4.4 Case study 4 (CS4 Hungary)

Concept focus	Construction of a model system
Activities implemented	Activities A-C
Inquiry skills	Planning investigations Forming coherent arguments
Scientific reasoning and literacy	Scientific reasoning (drawing conclusions, identification of variables, transfer of knowledge from model to real system)
Assessment methods	Classroom dialogue Teacher observation Peer-assessment Worksheets Student devised materials (pudding) Presentations
Student group A	**Grade:** lower second level (science class) **Age:** 15-16 years **Group composition:** co-ed class, mixed ability (24 students) **Prior experience with inquiry:** Some experience
Student group B	**Grade:** upper second level (biology class) **Age:** 17-18 years **Group composition:** co-ed class, mixed ability, higher level of prior knowledge (10 students) **Prior experience with inquiry:** Some experience

This case study describes implementation with two classes – one lower and one upper second level. The key skill identified for assessment was *planning investigations*, as well as *scientific reasoning*, which was evidenced by ability to identify variables, draw conclusions and transfer knowledge from the model system to the real pudding. The teacher provided formative oral feedback throughout the lessons, as well as evaluation of written artefacts using a rubric and a student questionnaire.

(i) How was the learning sequence adapted?

In this case study, the **Proof of the Pudding** SAILS inquiry and assessment unit was implemented with two classes at lower and upper second level in an alternative secondary school. We compiled the plan of the unit on the basis of non-structured (*open inquiry*) or semi-structured (*guided/open inquiry*) problems using our prior experiences with this teaching method. Finding a topic that was interesting for students and that encouraged them to conduct individual research was an important consideration for choosing to implement this unit. The topic is appropriate for using practical and manual skills, and is linked to everyday experiences.

Adapted learning sequence of the unit

The learning sequences for activities A and B are detailed in Table 1 and Table 2, respectively.

Table 1: Activity A: Preparation of inquiry

Student learning activity	Supportive teacher questions
Warming up Raising interest and enthusiasm, looking up the background of the task ***Theoretical introduction*** Recalling, organising and complementing conceptual knowledge linked to the task necessary for solving the problem ***Formulating inquiry question*** with students, e.g. ***How can we make really good pudding?*** • Simplification of the end product, • Construction of a model that enables the formulation of the desired state. ***Students' task:*** 1. Choice of a suitable condenser, 2. Defining the addition rate, 3. Planning an experimental system ("a pudding model") in connection with point (2) 4. Making and analysing dilution series.	What makes the pudding good or bad – what positive features or quality problems could you define? Which pudding can be made more easily? What kind of main nutrient groups do you know? What kind of advantages or disadvantages do those nutrients groups have? With consideration to what would you choose the main nutrients? How could you define when the pudding is in an appropriate state? What methods could you find in order to define the differences between the thickener materials? How could you get the jelly-like consistency of the custard in the simplest way? How could you find out the proportion of compounds in the model?

Table 2: Activity B: Planning the investigation – applying the model to make a real pudding

Student learning activity	Supportive teacher questions
On the basis of common concepts agreed by the group plan the making of real pudding according to the following instructions: 1. The weight must be exactly 500 g, 2. It must have a jelly-like consistency, 3. It must contain as many nutrients as possible, 4. It has to have as little energy content as possible Formulating quality considerations and planning the content accordingly.	What kind of qualities can pudding have? How could you rank these criteria? On the basis of what considerations could you define the proportion of compounds? How can the pudding change with the addition of further ingredients? Which ingredients could be minimised or maximised? How can you calculate the energy content of the pudding?

During the preparatory phase the students' prior knowledge and the deficiencies to be complemented before the investigation could be assessed. In this phase the teacher's presentation dominated, and after some thinking time, students answered the teacher's questions. During the preparatory phase the students got acquainted with the task, their interest rose and their conceptual knowledge was activated.

In the second phase of the task the students had to recognise the importance of constructing the model system. They had to realise that the end product contains a lot more compounds than the simple model system. They had to realise that they could define the conditions of jelly state only with experiments. From this solution, with the help of inductive thinking, they had to understand that it is best to investigate what works and how using a model system, before doing the real process on a large scale.

The students had to transfer the results of model system experiment to the process of preparing the end product. They could use the defined condenser and dilution rate, while in order to increase taste and nutrient value they had to add further ingredients to the pudding. During this phase they had to collect data about the ingredients, and analyse their nutrient value and energy content. They had to define the rates of compounds of the fixed total amount, taking care to meet the proposed criteria.

In the third phase of the task the presentation of the end products took place. The groups presented their ideas formulated during the planning and implementation and compared them with the features of the end product. They evaluated one another's work and they expressed critical comments if it was necessary. Both self- and group assessment took place, during which the students could practice reflective and critical thinking.

(a)  (b) 

Figure 1: (a) Students engaging with the task, and (b) the final product

(ii) Which skills were to be assessed?

From an IBL viewpoint the developmental focus of this task was the construction of a model system and use of system thinking. The supportive and diagnostic questions given to the groups provided the basis of the formative assessment. During the planning of the models the teacher visited each group, asked some questions and, on the basis of the given answers, the students' improvement could be clearly detected. During the preparation of the end product, the groups worked less collaboratively and it was difficult for the teacher to observe the collection of information, argumentation and debates. Instead, this work phase could be evaluated based on the groups' final presentations.

In order to assess the construction of the model system, it had to be stated if the students understood its importance and connection with the end product. In the case of the evaluation of the practical implementation, it had to be observed that the students worked with appropriate measures, materials and methods. During the preparation of the end product, the quality of the pudding was worked out by setting the variables. The appropriate handling of the data on specific energy had to be evaluated and whether the students choose the main groups of nutrients in an adequately varied way. In the final phase of the task, reflective thinking was evaluated, for example how much the students are able to recall their own thinking, if they identified their mistakes, and whether or not they argued for or against the choices of alternatives.

The main tool of formative assessment is the teacher's oral feedback. In inquiry based learning these are helping questions, and are connected to the students' activities. We used different written assessment tools in both student groups. In science class we used a rubric method to represent student's performance (Table 3), while in biology class we used a questionnaire (Figure 2).

Table 3: Three-point rubric used for assessment of skills in science class in CS4

Assessed Skill	Acceptable	Needs improvement	Poor/NA
Planning investigations	You are able to investigate a problem or to solve it and to formulate independent suggestions. On the basis of testing the suggested method you are able to revise your original ideas. You can independently recognise the variables even if they are not identified in the task. You are able to control the independent variable properly.	You can start investigating and solving the problem on the basis of given instructions but you are able to find solutions independently to emerging problems. You are not able to recognise the variables independently but on the basis of given instructions you are able to comprehend and control them.	You can hardly understand the purpose of investigating the problem but you can complete the given instructions. In the case of difficulties you need help. You are not able to recognise the variables independently, you can hardly understand them on the basis of the instruction, you often make mistakes while controlling them.
Scientific reasoning	You are able to draw conclusions on the basis of experimental results examining and measuring variables. You can transfer the results of experiment or model to real problems.	You record the results of the experiments properly but on the basis of them you are not able to draw conclusions. You can be led to the connection between the experiment, the model and real problems, but you are not able to recognise them independently.	You are not able to draw conclusions on the basis of experimental results and observations. You cannot transfer the results of experiment or model to real problems.
Experimenting	You are able to carry out the planned experiment by yourself, to recognise to causality, you can write/draw the process and results of an experiment exactly.	You are able to carry out experiments with somebody's help, mostly you can recognise the causality with somebody's help, you can write/draw the process and results of an experiment with only a few mistakes.	You cannot carry out experiment by yourself at all, you cannot recognise the causality during the experiments, you are not able to write/draw the process and results of an experiment

(iii) Criteria for judging assessment data

For the lower second level class (science class) we use a three-point rubric to assess the skills of *planning investigations*, *forming coherent arguments* and *scientific reasoning,* and experimenting (Table 3).

We constructed a questionnaire to assess the biology group. It included the key elements of inquiry, the thinking steps and skills (Figure 2). At the end of the lesson every students completed the questionnaire. During the next learning period we discussed the answers.

Students' questionnaire

I. Preparation of inquiry

A. Warming up

1. What are the aspects based on which you could compare home made pudding to industrially produced pudding?

2. What makes a pudding good or bad? What positive features and quality issues can you find?

B. Theoretical introduction

1. What basic nutrient groups can you name?

II. Planning and implementing the inquiry

A. Planning of the jelly state – creating a model

1. Which aspects/methods could you find to define the differences between condenser materials?

2. How could you define/test the rate of the compounds of the model system?

3A. Which variables are in the model experiment? Which ones should you fix and which might be independent variables?

3B. How could you define the appropriate state/density of the pudding? Which observation, test or measurement is appropriate for it?

B. Planning the compounds of 500 g pudding

1. What are quality specifications for a pudding? Put them into order of importance.

2. Which ingredients' quantity should be minimised and which should be maximised in your opinion? Why?

3. How would you calculate the energy content of the pudding?

4. Write down the list of ingredients of the pudding made by your group:

Figure 2: Student questionnaire used for assessment in CS4

(iv) Evidence collected

Teacher opinion

We examined the assessment tools and strategies used during IBSE lessons from the point of view of formative and diagnostic functions. The appropriate support of the learning process is an essential condition of the success of inquiry based learning methods. Teacher's instruction with oral questions and feedback help to avoid mistakes noted by critics of the IBL methods, help to concentrate on the relevant topic and to maintain effective timing. The rubric method of assessment connected directly to the class is a formative tool while it can also assist the students' further progress beyond their existing skill level. These rubrics can contain sentences written in advance and they are appropriate for the assessment of science learning generally. The method is more effective if the sentences apply to the task that is being assessed. These assessment tools should be compiled as elements of the unit connected to several critical points and thinking steps of the inquiry. In our science class we used fairly general assessment sentences since the students had completed similar tasks, and we have ideas about their skills and knowledge. In the future we would like to compile rubrics connected to a certain unit.

In the biology group we used an assessment method in which we asked questions in connection with the content elements and inquiry skills of the examined problem. The students completed this questionnaire during the learning session or immediately after it. The written form was effective because we received answers from each student in contrast with the oral questions during group work. We analysed in detail the questions and answers during the next lesson, so the students could think about thinking in a metacognitive way. The metacognition can help self-directed learning of science. For the teacher this form is connected to diagnostic function of assessment.

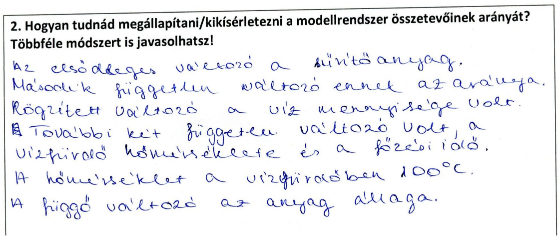
On the basis of students' answers collected through the questionnaire method our previous picture about the heterogeneity of student group is confirmed. This heterogeneity appears partly because of differences in the development of skills, and partly because of the differences in prior knowledge. The best students were able to make the most of the IBSL method; they formulated hypotheses independently, and used their own methods to test them. Being able to modify the methods indicates flexible thinking and creativity. The students who need further assistance were not able to do this independently; they could only solve the emerging problems with help. During the debate with peers these two types of students could cooperate, so instead of the teacher's support they could often help each other.

Sample student artefacts

Student artefacts from the assessment questionnaire are shown.

II. Planning and implementing the inquiry – A. Planning of the jelly state – creating a model

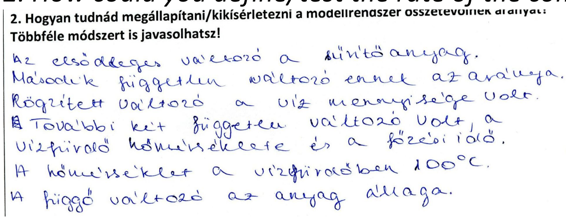
1. What methods could you find to define the differences between condenser materials?


2. Hogyan tudnád megállapítani/kikísérletezni a modellrendszer összetevőinek arányát? Többféle módszert is javasolhatsz!

Az elsödleges valtozó a sürítö anyag.
Második független valtozó ennek az aránya.
Rögzített valtozó a víz mennyisége volt.
További két független valtozó volt, a vízfürdö hömérséklete és a főzési idö.
A hömérséklet a vízfürdöben 100°C.
A függő valtozó az anyag állaga.

We can examine the compounds and its origins. Also, we can choose them on the basis of effectiveness. We can control it with a test. The group decided to try all of them and on the basis of the results to choose the most appropriate one

2. How could you define/test the rate of the compounds of the model?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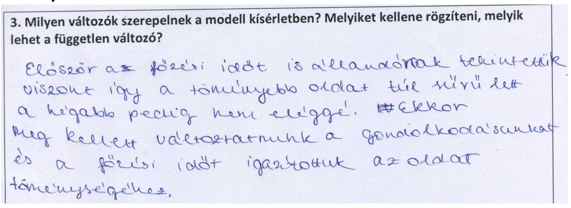
A hömérséklet a vízfürdöben 100°C.
A függő valtozó az anyag állaga.

The first variable is the type of condenser. The second independent variable its rate. The fixed variable is the quantity of water. Further two independent variables were the temperature of water bath and the heating time. The temperature of the water bath was 100 °C. The dependent variable is the state of the mixture.

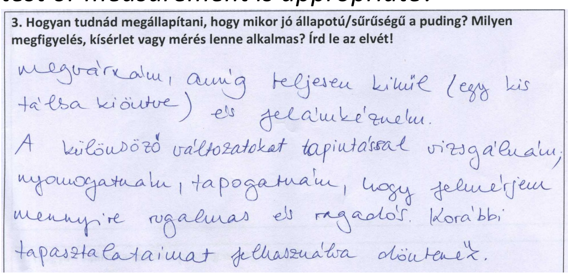
3A. Which variables are in the model experiment? Which ones should you fix and which might be independent variables?


3. Milyen változók szerepelnek a modell kísérletben? Melyiket kellene rögzíteni, melyik lehet a független változó?

Először a főzési idöt is állandónak tekintettük viszont így a töményebb oldat túl sürü lett a hígabb pedig nem elégge. Ekkor meg kellett változtatnunk a gondolkodásunkat és a főzési idöt igazítottuk az oldat töménységéhez.

Firstly we considered the heating time as a constant but the concentrated solution became too dense, while the less concentrated was not dense enough. Then we had to change our mind and to adjust the cooking time to the concentration of the solution.

3B. How could you define the appropriate consistency/density of the pudding? Which observation, test or measurement is appropriate?


3. Hogyan tudnád megállapítani, hogy mikor jó állapotú/sűrűségű a puding? Milyen megfigyelés, kísérlet vagy mérés lenne alkalmas? Írd le az elvét!

megvárnám, amíg teljesen kihül (egy kis tálba kiöntve) és felcímkézném.
A különbözö változatokat tapintással vizsgálnám, nyomogatnám, tapogatnám, hogy felmérjem mennyire rugalmas és ragadós. Korábbi tapasztalataimat felhasználva döntenék.

I would wait while it will cool down and I would label it (packed it into a small glass plate). I would examine the different samples with touching and pushing to measure how it is flexible and sticky. I would decide using my previous experiences

(v) Use of assessment data

The unit allows for different follow-ups if two groups are present. Investigational skills of half-structured problems were developed in the group whose participants study science. They may deal with more problems of this type in the future and could advance to the point of investigating non-structured problems.

The upper second level biology group could apply the conceptual knowledge in the following topic:

- Colloidal systems in living organisms
- Colloidal systems in technology (e.g. paints),
- Sol-gel transition

(vi) Advice for teachers implementing the unit

The pre-requisite of the successful adaptation of the unit is a basic level of experimenting skills on the students' part. They have to be familiar with the tools and the techniques used as well as the rules of handling substances. In case they are considerably new to these skills, they will need more detailed instructions either orally or on their worksheets. The degree of teacher involvement needs to be designed in such a way that students will be able to work independently and with proper efficiency at the same time, their activities staying in the area of the topic to be investigated.