Int. j. adv. multidisc. res. stud. 2026; 6(6):848-853

Received: 29-09-2026
Accepted: 09-11-2026

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

From Mixing to Separating: An Inquiry-Based, ICT-Enhanced Lesson Sequence on Mixtures for Fourth-Grade Primary School Students

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Abstract

Mixtures and their separation are among the first chemistry-related topics that primary school pupils meet, yet everyday experience often leads children to believe that a dissolved substance simply disappears, that every material dissolves in water, or that any mixture can easily be separated. This paper presents and analyses a two-lesson teaching sequence for the fourth grade of the Greek primary school, built on the Environmental Studies units "We mix materials" and "How do we separate mixtures?". The sequence combines guided inquiry, cooperative group work and hands-on experimentation with everyday materials (rice, lentils, flour, sugar, salt, water, oil, vinegar, sand and iron filings) and is supported by the school e-Class learning management system and interactive H5P activities such as dialog cards, drag-and-drop classification tasks and crosswords. In the first lesson pupils classify materials as solids or liquids and create solid-solid, solid-liquid and liquid-liquid mixtures, recording quantities and observations on structured worksheets. In the second lesson they match mixtures to suitable separation methods and apply hand sorting, magnetic separation, sieving and filtration. The paper describes the learning objectives, classroom organisation, activity flow, digital resources and three-stage assessment (initial, formative and final), and discusses how each design decision addresses known misconceptions. The sequence is offered as a transferable model for teachers who wish to integrate low-cost experimentation with digital tools in primary science.

Keywords: Primary Science Education, Mixtures and Solutions, Separation Methods, Inquiry-based Learning, H5P, e-Class

1. Introduction

Science education in the early years of schooling aims not only to transmit factual knowledge but also to cultivate the processes through which scientific knowledge is produced: Observing, measuring, predicting, experimenting, interpreting data and communicating findings [1, 2]. European and international policy documents have repeatedly called for a shift from transmissive teaching towards inquiry-based approaches in which children actively investigate phenomena and construct explanations [2]. A research synthesis of inquiry-based science instruction found a clear trend favouring approaches that engage students actively with scientific phenomena and require them to think about the data they collect [3].

The topic of mixtures is an ideal context for such an approach. It connects directly with pupils' everyday experience in the kitchen and at home, it can be investigated with safe, inexpensive materials, and it lays the conceptual foundations for later study of solutions, solubility and the particulate nature of matter. At the same time, it is a topic in which children hold persistent alternative conceptions. Research on children's ideas has shown that pupils often believe that sugar or salt "disappears" when it dissolves in water, that dissolving is the same as melting, or that all solids dissolve if stirred long enough [4, 5, 6]. Similarly, children may assume that every mixture can be separated by simple means, or they may not recognise that the choice of separation method depends on the physical properties of the components, such as particle size, magnetic behaviour or solubility [6].

In the Greek primary curriculum, mixtures are introduced in the fourth grade through the Environmental Studies textbook, Unit 6 "We study the physical world", Chapter 1 "We mix materials" and Chapter 2 "How do we separate mixtures?" [7]. These two chapters form a natural pair: The first lesson asks pupils to create mixtures, and the second asks them to reverse the process. Treating them as one coherent sequence allows the teacher to reuse the mixtures that pupils themselves created and to frame

the second lesson as a genuine problem: "Can we get our materials back?".

Digital technologies offer additional possibilities for such lessons. Learning management systems such as the e-Class platform of the Greek School Network [8] allow teachers to organise material and activities in one place, while authoring tools such as H5P [9] make it possible to create interactive classification tasks, dialog cards, quizzes and crosswords without programming knowledge. When combined thoughtfully with hands-on work, such tools can support visualisation, immediate feedback and retrieval practice [10, 11]. The integration of technology, pedagogy and content must, however, be deliberate rather than incidental, as emphasised by the Technological Pedagogical Content Knowledge (TPACK) framework [12].

The aim of this paper is to present and analyse a two-lesson teaching sequence on mixing and separating materials for fourth-grade pupils (aged 9-10 years). Specifically, the paper (a) describes the objectives, organisation, materials and activity flow of each lesson; (b) explains the pedagogical rationale for the combination of guided inquiry, cooperative learning, experiential activity and ICT; and (c) discusses how the design addresses common misconceptions and how it can be adapted and evaluated in other classrooms.

2. Materials and Methods

2.1 Theoretical framework

The sequence draws on three complementary pedagogical traditions. The first is **discovery and inquiry-based learning**, rooted in Bruner's argument that knowledge which learners discover for themselves is better understood and more readily transferred [13]. Because unguided discovery can overload novice learners [14], the sequence adopts *guided* inquiry: The teacher poses structured questions, provides worksheets that scaffold observation and recording, and summarises findings at key points. Meta-analytic evidence indicates that such enhanced, guided forms of discovery are more effective than both unassisted discovery and purely explicit instruction [15], and scaffolding is regarded as the key to the success of inquiry learning [16].

The second tradition is **experiential learning**, which views learning as a cycle of concrete experience, reflective observation, abstract conceptualisation and active experimentation [17, 18]. Pupils first handle and mix real materials, then observe and record what happens, then name the patterns (for example, "uniform" versus "non-uniform" mixtures) and finally apply the new ideas when choosing separation methods. Practical work is most productive when it is "hands-on" and "minds-on" at the same time, that is, when pupils are explicitly asked to think about what they observe rather than just follow a recipe [19, 20].

The third tradition is **cooperative learning** grounded in social constructivism [21]. Pupils work in small heterogeneous groups of three to four, share materials and responsibilities, and must agree on what to record. Positive interdependence and individual accountability, the defining elements of effective cooperative learning, are built into the shared worksheets and the presentation of group results [22].

ICT is integrated according to multimedia learning principles [10] and dual coding theory [23]: Images of everyday mixtures accompany verbal explanations, and interactive H5P tasks provide immediate feedback, which supports formative assessment [24] and retrieval practice [11].

2.2 Context and participants

The sequence was designed for a fourth-grade class of a Greek public primary school and was prepared on the school's e-Class course for Environmental Studies. It targets pupils aged 9-10 years and assumes a typical class of 20-25 pupils organised into groups of three to four. Each lesson lasts one teaching period of 45 minutes. No prior formal teaching on mixtures is assumed; however, pupils are expected to bring rich everyday experience, for example of stirring sugar into milk, of making mud from soil and water, or of seeing oil float on water.

2.3 Learning objectives

The objectives of the two lessons were formulated across cognitive, ICT-related, learning-process, affective and psychomotor domains, as summarised in Table 1.

Table 1: Learning objectives of the two-lesson sequence

Domain	Lesson 1: We mix materials	Lesson 2: How do we separate mixtures?
Cognitive	Classify materials as solids or liquids; create solid-solid, solid-liquid and liquid-liquid mixtures; distinguish mixtures in which the components remain visible from those that appear uniform (solutions); give examples of mixtures used in everyday life.	Separate the components of mixtures using hand sorting, sieving, magnetic separation and filtration; relate each method to a property of the components; connect separation methods with everyday applications (e.g., recycling, cooking, construction).
Scientific processes	Observe, measure (in spoonfuls), record in tables, interpret and communicate results.	Predict, test, count and record outcomes, compare methods and draw conclusions.
ICT	Use e-Class and H5P activities (dialog cards, drag and drop); use multimedia presentations to consolidate concepts.	Use H5P drag-and-drop tasks to match mixtures to separation methods; complete an online quiz at home.
Learning process	Collaborate in groups, respect others' views, show initiative and self-regulation.	Collaborate in groups, justify choices of method, reflect on results.
Affective	Develop a positive attitude towards scientific investigation and confidence in conducting experiments.	Develop a positive attitude towards inquiry; show responsibility, respect and team spirit.
Psychomotor	Carry out mixing experiments correctly and safely; observe, record and compare results.	Use magnets, sieves, strainers and filter paper correctly and safely.

2.4 Materials and digital resources

All physical materials are inexpensive and available in any household, which makes the sequence easy to reproduce. For Lesson 1 each group receives rice, lentils, sugar, salt, water, olive oil and vinegar, together with transparent plastic cups, plastic spoons, plates, gloves, kitchen paper and wet wipes. For Lesson 2 each group receives beans and lentils, sand and iron filings, flour and lentils, water and rice, as well as magnets, a sieve or kitchen strainer and filter paper. A computer with a projector, a whiteboard, the pupil's textbook and printed worksheets complete the equipment.

Three categories of software were combined. First, the **e-**

Class platform of the Greek School Network [8], an asynchronous learning management system, served as the hub where the teacher organised presentations, interactive activities and homework. Second, **presentation software** (PowerPoint) was used to display photographs of everyday materials, mixtures and separation methods. Third, **H5P interactive content** [9], embedded in e-Class, was used for (a) dialog cards in which pupils decide whether a pictured material is a solid or a liquid (Fig 1); (b) a drag-and-drop task in which pupils classify everyday mixtures as solid-solid, solid-liquid or liquid-liquid (Fig 2); (c) a drag-and-drop task in which mixtures are matched with separation methods (Fig 3); and (d) a crossword and a quiz assigned as homework.

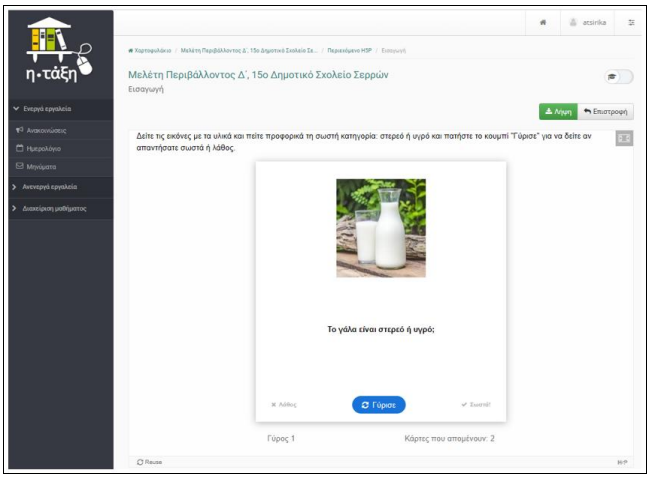


Fig 1: H5P dialog cards on the school e-Class course: Pupils decide whether each pictured material is a solid or a liquid

2.5 Procedure of Lesson 1: "We mix materials"

Lesson 1 is organised in two phases (Table 2). Phase A (10 minutes) activates prior knowledge. The teacher shares the lesson goals and projects photographs of everyday materials and mixtures, acting as an advance organiser [25]. A structured brainstorming follows, guided by questions such as "Which of these are liquids and which are solids?", "What is a mixture? Can you give an example from everyday life?" and "Can we make a mixture of a solid with a solid? A solid with a liquid? A liquid with a liquid?". Answers are written on the board, and the teacher steers the discussion so that the basic categories of mixtures emerge from the pupils' own examples. Pupils then classify materials using the H5P dialog cards.

Phase B (35 minutes) is the core experiential activity, organised in three 10-minute experiments. In the **solid-solid** experiment, each group chooses three of the four available solids (rice, lentils, sugar, salt), lists the possible pairs, mixes each pair using a recorded number of spoonfuls, and notes whether the components can still be distinguished. In the **solid-liquid** experiment, pupils half-fill two transparent cups with water, add one spoonful of salt to the first and one spoonful of rice to the second, label the cups, stir, wait and record their observations. In the **liquid-liquid** experiment, the same procedure is followed with two spoonfuls of oil and two spoonfuls of vinegar. Parallel slides consolidate the concepts of mixture and solution, and the lesson closes with the H5P drag-and-drop classification of everyday mixtures (Fig 2).

Table 2: Activity flow of Lesson 1 (45 minutes)

Phase	Time	Activity	Purpose / tools
A. Introduction	5'	Presentation of goals; photographs of solids, liquids and mixtures; structured brainstorming recorded on the board.	Activation of prior ideas; advance organiser; PowerPoint.
	5'	Classification of materials into solids and liquids.	Initial assessment; H5P dialog cards on e-Class.
B. Creating mixtures	10'	Experiment A: Solid-solid mixtures (rice, lentils, sugar, salt); record quantities and whether components remain distinct.	Observation, measurement, recording; Worksheet 1.
	10'	Experiment B: Water + salt and water + rice; stir, wait, observe.	Distinguish solutions from non-uniform mixtures; Worksheet 2.
	10'	Experiment C: Water + oil and water + vinegar; stir, wait, observe.	Miscible vs. immiscible liquids; Worksheet 3.
	5'	Consolidation slides; H5P drag-and-drop classification of everyday mixtures; review and preview of next lesson.	Final assessment; feedback.

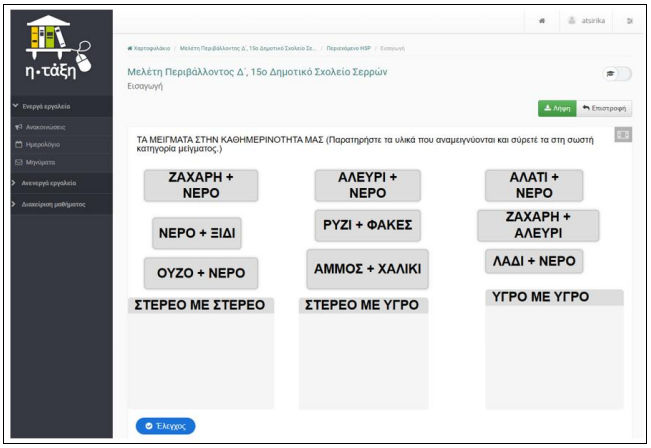


Fig 2: H5P drag-and-drop task: Pupils classify everyday mixtures (e.g., sugar + water, rice + lentils, oil + water) as solid-solid, solid-liquid or liquid-liquid

2.6 Procedure of Lesson 2: "How do we separate mixtures?"

Lesson 2 begins (Phase A, 20 minutes) with a short story problem: "Grandfather's worry beads broke, and the beads were scattered and buried in the sand. How can we help him find them?". The teacher then asks whether the mixtures created in the previous lesson can be separated back into their components, and by what means. Pupils' suggestions are recorded, after which a short presentation introduces six separation methods (hand sorting, sieving, magnetic separation, filtration, sedimentation and evaporation) with everyday examples, such as sorting olives from leaves, separating recyclable materials, sieving flour in a bakery and sieving sand on a building site. Pupils then complete an H5P drag-and-drop task in which each mixture (e.g., water + salt, rice + sugar, sand + iron, lentils + wheat, water + semolina) must be placed under the appropriate method (Fig 3).

In Phase B (25 minutes), each group applies four methods in sequence, five minutes each: (a) **hand sorting** of a bean-lentil mixture, counting how many beans and lentils it contained; (b) **magnetic separation** of sand and iron filings, noting which material is attracted by the magnet and which remains; (c) **sieving** of a flour-lentil mixture, noting which material stays in the sieve and which passes through; and (d) **filtration** of a water-rice mixture, noting what remains on the paper and what passes through. Results are recorded on a structured worksheet (Table 3). The lesson closes with a final H5P activity and an online quiz assigned as homework.

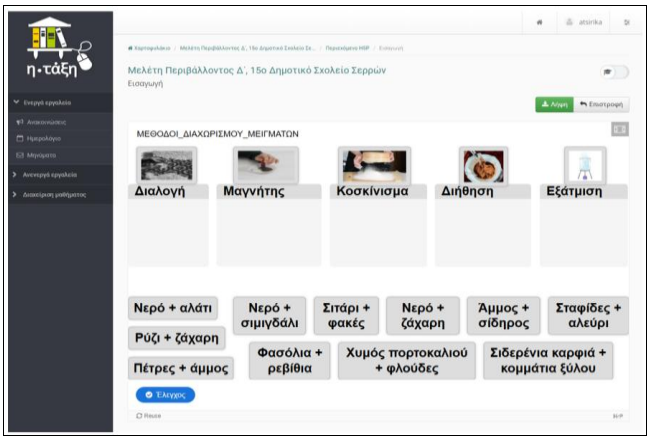


Fig 3: H5P drag-and-drop task on e-Class: Matching mixtures with separation methods (hand sorting, magnet, sieving, filtration, evaporation)

Table 3: Structure of the Lesson 2 experimental worksheet

Mixture	Method	Material A	Material B
Beans - lentils	Hand sorting	How many beans?	How many lentils?
Sand - iron filings	Magnet	Which material did the magnet attract?	Which material remained?
Flour - lentils	Sieving	Which material stayed in the sieve?	Which material passed through?
Water - rice	Filtration	Which material stayed on the paper?	Which material passed through?

2.7 Role of the teacher and assessment

Throughout the sequence the teacher acts as guide, coordinator and facilitator: Posing questions, circulating among groups, prompting pupils to justify their observations and intervening when safety or misconceptions require it. Assessment is organised in three stages. **Initial assessment** takes place through the brainstorming and the H5P classification of materials (Lesson 1) or of mixtures and methods (Lesson 2), revealing what pupils already know. **Formative assessment** is continuous, as the teacher monitors each group's work, checks the worksheets and discusses results with the whole class [24]. **Final assessment** uses the closing H5P drag-and-drop activity, in which representatives of each group classify mixtures or match them with methods, while the crossword (Lesson 1) and the quiz (Lesson 2) on e-Class extend practice at home.

3. Results and Discussion

Since the present work is a design study, this section does not report measured learning gains. Instead, it analyses the internal coherence of the design, the way it addresses documented misconceptions, the contribution of ICT, and the practical conditions for its implementation.

3.1 Alignment of objectives, activities and assessment

A well-designed lesson aligns what pupils are expected to learn, what they do and how their learning is checked. Table 4 maps the main cognitive objectives of the sequence onto the corresponding activities and assessment evidence, showing that every objective is both practised and assessed at least once.

Table 4: Alignment between objectives, activities and assessment evidence

Objective	Activity	Assessment evidence
Classify materials as solids or liquids	Brainstorming; H5P dialog cards	Correct responses in dialog cards; oral answers
Create mixtures of different types	Experiments A, B, C (Lesson 1)	Worksheets 1-3 (quantities and observations)
Distinguish uniform from non-uniform mixtures	Observation after stirring and waiting	Worksheet "separates YES/NO" column; class discussion
Classify everyday mixtures by type	H5P drag and drop (Fig 2)	Automatic feedback and group score
Match mixtures with separation methods	H5P drag and drop (Fig 3); matching worksheet	Correct placements; worksheet answers
Apply four separation methods	Experiments (Lesson 2, Phase B)	Experimental worksheet (Table 3)
Relate methods to everyday life	Story problem; examples in slides	Oral explanations; homework quiz

3.2 Addressing misconceptions

Several design choices deliberately target known alternative conceptions. The salt-in-water experiment, followed by the question of whether the salt can be recovered, confronts the idea that a dissolved substance "disappears" [4, 5]. Placing salt water and rice water side by side makes the contrast between a solution and a heterogeneous mixture directly observable. The oil-vinegar comparison shows that liquids also differ in whether they mix, countering the belief that all liquids blend together. In Lesson 2, the opening question of whether the mixtures created earlier can be separated, together with the inclusion of evaporation and sedimentation in the presentation, challenges the assumption that every mixture, even a perfume, can be taken apart by simple mechanical means in the way beans and lentils can [6].

Two refinements are suggested for teachers who adopt the sequence. First, the water-rice mixture is, strictly speaking, separated by straining (a form of sieving) rather than filtration through paper; a sand-water or chalk-water mixture would illustrate the specific function of filter paper more clearly. Second, the recovery of salt from salt water by evaporation, presented only in the slides, could be demonstrated by leaving a saucer of salt water near a window and observing it in the following lesson. This would close the conceptual loop between dissolving and recovering a solid and would connect to the next topic in the curriculum, water and its states [26].

3.3 Contribution of ICT

In this design ICT does not replace hands-on experimentation; it frames and consolidates it. The photographs at the start provide shared visual references, the H5P activities give each group instant feedback and make classification decisions visible to the whole class, and the e-Class course gives pupils access to the same activities at

home. This combination corresponds to the TPACK view that technology should serve a specific pedagogical purpose within specific content [12]. Retrieval-based homework activities, such as the crossword and the quiz, exploit the testing effect, which is known to strengthen long-term retention [11].

3.4 Practical considerations and limitations

The tight timing (five to ten minutes per experiment) requires materials to be pre-portioned per group and roles (materials manager, recorder, reporter) to be assigned in advance. Safety rules must be explicit, especially regarding tasting, which should be avoided, and the handling of iron filings, which should be kept away from eyes and collected with a magnet wrapped in a plastic bag. Equitable participation should be monitored, since in group work some pupils may dominate the manipulation of materials. Finally, the sequence has not yet been evaluated systematically. Its effectiveness should be examined in future work through pre- and post-tests of conceptual understanding, analysis of worksheets and H5P logs, and observation of group interaction, ideally in comparison with conventional teaching.

4. Conclusion

This paper presented a two-lesson, inquiry-based and ICT-enhanced sequence on mixing and separating materials for fourth-grade pupils. By linking the creation of mixtures directly to the problem of separating them, the sequence gives pupils a coherent experience of a central idea in chemistry: That the components of a mixture keep their properties, and that these properties determine how the mixture can be separated. The combination of everyday materials, structured worksheets, cooperative group work and H5P activities on e-Class makes the design inexpensive, reproducible and adaptable to different classroom conditions. Future work should implement the sequence in several classrooms and evaluate its impact on conceptual understanding, inquiry skills and attitudes towards science.

5. Recommendations

- Teach the two lessons consecutively and reuse pupils' own mixtures from Lesson 1 as the starting problem of Lesson 2.
- Prepare materials in labelled group kits and assign rotating group roles to protect the tight timing.
- Add a sand-water filtration and a salt-water evaporation demonstration to complete the set of separation methods.
- Use the H5P activity reports in e-Class as additional formative evidence of each pupil's progress.
- Collect systematic pre- and post-test data in future implementations to evaluate learning outcomes.

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