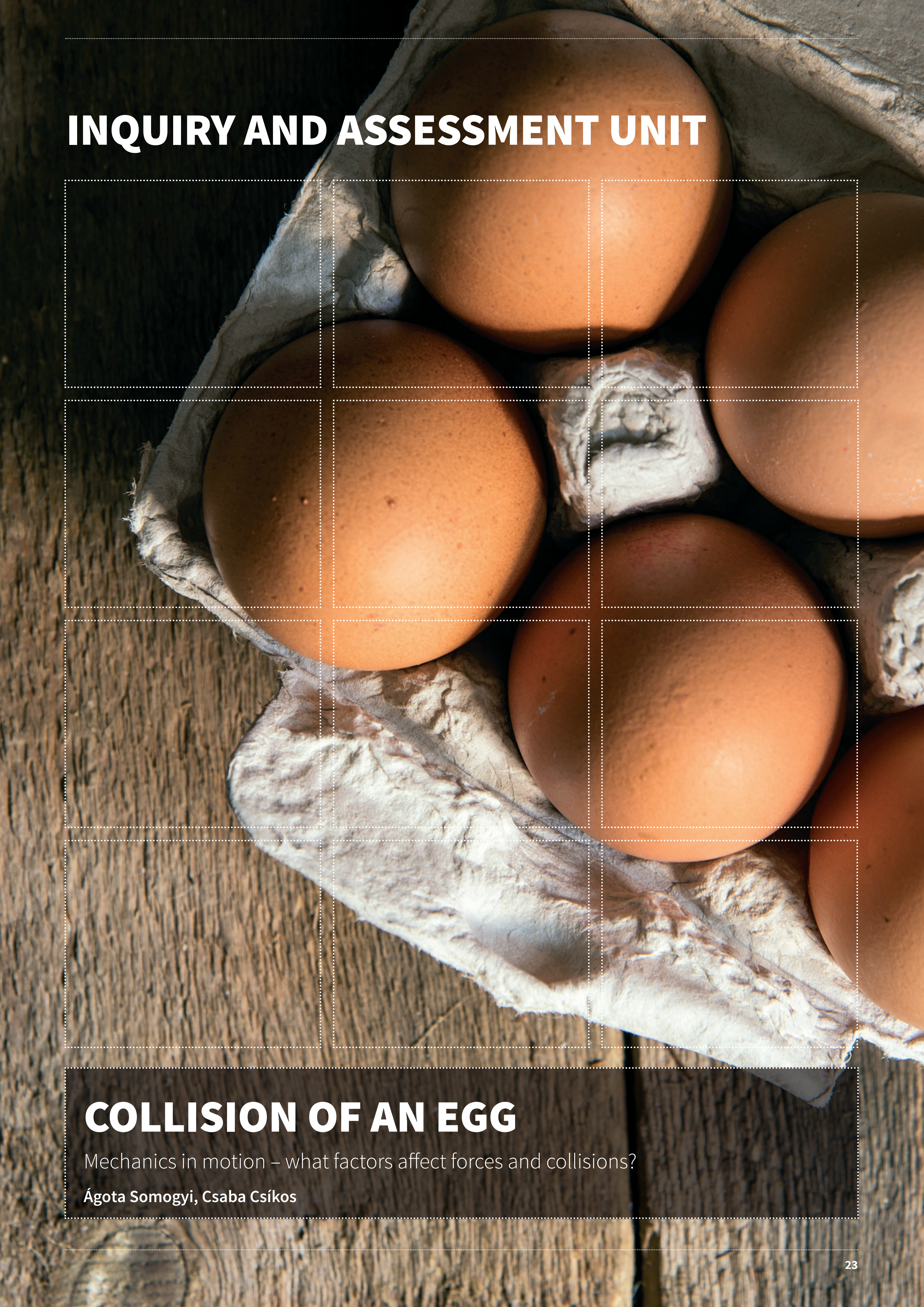

INQUIRY AND ASSESSMENT UNIT

COLLISION OF AN EGG

Mechanics in motion – what factors affect forces and collisions?

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COLLISION OF AN EGG

MECHANICS IN MOTION – WHAT FACTORS AFFECT FORCES AND COLLISIONS?

Overview

KEY CONTENT/CONCEPTS

- Mechanics – force and momentum
- Collision of a free falling egg with ground surfaces
- Understanding the relationship of egg collisions with daily life situations
- Identification of effects on the forces during collision
- Designing an experiment – identifying variables, taking measurements

LEVEL

- Lower second level
- Upper second level

INQUIRY SKILLS ASSESSED

- Developing hypotheses
- Planning investigations
- Working collaboratively

ASSESSMENT OF SCIENTIFIC REASONING AND SCIENTIFIC LITERACY

- Scientific reasoning (drawing conclusions, critiquing experimental design)
- Scientific literacy (presentation of scientific data, communicating scientifically)

ASSESSMENT METHODS

- Classroom dialogue
- Teacher observation
- Peer-assessment
- Self-assessment
- Student devised materials (experimental plan, graph, documentation of inquiry, recordings, reports)
- Presentations

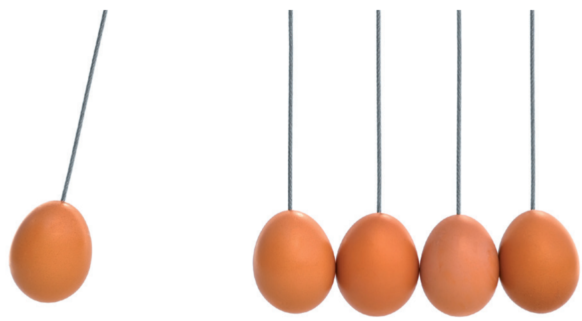
Classroom materials for this Inquiry and Assessment Unit are available at WWW.SAILS-PROJECT.EU

1. INQUIRY AND ASSESSMENT UNIT OUTLINE – COLLISION OF AN EGG

The **Collision** of an egg SAILS inquiry and assessment unit asks students to solve an unstructured problem in the theme of mechanics – “What factors influence forces during collision?” To understand the interactions during a collision, the students study the impacts on an egg. Two approaches are recommended, first to consider “What factors make it possible for the egg to land safely?” and secondly “From how high can you drop an egg into a bucket of flour, without it breaking?” Through this activity, students explore the connection between force and momentum and can apply this knowledge in the context of road safety.

This unit focuses on the inquiry skill of *planning investigations* (designing an experiment), in particular considering variables. In addition, students engage in *developing hypotheses*, and their motivation can be enhanced through immersion in doing science. *Working collaboratively* with peers is important when developing and implementing the research plan. Possible assessment opportunities include teacher observation, evaluation of student artefacts using rubrics and self-assessment.

This unit was trialled by teachers in four countries – Hungary, Denmark, United Kingdom and Germany – producing six case studies (students aged 12-16 years; mixed ability and gender). The teaching approach was open or *open/guided inquiry* in all cases; students were free to plan the experiment but the materials and equipment were provided. Inquiry skills assessed were *planning investigations, developing hypotheses* and *working collaboratively*.



2. IMPLEMENTING THE INQUIRY AND ASSESSMENT UNIT

2.1 Activities for inquiry teaching & learning and their rationale

The **Collision of an egg** SAILS inquiry and assessment unit was developed by the team at the University of Szeged as part of the SAILS project. In this unit, students are asked to solve an unstructured problem. The theme of the task is that of mechanics, the connection between force and momentum, with some reference to road safety. With consideration to the age group and the background knowledge, the calculations may be skipped.

In this unit, there are several aspects to be considered in the context of inquiry-based learning:

- *Developing hypotheses* (inquiry directed by the students)
- *Planning investigations* (solving of unstructured problems)
- *Forming coherent arguments* (question assisted independent learning)
- *Working collaboratively* (group learning)
- *Scientific reasoning* (using the students' background knowledge)
- *Scientific literacy* (theoretical knowledge gained through inquiry)

Concept focus	Mechanics; identification of variables Egg collisions as a model system for real-world collisions
Inquiry skill focus	Developing hypotheses Planning investigations Working collaboratively
Scientific reasoning and literacy	Scientific reasoning (identification of variables) Scientific literacy (presentation of scientific data)
Assessment methods	Classroom dialogue Teacher observation Worksheets Student devised materials

Rationale (teacher supports)

Goals: Students will learn to plan and implement experiments, be proficient in identification of variables, apply newly learned knowledge to everyday context (e.g. road accidents).

Scientific background: Experimentation with the eggs was developed because the speed on impact is easy to control through the selection of the height from which it is dropped. The mass of the eggs is close to constant. With the modification of the surface of impact, it is easy to identify the role of time during deceleration.

Pedagogy and context: The experiment can be most effectively performed by students aged 14-16 years. There are many opportunities for collisions in sports or on the roads; the altering of forces during these collisions is the basis of developing safety systems. Hopefully the observations by the students will encourage interest in safety.

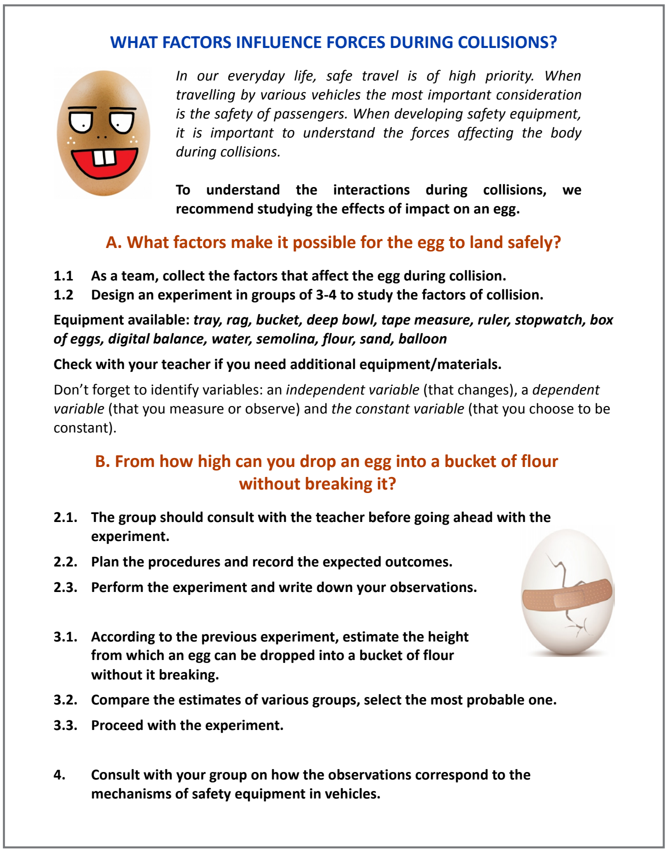
Recommendations: It is important to encourage the students to work as part of a diverse group. This supports critical thinking and teamwork. The teacher should observe student progress and facilitate it with helpful questions. If there is a disagreement, help should be given to resolve the problem in question. Groups should not be allowed to proceed to implementation, unless they have defined all of the variables in their experimental plan. During the planning phase of the experiment, the teacher should listen to the group and guide the designing of the experiment with questions.

Suggested lesson sequence

1. The teacher introduces the topic of "collisions" and encourages students to think about factors that influence impact of collisions. This can be in the context of mechanics or safety aspects.
2. The teacher introduces the task, to investigate the impact of collisions using an egg.
3. Students form small groups (3-4 students) and receive the student worksheet (Figure 1).
4. Students carry out part A of the activity (Question 1.1 Discuss factors that affect the egg during collision and Question 1.2 Design an experiment to study the factors of collision).
5. Students consult with the teacher before moving on to part B of the activity, to ensure that they have identified suitable variables for consideration during their experiment.
6. Students carry out their experiment and record their results and observations.
7. Students review their results, and devise a new experiment to consider influence of height on the collision of the egg. They engage in a class discussion to determine criteria for the experiment.
8. At the end of the experimentation phase, students are asked to transfer the newly acquired knowledge to another context – that of road safety. This seeks to consolidate the new knowledge in their minds.

Possible teacher questions

- What physical variables affect the forces generated on objects?
- How does the change in momentum affect force?
- What does momentum depend on?
- How can an object's momentum be changed?
- What does impact speed depend on?
- How do you calculate the speed of an object in free fall?
- Which variable can be taken as constant?
- How do you find connections between the variables?
- How does the drop height affect the egg's collision?
- How does the surface affect the collision?
- Why does the egg remain intact in flour and in semolina?


WHAT FACTORS INFLUENCE FORCES DURING COLLISIONS?

In our everyday life, safe travel is of high priority. When travelling by various vehicles the most important consideration is the safety of passengers. When developing safety equipment, it is important to understand the forces affecting the body during collisions.

To understand the interactions during collisions, we recommend studying the effects of impact on an egg.

A. What factors make it possible for the egg to land safely?

1.1 As a team, collect the factors that affect the egg during collision.
1.2 Design an experiment in groups of 3-4 to study the factors of collision.

Equipment available: ***tray, rag, bucket, deep bowl, tape measure, ruler, stopwatch, box of eggs, digital balance, water, semolina, flour, sand, balloon***

Check with your teacher if you need additional equipment/materials.

Don't forget to identify variables: an *independent variable* (that changes), a *dependent variable* (that you measure or observe) and *the constant variable* (that you choose to be constant).

B. From how high can you drop an egg into a bucket of flour without breaking it?

2.1. The group should consult with the teacher before going ahead with the experiment.
2.2. Plan the procedures and record the expected outcomes.
2.3. Perform the experiment and write down your observations.

3.1. According to the previous experiment, estimate the height from which an egg can be dropped into a bucket of flour without it breaking.
3.2. Compare the estimates of various groups, select the most probable one.
3.3. Proceed with the experiment.

4. Consult with your group on how the observations correspond to the mechanisms of safety equipment in vehicles.

Figure 1: Student worksheet for the **Collision of an egg** SAILS inquiry and assessment unit

2.2 Assessment of activities for inquiry teaching & learning

There are opportunities throughout this unit for the development and assessment of inquiry skills. Evidence of both content knowledge and skill development can be collected in the form of student artefacts (hypotheses proposed, experimental work plan), through teacher observation and self-assessment. While some assessment tools (3-point rubrics) are described within this unit, teachers should be free to devise and implement their own assessment instruments. Suggested skills to be assessed during implementation of this unit include *developing hypotheses, planning investigations*, and *scientific reasoning* (drawing conclusions based on evidence).

The teachers can provide formative assessment in class, using the rubric shown in Table 1 to assign performance levels, and encourage inquiry through asking helpful questions, such as:

- How would you like to observe the situation?
- What would you like to learn from the experiment?
- What variables do you want to study?

Table 1: Rubric for the assessment of forming inquiry questions

Inquiry skill	Level 1	Level 2	Level 3
Forming inquiry questions	The student is not helped by the question, is not able to recognise the connections.	The student recognises the connection between the question and the experiment, but the question does not help.	The student recognises the connection between the question and the experiment and implements the answer systematically.

To ensure adequate time for the assessment in class, teachers should do some preparation – prepare an evaluation plan and define the primary points for the assessment, implement the task according to given circumstances (adapt as appropriate for your class – based on ability, goals and resources available). In class, the teacher should communicate clearly the modes of evaluation that will be used, and should take into account the students' feeling about the evaluation procedures. After class, the teacher can give formative assessment in writing, evaluate the suitability of the assessment tools and consult with students and other teachers about the inquiry activity.

Developing hypotheses

The teacher can assess students' skill in *developing hypotheses* through teacher observation or using student artefacts in or after the lesson. A suggested rubric for the assessment of this skill is provided in Table 2.

Teacher questions to aid students in developing their hypotheses include:

- What do you expect to happen?
- Why does it happen?
- Can you explain how your hypothesis follows from what you have learnt?

Table 2: Rubric for the assessment of developing hypotheses

Inquiry skill	Level 1	Level 2	Level 3
Developing hypotheses	The student formulates a hypothesis but is unable to explain it.	The student formulates a hypothesis and is able to explain it with the help of questions.	The student explains the hypothesis and supports it with scientific facts.

Planning investigations

The teacher can assess students' skill of *planning investigations* at several stages of this activity – looking at skills in both planning and implementing an experiment. Possible assessment opportunities include teacher observation or by assessing student artefacts, during the lesson or after the activities are completed. A rubric for the assessment of this skill is provided in Table 3. Teacher questions to aid students in *planning investigations* include:

- How can the experiment be implemented?
- Which physical variable should be studied?
- How can a connection be found between variables?
- What can you do in order to accurately control the measurements?
- More specific questions in teacher support.

Table 3: Rubric for the assessment of planning investigations

Inquiry skill	Level 1	Level 2	Level 3
Planning investigations	The student makes suggestions on how the experiment should be carried out, but is unable to proceed and does not understand the process.	The student makes suggestions on how the experiment should be carried out and understands the process, but is unable to proceed.	The student makes suggestions on how the experiment should be carried out and understands the process, can proceed with the planning of the experiment.
Implementing the investigation **Recording observations**	The student implements the experiment with help from the teacher and writes down observations sporadically.	The student implements the experiment with some help needed occasionally and writes down observations inaccurately.	The student implements the experiment without help and writes down observations accurately.

Scientific reasoning and forming coherent arguments (drawing conclusions based on evidence)

The teacher can assess students on their *scientific reasoning* when they are interpreting their results. Possible assessment opportunities include teacher observation or by assessing student artefacts during or after the lesson. A rubric for the assessment of this skill is provided in Table 3. Teacher questions to aid in assessing students performance in *forming coherent arguments* include:

- Can the student draw conclusions based on their results?
- Can the student identify errors or mistakes in the experiment?

Table 4: Rubric for the assessment of scientific reasoning and forming coherent arguments

Inquiry skill	Level 1	Level 2	Level 3
Drawing conclusions	The student demonstrates the experiment, however uses little observation data to explain the hypothesis.	The student demonstrates the experiment, uses the data collected during the experiment to explain the hypothesis.	The student demonstrates the experiment, uses the data collected during the experiment to explain the hypothesis and explains the reasons behind the observations.
Evaluating the experiment **Recognising mistakes**	The student recognises the possible mistakes and determines the credibility of the results.	The student recognises the possible mistakes and determines the credibility of the results. Identifies own mistakes.	The student recognises the possible mistakes and determines the credibility of the results. Explains the effects of mistakes on the results.

3. SYNTHESIS OF CASE STUDIES

This unit was trialled in four countries producing six case studies of its implementation – **CS1 Hungary**, **CS2 Denmark**, **CS3 United Kingdom**, **CS4 United Kingdom**, **CS5 Germany** and **CS6 Germany**. The teaching approach in all case studies was that of *open inquiry* or *bounded inquiry*.

The students involved in the case studies were aged 11-16 years: ranging from just 11 years in **CS3 United Kingdom** to 16 years in **CS4 United Kingdom**. The students in each class were of mixed ability and usually mixed gender, although students were all male in **CS5 Germany**. **CS1 Hungary** and **CS6 Germany** implemented the activity in a single 90-minute lesson. In the other case studies the unit was implemented over several lessons – **CS2 Denmark** two lessons, **CS3 United Kingdom** four lessons, **CS4 United Kingdom** five lessons and **CS5 Germany** three lessons. Students worked in groups throughout the activity.

The skill of *planning investigations* was assessed in all case studies, while *developing hypotheses* was also identified as a key skill for the assessment. Other assessment opportunities included evaluation of *scientific reasoning*, looking at students' ability to identify variables or draw conclusions, and *scientific literacy*, through assessing students' ability to provide scientific explanations for the observed phenomena. The primary assessment methods were classroom dialogue and teacher observation, as well as teacher- and/or peer-assessment of student devised materials and presentations.

3.1 Teaching approach

Inquiry approach used

The teaching approach varied in the case studies; the unit was mainly implemented as an unstructured problem in **CS1 Hungary**, **CS2 Denmark**, **CS3 United Kingdom** and **CS5 Germany** (*open inquiry*), however materials and equipment were provided. In **CS4 United Kingdom**, students were encouraged to generate a list of equipment that they needed for their inquiry, which was made available in the next lesson for implementation. In **CS6 Germany**, after having a class-level conversation, the hypothesis to be tested was agreed, nevertheless, students had the freedom to plan their experiments; thus this was a *bounded inquiry*. Students worked in groups in all case studies, as detailed in Table 5. They usually worked in groups of 4, although **CS2 Denmark** and **CS6 Germany** did not give exact data.

Adaptations of the unit

The unit allows for various implementation designs and various levels of teacher guidance. For example, in **CS3 United Kingdom** students were provided with equipment and materials, and compiled a wish list of further items, while in **CS4 United Kingdom** students devised their experiments and chose all equipment and materials during their planning phase. In **CS1 Hungary**, the teacher asked lots of questions to aid the students, introducing an element of guidance to the inquiry.

Table 5: Summary of case studies

Case study	Duration	Group composition
CS1 Hungary	One lesson (90 min)	• Groups of 3-4 students • Mixed ability and gender
CS2 Denmark	One double lesson (120 min)	• Small groups of students (21 students) • Mixed ability and gender (9 girls, 12 boys)
CS3 United Kingdom	Four lessons (60 min each)	• Groups of 4 students • Mixed gender and ability; including students from "designated special provision" which works with autistic students
CS4 United Kingdom	Five lessons (45 min each)	• Groups of 4 students (24 students) • Mixed ability and gender
CS5 Germany	Three lessons (60 min each)	• Groups of 3-4 students • All boys, mixed ability
CS6 Germany	One lesson (90 min)	• Small groups of students (30 students)

In each implementation, lesson design took into account students' previous experiences in inquiry lessons. For example, in **CS3 United Kingdom** the students aided in design of the assessment tools, while in **CS4 United Kingdom** the teacher did not utilise rubrics. The **CS2 Denmark** students were novices to inquiry, therefore the teacher tried to follow pre-planned sequential lesson phases. In **CS5 Germany**, the teacher modified the activity so that it did not include eggs; rather he looked at the use of inclined planes and collisions of small cars. He found that this context was more in keeping with curricular objectives, but implemented an open inquiry based on the modified premise.

3.2 Assessment strategies

Even though the unit gives the possibility of assessing several inquiry skills, in real classroom situations teachers are advised to focus on at most two (or in exceptional cases three) inquiry skills, as shown in Table 6. In the case of six groups this might mean 6x2 group-level assessment protocols, which in practice seems to be quite a challenge to carry out.

Table 6: Inquiry skills identified by teachers in the case studies

CS1 Hungary	• Developing hypotheses (developing research questions) • Planning investigations (implementing experiment, collecting data) • Scientific reasoning (drawing conclusions, critiquing experimental design)
CS2 Denmark	• Developing hypotheses • Planning investigations (carrying out investigation)
CS3 United Kingdom	• Planning investigations (carrying out investigation) • Scientific reasoning (representing data, drawing conclusions • Scientific literacy (presenting scientific data)
CS4 United Kingdom	• Developing hypotheses • Planning investigations • Scientific reasoning (writing conclusions and evaluations) • Scientific literacy (understanding relevant data and communicating this to others; presenting scientific data)
CS5 Germany	• Developing hypotheses • Planning investigations (carrying out investigations) • Scientific literacy (understanding how things relate to real world context)
CS6 Germany	• Developing hypotheses • Planning investigations (carrying out investigations) • Working collaboratively (debating with peers)

The rubrics presented in the assessment of teaching and learning activities section of the unit served as the basis of formative assessment, even when there were deviations from those. These rating scales provide examples for differentiating between three different levels of student performance. The teacher in **CS1 Hungary** provided formative assessment in class, and reassessed the student artefacts after the inquiry was completed. The teacher then provided oral feedback to the class. This method of assessment was also utilised in **CS5** and **CS6 Germany**. The teacher in **CS2 Denmark** tried to use what she remembered from the rubrics intended for the assessment, but real-life procedures overwrote her plan, and the rubrics became unusable. **CS4 United Kingdom** reports on conscious deviation from the rubrics given in the unit draft, and the teacher assessed students using her own understanding. **CS3 United Kingdom** describes the use of rubrics, which were developed in cooperation with the students (Figure 2). The teacher and students first discussed what qualities were important for each of the skills to be assessed. Ideas from all students were compiled in a draft rubric, which the teacher then compiled in rubrics for use by the students for peer-assessment and for the teacher to use for evaluation of artefacts. The method of assessment ensured that students were aware of the criteria for the assessment and understood what was expected of them.

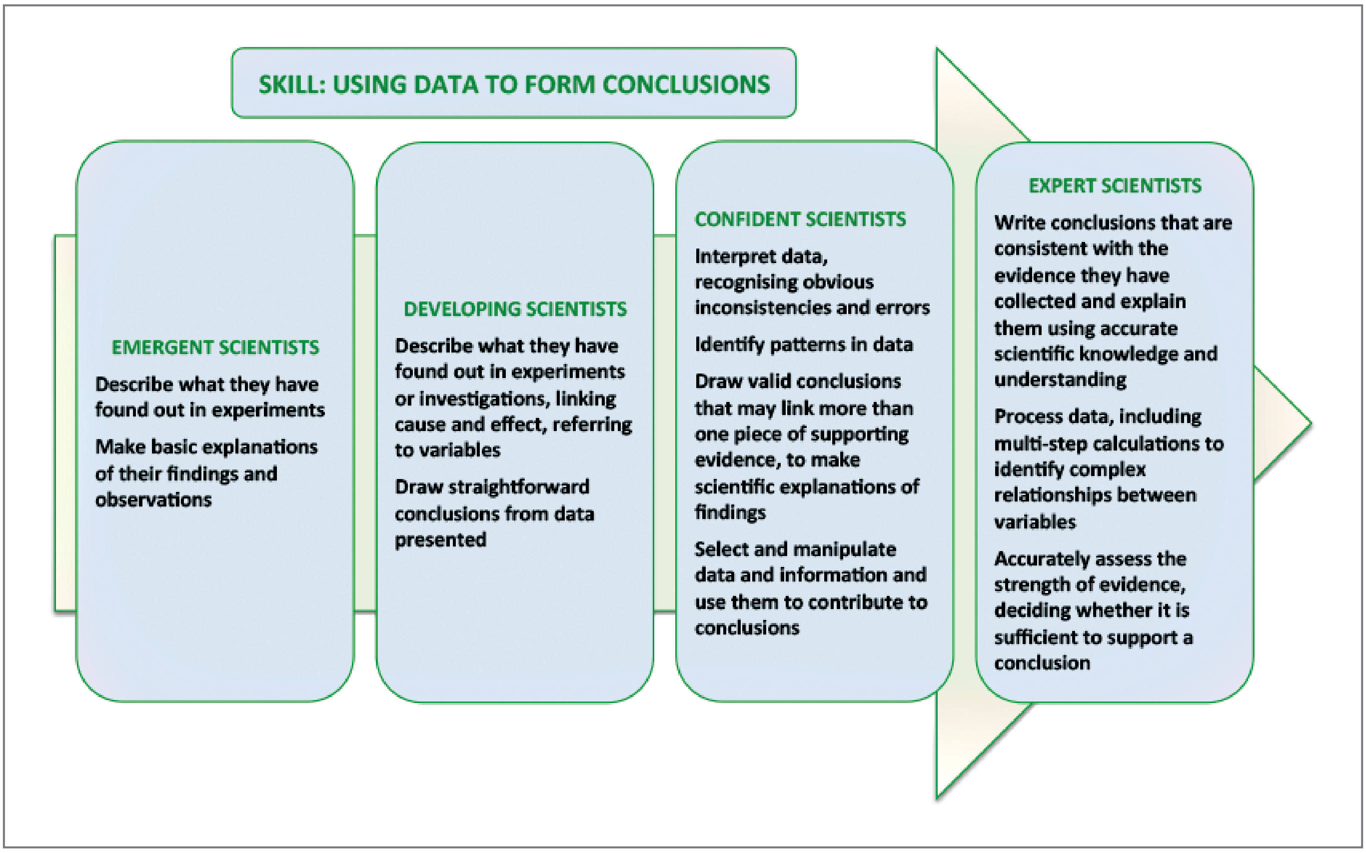


Figure 2: Arrow rubric for peer-assessment of forming conclusions used in **CS3 United Kingdom**

Further examples of peer-assessment can be found in **CS3 United Kingdom**, in which students used a peer-assessment form or checklist for the assessment of inquiry skills in writing conclusions (Table 7) and presenting data (Table 8).

Table 7: Peer-assessment form for writing conclusions

Success criterion	Peer comments
Averages calculated correctly	
Reference to data	
Reference to repeatability	
Suggested reasons for findings	
Use of paragraphs	

Table 8: Peer assessment checklist for presentation of data

Success criterion	Peer comments
Correct graph/chart selected?	
x- axis and labels	
y-axis and labels and units	
Bars the same width	
Bar height accurately drawn	

Planning investigations

This inquiry skill is the focus of the **Collision of an egg** SAILS inquiry and assessment unit. The 3-level scale shown in Table 3 is based on the assumption that students will surely make some suggestions regarding how the experiment should be carried out. This assumption may be far too optimistic, and may only be applicable to the proposed 15-year-old population, or older. Nevertheless, students' suggestions may be of different value, from just raising quick ideas to elaborating whole plans. The two component skills in the rubrics are understanding the process and proceeding with the planning of the experiment. According to the case studies, students' previous involvement in classroom inquiry will give the basis for any rubrics or other ordinal scale assessment. Those who have already had some knowledge about dependent and independent variables may receive feedback based on the quality and feasibility of their chosen variables (for example **CS3 United Kingdom**). Those who are completely new to classroom inquiry, such as **CS2 Denmark**, may be assessed according to their intuitive understanding of keeping constant one variable while manipulating the other. Students' self-assessment may also be used to assess development of this skill (**CS3 United Kingdom** and **CS6 Germany**). In **CS5 Germany**, the teacher explicitly focused on this skill and its assessment involved extensive observation; collecting and commenting on students' ideas proved to be an appropriate formative assessment strategy.

Developing hypotheses

This skill can be measured on a 3-point ordinal scale, as suggested in Table 2. Even at the lowest performance level, students are expected to form a hypothesis, and on higher levels they can justify and explain it. In **CS4 United Kingdom**, the assessment of this skill was based on “how students identified what variable to measure,” while in **CS3 United Kingdom**, peer-assessment was carried out on the basis of “is this hypothesis a testable statement.” In **CS6 Germany**, the teacher found that students had a lot of difficulties with this skill and required a lot of teacher input.

Working collaboratively

This inquiry skill was also addressed in the case studies, albeit not explicitly. In all case studies the students worked in small groups. The teachers observed these groups, and some noted the ability of students to work collaboratively, for example in **CS4 United Kingdom** the teacher observed that teacher-selected groups would be beneficial, to ensure a mix of ability. In **CS5 Germany**, the teacher was satisfied with the students’ ability to cooperate, but noted that students again had varied ability and took on different roles within their groups. In **CS6 Germany**, the teacher had hoped to assess *working collaboratively* through self-assessment of the planning investigations activity, but did not have sufficient time. Of particular interest is **CS3 United Kingdom**, in which students from the designated special provision unit, which works with autistic students, joined the class. The teacher noted that the autistic students were very engaged and worked well as part of a team. The specialist staff member who worked with one autistic boy commented that this collaboration and motivation represented a significant positive change as previous “animosity” seen in some group work had been completely ignored. Thus many opportunities for the assessment of the skill *working collaboratively* were identified, and methods for assessment suggested.

Assessment of other skills

In **CS3 United Kingdom**, the teacher outlines a tool for the self-assessment of other inquiry skills developed during the inquiry process. This learning landscape lists 21 skills that may be demonstrated during an inquiry activity, but that are unlikely to be assessed. Using the learning landscape, students can become familiar with transferable skills and encouraged to consider how these skills may be beneficial in the future. They are asked to choose three skills that they feel they have developed during the current lesson, as well as three skills that they should work on in the future. This learning landscape can be used throughout the school year, to monitor development of these skills.

Name:____________________

LEARNING LANDSCAPE

Personal qualities not often measured by tests.

Creativity	**Collaboration**	**Leadership**
Critical thinking	**Endurance**	**Compassion**
Resilience	**Reliability**	**Courage**
Motivation	**Enthusiasm**	**Independence**
Problem-solving	**Self-awareness**	**Resourcefulness**
Curiosity	**Self-discipline**	**Spontaneity**
Questioning	**Empathy**	**Tenacity**

In green pen explain how you have successfully demonstrated any of these personal qualities.

In purple pen explain why you might want to take the opportunity to develop any of these qualities in other enquiries.

Date the boxes you have filled in.

Do not address any ‘qualities’ you have not reflected on as a result of the current inquiry.

Figure 3: Learning landscape used in **CS3 United Kingdom**.