in its own right - a whole-school reflexive layer assembled from standard psychological monitoring will not, without modification, evidence change in science teaching, a design gap the whole-school ESD literature has also noted (Gericke & Torbjörnsson, 2022; Seiser et al., 2022).

The self-assessment sheet also contains a SWOT analysis of the science cluster, and its internal diagnosis is more pointed than the participation registers. It names as strengths a staff with innovation experience and an existing algorithm of pedagogical support; as weaknesses the uneven psychological-pedagogical preparation of some science teachers for multi-ethnic and multilingual classrooms and a limited offering of supplementary science education; as opportunities systematic joint work across teachers, students and parents; as threats a perceived decline in general family culture. That the school names uneven teacher preparation for multilingual science classrooms as a weakness, in its own internal document, is the clearest evidence in the corpus that the cluster understands the object of the program in the same terms as the international literature (Lee & Buxton, 2010; Penner-Williams et al., 2019; Charamba, 2023).

One further set of figures is reported for completeness and forms no part of the analysis; a reader comparing this article with the school's own documentation would otherwise find it missing. The methodological guidelines report a three-point diagnostic sequence administered to teachers across the preparatory year - September 2024, December 2024, May 2025 - with cultural competence rising from 48% to 65% to 81% and cultural intelligence from 45% to 63% to 78%. These are the only teacher-level longitudinal figures in the corpus, and they cannot bear evidential weight: the source names no established scale, reports no sample size, gives no administration procedure, provides no external validation, and measures self-assessment by the same body that designed and delivered the intervention. They are therefore reported as the school's own account of its progress and excluded from every inference drawn here - a status that illustrates the argument rather than weakening it: a whole-school arrangement generates self-assessment readily and instrumented evidence only by deliberate design.

The Linguistic Dimension

Multi-ethnic science classrooms in this school operate across Kazakh and Russian scientific terminology, with English entering in selected upper-secondary classes. The two terminological systems diverge for the same concept, and students translate informally between them during inquiry. The February seminar on instruction in multilingual schools and the science cluster's short in-service module both address this directly, and the cluster's own SWOT names preparation for multilingual classrooms as its principal weakness.

The international literature offers a well-developed frame for what is at stake. Research on second-language learners established early that science learning and language learning develop in tandem when instruction attends to both (Lee, 2005; Lee & Buxton, 2010), and pedagogical translanguaging research has since documented that treating learners' full linguistic repertoire as a resource rather than as interference supports the construction of scientific knowledge (Probyn, 2015, 2019; Ollerhead, 2018; Charamba, 2020, 2023; Wong & Tian, 2025). Read against that literature, the practices reported by the cluster - acceptance of term variants from students whose strongest language of scientific reasoning differs from the language of instruction, bilingual labeling of laboratory materials - are recognizable instances of pedagogical translanguaging arrived at pragmatically rather than through the framework. That gap is itself the professional development opportunity, and it is where a school pursuing SDG 4.7 has most to gain from the international literature (Karabassova, 2020; Kambatyrova, 2022; Mehisto & Winter, 2022; Goodman et al., 2023).

A Conceptual Comparison: Two Pathways for Culture in Science Education

The comparison with the Indonesian Ethnoscience tradition is conceptual, not empirical, and the asymmetry should be stated plainly.

Five questions must be answered before setting the two pathways side by side. Why these two systems: both are middle-income states pursuing SDG 4.7 through science education in classrooms that are neither monolingual nor mono-cultural. Why they are theoretically comparable: both answer the same question: how canonical science is to meet the cultural repertoires students bring to it, which is Aikenhead's (1996) border crossing. This frame organizes this article throughout. What is compared: not countries, systems, or outcomes, but the logic of two pathways - where each locates the pedagogical work and what evidence each produces. Why Indonesian Ethnoscience rather than another multicultural framework: it has the largest published body of designed interventions in science education specifically, it is developed in this journal, and it works from a single regional cultural frame, whereas this case draws on several co-present ones. On what dimensions: the seven in Table 7 were derived from the coding frame applied to the Kazakhstani corpus and then applied to the Indonesian literature, not induced from the pair. Because the two bodies of evidence are of different kinds - a mature published literature of designed

interventions with measured learning outcomes (Parmin et al., 2017; Sumarni et al., 2021; Irfandi et al., 2023; Uslan et al., 2024; Nur Hikmah et al., 2025) against one school’s institutional documentation for a single preparatory year - what

follows is a conceptual discussion of two pathways and not a comparison of two cases, and no claim of relative effectiveness is made or could be supported.

Table 7. Two Pathways for Integrating Culture into Science Education: A Conceptual Comparison

Dimension	Indonesian Ethnoscience pathway	Kazakhstani whole-school governance pathway
Cultural frame	One regional or indigenous culture as ethno-cognitive frame	Several co-present ethno-linguistic repertoires, none primary
Locus of pedagogical work	Design of the instructional sequence	Design of school-level routines into which lessons are inserted
Principal artefact	Learning module, teaching material, worksheet	Programme document, thematic cycle, self-assessment sheet
Teacher’s core task	Mediating between indigenous and canonical knowledge claims	Managing repeated low-risk border crossings among several worlds
Language dimension	Usually single-language, with local terms introduced	Constitutive: two to three scientific terminologies in one lesson
Evidence typically produced	Student learning outcomes, scientific literacy measures	Institutional artefacts, participation records, climate indicators
Principal limitation	Transfer beyond the originating culture is not automatic	Cannot, by itself, evidence change in instruction

Read as a continuum rather than a dichotomy, the pathways address different classroom demographics. Teachers prepared for mono-ethnic regional schools gain more from the Indonesian curricular approach, in which the cultural frame can be specified in advance and built into materials; teachers prepared for multi-ethnic urban schools gain more from the governance approach, in which no single frame can be specified, and competence lies in managing plurality in real time. Comparing their limitations is more instructive than comparing their strengths: The Ethnoscience pathway produces measurable learning outcomes but transfers imperfectly across cultures, while the governance pathway transfers readily but does not, by itself, measure anything about teaching.

The extension of the Ethnoscience tradition towards the Sustainable Development Goals in recent work in this journal (Pada et al., 2025; Rosyidah et al., 2025; Nurkanti et al., 2026; Tolba & Youssef, 2026) suggests where the two converge. Both are, in SDG 4.7 terms, attempts to make cultural diversity a working component of science education rather than a decorative one: The Indonesian route through content, the Kazakhstani through institutional design. Neither is sufficient alone, and the negative findings of this case show why: institutional design without a lesson-facing instrument produces activity without evidence. Figure 4 displays the two pathways positioned on a continuum from single-frame curricular integration to multi-frame institutional governance.

Characteristic	Kazakhstan Model (Multicultural Science Education)	Indonesian Model (Ethnoscience Tradition)
Context	Multi-ethnic, post-Soviet	Mono-ethnic (regional), post-colonial
Main Challenge	Managing multiple coexisting cultures	Integrating indigenous knowledge into science education
Key Mechanism	School governance (plan, cycle, monitoring)	Instructional sequence design (learning trajectory)
Role of Language	Trilingualism (Kazakh, Russian, English) – terminology variants	Indonesian + local dialect/language
Example	Different food traditions of Kazakhs, Russians, Koreans, Uighurs, etc.	Fermentation based on traditional cuisine
Ultimate Goal	Developing culturally competent science teachers who bridge multiple cultures in the classroom	Developing science learning rooted in local wisdom while achieving scientific literacy
Expected Outcome	Inclusive school climate, equitable participation, and cross-cultural understanding	Culturally relevant science learning, identity affirmation, and community empowerment

Figure 4. The Two Pathways Positioned on a Continuum from Single-Frame Curricular Integration to Multi-Frame Institutional Governance

Four implications follow. First, cultural competence in this setting is an organizational achievement before it is an individual one: it is enacted as a portfolio of school-wide processes - program document, thematic cycle, self-assessment sheet, monitoring routine, participation register - rather than as the accumulated initiative of individual teachers. This supports the whole-school proposition (Miled, 2019; Brown & Flood, 2020; Nguyen et al., 2021; Gericke & Torbjörnsson, 2022) and specifies its mechanism in a centrally administered system: external authorization, voluntary in-hours labor, documentary accountability. Second, the post-Soviet framing is substantively different and should not be assimilated. The program's object is cultural formation and cohesion under state-led modernization, not redress of structural disadvantage, which makes the case a reference point for multicultural science teacher preparation under nation-building reform, distinct from the rights-based framings dominant in Anglophone research (Sleeter, 2017; Brown & Boda, 2018; Miller et al., 2024) and grounded instead in the culturological tradition (Benin et al., 2013).

Third, the linguistic dimension offers the greatest leverage. In a classroom operating across two or three scientific terminologies, managing that plurality is not a peripheral skill but central to what cultural competence means for a science teacher. The case shows a cluster performing translanguaging pragmatically without the framework that would let it do so systematically (Probyn, 2019; Charamba, 2023; Wong & Tian, 2025) - the highest-yield target for in-service work in comparable settings.

Fourth, and derived from the case's negative findings, a whole-school arrangement requires a lesson-facing instrument to evidence anything about teaching. Program documents, thematic cycles, participation registers, and climate monitoring together produce a rich account of school activity. No account of instructional change, and frameworks that treat culturally responsive science teaching as a property of instructional sequences rather than of individual teachers (NGSS Lead States, 2013; Lee et al., 2014) presuppose exactly such an instrument. Those capable of closing the gap - structured peer observation with a subject-specific protocol, Lesson Study cycles, teacher accounts of changed practice (Penner-Williams et al., 2019; Vermunt et al., 2019; Elkomy & Elkhail, 2022) - are inexpensive and already named in the school's planning for 2025-2028; their absence from the preparatory-year record is the most consequential gap described here.

Two consequences follow for teacher preparation. Initial teacher education would gain from moving beyond stand-alone culturological competence courses towards analysis of school-level artifacts (Chisingui & Costa, 2020; Vidal & Kuckuck, 2025); for in-service provision, the subject cluster rather than the individual teacher is the more productive unit of intervention (Voelkel & Chrispeels, 2017; Chou & Su, 2018; Doğan & Adams, 2018; Siliunas & Wan, 2024).

Five limitations bound these conclusions, and each carries a specific consequence for generalization.

The design is a single case, and generalization is analytical rather than statistical (Yin, 2018): the three-layer arrangement is a proposition to be tested against other schools. Because the school was selected for the completeness of its documentation, the arrangement described is closer to a best case than to a typical one.

The evidence covers a single academic year, and that year precedes the formal award of experimental-site status. The study documents the formation of a governance arrangement, not its steady-state operation; whether it survives the transition from preparatory year to funded program is an open empirical question.

The evidence base is documentary: institutional artifacts record what a school undertakes and reports, not what happens in a lesson. The study therefore does not claim instructional change, teacher belief, or student learning, and the negative findings reported concern the instruments, not the teachers.

An insider team conducted the research, with the first author being the school's principal. The four mitigations described in the methods reduce but do not eliminate the risk that a principal's reading of her own school is more favorable than an outsider's; the unusually specific negative findings reported here are offered partly as evidence that the mitigations bit.

Finally, the authors received the psychodiagnostic data as service-level aggregates. No disaggregation by language of instruction, ethnicity, or subject was available, and this evidence cannot address whether affective indicators covary with multicultural practice in science lessons.

Four designs would address these limitations directly, in ascending order of cost. A multi-site comparative documentary study across eight to twelve Comfortable Schools, applying the coding frame used here to their program documents, thematic plans, and self-assessment sheets, would establish whether the three-layer arrangement is characteristic or idiosyncratic.

A Lesson Study intervention study within the science cluster, running three to four cycles across a year with a subject-specific observation protocol focused on multilingual interaction during laboratory work and inquiry, would supply the lesson-facing evidence the present design lacks; Vermunt et al. (2019) and Elkomy and Elkhail (2022) provide validated designs for measuring teacher learning within such cycles.

A repeated-measures teacher survey administered to the cluster at the start and end of two consecutive years, combining a validated culturally responsive teaching self-efficacy instrument with open items on changed practice, would allow within-school change to be estimated and related to program participation (Underwood & Mensah, 2018; Penner-Williams et al., 2019; Siilunas & Wan, 2024).

A classroom discourse study of translanguaging across Kazakh-medium and Russian-medium science lessons, following the approach established for multilingual science classrooms elsewhere (Probyn, 2019; Charamba, 2023; Wong & Tian, 2025), would test whether the practices reported by this cluster function as pedagogical translanguaging in the technical sense; a longitudinal follow-up of student science identity and achievement, while desirable, presupposes the instruments established by the designs.

CONCLUSIONS

This study explores how a multi-ethnic Kazakhstani school implements a national infrastructure program to enhance the cultural competence of its science teachers in biology, chemistry, and physics. Examination of the operationalization at the governance level reveals that the initiative relies on three interlinked layers: a regulatory layer, which is a multi-year program based on national policy that legitimizes additional work for teachers; an operational layer, which facilitates a year-long thematic cycle distributing responsibilities to teachers, students, and parents at minimal cost; and a reflexive layer that employs self-assessment tools to document efforts and inform adjustments. These components are characterized as accessible administrative artifacts rather than specialized instruments, enhancing their applicability. Regarding the specified routines for science lessons and their assessments, the instructional output includes a didactic approach endorsed by the city's Expert Council that links cultural contexts to scientific concepts. However, it provides little direct evidence linking these outputs to actual lessons, such as lesson plans

or student work. Despite documenting natural science content for part of the year and teacher participation in competitions, the report provides no concrete evidence of changes in science teaching practices. This study discusses the implications for science education globally and contrasts this approach with Ethnoscience. While the regulatory and operational layers of the program can be quickly implemented, they should be accompanied by methods for observing teaching to realize their full potential. The school plans to use Lesson Study for this purpose in its 2025-2028 strategy. The findings suggest that the approach allows cultural integration through curriculum design, operating within one cultural frame while also acknowledging the coexistence of multiple frameworks that may create inefficiencies. Ultimately, the study presents a documented, post-Soviet, trilingual alternative to the Ethnoscience model, proposing a framework of culturological competence aligned with state-driven modernization, distinct from equity-focused frameworks in Anglophone research.

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