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Nadežda Žguna
DESIGNING COLLABORATIVE INQUIRY-BASED LEARNING
EXPERIENCES IN GRADE 8 CHEMISTRY CLASSROOMS
MA thesis

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Tartu, 2026

Abstract

Designing Collaborative Inquiry-Based Learning Experiences in Grade 8 Chemistry Classrooms

This study investigated the design and implementation of a collaborative inquiry-based teaching–learning sequence on solubility in Grade 8 chemistry. A structured, four-lesson sequence was implemented with 110 students at a Latvian school. Data included pre- and post-tests, student worksheets, classroom observations, and a reflection questionnaire. Results indicated improvement in students’ conceptual understanding of solubility and reduction of several common misconceptions. Worksheet analysis showed increasing use of evidence-based reasoning and collaborative meaning-making, while questionnaire responses highlighted positive perceptions of peer discussion. The findings suggest that collaborative, guided inquiry can effectively support conceptual understanding in authentic chemistry classroom settings.

Keywords: chemistry education, inquiry-based learning, collaborative learning, guided inquiry, conceptual understanding.

Table of Contents

Introduction	4
Purpose of the Study	5
Theoretical Overview	6
The Challenge of Chemistry Education in Lower Secondary School.....	6
Inquiry-Based Learning in Science Education.....	8
Collaborative Inquiry in Science Education.....	11
Methods	13
Research Design.....	13
Sample and Context	14
Data Collection.....	14
Data Analysis.....	17
Ethical Considerations.....	18
Results and Discussion	18
Pre-test and Post-test Results: Conceptual Understanding of Solubility	18
Worksheet analysis: Reasoning and collaborative meaning-making	24
Students' perceptions of collaborative learning and groupwork.....	28
General Discussion of the Results.....	32
Further Development of the TLS	34
Acknowledgments.....	36
Author's Declaration.....	37
References	38
Appendix 1. Lesson 1 worksheets	
Appendix 2. Lesson 2 worksheets	
Appendix 3. Lesson 3 (lab work) worksheets	
Appendix 4. Lesson 4 worksheets	

Introduction

Chemistry education in lower secondary school presents challenges that extend beyond teaching factual knowledge. Students are expected not only to learn chemical concepts but also to develop scientific reasoning, problem-solving abilities, and inquiry skills. However, chemistry is inherently difficult because meaningful understanding requires students to connect observable phenomena with invisible submicroscopic processes and symbolic representations such as formulas and equations (Johnstone, 1982). At the same time, modern science curricula increasingly emphasize inquiry learning, critical thinking, and active student participation, creating a need for instructional approaches that support deeper conceptual understanding and scientific thinking in authentic classroom settings.

Inquiry-Based Learning (IBL) has become one of the central approaches promoted in science education because it encourages students to actively investigate problems, evaluate evidence, and construct explanations rather than passively receive information (Constantinou et al., 2018). Research suggests that inquiry-based approaches can support conceptual understanding, motivation, and scientific literacy when implemented effectively (Pedaste et al., 2015). In particular, guided inquiry is considered more appropriate for novice learners than minimally guided or fully open inquiry, as it combines student activity with structured instructional support (Blanchard et al., 2010; Kirschner et al., 2006). Collaborative inquiry further supports learning by enabling students to share reasoning, discuss ideas, and distribute the cognitive demands of complex tasks. However, there is limited research exploring how collaborative guided inquiry functions in lower secondary chemistry, where students are still developing formal reasoning skills.

Despite the potential benefits of inquiry-based approaches, their implementation in regular chemistry classrooms remains challenging. Teachers often face structural constraints such as limited laboratory resources, large class sizes, time pressure, and content-heavy curricula (Orosz et al., 2022; Stojanovska et al., 2020). In addition, students may struggle with important aspects of inquiry, including hypothesis formation, evidence evaluation, and overcoming misconceptions or confirmation bias (Orosz et al., 2022). Previous research has often focused on relatively short-term interventions or contexts with substantial instructional support, while fewer studies have examined how collaborative guided inquiry can be systematically designed and implemented in authentic lower secondary chemistry classrooms as part of regular teaching practice (Anderson & Shattuck, 2012).

Therefore, there is a need for research that combines guided inquiry, structured collaboration, and design-based research in authentic lower secondary chemistry settings. Such work can contribute to both the theoretical understanding of inquiry processes and the practical development of implementable instructional designs.

Purpose of the Study

The purpose of this study is to design, implement, and investigate a collaborative inquiry-based Teaching–Learning Sequence (TLS) for Grade 8 chemistry. The study examines how structured collaborative inquiry can be realized in a lower secondary classroom and how participation in such instruction influences students’ conceptual understanding of solubility and their collaborative learning experiences.

Although inquiry-based learning is widely promoted in science education, its effectiveness depends on how it is structured and supported in classroom practice. Guided inquiry is particularly suitable for lower secondary students because it combines student autonomy with instructional scaffolding, while collaborative inquiry may further support reasoning and conceptual understanding through shared problem-solving. This study designs and implements a collaborative inquiry-based TLS in an authentic classroom setting using a single-cycle design-based research approach. Data are collected through students’ written work, classroom observations, pre- and post-tests, and student questionnaires on collaboration and learning experiences. While the TLS is designed to foster the development of inquiry skills, the systematic assessment of these skills lies beyond the scope of the present study and may serve as a focus for future research. Instead, this study concentrates on (a) the design and implementation of collaborative guided inquiry activities in a Grade 8 chemistry classroom and (b) their influence on students’ conceptual understanding and collaborative classroom experiences.

Research Questions

- 1) How can collaborative inquiry-based learning activities be designed and implemented in a Grade 8 chemistry classroom?
- 2) How does participation in collaborative inquiry-based lessons influence students’ conceptual understanding of solubility?
- 3) How do students perceive collaborative inquiry-based learning and groupwork during the implemented teaching–learning sequence?

Theoretical Overview

The Challenge of Chemistry Education in Lower Secondary School

Chemistry education in lower secondary school faces ongoing challenges that go beyond simply teaching facts. In addition to learning content, students are expected to develop scientific thinking and inquiry skills, which can be difficult to achieve in regular classroom settings. In many classrooms, instructional practice continues to emphasize traditional teacher-led approaches, while curriculum reforms in Latvia have aimed to integrate scientific inquiry more explicitly into chemistry education. Overall, effectively organizing and supporting student inquiry remains a challenge, indicating a gap between curricular aspirations and classroom realities (Volkinsteine et al., 2014).

The Inherent Difficulty of Chemistry

A primary barrier is the abstract nature of chemistry itself. To truly understand the subject, students must think simultaneously at three levels: the macroscopic (visible properties), the submicroscopic (invisible atoms and molecules), and the representational (symbols and formulas) (Johnstone, 1982). Many students find the chemical specialist language hard to understand and to relate to the invisible and untouchable. Textbooks can even make this worse by presenting science as a set of fixed facts, rather than showing that scientific knowledge develops through questioning, uncertainty, and human effort (Cardellini, 2017).

Environmental and Structural Obstacles

Environmental and structural conditions in chemistry education often make it difficult to implement active, inquiry-based learning. These barriers range from limited physical resources to systemic issues within curriculum design and educational policy. As a result, even teachers who value inquiry-based approaches may struggle to apply them consistently.

One major obstacle is the lack of adequate infrastructure and resources. Many schools lack properly equipped laboratories, forcing experiments to be conducted in regular classrooms. Teachers often lack essential materials and must manage preparation, safety, and cleanup on their own, which increases their workload and limits practical work (Orosz et al., 2022; Stojanovska et al., 2020).

Classroom dynamics also limit what is pedagogically possible. Large class sizes, ranging from 30 to 35 students and sometimes more, make it difficult for a single teacher to

effectively monitor several experimental groups. High student-to-teacher ratios increase safety risks during practical activities, leading teachers to reduce or avoid laboratory work altogether (Gafoor, 2024; Orosz et al., 2022; Stojanovska et al., 2020).

Pedagogical Challenges and Teacher Qualifications

The effectiveness of chemistry education is deeply tied to the teacher. However, many schools lack professionalism, with non-chemistry graduates being asked to teach the subject due to staff shortages (Stojanovska et al., 2020).

In their book “Visible Learning and the Science of How We Learn”, Hattie and Yates identify the main pedagogical challenges in teaching science. They claim that a significant challenge in science teaching stems from the “curse of knowledge,” in which expert teachers underestimate the difficulties that novice learners face. Because experts rely on automated, tacit knowledge, they may omit essential step-by-step explanations and use abstract language that beginners struggle to process. Also, teacher-led recitation methods limit sustained attention, while time-pressured curricula encourage superficial coverage rather than deep conceptual integration. As a result, students may develop fragmented knowledge rather than coherent scientific understanding.

Science learning also imposes a high cognitive load. Students must often coordinate multiple interacting elements simultaneously, which can overwhelm working memory. When learners are asked to solve complex problems before mastering foundational knowledge, cognitive resources are diverted from building stable mental structures. Research therefore suggests that novices benefit more from guided instruction and worked examples than from unguided problem-solving. In addition, students often enter science classrooms with persistent misconceptions. These are resistant to traditional lecture-based explanations and require structured challenge, discussion, and targeted feedback to be meaningfully revised (Yates & Hattie, 2013).

Assessment systems and policy decisions can complicate the implementation of inquiry-based science learning. Standardized tests frequently emphasize factual recall rather than higher-order reasoning, encouraging teaching practices focused on memorization (Gafoor, 2024; Orosz et al., 2022).

Finally, rapid curriculum reforms, such as mirroring foreign systems without providing necessary handbooks or assistants, introduced without sufficient support or consultation, may leave teachers feeling unprepared (Stojanovska et al., 2020; Volkinsteine et

al., 2014). Together, these structural factors significantly shape what is realistically possible in chemistry classrooms.

Inquiry-Based Learning in Science Education

Inquiry-Based Learning (IBL) has become a key approach in modern science education, shifting classrooms from passive listening to active exploration (Constantinou et al., 2018; Fadillah et al., 2025). In chemistry, where students must understand abstract ideas and symbolic representations, IBL helps make the often invisible world of atoms and molecules more understandable (Cardellini, 2017). However, IBL is not limited to conducting experiments; it also involves identifying problems, asking meaningful questions, evaluating evidence, and developing well-reasoned conclusions (Constantinou et al., 2018; Volkinsteine et al., 2014).

Constructivist Foundations of IBL

The theoretical bedrock of inquiry-based learning is constructivism, a philosophy of learning that asserts that knowledge is actively constructed by the learner rather than being absorbed from a teacher. This perspective is grounded in the work of several key theorists:

- John Dewey is often referred to as the father of experiential education. Dewey rooted inquiry in human experience and “learning by doing”. He argued that scientific knowledge should be obtained from phenomena and that reflection is vital to the learning process (Cheng et al., 2019; Constantinou et al., 2018).
- Jean Piaget’s work on conceptualization and knowledge construction emphasized the role of individual experience in building mental models (Constantinou et al., 2018).
- Lev Vygotsky highlighted the social meaning of learning, suggesting that reasoning and understanding are social processes best fostered through interaction with peers and mentors (Constantinou et al., 2018; Gomez, 2025).
- Jerome Bruner promoted discovery learning, where students go “beyond the information provided” to solve problems in a manner that resembles the scientific process (Constantinou et al., 2018; Kotsis, 2024).

Inquiry Cycle Models

To guide students through the complex scientific process, researchers have developed various inquiry cycles that divide the experience into logically connected units (Pedaste et al., 2015;

Pozuelo-Muñoz et al., 2025). One of the most comprehensive frameworks is the synthesized inquiry cycle by Pedaste et al. (2015), which identifies five general phases:

1. Orientation (stimulating interest in a topic through a problem statement).
2. Conceptualization (students generating research questions and hypotheses).
3. Investigation (data generation, experimentation, and data interpretation).
4. Conclusions (comparing data inferences with the original hypotheses).
5. Discussion (students present findings and engage in reflection).

Other standard inquiry cycle models include the 5E instructional model (Engagement, Exploration, Explanation, Elaboration, and Evaluation) (Bybee et al., 2006) and the POE model (Prediction, Observation, and Explanation) (Fadillah et al., 2025), both of which could be used to structure chemistry lessons.

Levels of Inquiry in IBL

The effectiveness of IBL is often determined by the degree of student autonomy and the amount of information provided by the teacher. These are generally categorized into four levels (Blanchard et al., 2010; Vilela et al., 2025):

- *Level 0 or Confirmation Inquiry.* The teacher provides the research question and the procedure, and the results are known in advance; students verify the principle.
- *Level 1 or Structured Inquiry.* The teacher provides the question and the procedure, but students must reach their own conclusions based on evidence.
- *Level 2 or Guided Inquiry.* The teacher provides the problem or question, but students are responsible for designing the experimental methods and interpreting the results. This is the "sweet spot" for many secondary students, providing a balance of freedom and support.
- *Level 3 or Open Inquiry.* Students formulate their own questions, design their own procedures, and determine their own conclusions. This level requires advanced reasoning and is often the most challenging for novices.

Benefits and challenges of IBL

Quantitative research supports IBL as a superior instructional approach. Meta-analyses have reported strong effect sizes (Hedges's $g = 0.893$) favoring IBL over traditional instruction. Inquiry-Based Learning offers several important benefits for science education. It promotes higher-order thinking skills such as critical thinking, problem-solving, and metacognitive

awareness. Providing students with opportunities for choice and autonomy can increase engagement and motivation while helping reduce anxiety about learning science. In addition, IBL supports the development of collaborative skills and scientific literacy, which are essential for addressing complex societal challenges. Research also suggests that active participation in investigations enhances long-term retention of scientific concepts compared to passive instructional approaches (Gomez, 2025; Pedaste et al., 2015).

Despite its widespread support, inquiry-based learning has also been subject to substantial criticism. From the perspective of cognitive load theory, minimal guidance may be ineffective for novices because it fails to account for the limits of working memory, leading to open problem-solving that creates excessive cognitive load and does not support long-term learning (Kirschner et al., 2006). In addition, the so-called “expert blind spot” can lead teachers to underestimate task difficulty and to rely on abstract language that beginners struggle to understand (Yates & Hattie, 2013). Practical constraints further complicate implementation, as inquiry-based approaches are time-consuming and often conflict with content-heavy curricula, resulting in fragmented understanding (Constantinou et al., 2018; Orosz et al., 2022). Finally, successful implementation requires strong pedagogical content knowledge, and some teachers may lack the preparation or confidence needed to move beyond traditional teacher-centered instruction (Pedaste et al., 2015).

IBL in Chemistry Education

Chemistry presents unique pedagogical challenges because meaningful understanding in chemistry requires students to coordinate macroscopic, submicroscopic, and symbolic levels of representation simultaneously. IBL helps bridge these gaps by allowing students to see macroscopic changes and then use inquiry to model what is happening at the submicroscopic level (Cardellini, 2017). However, chemistry students often suffer from confirmation bias. In a case study involving 9th-graders, more than half of the students disregarded contradictory experimental evidence and accepted their original hypotheses to appear successful (Orosz et al., 2022). This highlights the need for teachers to act as facilitators, clarifying the scientific model of experimentation (finding causal relations) versus the engineering model (merely seeking a desired outcome).

Collaborative Inquiry in Science Education

Collaborative inquiry in science education combines inquiry-based learning with structured group work, shifting the classroom from individual task completion to shared knowledge construction (Chen & Chen, 2025; Manalo & Chua, 2020). In this approach, students work together to carry out key elements of scientific practice, such as formulating hypotheses, gathering evidence, and developing explanations. Through discussion and negotiation, understanding is built socially rather than individually (Chen & Chen, 2025). Collaborative inquiry is grounded in social constructivist perspectives, particularly those influenced by Vygotsky, which emphasize that learning develops through interaction (Constantinou et al., 2018). As students explain, question, and critique each other's ideas, they engage in meaningful argumentation that deepens conceptual understanding. This shared reasoning process encourages students to clarify their thinking and justify their claims (Cheng et al., 2019).

Group work plays an important cognitive and motivational role in the inquiry process. From the perspective of cognitive load theory, complex scientific tasks can easily overwhelm an individual student's working memory. When students work in small, well-structured groups, they can distribute the cognitive demands of the task. In this way, the group functions as a shared problem-solving system, enabling students to manage complexity more effectively than they might alone (Yates & Hattie, 2013).

In addition, working in teams can strengthen collective efficacy. When students perceive their group as capable and supportive, they are more likely to remain engaged and persist with challenging tasks. Collaborative settings also promote knowledge integration, as students bring prior understandings into discussion and negotiate the meaning of new, abstract concepts. This interaction can help surface and address misconceptions more effectively than individual work alone (Cheng et al., 2019; Sun et al., 2013).

Role of the teacher as facilitator

In a collaborative inquiry environment, the teacher's role changes significantly. Instead of simply delivering information, the teacher becomes a facilitator and learning guide, supporting students as they work through complex problems. This involves carefully planning and organizing activities, as well as providing structured support such as guiding questions, checklists, or templates that help students think through tasks without giving them direct answers (Constantinou et al., 2018; Kotsis, 2024).

Rather than following a fixed script, the teacher must pay close attention to the specific needs of different groups. By observing discussions and progress, the teacher can offer timely feedback that helps students move forward and refine their thinking. At the beginning of open-ended inquiry tasks, students may feel uncertain or disoriented. In these moments, the teacher plays an important role in clarifying goals, ensuring that everyone understands the research question, and establishing a clear starting point (Pozuelo-Muñoz et al., 2025; Vilela et al., 2025; Yates & Hattie, 2013).

Finally, effective collaborative inquiry depends on a supportive classroom climate. Teachers must foster an atmosphere of trust where students feel safe to express uncertainty, ask questions, and make mistakes. Such an environment encourages open dialogue and helps students engage more deeply in the learning process (Yates & Hattie, 2013).

Benefits and challenges of collaborative inquiry

Collaborative inquiry has been shown to benefit students in cognitive, social, and emotional ways. Research indicates that it can improve academic achievement, including conceptual understanding and higher-order thinking skills, compared to more traditional forms of instruction (Gomez, 2025). It also supports the development of important competencies such as critical thinking, scientific reasoning, communication, and collaborative problem-solving (Chen & Chen, 2025; Manalo & Chua, 2020). Students often report higher levels of motivation and engagement when they are given some autonomy and can work socially with peers. In addition, collaborative inquiry can reduce science anxiety and promote more positive attitudes toward the subject. By encouraging students to debate ideas, evaluate evidence, and discuss socio-scientific issues, it also prepares them for informed participation in real-world decision-making (Constantinou et al., 2018; Manalo & Chua, 2020; Sun et al., 2013).

Despite these advantages, implementing collaborative inquiry presents considerable challenges. It is time-consuming and may conflict with curriculum pressures that require teachers to move quickly through content (Yates & Hattie, 2013). Large class sizes can make it difficult for a single teacher to monitor multiple groups and provide meaningful, effective feedback (Cheng et al., 2019; Stojanovska et al., 2020). Within groups, unequal participation can occur, with some students dominating while others remain passive (Gafoor, 2024). Without careful guidance, misconceptions may persist or even strengthen, especially if students ignore evidence that contradicts their initial ideas (Orosz et al., 2022).

In sum, collaborative inquiry offers significant potential to promote scientific literacy and student engagement. However, its success depends on thoughtful design, ongoing teacher

support, and a classroom culture that values exploration and reasoning as much as correct answers.

Methods

Research Design

This thesis adopts a design-based research (DBR) approach, focusing on the design and implementation of an instructional intervention in an authentic classroom context. DBR is particularly suited to addressing the gap between educational theory and classroom practice by systematically studying learning environments in real-life settings. In contrast to controlled experimental approaches, DBR examines how educational innovations function within the complexity of everyday classroom conditions, where learning emerges through interactions between students, teachers, materials, and context (Baumgartner et al., 2002).

This approach aligns directly with the research gap identified in this thesis, which highlights the need for studies that design and implement inquiry-based TLS in regular lower secondary chemistry classrooms. DBR emphasizes the development and testing of meaningful instructional interventions that are responsive to contextual constraints and can inform both practice and theory (Anderson & Shattuck, 2012; Baumgartner et al., 2002). Therefore, it provides an appropriate framework for investigating how a collaboratively structured, guided inquiry sequence can be enacted in a real classroom and how it supports students' conceptual understanding under typical school conditions.

The study involved the design and implementation of a four-lesson Teaching–Learning Sequence on solubility, based on the principles of guided inquiry and collaborative learning. Students worked in groups of three to four on structured tasks that involved conducting experiments, interpreting observations, discussing ideas, and constructing explanations. All groups completed identical tasks to ensure consistency and comparability of both the learning experience and the collected data. The intervention followed a single-cycle design and aimed to explore how collaborative guided inquiry supports students' conceptual understanding in practice.

The inquiry design was highly structured. Students were not required to design experimental procedures; instead, the focus was placed on interpreting results and constructing explanations. This approach is consistent with research suggesting that guided

inquiry is more effective than minimally guided approaches for novice learners (Blanchard et al., 2010; Kirschner et al., 2006).

Collaboration was a central element of the design. Students were expected to discuss ideas, compare explanations, and justify their reasoning within their groups. Such collaborative inquiry settings are known to support conceptual understanding through shared reasoning and distributed cognitive load (Chen & Chen, 2025; Manalo & Chua, 2020).

Sample and Context

The study was conducted in a State Gymnasium in Riga, Latvia. The sample included 110 Grade 8 students (aged 14–15) from four classes, with 27–30 students in each class. All participants were taught by the author of this thesis during the 2025–2026 school year. The majority of students were academically capable and generally well-motivated, allowing for the implementation of cognitively demanding tasks involving reasoning and discussion.

The intervention took place during regular chemistry lessons under typical classroom and school laboratory conditions. These included standard time constraints (40 minutes per lesson) and the management of multiple student groups by a single teacher.

Data Collection

Data collection consisted of four stages:

1. **Pre-test** to assess students' prior conceptual understanding of solubility.
2. **Implementation of the four-lesson TLS**, during which students engaged in group work in both the regular classroom and the school laboratory, generating written artifacts (worksheets).
3. **Post-test** to assess students' conceptual understanding after the intervention.
4. **Reflection questionnaire** to capture students' perceptions of their learning and collaborative experiences.

Multiple data sources were collected to capture both learning outcomes and students' experiences: pre- and post-tests, groupwork artifacts (worksheets), and a reflection questionnaire.

Pre- and post-tests

The pre- and post-tests, consisting primarily of open-ended questions, were designed to assess students' conceptual understanding of solubility.

In pre–post designs, test instruments may be either identical or parallel (i.e., similar in structure but with different items). Identical tests allow for more direct comparison of responses but may introduce recall effects, whereas parallel tests reduce recall but may limit comparability if tasks differ in difficulty (Cohen et al., 2007; Fraenkel et al., 2012). In this study, the tests were designed to be closely comparable in structure and content, with minor variations in item formulation, in order to balance comparability with reduced recall effects.

The study follows a one-group pretest–posttest design, in which the same group of students is assessed before and after the intervention. While this design is widely used in classroom-based research, it is considered methodologically limited because it does not control for external factors such as maturation or prior experience (Fraenkel et al., 2012). However, using a control group was not feasible in this context due to practical and ethical considerations, including limited instructional time and the need to provide all classes with the same learning opportunities. The design was therefore considered appropriate for exploring changes in students' conceptual understanding within a regular classroom setting.

Content validity was supported by aligning test items with the key concepts addressed in the instructional sequence.

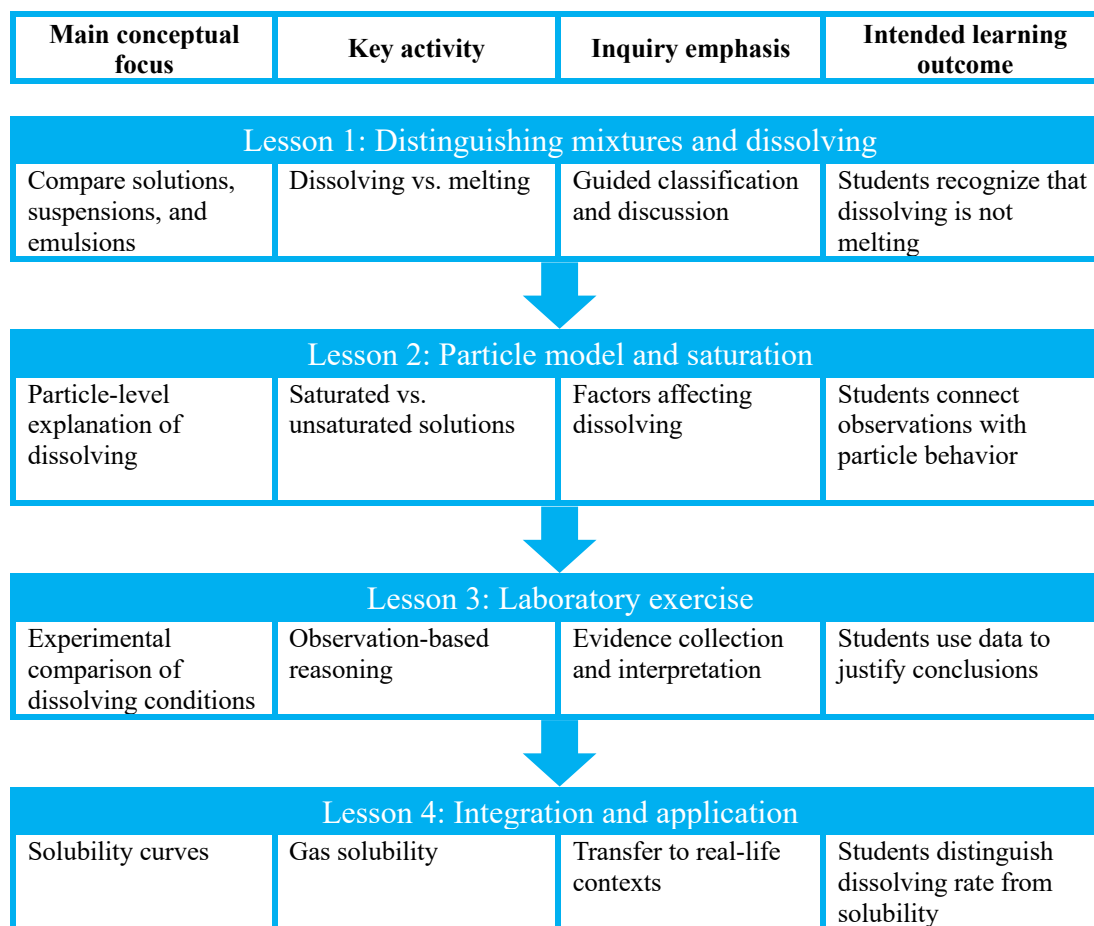
Group artifacts (student worksheets)

Student worksheets produced during the inquiry activities were collected as a primary source of data on the students' learning processes. During the lessons, students completed worksheets individually, and each group also produced a final shared version for submission. The shared worksheet was collected, while individual worksheets were retained by students for their own learning and revision.

The teaching–learning sequence consisted of four 40-minute lessons, each focusing on a different aspect of solubility. The lessons were designed to build progressively from distinguishing types of mixtures and understanding the dissolving process to particle-level explanations, experimental investigation, and the application of concepts such as solubility curves and gas solubility. Figure 1 provides an overview of the sequence and its conceptual progression.

The worksheets were aligned with the specific learning goals of each session. They included primarily open-ended tasks requiring students to record observations, construct explanations, and justify their reasoning. In addition, worksheets provided structured prompts, supporting information, and visual elements (e.g., guiding illustrations) to scaffold students' thinking.

Figure 1. Overview of the four-lesson teaching–learning sequence, illustrating the progression from macroscopic observations to particle-level explanations, experimental investigation, and integrated conceptual understanding.



Altogether, these artifacts provide insight into how students developed their understanding during the inquiry process, including the construction of explanations and the presence of misconceptions. The use of student-generated artifacts is recommended in inquiry-based research, as it allows for the analysis of reasoning processes rather than only final learning outcomes (Orosz et al., 2022; Pedaste et al., 2015). Worksheets for all lessons are included in the appendices.

Reflection questionnaire

A reflection questionnaire was administered at the end of the intervention to capture students' perceptions of their collaborative work and learning experiences. The use of self-report questionnaires is well established in educational research for examining aspects of learning that are not directly observable, such as engagement, collaboration, and perceived understanding (Hadwin et al., 2025; Heirweg et al., 2019). In the context of collaborative

learning, student-reported data are particularly important for capturing group interaction, participation, and shared problem-solving processes (Johnson & Johnson, 2009).

The questionnaire was based on the Groupwork Skills Questionnaire (GSQ), which assesses students' perceptions of task-related and interpersonal groupwork skills. The GSQ has demonstrated content and structural validity, as well as acceptable internal reliability, making it a suitable foundation for examining group dynamics in educational settings (Cumming et al., 2014). For the purposes of this study, the questionnaire was adapted to refer specifically to students' experiences within the implemented TLS. In addition to the original GSQ dimensions, several items were added to capture students' perceptions of their learning in a collaborative inquiry setting, including perceived understanding and the role of group discussion in supporting explanation-building. This adaptation was based on research on cooperative learning, which shows that effective group work involves not only managing tasks and interacting with others, but also building understanding together through discussion and shared reasoning (Gillies, 2007). The original Likert-scale format was retained to maintain consistency with the validated structure of the questionnaire.

The optional open-ended questions were added at the end of the questionnaire, allowing students to elaborate on their experiences in their own words and providing additional qualitative insight into both group dynamics and perceived learning.

Data Analysis

Data analysis combined quantitative and qualitative approaches to examine changes in students' conceptual understanding as well as their learning processes and experiences. Data from multiple sources were analyzed to ensure a more comprehensive understanding of the results.

Pre- and post-test responses were analyzed to identify changes in students' conceptual understanding of solubility. A quantitative comparison focused on overall performance, while qualitative analysis of open-ended responses examined the nature of students' explanations and identified recurring misconceptions.

Student worksheets were analyzed qualitatively as evidence of learning processes. The analysis focused on the correctness of explanations, the development of reasoning, and common patterns in students' understanding across groups.

Responses to the reflection questionnaire were analyzed using a combination of descriptive and qualitative methods. Likert-scale items were summarized to provide an

overview of students' perceptions, while open-ended responses were analyzed using simple thematic coding to identify recurring themes related to collaboration and perceived learning.

Ethical Considerations

The study was conducted in accordance with ethical guidelines for educational research in Estonia (Eessalu et al., 2023). Participation in the research component of the study was voluntary. The intervention took place during regular classroom lessons, and while all students participated and completed the required classroom activities, they were given the option to opt out of having their data used for research purposes. Informed consent was obtained from parents or guardians, and assent was obtained from students. Students were informed that they could withdraw their data from the study at any time without negative consequences.

Given the researcher's dual role as classroom teacher, particular care was taken to minimize pressure to participate. No grades were assigned to the work completed during the TLS. The reflection questionnaire was completed anonymously, with no identifying information collected. All collected data were anonymized prior to analysis, and only aggregated results are reported in the thesis to ensure confidentiality.

Results and Discussion

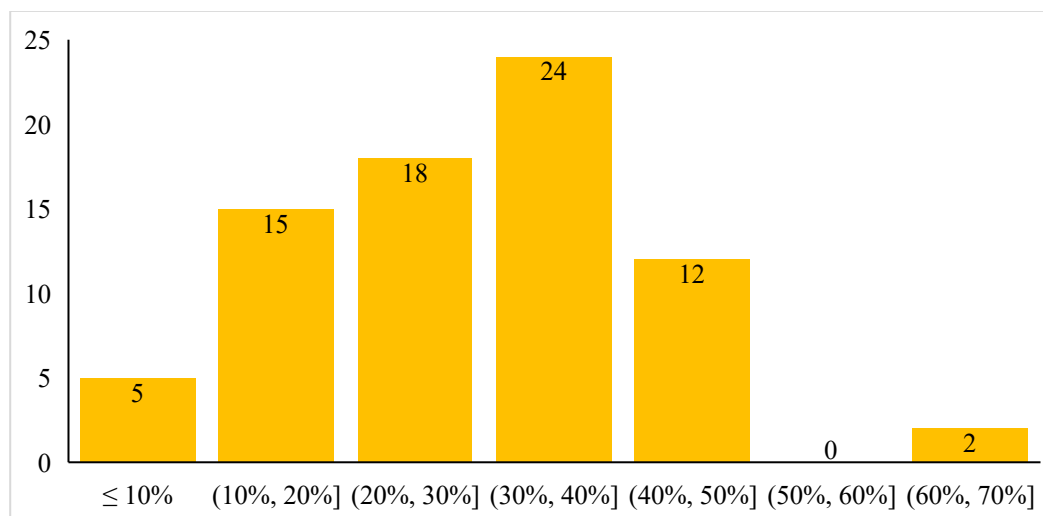
Pre-test and Post-test Results: Conceptual Understanding of Solubility

This section addresses the research question: How does participation in collaborative inquiry-based lessons influence students' conceptual understanding of solubility? The analysis combines quantitative comparison of pre- and post-test results with qualitative examination of student responses, with particular attention to conceptual development and misconceptions.

Overall performance and learning gains

To evaluate changes in conceptual understanding, matched pre- and post-test data were analyzed for 78 students who completed both assessments. The mean score increased from 41% in the pre-test to 71% in the post-test, indicating a substantial improvement in students' performance. Notably, all 78 matched students demonstrated an increase in their individual scores. The variability in individual gains is further illustrated in Figure 2, which shows a distribution of score increases across students, with most gains concentrated in the mid-range.

Figure 2. Distribution of individual score gains (%) between pre-test and post-test, showing variability in learning gains across students (n = 78).



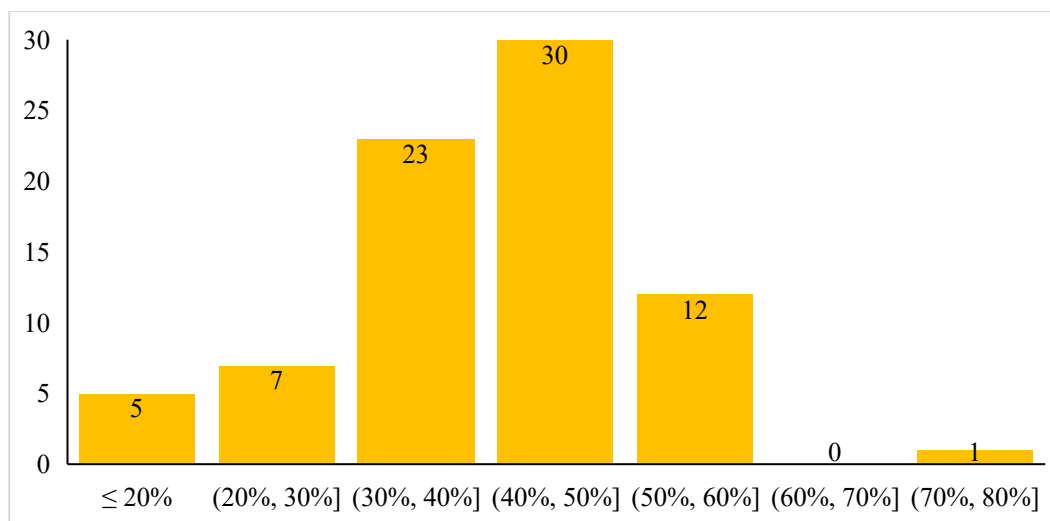
The magnitude of improvement varied considerably, ranging from 7% to 64%, with most students showing gains in the 25–40% range, and an average gain of 31%. This variation indicates that, while the instructional sequence supported learning for all participants, the extent of conceptual development varied among participants.

Given the one-group pretest–posttest design, this improvement should be interpreted cautiously, as it cannot be attributed solely to the intervention without considering potential external influences such as maturation or prior learning experiences (Fraenkel et al., 2012). However, the consistency of improvement across nearly all students suggests a meaningful shift in conceptual understanding during the implemented TLS. From a theoretical perspective, such broad improvement is consistent with research indicating that guided inquiry approaches, particularly those that provide structured support for novice learners, can effectively promote conceptual development (Blanchard et al., 2010; Kirschner et al., 2006).

Distribution of results

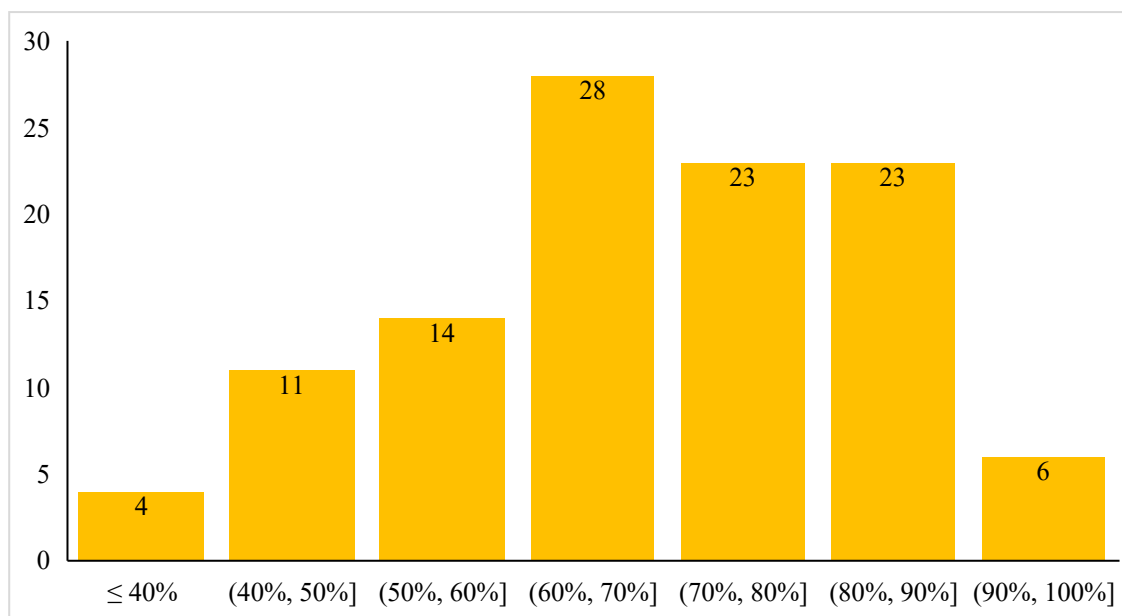
Although the increase in mean scores indicates overall improvement, a more detailed understanding of student learning requires examining how results are distributed across the group. The distribution of scores provides insight into patterns of performance, including clustering, spread, and shifts across achievement levels. Figures 3 and 4 present the distribution of student scores in the pre-test and post-test.

Figure 3. Distribution of pre-test scores (%) across students ($n = 80$), showing a concentration of results in the lower and lower-middle performance ranges.



The pre-test results in Figure 3 show a distribution concentrated in the lower and lower-middle performance ranges, with most students scoring below 50%. This clustering confirms that, prior to the intervention, students' conceptual understanding of solubility was limited and relatively homogeneous at a lower level.

Figure 4. Distribution of post-test scores (%) across students ($n = 111$), showing a shift toward higher performance ranges and a more dispersed distribution.



In contrast, the post-test distribution in Figure 4 shifts clearly toward the middle and higher performance ranges, with a peak in the 60–70% interval. In addition to this rightward shift, the distribution becomes less compressed and more spread out, indicating increased

differentiation in student performance. This change in distribution can be interpreted in two ways. First, the overall shift toward higher score ranges reflects improved conceptual understanding across the group. Second, the increased spread indicates that while most students improved, they did so to varying degrees, potentially reflecting differences in how individual students engaged with and benefited from the instructional activities.

From a learning perspective, such a pattern aligns with the idea that guided inquiry does not produce uniform outcomes, but rather supports learning trajectories that depend on students' prior knowledge, participation, and interaction with the learning environment. The observed shift without excessive compression at the top end also demonstrates that the tasks remained cognitively demanding, allowing stronger students to extend their understanding rather than reaching an artificial ceiling.

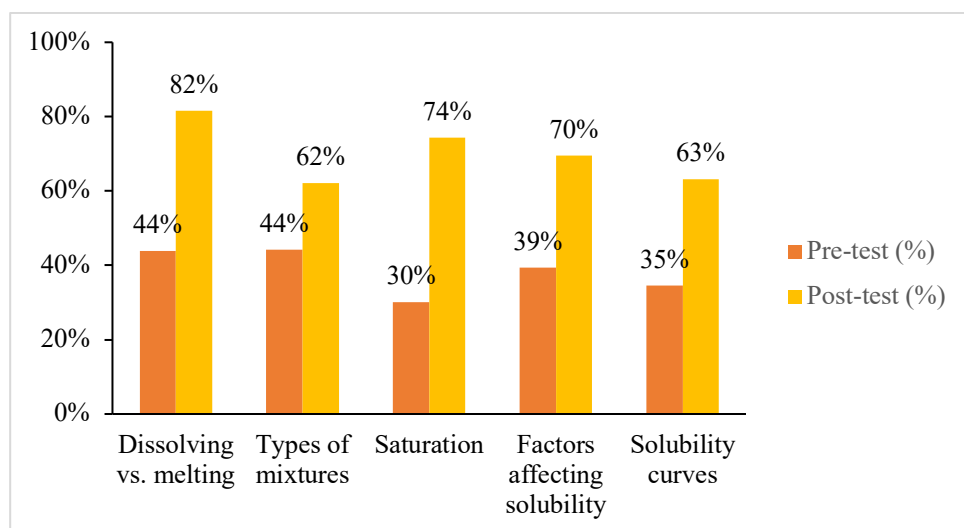
Task- and topic-level analysis

To gain a more detailed understanding of conceptual development, tasks were grouped by key conceptual areas addressed in the TLS:

1. dissolving vs. melting,
2. types of mixtures (solutions, suspensions, emulsions),
3. saturation,
4. factors affecting solubility,
5. interpretation of solubility curves.

Across most conceptual areas, a clear increase in the proportion of correct responses was observed from pre-test to post-test, as summarized in Figure 5.

Figure 5. Pre-test and post-test performance across five conceptual categories, demonstrating improvements in students' understanding of key concepts related to solubility.



For the **dissolving vs. melting** tasks, a substantial number of students in the pre-test described dissolving as a process involving melting or physical disappearance. In the post-test, this misconception was almost completely resolved, with the majority of students correctly identifying dissolving as a process involving the distribution of particles within a solvent. Only a small number of isolated cases retained elements of the initial misconception. This suggests that the TLS effectively supported students in distinguishing between macroscopic observations and underlying processes.

Pre-test responses to tasks on **saturation and amount of substance** often reflected the idea that substances “stop dissolving because there is more solute than solvent,” without reference to saturation. In the post-test, students more frequently used the concept of saturation to explain this limit. This indicates a substantial conceptual shift, although some responses still relied on partially intuitive reasoning. The improvement shows that repeated exposure to comparative tasks and guided interpretation helped students refine their explanations.

A notable misconception in the pre-test regarding the **factors affecting solubility** was the belief that density determines solubility. This misconception was fully resolved in the post-test, with students no longer referring to density as a relevant factor. Instead, responses more frequently focused on appropriate variables such as temperature or the nature of the substances involved.

Students demonstrated a high level of understanding in interpreting solubility curves, particularly in identifying whether a solution is saturated or unsaturated under given conditions. While some difficulties remained in more complex interpretations, overall performance indicates that students were able to use graphical representations effectively after the intervention.

In contrast to other areas, little improvement was observed in students’ **use of formal terminology**. Many students continued to rely on descriptive expressions such as “layered mixture” or “non-dissolved matter” rather than using correct scientific terms. So, while students may have developed an adequate intuitive understanding of observable differences, this did not consistently translate into accurate use of terminology. This pattern persisted throughout the TLS, suggesting that students were still transitioning toward scientific discourse and that terminology required more explicit reinforcement.

Misconceptions: development and change

Analysis of open-ended responses revealed several key misconceptions in the pre-test, including:

- the idea that dissolving involves melting,
- the belief that density determines solubility,
- and the assumption that substances stop dissolving simply because there is “too much” solute.

Following the intervention, most of these misconceptions were either fully resolved or significantly reduced, leaving only a few isolated cases. This pattern is consistent with research on conceptual change, which emphasizes the importance of structured challenge and guided explanation in revising prior knowledge.

An additional finding from the post-test data was, surprisingly, the **emergence of a new misconception**: a number of students wrote that a new substance forms during dissolution. This idea was not present in the pre-test and therefore appears to have developed during the instructional sequence.

One possible explanation for this development lies in the design of the first lesson and its associated worksheets. The tasks in Lesson 1 focused primarily on macroscopic observation and comparison (e.g., identifying whether a substance “disappears” or remains visible), while only implicitly addressing the underlying nature of the dissolving process. For example, students were prompted to consider whether a substance “disappears” during dissolving, but were not yet explicitly guided to interpret this observation in terms of particle distribution within a solvent. As a result, students may have attempted to reconcile the apparent disappearance of a substance with their existing conceptual frameworks, leading them to construct an explanation in which a new substance forms.

This effect may have been further reinforced by the instructional approach used in the first lesson. At the beginning of the sequence, students were introduced directly to the worksheets without a prior conceptual overview. Observations from the lesson indicate that many students initially experienced uncertainty about how to approach the tasks. In such situations, students are more likely to rely on intuitive reasoning or collectively constructed explanations within their groups. While collaborative work can support conceptual development, it may also contribute to the stabilization of partially incorrect ideas if not sufficiently guided.

In response to this, subsequent lessons included a short theoretical introduction before group work, providing students with a clearer conceptual starting point. This adjustment

reflects the importance of balancing inquiry with structured guidance, particularly for novice learners, and is consistent with research stating that some level of explicit framing is necessary to support effective conceptual understanding

The appearance of such a misconception highlights an important characteristic of conceptual learning: as students move beyond purely descriptive reasoning, they may construct new, partially incorrect explanatory models. This reinforces the need for continued instructional support and iterative refinement of understanding.

Interpretation of results in relation to instructional design

Overall, the results demonstrate that participation in the collaboratively structured, guided inquiry-based TLS was associated with a substantial improvement in students' conceptual understanding of solubility, as reflected in both quantitative gains and qualitative changes in explanations.

The pattern of improvement, particularly the widespread gains across students and the reduction of key misconceptions, aligns with theoretical perspectives emphasizing the effectiveness of guided inquiry for novice learners. By providing structured tasks, scaffolding, and opportunities for interpretation rather than requiring students to independently design procedures, the TLS likely reduced cognitive load and supported more focused conceptual development (Blanchard et al., 2010; Kirschner et al., 2006).

The findings also illustrate that conceptual development is not uniform across all areas. While core concepts such as dissolving and saturation showed strong improvement, more formal aspects such as scientific terminology proved more resistant to change. This suggests that different types of knowledge require different forms of instructional support.

Given the design of the study, these findings should be interpreted as indicative rather than conclusive. The absence of a control group and the reliance on a one-group pretest–posttest design limit the ability to attribute observed changes solely to the intervention. Nevertheless, the consistency of the results, combined with their alignment with established theoretical perspectives, supports the conclusion that the instructional approach contributed meaningfully to students' conceptual development.

Worksheet analysis: Reasoning and collaborative meaning-making

To complement the analysis of pre- and post-test performance, the group worksheets collected throughout the four lessons were qualitatively analyzed to examine how students constructed

explanations, negotiated meaning, and applied emerging scientific ideas during the learning process. In total, worksheets from 31 groups across the full TLS were reviewed.

Generally, the worksheet analysis shows that the collaboratively structured guided inquiry approach functioned largely as intended. Students actively engaged in discussion, collectively constructed explanations, and refined their ideas through comparison of observations and reasoning. Across the sequence, a gradual shift could be observed from intuitive, everyday explanations toward more scientific forms of reasoning. The worksheets also revealed several areas where students required additional scaffolding, particularly in the use of scientific terminology and in interpreting observations at the particle level.

Lesson 1: Macroscopic reasoning and initial misconceptions

The first lesson, which focused on distinguishing solutions from other mixtures and differentiating dissolving from melting, showed that most groups were able to classify mixtures based on observable properties. Solutions were typically identified by the absence of visible particles and the formation of a uniform mixture, while suspensions and emulsions were associated with visible particles, layers, or cloudiness. Overall, students were generally successful in using macroscopic observations as evidence for classification.

Lesson 1 worksheets also revealed how misconceptions could emerge from partially correct reasoning. Several groups struggled to classify milk and wastewater, leading to productive discussions and requests for clarification from the teacher. In tasks comparing dissolving and melting, 5 groups incorrectly stated that dissolving involves a change of state, while others described it as the formation of a new substance or a chemical reaction. These responses appeared to reflect attempts to interpret unfamiliar phenomena using existing intuitive ideas rather than random guessing.

This pattern was particularly visible in Task 5 of Lesson 1, where students were asked whether sugar “melts” in hot tea. Several groups engaged in extensive discussion before approaching the teacher for clarification of the sugar melting temperature. After learning that table sugar melts at approximately 160°C, many groups revised their initial assumptions and concluded that melting does not occur in tea. Such episodes illustrate productive struggle within collaborative inquiry settings, where students first attempted to reason collectively before seeking additional guidance. However, 6 groups continued to explain the process using mixed reasoning, claiming that sugar both melts and dissolves because it “disappears” in tea. These responses demonstrate the persistence of everyday interpretations of dissolving as disappearance and highlight the importance of explicit conceptual scaffolding.

Lesson 2: Particle reasoning and causal explanations

In Lesson 2, students began engaging more consistently with particle-level explanations of dissolving and saturation. Many groups correctly explained dissolving as a process in which particles separate and become surrounded by water molecules, while also recognizing that only a limited amount of substance can dissolve because water molecules can “hold” only a limited number of particles. Compared to Lesson 1, explanations were more closely connected to observations and to underlying particle behavior.

However, the worksheets also showed that students frequently reproduced partially correct ideas from the provided particle model. For example, some groups incorrectly concluded that each ion must be surrounded by exactly five water molecules because this was represented in the illustration. Other groups wrote that particles “become smaller” during dissolving or that dissolved particles “join together again” when the solution becomes saturated. These findings suggest that visual models supported conceptual understanding, but also introduced opportunities for literal interpretation when not sufficiently discussed.

Lesson 2 additionally highlighted both the strengths and limitations of collaborative reasoning. In tasks addressing factors affecting dissolving, many groups produced scientifically plausible explanations by collectively reorganizing information from tables and diagrams into coherent statements. Several groups noticed similarities between the effects of stirring and temperature, explaining that both help particles move and spread faster, although “temperature happens by itself, while stirring happens because we do it.” Such responses indicate emerging relational reasoning rather than simple recall of isolated facts.

Some explanations demonstrate that students were actively attempting to build causal models, even when those models remained scientifically inaccurate (e.g., attributing the dissolution of smaller particles to “weaker interaction”, or that small particles require “less water” to dissolve). From the perspective of inquiry-based learning, such responses are important because they provide insight into students’ developing reasoning processes rather than merely indicating whether an answer is correct or incorrect.

Lesson 3: Observation-based reasoning in the laboratory

The laboratory lesson (Lesson 3) provided additional evidence of increasing reliance on observation-based reasoning. Nearly all groups correctly interpreted the effects of stirring and particle size on dissolving rate, frequently supporting their explanations with references to observed dissolution times or visible differences between samples. Compared to earlier lessons, students more consistently justified conclusions using experimental observations

rather than purely intuitive reasoning. Some groups explicitly referred to surface area or comparative observations, such as “the powder dissolved while the cube did not,” demonstrating an increasing ability to connect evidence with explanation.

A laboratory task also revealed limitations in the instructional design. Students found it difficult to determine the exact temperature at which sugar fully dissolved, leading to highly variable measurements across groups. Although most groups correctly concluded that higher temperatures increase both the dissolution rate and solubility, the experiment lacked sufficiently clear visual indicators of complete sugar dissolution. From a design perspective, this finding highlights areas for refinement in future implementations. A crystallization-focused experiment may provide clearer observable outcomes while also strengthening understanding of crystallization, which received limited attention in the present TLS.

Lesson 4: Integration and transfer of concepts

By Lesson 4, many groups demonstrated increasingly integrated reasoning across concepts introduced throughout the TLS. Students generally distinguished between the dissolving rate and solubility, explaining that stirring and particle size influence how quickly a substance dissolves, while temperature may influence both the rate and solubility. Importantly, some groups explicitly referenced previous laboratory activities or the constructed solubility curves when justifying their answers, suggesting that students increasingly viewed the lessons as interconnected rather than isolated activities. This transfer of ideas across lessons supports the interpretation that the TLS functioned as a coherent conceptual sequence.

Even in the final lesson of TLS, students mostly relied on descriptive explanations rather than formal terminology. For example, although many groups correctly explained saturation, only one explicitly used the term “saturated solution.” This reinforces the earlier finding that conceptual understanding developed more rapidly than scientific vocabulary.

The final tasks on gas solubility further illustrated both conceptual development and the continuing role of everyday language. Most groups correctly concluded that oxygen becomes less soluble at higher temperatures and connected this to fish dying in warm water. However, many students expressed this understanding in everyday terms, such as “oxygen escapes from the water,” rather than explicitly referring to reduced gas solubility. Several incorrect explanations also appeared, including ideas that oxygen “evaporates” or that fish cannot “catch” fast-moving particles in warm water. Once again, these responses confirm that students were actively attempting to construct causal explanations, even when scientific terminology and mechanistic understanding remained incomplete.

Table 1. Conceptual development across the teaching–learning sequence, showing the progression of key concepts, common misconceptions, and observed changes in student reasoning.

Lesson	Main Conceptual Focus	Common Difficulties	Evidence of Conceptual Development	Remaining Challenges
1	Solutions vs. other mixtures; dissolving vs. melting	Dissolving interpreted as melting or formation of a new substance	Students classified mixtures using observable properties and began distinguishing dissolving from melting	Frequent use of everyday language; several misconceptions persisted
2	Particle model of dissolving; saturation; factors affecting dissolving	Literal interpretation of particle diagrams; intuitive explanations of saturation	Students increasingly connected particle behavior to macroscopic observations and developed causal explanations	Some overinterpretation of models; incomplete mechanistic reasoning of the phenomena
3	Experimental investigation of dissolving rate and solubility	Difficulty identifying exact dissolution point in lab exercise	Students more consistently justified conclusions using experimental evidence	Imprecise determination of experimental endpoint
4	Integration of concepts; gas solubility	Continued reliance on descriptive explanations	Students distinguished dissolving rate from solubility and transferred ideas across lessons	Scientific terminology remained inconsistent

Table 1 summarizes students' conceptual development across the four lessons, highlighting the major concepts addressed, common misconceptions, and key shifts in reasoning observed in the worksheet analysis.

Together, the worksheet analysis provides insight into how conceptual understanding developed during the collaboratively structured inquiry process. Students were not merely reproducing memorized definitions, but actively attempting to construct explanatory models, negotiate meaning within groups, and connect observations with underlying scientific ideas. Productive struggle, peer discussion, and collective reasoning were visible throughout the sequence and frequently supported conceptual refinement. At the same time, the worksheets highlight the importance of scaffolding within guided inquiry environments. Misconceptions often emerged not from disengagement but from students' efforts to reason scientifically using incomplete conceptual tools. The findings therefore support the importance of balancing inquiry-based learning with explicit conceptual framing, opportunities for clarification, and continued reinforcement of scientific terminology.

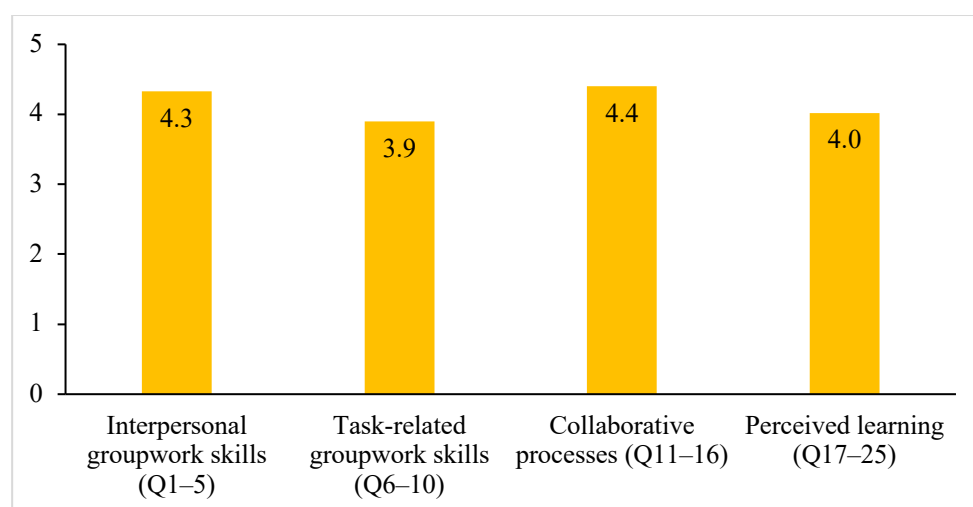
Students' perceptions of collaborative learning and groupwork

This section addresses the research question: How do students perceive collaborative inquiry-based learning and groupwork during the implemented teaching–learning sequence?

To complement the analysis of conceptual understanding, students' perceptions of their collaborative work and learning experiences were examined using a reflection questionnaire ($n = 105$). The analysis combines Likert-scale responses with qualitative insights from open-ended questions to provide a more comprehensive picture of how students experienced the collaboratively structured, inquiry-based lessons.

As shown in Figure 6, students reported consistently higher levels of interpersonal and participatory aspects of collaboration, including peer support, respectful communication, and active involvement in group discussions. In contrast, lower ratings were observed for task-related dimensions, particularly those associated with organizing group work and evaluating progress toward goals. This pattern suggests that while students experienced groupwork as socially supportive and engaging, the regulatory aspects of collaboration were less consistently developed. The figure thus provides a general overview of students' experiences, highlighting the contrast between strong interpersonal interaction and more variable task management, which is explored in more detail in the following sections.

Figure 6. Mean Likert-scale responses across questionnaire categories ($n = 105$), showing differences between interpersonal, task-related, collaborative process, and perceived learning dimensions.



Groupwork dynamics

Students reported highly positive experiences with interpersonal groupwork skills. Across items related to support, respect, and communication, responses were strongly skewed toward the higher end of the scale (“often” and “always”), indicating that most students perceived their groups as supportive and respectful environments. This is further reinforced by open-ended responses, in which students frequently identified their groupmates as the most important factor supporting their learning. Many noted that peers helped explain ideas, answer

questions, and provide encouragement, showing that helping behavior was a shared norm within the groups.

Students also reported contributing to a positive atmosphere and feeling comfortable interacting with others. Several responses highlighted the importance of a psychologically safe environment, for example, noting that it was possible to “freely ask questions,” “express even incorrect ideas,” and learn through discussion without fear of negative judgment. Such perceptions align with research on cooperative learning, which emphasizes the role of supportive interaction and positive group climate in facilitating engagement and persistence (Gillies, 2007; Johnson & Johnson, 2009).

In contrast, task-related aspects of groupwork showed greater variability. While many students reported contributing ideas and helping the group progress, items related to organizing work and evaluating progress received lower and more dispersed ratings. Open-ended responses help to explain this pattern: students frequently mentioned difficulties in reaching a common decision, combining multiple ideas into a single answer, and ensuring that all group members were equally involved. Time management also emerged as a recurring challenge, with students noting that it was sometimes difficult to complete discussion, reasoning, and written work within a single lesson.

Although students were generally successful in establishing positive interpersonal interactions, they were less consistent in managing and regulating the group process. This distinction is also documented in the literature and indicates that effective collaboration requires not only social engagement but also explicit structuring of roles, goals, and monitoring strategies (Gillies, 2007).

Collaborative processes

Students’ responses indicate that collaborative processes, such as participation, discussion, and shared reasoning, were central to the learning experience. Items related to participation were among the most highly rated, with most students reporting that everyone in the group had an opportunity to contribute and that they themselves actively engaged in discussions. This is supported by qualitative responses, where students frequently described “discussing ideas,” “debating answers,” and “explaining thinking to each other” as key elements.

In addition, many students emphasized that listening to others and comparing different ideas helped them better understand the topic. For example, responses described how hearing different perspectives allowed them to “think through ideas more deeply” or “better evaluate which answer makes sense.” Such descriptions reflect the core mechanisms of collaborative

inquiry, in which understanding is constructed through dialogue, negotiation, and explanation (Chen & Chen, 2025; Manalo & Chua, 2020).

Furthermore, the open-ended responses reveal some of the inherent challenges of these processes. Students reported that it was difficult to agree on a single answer when multiple ideas were present, and that discussions could become chaotic when several group members spoke simultaneously. Some also noted that differences in working pace or levels of engagement made collaboration more demanding. These challenges are consistent with previous research indicating that collaborative inquiry can place significant demands on students' communication skills, particularly in larger groups (Cheng et al., 2019).

Group size and composition emerged as an additional factor influencing collaboration. While many students appreciated working with familiar peers, some expressed the idea that smaller groups (e.g., two to three students) would allow for more efficient discussion and less chaos. Others proposed working with different classmates to gain new perspectives. This suggests that group composition involves a trade-off between familiarity, which supports confidence and openness, and diversity, which may enrich discussion. As such, varying group composition in future implementations may help balance these benefits.

Perceived learning in a collaborative inquiry setting

Students' perceptions of their learning indicate a generally positive evaluation of the collaborative inquiry approach. Most students reported that they understood the topic of solubility well after the lessons, and many attributed this understanding to group-based processes such as discussion, explanation, and peer support. In particular, students frequently highlighted that explaining their ideas to others and hearing alternative explanations helped them clarify and deepen their understanding.

These findings are consistent with research on inquiry-based learning, which emphasizes the role of explanation and argumentation in supporting conceptual development (Cheng et al., 2019; Pedaste et al., 2015). From a social constructivist perspective, the process of articulating and negotiating meaning within a group is central to building understanding (Constantinou et al., 2018). The alignment between students' reported experiences and these theoretical mechanisms shows that the collaborative structure of the TLS functioned as intended in supporting learning.

At the same time, responses to items comparing groupwork with teacher-led instruction were more varied. While many students agreed that groupwork supported their learning, fewer indicated that it was more effective than teacher explanation alone. This

pattern is also reflected in the open-ended responses, where students frequently mentioned both peer discussion and teacher input as crucial for learning. Several students explicitly noted that short theoretical explanations at the beginning of lessons helped them understand the tasks and engage more effectively in groupwork. Also, students noted the lack of an option to check whether their answers were correct, and this should be considered for future iterations of the TLS.

This convergence between student perceptions and instructional adjustments made during the TLS is notable. As described earlier, the first lesson revealed that students experienced uncertainty when beginning tasks without prior conceptual framing. In response, brief theoretical introductions were incorporated in subsequent lessons. The questionnaire responses suggest that this form of scaffolding was not only effective from the teacher's perspective but also appreciated by students as a support for their learning. This finding is consistent with research showing that collaborative inquiry is most effective for novice learners when supported by appropriate scaffolding and brief teacher guidance (Blanchard et al., 2010; Kirschner et al., 2006). The responses, therefore, demonstrate that students viewed groupwork and teacher explanations as complementary rather than competing approaches.

Students also reported high levels of engagement and confidence, with most indicating that groupwork made lessons more interesting and that they felt comfortable sharing their ideas. These affective outcomes are important because they contribute to sustained participation and a willingness to engage in cognitively demanding tasks.

General Discussion of the Results

The findings of this study suggest that collaboratively structured guided inquiry can be meaningfully implemented in authentic lower secondary chemistry classrooms and support students' conceptual understanding of scientific concepts, such as solubility. Across the pre- and post-test results, worksheet analysis, classroom observations, and reflection questionnaire responses, a consistent pattern emerged: students gradually moved from intuitive, descriptive reasoning to more evidence-based, conceptually structured explanations. At the same time, the study also highlighted the importance of balancing inquiry with appropriate instructional guidance and conceptual scaffolding.

The overall pattern of findings aligns with previous research, which emphasizes that guided inquiry is particularly suitable for novice learners because it combines active engagement with structured support (Blanchard et al., 2010; Kirschner et al., 2006). Rather

than requiring students to independently design investigations, the TLS focused on interpreting observations, discussing explanations, and connecting evidence with scientific ideas. The results suggest that this level of structure allowed students to engage meaningfully with inquiry processes while avoiding some of the cognitive overload associated with minimally guided approaches. The positive role of brief theoretical framing observed during the later lessons further supports the argument that novice learners benefit from clear conceptual starting points before engaging in collaborative inquiry tasks.

The study also supports social constructivist perspectives on learning, particularly the idea that understanding develops through interaction, discussion, and shared meaning-making (Constantinou et al., 2018). Worksheet analysis and student reflections both demonstrated that peer discussion played an important role in helping students refine explanations, compare ideas, and evaluate evidence. These findings are consistent with research on collaborative inquiry and cooperative learning, which emphasizes the value of dialogue and collective reasoning in supporting conceptual development (Gillies, 2007; Manalo & Chua, 2020).

At the same time, the findings also illustrate some of the inherent challenges of collaborative inquiry-based learning. Although collaborative discussion often supported conceptual refinement, it could also contribute to the stabilization of partially incorrect ideas when guidance was insufficient. The emergence of misconceptions about dissolving as the formation of a new substance demonstrates that inquiry alone does not automatically lead to a scientifically accurate understanding. In addition, students frequently relied on descriptive everyday language even when their conceptual understanding appeared relatively strong. This suggests that conceptual development and acquisition of scientific terminology may progress at different rates and may require different forms of instructional support.

Several limitations of the study should be explicitly acknowledged. The one-group pretest–posttest design does not allow causal conclusions about the intervention's effectiveness, as external influences such as maturation or other learning experiences cannot be ruled out. The study was also conducted within a single school context with academically capable students, which may limit transferability to other educational settings. In addition, the researcher's dual role as teacher and researcher may have influenced both classroom interactions and the interpretation of qualitative data. Finally, the intervention was relatively short, so the long-term stability of conceptual change was not examined.

Despite these limitations, the study contributes to the growing body of research on collaborative inquiry in science education by providing a detailed example of how a collaboratively structured guided inquiry-based TLS can be designed and implemented under

typical classroom conditions. In particular, the study contributes practical design insights regarding the importance of conceptual framing, scaffolded collaborative tasks, explicit discussion of models and terminology, and opportunities for evidence-based reasoning. Rather than presenting inquiry-based learning as a fixed method, the findings emphasize the importance of continuously adapting instructional design to student thinking and classroom dynamics, consistent with the iterative principles of design-based research.

Further Development of the TLS

An important outcome of the study was the identification of specific aspects of the teaching–learning sequence that could be improved in future implementations. Analysis of student worksheets, classroom observations, and questionnaire responses revealed several recurring difficulties that informed concrete design adjustments. Table 2 illustrates how evidence collected during the implementation of the TLS can be used to refine the instructional design, consistently with the iterative nature of design-based research, and summarizes how the observed challenges will be translated into modifications to improve the instructional design.

Table 2. Design refinement showing how student responses and classroom observations were used to identify challenges, interpret their causes, and propose modifications for future iterations of the TLS.

Observation	Interpretation	Design Adjustment	Expected Improvement
Students were uncertain how to begin Lesson 1 tasks when no prior explanation was provided.	Novice learners benefited from a clearer conceptual starting point.	Introduced a brief theoretical overview before groupwork in subsequent lessons.	Improved task orientation and more focused discussion.
Some students concluded that a new substance forms during dissolving.	Macroscopic observations alone were insufficient to support accurate interpretation.	Added more explicit particle-level explanations and teacher clarification.	Better understanding of dissolving as physical mixing of particles.
Particle diagrams were sometimes interpreted too literally (e.g., each ion requires exactly five water molecules).	Visual models require explicit discussion of their representational limitations.	Discussed diagrams as simplified models rather than exact representations.	More flexible interpretation of particle models.
The sugar dissolution temperature task produced highly variable measurements.	The experiment lacked a clear observable endpoint.	Replace the task with a crystallization-focused investigation.	Clearer observations and stronger understanding of solubility changes with temperature.
Students rarely used formal terms such as “saturated solution.”	Conceptual understanding developed faster than scientific vocabulary.	Provide more explicit reinforcement of terminology throughout the TLS.	Greater use of scientific language in explanations.
Some groups reported difficulty reaching consensus and managing time.	Collaborative regulation skills were not equally developed across groups.	Add prompts for decision-making, role distribution, and progress monitoring.	More efficient and balanced collaboration.

In subsequent iterations of the TLS, the following design adjustments could improve both conceptual understanding and collaboration quality. The lessons would benefit from a brief introductory conceptual framing before groupwork to help students orient themselves to inquiry tasks. More explicit particle-level explanations and discussion of the limitations of particle diagrams could support more accurate interpretation of dissolving processes and models. The laboratory component could also be redesigned by replacing the unclear sugar dissolution temperature task with a crystallization-focused investigation that provides clearer observable outcomes. Additionally, scientific terminology such as “saturated solution” should be reinforced more consistently throughout the sequence, as students often demonstrated conceptual understanding without using formal vocabulary. Finally, collaborative learning could be strengthened by including more structured prompts for decision-making, role distribution, and progress monitoring within groups.

The identified refinements highlight the iterative nature of the design process. Rather than viewing difficulties as shortcomings, they were treated as valuable sources of information for improving the instructional sequence. In this way, the study not only evaluated the effectiveness of the TLS but also generated concrete design principles for future implementations.

Acknowledgments

I would like to express my sincere gratitude to my supervisor, Assoc. Prof. Leo A. Siiman, for his support, optimism, and insightful advice. I am also deeply grateful to Prof. Emanuele Bardone for introducing me to the philosophical dimensions of education and encouraging a deeper search for meaning behind educational practice.

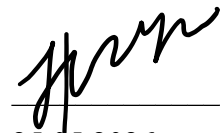
My sincere thanks go to my wonderful coursemates for sharing this journey, especially my study buddy, Graham. I greatly appreciated the many conversations, shared challenges, and moments of support shared with all of you throughout this year.

I would also like to thank my colleagues and students for supporting my learning journey, as well as my parents, family, and friends for their constant encouragement. Finally, I am especially grateful to my husband Pjotr, whose willingness to accompany me in every adventure, including this one, made this journey possible.

Author's Declaration

I hereby declare that I have written this thesis independently and that all contributions of other authors and supporters have been referenced. The thesis has been written in accordance with the requirements for graduation theses of the Institute of Education of the University of Tartu and is in compliance with good academic practices.

Nadežda Žguna

A handwritten signature in black ink, appearing to be 'Nadežda Žguna', written over a horizontal line.

25.05.2026

References

- Anderson, T., & Shattuck, J. (2012). Design-based research: A decade of progress in education research? *Educational Researcher*, 41(1), 16–25.
<https://doi.org/10.3102/0013189X11428813>
- Baumgartner, E., Bell, P., Hoadley, C., Hsi, S., Joseph, D., Orrill, C., Puntambekar, S., & Sandoval, W. (2002). Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher*, 32(1), 5–8.
<https://doi.org/10.3102/0013189X032001005>
- Blanchard, M. R., Southerland, S. A., Osborne, J. W., Sampson, V. D., Annetta, L. A., & Granger, E. M. (2010). Is inquiry possible in light of accountability?: A Quantitative comparison of the relative effectiveness of guided inquiry and verification laboratory instruction. *Science Education*, 94(4), 577–616. <https://doi.org/10.1002/sce.20390>
- Bybee, R. W., Carlson, J., Westbrook, A. L., Landes, N., Taylor, J. A., Gardner, A., & Van Scotter, P. (2006). The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications. *BSCS*.
- Cardellini, L. (2012). Chemistry: Why the Subject is Difficult? *Educación Química*, 23(2), 305–310. [https://doi.org/10.1016/S0187-893X\(17\)30158-1](https://doi.org/10.1016/S0187-893X(17)30158-1)
- Chen, F., & Chen, G. (2025). Technology-Enhanced Collaborative Inquiry in K–12 Classrooms: A Systematic Review of Empirical Studies. *Science and Education*, 34(3), 1731–1773. <https://doi.org/10.1007/s11191-024-00538-8>
- Cheng, S. C., Hwang, G. J., & Chen, C. H. (2019). From reflective observation to active learning: A mobile experiential learning approach for environmental science education. *British Journal of Educational Technology*, 50(5), 2251–2270.
<https://doi.org/10.1111/bjet.12845>
- Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education* (6th ed.). Taylor & Francis.
- Constantinou, C. P., Tsivitanidou, O. E., & Rybska, E. (2018). What Is Inquiry-Based Science Teaching and Learning? In *Contributions from Science Education Research* (Vol. 5, pp. 1–23). Springer International Publishing AG. https://doi.org/10.1007/978-3-319-91406-0_1
- Cumming, J., Woodcock, C., Cooley, S., Holland, M. J. G., & Burns, V. (2014). *Groupwork Skills Questionnaire Manual*. <https://doi.org/10.13140/2.1.2698.5764>

- Eessalu, M., Engelbrecht, J., Juurik, M., Koppel, A., Kulu, P., Lilles-Heinstar, L., Ling, K., Louk, K., Maimets, T., Marger, K., Mallo, T., Meriste, H., Niglas, K., Nurk, E., Parder, M.-L., Partlas, M., Sinijarv, U., Soone, M., Sutrop, M., Uustalu, T., Velbaum, K., Veski, L. (2023). *Estonian Code of Conduct for Research Integrity*.
- Eadillah, M. A., Usmeldi, U., Lufri, L., Mawardi, M., & Festiyed, F. (2025). Systematic literature review of inquiry-based learning models for optimizing learning outcomes at various educational levels. *Journal of Pedagogical Sociology and Psychology*, 7(4), 278–293. <https://doi.org/10.33902/jpsp.202532540>
- Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to Design and Evaluate Research in Education* (8th ed.). McGraw-Hill.
- Gafoor, K. A. (2024). *Modern Approaches and Trends in Education* [University of Calicut]. <https://doi.org/https://doi.org/10.13140/RG.2.2.22434.44481>
- Gillies, R. M. (2007). *Cooperative learning: integrating theory and practice*. Sage Publications, Inc. <https://doi.org/10.4135/9781483329598>
- Gomez, Ma. J. (2025). The Impact of Inquiry-Based Learning in Science Education: A Systematic Review of Student Engagement and Achievement. *Journal of Education, Learning, and Management*, 2(2), 353–363. <https://doi.org/10.69739/jelm.v2i2.1143>
- Hadwin, A. F., Rostampour, R., & Winne, P. H. (2025). Advancing Self-Reports of Self-Regulated Learning: Validating New Measures to Assess Students' Beliefs, Practices, and Challenges. *Educational Psychology Review*, 37, 8. <https://doi.org/10.1007/s10648-024-09977-9>
- Heirweg, S., De Smul, M., Devos, G., & Van Keer, H. (2019). Profiling upper primary school students' self-regulated learning through self-report questionnaires and think-aloud protocol analysis. *Learning and Individual Differences*, 70, 155–168. <https://doi.org/10.1016/j.lindif.2019.02.001>
- Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher*, 38(5), 365–379. <https://doi.org/10.3102/0013189X09339057>
- Johnstone, A. H. (1982). Macro- and Micro-Chemistry. *School Science Review*, 64, 377–379.
- Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, 41(2), 75–86. https://doi.org/10.1207/s15326985ep4102_1

- Kotsis, K. T. (2024). Significance of Experiments in Inquiry-based Science Teaching. *European Journal of Education and Pedagogy*, 5(2), 86–92.
<https://doi.org/10.24018/ejedu.2024.5.2.815>
- Manalo, F. K. B., & Chua, E. N. (2020). Collaborative inquiry approaches and level of thinking and reasoning skills: basis for sustainable science education. *International Multidisciplinary Research Journal*, 2(2), 91–98.
<https://doi.org/10.5281/zenodo.3918707>
- Orosz, G., Németh, V., Kovács, L., Somogyi, Z., & Korom, E. (2022). Guided inquiry-based learning in secondary-school chemistry classes: a case study. *Chemistry Education Research and Practice*, 24(1), 50–70. <https://doi.org/10.1039/d2rp00110a>
- Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, 14, 47–61.
<https://doi.org/10.1016/j.edurev.2015.02.003>
- Pozuelo-Muñoz, J., de Echave Sanz, A., & Cascarosa Salillas, E. (2025). Inquiring in the Science Classroom by PBL: A Design-Based Research Study. *Education Sciences*, 15(1), 53. <https://doi.org/10.3390/educsci15010053>
- Stojanovska, M., Mijic, I., & Petrusevski, V. M. (2020). Challenges and recommendations for improving chemistry education and teaching in the Republic of North Macedonia. *CEPS Journal*, 10, 145–166. <https://doi.org/10.25656/01:20258>
- Sun, D., Looi, C.-K., & Teo, E. (2013). Learning with Collaborative Inquiry: a Science Learning Environment for Secondary School Students. *CSCL 2013 Proceedings*, 462–469.
- Vilela, M., Morais, C., & Paiva, J. C. (2025). Inquiry-Based Science Education in High Chemistry: Enhancing Oral and Written Communication Skills Through Authentic and Problem-Based Learning Activities. *Education Sciences*, 15, 334.
<https://doi.org/10.3390/educsci15030334>
- Volkstein, J., Namsone, D., & Cakane, L. (2014). Latvian chemistry teachers' skills to organize student scientific inquiry. *Problems of Education in the 21st Century*, 59, 86–98. <https://doi.org/10.33225/pec/14.59.86>
- Yates, G. C. R., & Hattie, J. (2013). *Visible Learning and the Science of How We Learn*. Routledge, Taylor & Francis Group. <https://doi.org/10.4324/9781315885025>

Appendix 1. Lesson 1 worksheets

Task 1. Look at the images (on the screen). For each example, choose the appropriate category and explain your answer.

	Solution	Not a solution	Why
Salt + water	☐	☐	
Sand + water	☐	☐	
Copper(II) sulfate + water	☐	☐	
Oil + water	☐	☐	

What do all solutions have in common? _____

Task 2. Group the examples into categories.

Information:

- If a mixture is completely uniform and no particles can be seen, it is a **true solution**.
- If particles or sediment are visible in the liquid, it is a **suspension**.
- If liquids do not mix but form droplets, it is an **emulsion**.

	Solution	Suspension	Emulsion
Vinegar	☐	☐	☐
Iron powder in water	☐	☐	☐
Tap water	☐	☐	☐
Mayonnaise	☐	☐	☐

	Solution	Suspension	Emulsion
Sewage water	☐	☐	☐
Milk	☐	☐	☐
Tea with sugar	☐	☐	☐
Chalk (CaCO ₃) in water	☐	☐	☐

What is the main difference between a solution and other types of mixtures?

Task 3. Dissolving or melting?

Imagine the following situations:

- An ice cube melts in a glass at room temperature.
- Butter melts on a hot pan.
- Salt dissolves in water while stirring.

Complete the table about the differences between dissolving and melting processes (write *yes* or *no* in each column).

	Dissolving	Melting
Is another liquid needed?		
Does the substance “disappear”?		
Does the substance change its state of matter?		

Finish the sentences.

- Dissolving is a process, where _____
- Melting is a process, where _____

Task 4. Use the information from the previous tasks to write definitions.

Solution is _____

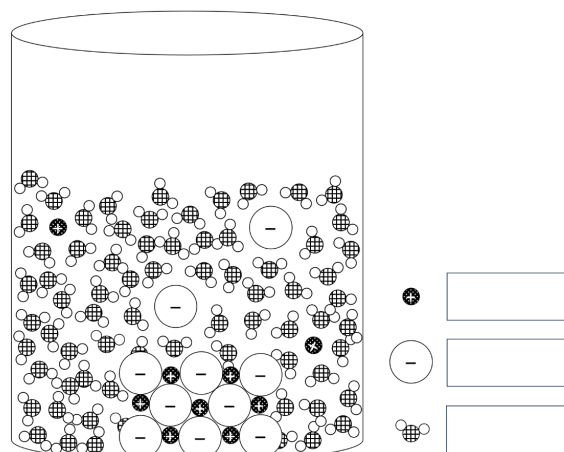
Dissolving is _____

Task 5. In everyday life, people often say that sugar “melts” in tea. Explain whether sugar actually melts in tea. Why or why not?

Appendix 2. Lesson 2 worksheets

Task 1. How Does Dissolving Happen? Read the text and examine the diagram.

Particles in a solid substance are held closely together by intermolecular forces. For a substance to dissolve, its particles must separate, which means these forces must be overcome. Water molecules can attract the particles of the substance. This process is called hydration — water molecules form a layer around the dissolved particles, keeping them in the solution. As a result, the particles become evenly distributed throughout the solution. The particles do not disappear; they remain in the solution, but separated from one another. However, only a certain amount of a substance can dissolve in a solution because the ability of water molecules to surround and hold particles is limited.



The diagram shows the process of table salt dissolving. Complete the diagram by writing the names of the particles in the empty boxes. Answer the questions.

1. What happens to the table salt particles when it dissolves?

2. Why can't an unlimited amount of salt dissolve in one glass of water?

3. What happens when there is no more "space" in the solution for new particles?

Unsaturated solution is a solution in which more substance can still dissolve at a given temperature.
Saturated solution is a solution in which no more substance can dissolve at a given temperature.

Task 2. What Affects Dissolving? Below are statements describing what happens at the particle level during dissolving. These processes can be influenced by different factors. Sort the statements into three groups depending on which factor causes them.

Factors influencing dissolving		
Temperature	Mixing	Particle size

1. Particles move faster.
2. The surface area between the substance and water increases.
3. The substance particles spread through the solution more quickly.
4. Water molecules collide more often with the substance particles.
5. The substance breaks into smaller particles more quickly.

How does increasing temperature affect the dissolving process?

How does mixing affect the dissolving process?

Why do smaller particles dissolve faster than larger ones?

Task 3. Solubility curves. Use the solubility curves in your textbook and answer the questions below.

1. How many grams of lead nitrate can dissolve in 100 g of water at 10 °C?
2. Which of the given substances has the highest solubility at 5 °C?
3. At 20 °C, 20 g of potassium nitrate is added to 100 g of water.
The solution will be: ☐ saturated ☐ unsaturated
4. At 70 °C, 30 g of barium nitrate is added to 200 g of water.
The solution will be: ☐ saturated ☐ unsaturated
5. Which of the given substances shows the smallest change in solubility as temperature increases?

Appendix 3. Lesson 3 (lab work) worksheets

Dissolving and Solubility

1. Does stirring affect dissolving?

Task: Investigate how stirring affects the rate at which sugar dissolves.

Equipment and materials: two beakers (150–200 mL), two 100 mL graduated cylinders, glass stirring rod, granulated sugar, water, timer (on a phone), balance, spoon.

Procedure:

1. Weigh 15 g of granulated sugar into each beaker.
2. Simultaneously, add 50 mL of distilled water to each beaker.
3. Continuously stir the contents of one beaker (gently and carefully). Do not stir the contents of the other beaker.
4. Observe the dissolving process at specific time intervals.

Recording data: mark as fully dissolved / partially dissolved / almost undissolved.

Time	Stirring	No stirring
0 s		
30 s		
60 s		
90 s		
120 s		
150 s		

Evaluation of results: How did stirring affect the rate of dissolving? Briefly explain your answer based on the observations.

2. Does particle size affect dissolving?

Task: Investigate how particle size affects the rate at which sugar dissolves.

Equipment and materials: two beakers (150–200 mL), two 100 mL graduated cylinders, glass stirring rod, balance, sugar cubes, granulated sugar, water, timer (on a phone), spoon.

Procedure:

1. Weigh 5 sugar cubes into one beaker and record their mass: _____ g
2. In the second beaker, weigh the same mass of granulated sugar.
3. At the same time, add 50 mL of distilled water to each beaker.
4. Continuously stir the contents of both beakers (gently and carefully).
5. Observe the dissolving process at specific time intervals.

Recording data: mark as fully dissolved / partially dissolved / almost undissolved.

Time	Sugar cubes	Granulated sugar
0 s		
30 s		
60 s		
90 s		
120 s		
150 s		

Evaluation of results: How did particle size affect the rate at which sugar dissolved? Briefly explain your answer based on the observations.

3. Temperature and Solubility

Task: Investigate how temperature affects the solubility of sugar in water.

Equipment and materials: three beakers (50–100 mL), 25 mL graduated cylinder, glass stirring rod, balance, thermometer, electric hot plate, granulated sugar, water, timer (on a phone), spoon.

Procedure:

1. Prepare three beakers. Weigh 25 g of sugar into the first beaker, 30 g into the second, and 35 g into the third.
2. Add 10 mL of distilled water to each beaker.
3. Stir and observe whether all the sugar dissolves.
4. Heat the beakers on the hot plate while continuously stirring with the glass rod (gently and carefully) and measuring the temperature with the thermometer. DO NOT STIR WITH THE THERMOMETER!

Recording data: record the temperature at which the sugar completely dissolves (no visible solid particles remain).

Temperature	Sucrose solubility g/10 g water	Sucrose solubility g/100 g water
	25	
	30	
	35	

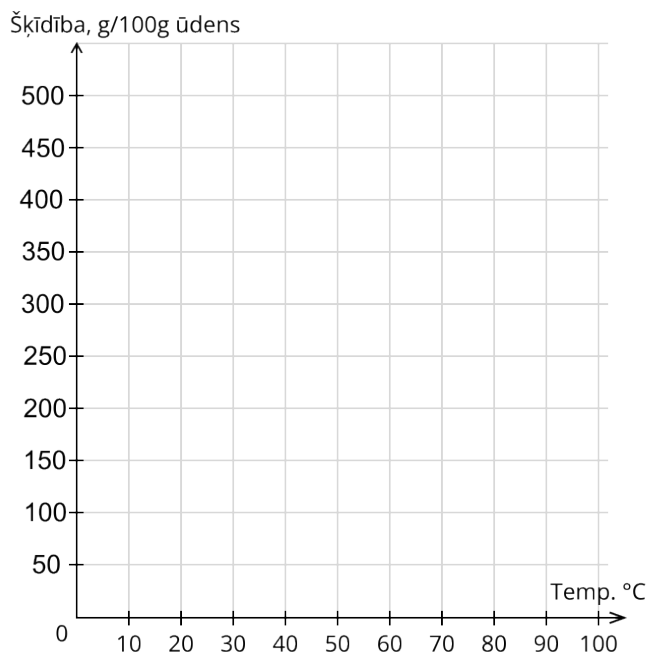
Evaluation of results: How did temperature affect the solubility of sugar? Briefly explain your answer based on the observations.

Appendix 4. Lesson 4 worksheets

Task 1. Using the data about the solubility of sugar in water, construct a solubility curve for sugar. Using a pen of a different color, also construct the solubility curve for table salt.

T, °C	Sucrose solubility, g/100 g water
20	204
40	238
60	287
80	362
100	487

T, °C	Table salt solubility, g/100 g water
20	36
40	37
60	38
80	39
100	40



Explain why sugar was chosen for the laboratory activity instead of salt.

Task 2. Evaluate the two situations. Answer the questions and complete the sentences.

Situation 1. Two glasses contain the same amount of water and the same amount of sugar. In one glass, the solution is stirred; in the other, it is not stirred.

Situation 2. Two glasses contain the same amount of water. In one glass, 20 g of sugar is added; in the other, 40 g of sugar is added. Both glasses are stirred equally.

1. In which situation does the rate of dissolving change?
☐ Situation 1 ☐ Situation 2
2. In which situation does the amount of dissolved substance (solubility) change?
☐ Situation 1 ☐ Situation 2
3. Stirring helps the particles of the substance _____.
However, this does not mean that _____.

Task 3. Evaluate the statements. For each statement, indicate whether it is correct or incorrect and briefly explain your choice.

1. Stirring increases the solubility of a substance.

☐ Yes ☐ No

Explanation: _____

2. Smaller particles allow more of the substance to dissolve.

☐ Yes ☐ No

Explanation: _____

3. Temperature can affect both how fast a substance dissolves and how much of it can dissolve.

☐ Yes ☐ No

Explanation: _____

4. If a substance does not dissolve, it just needs to be stirred longer until everything dissolves.

☐ Yes ☐ No

Explanation: _____

Extra task. Color only the boxes containing substances that are insoluble in water.

	Mg ²⁺	Ag ⁺	Ba ²⁺	Hg ²⁺	Zn ²⁺
I ⁻					
Br ⁻					
NO ₃ ⁻					
OH ⁻					
PO ₄ ³⁻					

Gas Solubility

Task 1. Compare the solubility curves of solids and gases (on the screen). Answer the questions.

How does the solubility of solids change as temperature increases?

How does the solubility of gases change as temperature increases?

Task 2. Complete the text about the difference between the solubility of solids and gases in water. Use these words: *faster, slower, helps, prevents, substances, escape, remain, in solution, increases, decreases, temperature*.

As the _____ increases, particles move _____. In the case of solids, solubility _____, the substance dissolves _____ in water, and a larger amount of the _____ can dissolve.

Gases behave differently. If you hold a test tube filled with cold water, it warms up. Gas bubbles can be observed on the walls. This means that the solubility of gases (air) _____ and it becomes easier for gas bubbles to _____ from the solution.

Task 3. During hot summers, the media sometimes reports that fish are suffocating in some Latvian lakes and fish ponds. How can you explain this?

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25/05/2026