

Motivate and Attract Students to Science

Early Inquiry - Exemplary Science Lessons, Recommendations for Educators and Training Activities





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1. Introduction

A declining interest in science

In recent years, many studies have highlighted an alarming decline in young people's interest for key science studies and mathematics. The origins of the declining interest among young people for science studies are found largely in the way science is taught in schools.⁹ The interest of students in science education drops because students find science difficult. In traditional science teaching practices, students are expected to remember large volumes of information and there is no time to understand it all. Moreover, the information is often disconnected from real life and, therefore, it does not make sense to students.¹

The MASS project

So how can we make science education more attractive and accessible for students? This is the main question in the Motivate and Attract Students to Science (MASS) project.

We found that issues of sustainable environmental education lend themselves particularly well to this purpose since they provide the motivational advantage of relating to students' everyday lives, are often the subject of public discourse and provide direct links to different scientific disciplines, enabling cross-disciplinary interactions, including not only the sciences but also the human dimension.

Eight countries (Czech Republic, Poland, Estonia, Latvia, Germany, Greece, Cyprus and the Netherlands) combined their expertise and joined forces to find answers to this question. Good practices from all countries were collected and analysed and are now being disseminated throughout Europe. The MASS project hopes to support teachers in their endeavour to provide attractive and motivating approaches to teaching science, which will hopefully help make students' learning experience in science more relevant, fun and accessible.

Three challenges

The MASS project has identified three major challenges in making science education more attractive for students.

1. Science through digital learning

The majority of today's generation of students use digital devices, internet applications and social media on a daily basis. *The MASS project shares good practices and experiences with using digital tools and media to make science education more meaningful.*

2. Early inquiry

Inquiry has proven to be an effective method to attract children to science to increase their learning success, especially at a young age. *The MASS project analyses barriers to using inquiry-based methods at schools and shows successful implementation of these methods into the science classroom practice, with a special focus on primary school learners.*

3. Low achievers in science

Science is a setting where we learn important lessons about the real world; that is why it must be delivered to every child. *The MASS project collects, pilots, adapts and shares practices that deal with attracting low achievers to science and help them develop some of the key Competencies that are basic life skills at the same time.*

For all of these challenges, products (i.e. tutorials, training sessions, lesson plans) have been developed. Check the MASS website www.mass4education.eu for the latest updates.

About this publication

The partners in the MASS project believe that by addressing these three challenges, we help significantly to show the relevance of science in real life that concerns every one of us. If we start speaking the language and using the tools that are attractive to our students, we can make science education more popular.

Studies also show that most of the problems children have with science in schools have their origins in their early years. Therefore it is very important for successful and interesting science education in high school to understand the role of science in early childhood.²³

Inquiry-Based Science Education (IBSE) is a relatively new teaching approach. Various research shows that the participatory and activating approach of IBSE increases students' motivation to learn and their interest in science. Similarly, the results show that students can apply the knowledge obtained by IBSE in their real life.¹

The aim of this material is to provide information that will help educators to implement IBSE when educating students between 6 and 14 years of age and develop their own lessons. The material contains information about IBSE, its use, advantages and disadvantages, as well as several activities for training the skills. The material also contains science lesson plans that are easy to implement into classroom practice.

2. Inquiry-based science education

2.1 History

Educators already realized that traditional forms of instruction – where people memorize information from instructional materials – were no longer sustainable back in the 1960s, when a discussion about the nature and aim of science education started in the USA.³ The debate has resulted in the introduction of a constructivist education approach. Inquiry-based learning is used as a constructivist approach for science education. In Europe, the pedagogical method started to appear in the 90s.⁷

2.2 Description and definition of the method

There are many approaches and opinions about what IBSE is. The expectations related to IBSE differ depending on the way IBSE is defined.⁸

According to Cincera (2013) IBSE does not represent a uniform methodology. It can be seen as a complex of approaches which put emphasis on different elements.⁵ Also Papacek (2010) states that IBSE is not a narrowly defined educational method, but its interpretation is related to the role of the teacher who uses IBSE.¹⁰

In the literature, IBSE is usually described as learning in which students construct knowledge through predicting, observation and hands-on experiments in the same way as during real research. Teachers guide the learning process, which is essentially student-centered. (e.g. 1, 2, 7...)

IBSE works with the presumption that inquiry is the essence of science. Planning, specification and realization of experiments is an important part of the process of acquiring key concepts. Inquiry gives students a chance not only to learn, but also to understand the process of producing scientific findings and thereby experiencing the nature of science. In IBSE, acquiring new concepts and research methods goes hand in hand.⁸

IBSE uses activating teaching methods: heuristic techniques, critical thinking, problem-based learning, experiential learning, project-based learning and situated learning.¹ A spectrum of approaches covered by IBSE is also presented in the following table published by the Centre for Excellence in Enquiry-Based Learning.

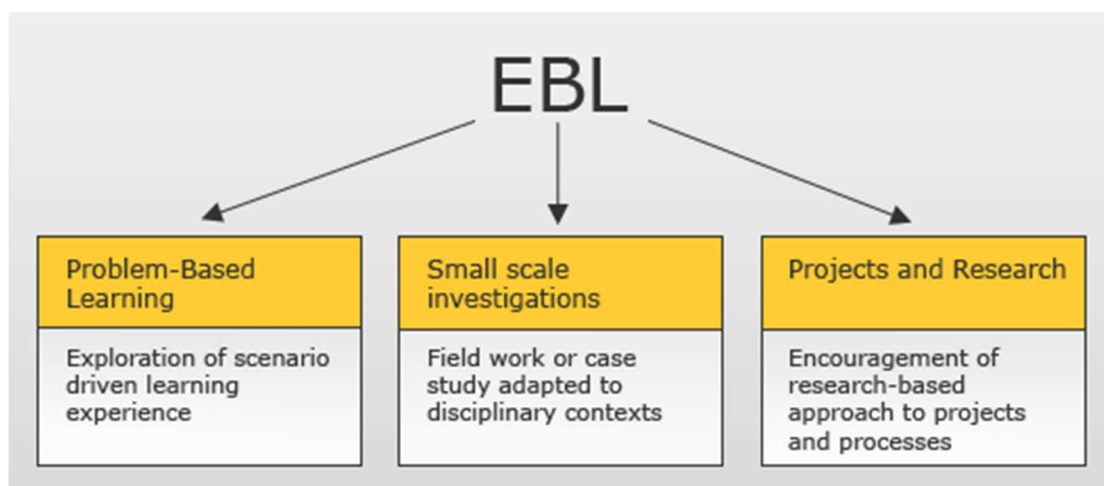


Figure 1: : A spectrum of approaches covered by IBSE²

Rocard et al. (2007) understands IBSE as an educational approach where knowledge is constructed by solving a specific problem in gradual steps.⁹ Teachers become facilitators; they provide encouragement and support to enable students to take responsibility for what and how they learn.² In a way the approach shows a blueprint for the real scientific research process. Starting with hypothesis formulation, through problem-solving by using a reasonable and justifiable method on which students and teachers have agreed in advance and through students' discussion, to documentation of the results, the IBSE approach facilitates own experience in the scientific process, builds trust and self-reliance, supports critical thinking and reduces the threshold to partake in science.¹⁰ This way students reach a point where they are not simply investigating questions posed by others, but they can formulate their own research topics and convert the research into useful knowledge. Students gain a deeper understanding of the subject and also the knowledge-development and leadership skills that are needed for solving real life problems.²

The emphasis is put on group work and use of the library, web and other information resources.

2.3 Research cycle description

The structure of the research process is based on the specific steps of investigation that logically follow after each other. The same sequence is applied in the classroom when students do an inquiry-based lesson or project. The cycle is divided into several steps:

1. Motivation
2. Posing questions
3. Finding information

In these three introductory steps, it is important to engage students and start a train of thought, such as "why it is like that?" or "what if..." in a student's mind. If the student develops an intrinsic motivation to investigate a topic, their interest in learning increases.

Skills developed

The student:

- thinks critically about a given topic
- gains more information from various sources
- classifies the obtained information
- evaluates credibility of information sources
- poses questions
- searches for answers and connects these to already gained knowledge and experience
- compares their questions and opinion to those of classmates and other sources
- chooses a research question

4. Predicting – hypothesis

IBSE allows students to experience the procedure of scientific work. Scientists search for evidence that supports or rejects their hypothesis. Based upon a clearly formulated research hypothesis, a suitable research method can be selected. Likewise, students' experiments or observations should confirm or reject a hypothesis. Thus the original research question is addressed through accepting or rejecting the hypothesis. While the scientific term "hypothesis" may be paraphrased by words such as assumption, prediction, result-estimation or in another way appropriate to students' age, the process which leads to a research method based upon an assumption is key to understanding "how science is made".

Skills developed

The student:

- articulates expectations concerning the result of an experiment based on current knowledge
- formulates a hypothesis related to the research question
- formulates a hypothesis based on the general criteria for hypothesis (see chapter 5.4)

5. Experiment – planning, preparing and conducting an experiment, observation and recording

A hypothesis can be verified by the study of information about the topic, consultation with an expert who should provide understandable and verifiable evidence rather than just an expert opinion, by observation or by experiment. When planning an experiment, all phases should be considered: preparation of materials, observation, measurement, conducting the experiment

and data recording. The results of the experiment should be recorded and presented using tables, charts or diagrams. Photo documentation can also be useful for the presentation of results, for example in the form of a poster or PowerPoint presentation.

Skills developed

The student:

- independently chooses and plans a method of how to verify a hypothesis
- cooperates in a group, agrees with others on division of roles
- systematically records data

6. Data analysis

Data analysis is a key aspect leading to meaningful organization of the data, extraction of the information relevant to the content and to supporting evidence. The student's reasoning for selecting a method of analysis is an important diagnostic tool to identify whether or not a student has grasped the concept of objective, evidence-based reasoning and argumentation. The range of data analysis methods is great, ranging from simple graphic display to statistical analysis. The appropriate choice depends largely on the student's age and the respective research hypothesis.

Skills developed

The student:

- develops analytical abilities
- processes and interprets data and presents them graphically

7. Return to hypothesis, conclusion – decision-making

The conclusion should not be drawn from personal opinions, preferences or expected results but rather from the evidence at hand provided by the data analysis. The final word on rejection or support of the hypothesis is made.

8. Presentation and context-finding

Articulating the findings of the research and reasoning based upon the available evidence using the appropriate terminology is key in this step.

9. Reflection

Here a critical reflection of one's own results and comparison to results obtained by others is important to understand the achievements as well as the limits of the research and to develop the follow-up research question, thus understanding science as an endless evolution of acquiring knowledge rather than a closed compilation of facts.

The last steps complete a research cycle, but can also be the beginning of a further inquiry process. The important part of these steps is an evaluation of the inquiry and assessing whether the assumption was proven. What new questions and doubts appear during the inquiry? How can I or other people use the obtained results and knowledge in real life? How will others learn about the inquiry? How can I present information about the inquiry in an interesting and clear way?

Skills developed

The student:

- deduces conclusions from results (tables, charts, pictures) or from a text
- clearly and with their own words summarizes important facts

- generalizes, relates the topic to their life and knowledge of the topic
- chooses important information for the presentation
- presents results
- states information sources and discusses their credibility
- answers questions

2.4 Explanation of teacher's and students' roles within inquiry lessons

According to The Explorers Project team (2013), in IBSE, students should determine a problem, pose questions, formulate a hypothesis and search for arguments confirming or rejecting the hypothesis. Students need to use critical thinking, consider alternatives and deduce results. They also work in teams, discuss, use arguments and have their results evaluated by others.¹

Preferably, the teacher assumes the role of a students' guide who plans a teaching process and methods (gives tasks, helps to find requisites and recommends literature sources) so that all students join in. If possible, the teacher does not interfere in the students' train of thought or in their work much. They help to find a good direction, so the students can find a solution to the problem themselves.

IBSE can be incorporated into education progressively. This gradual progress is important for making IBSE more understandable and thus attractive for students. Teachers can gradually shift more and more responsibility for the inquiry onto students.¹

The proportion of activity between a teacher and their students during IBSE is presented in the following figure. The change from a teacher-directed to a student-directed approach depends on the needs and readiness of the learner.¹²

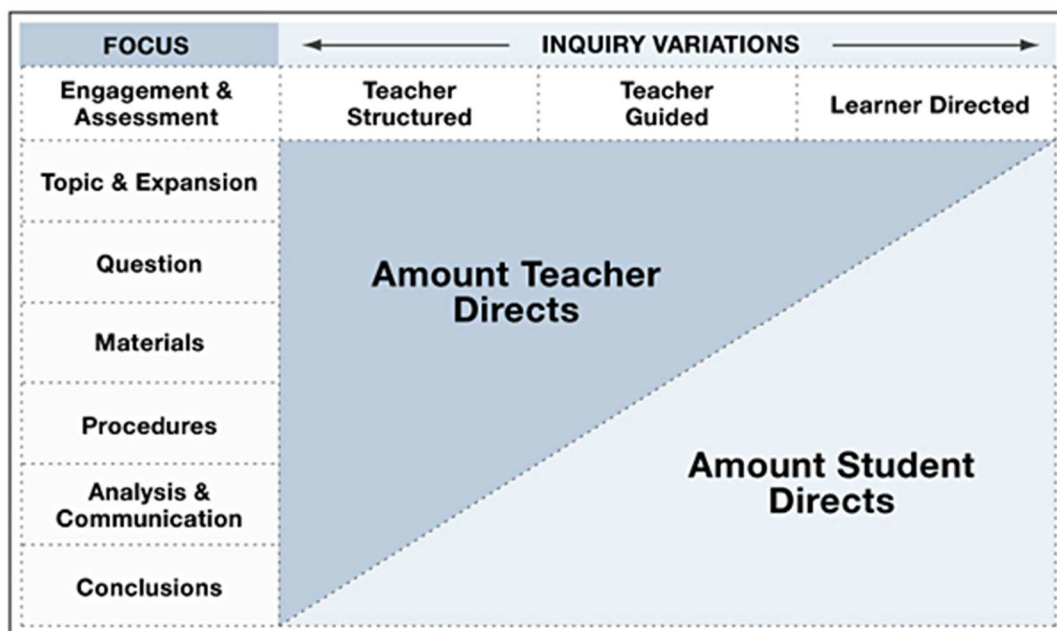


Figure 2: Proportion of activity between teacher and students during IBSE¹²

Another distribution of teacher-student activity was presented by Eastwell (2009):

- Confirmation inquiry – the responsibility for both the question and methodology is shifted to students; results are known, the aim is to verify them by students' work
- Structured inquiry – the question and a possible methodology is presented by the teacher; students formulate an explanation of the studied phenomenon
- Guided inquiry – teacher asks a research question; students create and realize a method
- Open inquiry – students ask questions, think about a method, conduct research and formulate results⁸

The extent of students involvement depends on their experience and on the way the responsibility for inquiry is gradually passed on to them by the teacher. The results of a gradual adaptation of the lessons can be seen in the table below.¹

The student	← extent of inquiry control by the teacher decreases, extent of inquiry control by the student increases →			
works with research questions	poses questions without problems and independently finds a solution	independently classifies given questions and poses new ones with which they subsequently work	specifies questions given by a teacher or found in another way and looks for a solution	searches for an answer to questions given by a teacher
focuses on searching for evidence and reliable data	searches for data necessary for confirmation or rejection of a hypothesis and analyzes them	under the guidance of a teacher acquires data, which they afterwards analyze and use as evidence	receives data and their task is to analyze the data so that they can be used as an evidence	receives data and instructions on how to analyze them

Table 1: The extent of students' involvement in an IBSE lesson. (The Explorers Project team, 2013)

When effective inquiry is taking place, students are:¹²

- Asking scientifically oriented questions
- Giving priority to evidence-gathering
- Formulating explanations from evidence
- Evaluating their explanations in light of alternative explanations
- Communicating and justifying their explanations

2.5 Skills that students learn during Inquiry-Based Science Education¹

IBSE develops many competencies in students, e.g. motivation to study, critical and creative thinking, logical deduction, ability to make a work plan, independence, responsibility and also cooperation among students, which is essential for scientific work and research.

IBSE is not only a preparation for a scientific career. Inquiry helps students to practice skills that are useful in various life situations, such as communication with co-workers or critical thinking about work tasks.

There are many skills that students can develop during inquiry. They can be learned gradually and the more the student learns, the better they feel in the role of the inquirer.

What do students learn through IBSE?

- Students are interested in the way the world works and learn new information.
- Students search for information connected to a topic. They learn how to choose important data.
- Students cooperate with their classmates. They learn how to divide up roles and responsibility.
- Students come to realize that they can learn much from their mistakes.
- Students do not overlook details and monitor changes in an observed subject. They estimate the reasons, origins and consequences of things.
- Before beginning an inquiry, students plan a method of how to verify their presumptions. They also plan a time frame.
- During inquiry, students write down their thoughts. They make sketches during observations and record data into tables.
- Students can express their thoughts. They discuss their inquiry with friends, teachers and parents.
- During inquiry, students assess where they are successful and what needs improvement. They are happy if they succeed.

Critical thinking

Critical thinking is connected not only to the ability to ask questions, but also with the ability to ask the right question at the right time. To think critically means to review what we hear, see, or read, to search for reasons and suggest solutions. It is a continual investigation of the reality which students face during learning. Very important is the way students work with mistakes. They do not accept failure as a fact, but think what could have been done in another way. Critical thinking is closely related to literacy. Students not only understand a text, but can also find contradictions or connections in it. They can also explain in their words what the text was about and express their opinion.

Cooperation

During IBSE, students often work in small groups where students cooperate and communicate, or they work in teams where each student has their own role. Roles such as record keeper, photographer or measurer are often part of IBSE lesson descriptions. But what does it mean that a student can cooperate? Cooperation ability means that a student can accept a role or task, or even ask for one – suggesting what they could help with during the lesson. Students take their roles responsibly and in case of failure they do not put the blame on others. On the contrary, students should learn how to ask others from the group for help.

Communication

Students use communication skills during the teamwork, but they practice them also when they speak on their own – for example while giving instructions, explaining the progress on an experiment or presenting results. If a student works in a team, they have to record their observations so that others can read and understand them.

2.6 Science education for young students

Science is vital for the progress of children from the very beginning. For years Jean Piaget's theory of cognitive development was the basis for an understanding of cognitive development in early childhood.¹⁶ However, from current neuroscientific and psychological research results we know that infants can already run through complex thinking processes like building categories or linking experiences.¹⁷

Because our world is substantially based on science and technology it is natural to integrate science in the first years of childhood. The first steps of young children in science according to Schäfer (2008) are diverse and varied experiences with nature and its phenomena. Children need to have opportunities to explore their surroundings. These experiences will give them an idea about the animate and inanimate parts of the world and a feeling for objects. With a vast amount of these experiences, children start to collect, organize and – parallel to the development of language – communicate these experiences.

Educators and teachers need to provide a wide range of opportunities to communicate with children. This can occur by motivating kids to tell a story, to draw a picture or a sketch, to build a scene or to play some kind of music they connect with these experiences or by addressing unusual topics.¹⁹ Through these varied methods of communication a transformation of experience-based knowledge to conceptualization of processes to theoretical thinking is supported. This transformation is the crucial step in the cognitive development of children.

How this transformation takes place is best described in the theories of conceptual and developmental change according to Kuhn, Vosniadou and Nelson. Most of the problems children experience with science in schools have their origins in their early years. Studies have shown that building of interest in scientific discovery already starts in pre-schools and kindergarten and if kids have had the opportunity to explore nature they are more likely to show interest in science and be motivated in their teenage years than children who did not have these opportunities. Therefore it is very important for successful and interesting science education in high school to understand the role of science in early childhood.²³

3. IBSE within the educational context

3.1 Recommendations on how to start with Inquiry-Based Science Education

a) Open communication

Development of IBSE is limited by many conditions, determined by each school, class, student or teacher. Therefore, it is important to set up a safe environment in the class where open communication and respect for others prevails and where students feel safe and comfortable. It is very difficult to apply IBSE in a class where students do not trust each other or their teacher, where they are afraid to communicate and to share their opinion.

b) Cooperation prevails over competition

In IBSE, an atmosphere of cooperation, rather than of a competition, should be supported. The aim is not to get the correct result for an experiment as quickly as possible, but to have one's own method and achieve a result, which can differ from the results of others. What is important is to realize that the goal is to develop all students' skills, not only the skill of the fastest and most competent ones.

c) Tools and equipment – keep it simple

IBSE certainly requires some supportive equipment and sometimes technical devices. However, IBSE can be applied even without expensive equipment such as microscopes or pH meters. In many lessons, plastic bottles, scissors and a ruler are sufficient.

d) Do not give answers to all the questions

The principle of IBSE is not to reply to all questions posed by students (even if the teacher knows the answers). Instead it aims at motivating students to search for answers individually by asking parents, through their own research and experiments, through literature reviews in books or on the Internet. In a proper inquiry lesson, students get interested in many new questions and their motivation to find the answers increases. Continuing the quest for the answers outside the school with parents, friends or on their own strengthens particularly the self-reliance and confidence to address scientific questions. In this way, the interest in the topic is kept high and students look forward to future lessons.

e) Teachers act as researchers

Teaching IBSE in class certainly places considerable demands on the teacher. They should be able to turn into a researcher themselves, to pose questions, to investigate and be enthusiastic about students' discoveries. IBSE is based on instigation of students' natural curiosity and on the development of their creativity and fantasy. IBSE is skill- and competence-oriented, thus an output approach should be used rather than an input-oriented approach such as lectures. Integrating IBSE into the curriculum and thereby utilizing the motivational potential of the approach therefore poses a particular challenge. IBSE should not be perceived as just another method as part of the curriculum.

How to start with IBSE – tips from teachers:

1. Alternate IBSE and common (regular) teaching practices.
2. Choose diverse lessons (e.g. do not to have two lessons focused on reading in a row).
3. Adapt lessons to the needs and aims of teaching and to the age of your students.
4. Start with individual inquiry steps. Thanks to gradual training, students master inquiry skills step-by-step and thus focus better on topics with which they are working for the first time.
5. Swap experiences with your colleagues. It is very helpful if multiple teachers use IBSE at one school so that they can discuss the progress of their approaches, results and obstacles that they have encountered.

Science notebooks

For IBSE, it is very important that students continuously reflect on what they are working on and why. Owing to the enthusiasm of inquiry, it can easily occur that students forget about the aim of an activity. The science notebook is a simple tool that helps students to stay on track during an inquiry cycle. Regular recording of each step ensures that students are aware of the logical sequence of steps of the inquiry cycle. The science notebook also records students' train of thought and shows what students think of the inquiry. It is recommended that you start with a science notebook at the beginning of the school year or at the beginning of an inquiry project.

Students regularly make notes about the inquiry process. They write down questions, hypothesis and suggestions for an experiment. Notes can be supplemented with sketches, tables, and charts that document the experiment. At the end, students write the conclusions of their inquiry. The notebook is not only a worksheet, but also space for students' ideas, thoughts and original solutions.

For teachers, the science notebook is one of the teaching aids which enable them to follow students' progress in inquiry skills.

Instructions for making a science notebook can be found in Annex 1.

Choosing a topic

The teacher should focus on a topic that is meaningful for students. Every topic (even a commonly taught one) could be interpreted in an attractive way and connected to a real-life experience of students.

A topic is attractive for students if:

- it makes sense from their point of view or if they can use it in real life
- it is controversial or mysterious
- it is topical and related to the real world
- it offers a choice (what will a student work on?)
- it involves surprising moments
- it gives an opportunity for self-realization
- it is appropriate for their age

Questions that can help to verify suitability of the chosen topic:

- Can students verify a chosen matter on their own?
- Can they do it at school?
- Do they have enough time for the topic?

Avoid choosing broad topics, such as water. It is better to narrow them down so that they are easily understood by students.

3.2 Benefits and obstacles of using Inquiry-Based Science Education

IBSE is a relatively new teaching approach and opinions on the result of this method vary considerably from being very positive to skeptical. Some researches show that the IBSE approach increases students' motivation to learn and supports their interest in science. Similarly, results described in the literature show that students can apply the knowledge obtained by IBSE in their real life.¹

However, some research does not confirm the effectivity of IBSE. According to Cincera (2013), the success of the method depends on contextual factors of teaching, on the teacher's competencies and, especially, on the extent to which the teacher embraces the method. Furthermore, it can vary based on initial knowledge and students' skills.⁵

The incorporation of IBSE into education has many advantages and benefits, but it is connected with problems and obstacles, too. An overview of both can be found in the following text.

A) Benefits

Every student is gifted with an inborn creativity and curiosity. If a student has a natural and meaningful experience with science at a very young age, they are more likely to respond positively to complicated learning challenges later on. As a study by Rocard et al. (2007) declares, IBSE proves to be a very effective method for offering such an opportunity. The use of the innate curiosity of students is a big advantage in IBSE.¹

According to Rocard et al. (2007), IBSE is efficient at primary and secondary levels in both increasing students' interest and at the same time stimulating a teacher's motivation. Moreover, IBSE and traditional deductive approaches are not mutually exclusive and should be combined.

The Centre for Excellence in Enquiry-Based Learning (CEEBL) states that as IBSE learning is more relevant to students' own needs, they are more engaged with the subject, enthusiastic and ready to learn. IBSE allows students to follow their own research interests and gives them the freedom and the responsibility to organize their own work within certain limits of the task. According to CEEBL, knowledge gained by IBSE is more readily retained because it has been acquired by experience and in relation to a real problem.²

Edelson, Gordin, Pea (1999), and others describe benefits of IBSE. Below is the summary of benefits described in their study:

- an opportunity to develop general inquiry abilities
- an opportunity to acquire specific investigation skills
- a chance to develop an improved understanding of science
- students can discover scientific principles through their inquiry activities
- recognition of gaps in students' knowledge and their filling by systematic inquiry, refining of students' understanding of scientific principles and their application

The results of MASS project survey revealed the following benefits and strengths of IBSE⁶:

- IBSE is considered meaningful to increase interest in science.
- IBSE is effective with all kinds of students, highly supportive for low achievers
- IBSE is efficient at both primary and secondary level

- IBSE is motivating not only for students (they enjoy IBSE science classes), but also for teachers
- IBSE can be and should be combined with traditional deductive approaches in science lessons
- IBSE is low-cost: no special equipment and tools are needed
- IBSE has a positive impact on the classroom community – collaboration, teamwork

B) Obstacles, challenges and how to face them

Implementation of any new teaching method is connected not only with benefits, but also with several obstacles and complications. It places high demands on teachers' erudition, teaching competencies, flexibility, quick-wittedness, invention and creativity.⁷ According to Schwarz and Crawford (2004), teacher experience is crucial for implementation of IBSE. They mainly need to understand the method and decide what science skills can be developed through IBSE.⁷

This chapter describes obstacles that teachers face during implementation of IBSE methods along with several recommendations of how to face them.

The results of the MASS Project survey revealed several weaknesses and barriers to using the IBSE method:⁶

- The initial stage of transfer to inquiry-based lessons may be difficult for teachers and students
- IBSE is more time-consuming than frontal instruction
- Lack of training support – teachers ask for continuous support in IBSE implementation (no systematic support by school authorities, lack of funding)
- Large size of classes – IBSE is easier to apply with fewer students in a class
- The hypothesis concept is difficult for young kids (9-11) – simplification is needed
- Lack of adequate time to prepare IBSE materials
- Heavily charged curriculum – limited time for IBSE

Limiting factors for IBSE implementation are described also by Stuchlikova (2010), who divides them into two categories:

- logistic factors – factors related to school facilities, class sizes and time frame
- factors connected to students' readiness – their motivation, knowledge, mathematical abilities for recording and assessing results, skills needed for laboratory work

Challenges for successful engaging of students in IBSE are described in detail by Edelson, Gordin and Pea (1999). The challenges are summarized as follows:

- Motivation – to engage students in inquiry in a way which can contribute to a useful learning, they must be sufficiently motivated
- Accessibility of investigation techniques – students must be able to master scientific investigation techniques, such as data collection and analysis
- Background knowledge – students need opportunities to develop and apply a science content knowledge in order to formulate research questions, to develop a research plan, and to collect, analyze and interpret the data obtained
- Management of extended activities – students must be able to organize and manage activities, such as planning and coordination of an activity and the management of resources and work products

- The practical constraints of the learning context – technologies and activities of inquiry-based learning – must fit within the practical constraints of the learning environment, such as the restrictions imposed by available resources and fixed schedules.

Edelson, Gordin and Pea (1999) also suggest strategies how to address the above described challenges:

- Meaningful problems – a problem has to be meaningful to students in order to establish a motivating context for the inquiry
- Staging activities – structured activities that introduce students to investigation techniques and help them to develop a background knowledge
- Bridging activities – activities that help to bridge the gap between students' and scientists' approach. They use practices that are familiar to students for introducing unfamiliar scientific practices.
- Supportive user-interfaces – aim to make investigation tools more accessible to students
- Record-keeping tools – they help students to record the process and results of their activity.

3.3 Interconnection between Inquiry-Based Science Education and digital technologies

Nowadays, communication ability is very often connected with media use skill. When a student needs to document an experiment, they learn how to work with a camera, enter data into computer tables, print out the results and make a photo presentation. The possibilities are endless. In schools, devices such as smart boards, computers, tablets or various sensors become an inseparable part of the lessons. They help to make the science lessons more attractive for Generation Z. New technologies also extend the possibilities for all parts of the inquiry process, especially for the phases of gathering data, experimenting and presenting results.

However, it should be kept in mind that it is not necessary to make use of technologies. Students can also use simple ways of practicing inquiry skills. They can draw the experiment progress with a pen, make a table using a pen and ruler or prepare a poster instead of a digital presentation.






4. Evaluation methods/tools/materials

Evaluation of the lesson by students – Example 1: A questionnaire ^{1, 14}































We would like to ask you to answer a few quick questions about today’s inquiry-based lesson. Thank you for your help!
















In this questionnaire, we always ask you something which has two extreme options. For example, whether you were more cold or hot in class. The more you agree with one of the options, the closer smiley you colour in. The smiley with a straight mouth means that you do not know how to decide.

Look at the example:

Today in the class it was	hot	    	cold
---------------------------	-----	--	------

If anything is not clear to you, ask your teacher. Thank you!

Today’s lesson was	fun	    	boring
Cooperation with your schoolmates was	great	    	horrible
I learned	a lot	    	nothing
I could influence the course of the work	completely	    	not at all
For me the lesson was	easy	    	difficult
Would you prefer the next lesson to be similar to today’s one?	yes	    	no

The topic was	interesting						boring
I could examine questions which crossed my mind	yes						no
The worksheet was	under-standable						unclear

Please fill in the next sentences concerning what you have learned today.

- Before this lesson I did not know that.....
- I was surprised the most that.....

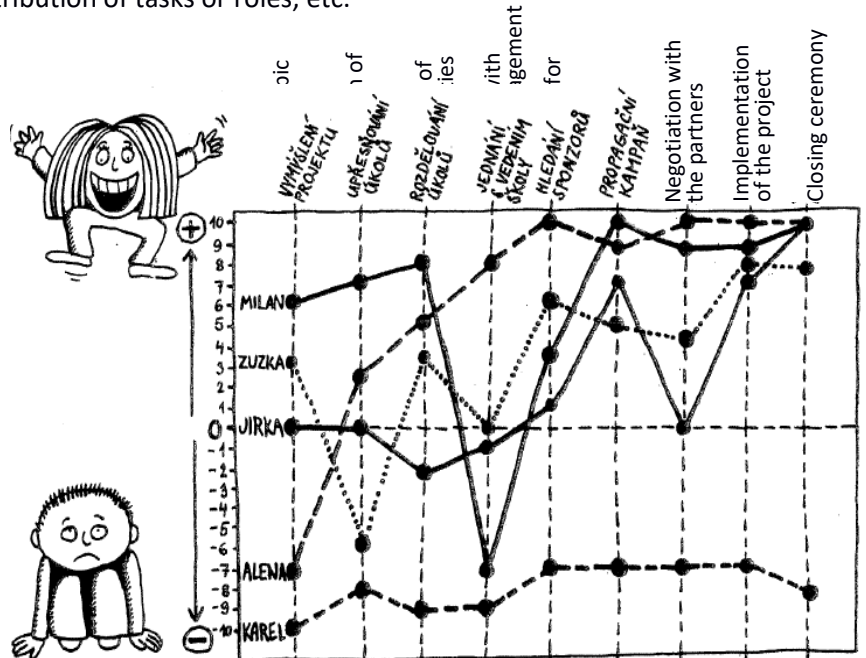
Evaluation of the lesson by students – Example 2: A chart of feelings

Into the chart, draw vertical lines for important moments in your lesson, for example: the beginning, the start of the experiment, the distribution of tasks or roles, etc.

The horizontal line in the middle of the chart represents your neutral feelings (I don't know, I don't remember, it didn't affect me).

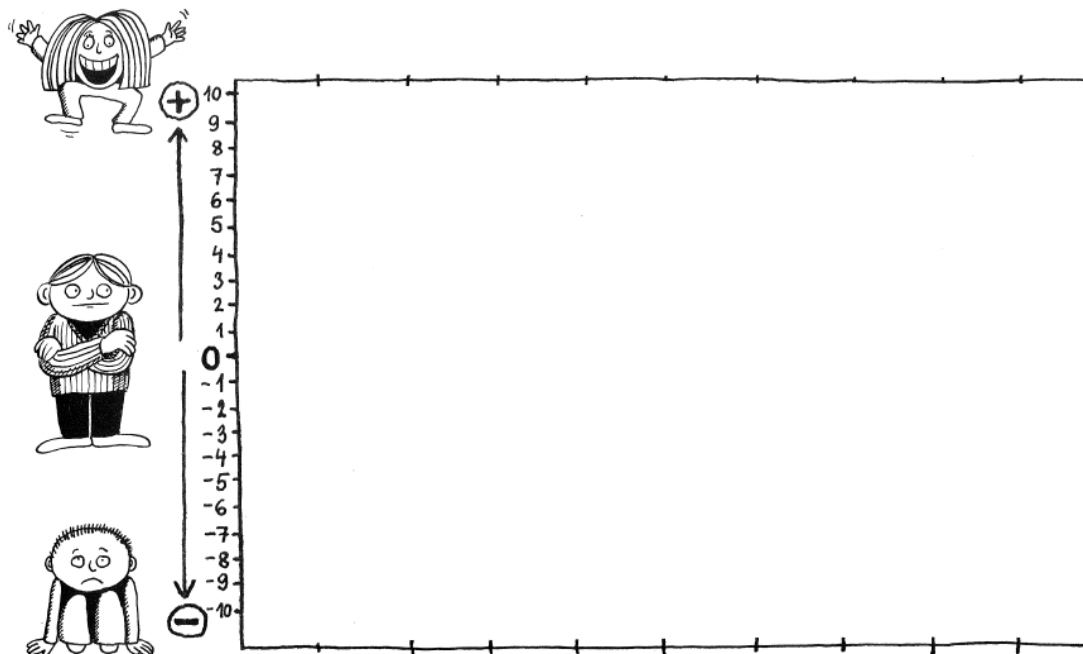
Above the line (1 to +10), you draw your positive feelings and evaluation (it was great, I had a good feeling, it was successful).

Under the line (-1 to -10), you draw your negative feelings and evaluation of each part of the lesson (I didn't like it, we didn't succeed, I am disappointed).



Picture 1: A chart of feelings

Each of the students takes a pen and on the vertical lines (important moments in the lesson) draws their personal feelings and evaluation in the range -10 to +10. The result of the lesson will be visible at first sight. You can also make an average of the personal feelings and draw a chart of feelings of the whole group.



Picture 2: A chart of feelings²⁴

Evaluation of students by teachers

How to evaluate participation of students in various parts of the inquiry cycle? How to evaluate a lesson in which each student formulated their own hypothesis individually? It is very important to observe students during the class and take notes on how they worked.

Questionnaire

Teachers can use the following questionnaire to observe students in class. Not all the described abilities have to be achieved. Teachers can choose those that fit the focus of the lesson. These are not intended as criteria which students have to fulfil so that the approach to the lesson can be considered IBSE. The questionnaire can also be used for self-evaluation of students.

A student manages the described activities: **Very well** – **Average** – needs to **Improve**

- Gaining and sorting information
- A** Posing questions related to the topic
- Formulation of a research question
- I** Formulation of a hypothesis that is based on a research question and can be verified by the available materials
- Planning of an experiment that leads to verification of the hypothesis
- Describing the methodology and necessary requisites
- V** Conducting of experiment
- Recording of experiment progress
- Evaluation of experiment and formulation of its results
- Assessing if hypothesis was confirmed or rejected
- Searching for connections between the topic and real life
- Presentation of results
- Posing new questions
- Group work, playing a role, cooperation with others in a group
- Participation in in-class discussion

5. Inquiry-Based Science Education step-by-step and training activities

5.1 Motivation

How to do it

- Come up with something that would get your class engaged. Look into popular science literature, videos, children's magazines, films, etc. Or follow up on a question that was asked in one of the previous lessons.
- Test your plan. Find a student of a given age category in your surroundings and try to win them over for a topic the same way you have it ready for the class. Watch how they react, listen to their questions. Ask them where they heard about the topic.

What to avoid

- Inquiry topic is introduced as a common teaching topic ("Today, we will talk about...").
- Topic name sounds like a textbook chapter ("Plants and water").
- Using a video demonstration or a picture that is not interesting to the given age group or only marginally connected to what the students will do in a unit.
- Forgetting to clarify the meaningfulness and importance of a topic to the students.

Source examples to help with the introductory motivation

Students up to 10 years of age

- fairy tales, stories, film heroes the students like
- a real story that happened (comics, narration, video, reading)
- the induction of a problem situation
- a demonstration experiment that would surprise the students
- showing an unusual product of nature (a huge cone, a mysterious seed, fruit or carnivorous plant)
- a mysterious object (object photo) with a mysterious story
- the captivation of senses (fruit tasting, scented spice, sound-making insect)
- provocative or "biting" question which would surprise the students and keep their thinking busy
- a task that the students solve independently in the field

Students from 11 to 15 years of age

- possible to use all the above-mentioned means; however, this age category is especially interested in various media, websites and interactive means and topics from students' common life
 - technical and popular science magazine articles (provocative opinion, an article full of contradiction, a discussion of sides that have opposite opinions)
 - TV programs (quality documentaries, discussions, news)
 - Videos can be found using key words or topics in the rich web database of www.youtube.com or in cartoon video units at <http://ed.ted.com/>

5.2 Bibliography (Information, Resources)

How to do it

Think about how the students can map what scientists, parents, co-students or other people, sources, media say about a topic. Consider the ways of getting information that would be acceptable and attractive for your class.

Students up to 10 years of age

The students can map the opinions of their co-students or conduct a survey in their families. They can also study literature. However, if the texts are demanding, assist students with the search. You can prepare sample sources (selected articles, chapters) and model the work with a technical text (what is important and what is not). Encourage the students to ask people, i.e. to get the information from their classmates and family.

Students from 10 to 12 years of age

Encourage your students to get the information directly in the field (in school, garden, at home) or give it to the students as a homework. When working with the sources, make the students draw the information from multiple sources and cite them correctly.

Students from 13 to 15 years of age

Getting information in the field can be done using a more difficult method (poll, interview, survey, measurements). Students can use media and technologies that they are familiar with, such as recordings, videos, photos, social media (online poll between friends, question collecting), newspapers, books, films, etc. You may set a minimum number of different media (5–8 sources) to be used by the students.

Other recommendations

- Records of obtained information – lead the students to record their initial stage of cognition (what do I know about a topic now and what have I found from other sources) using notes as well as e.g. drawings, maps, diagrams. A suitable tool for systematic recordings and thinking about inquiries is a so called science notebook.
- Discuss the credibility of sources (citations, facts vs. opinions, various media, etc.) with the students. Talk about citation significance in texts with them. Make them understand that the citations are important for everyone to find out more details.

What to avoid

- Choosing too difficult texts – the students can lose the motivation to search for more information. Think about the adequacy of a text related not only to its content, but also its extent, alternatively extract only a part of it.
- Working with one-area-only sources (textbooks, technical books, or just the Internet) – diversity, comparison is missing.
- The students use various sources non-critically – information credibility needs to be discussed with them.
- A teacher prepares everything for the students “on a silver platter” – try the opposite! Searching for information can be trained; firstly, you can describe to the students how you would search for information (for a different topic).

Activity – Stem and Roots

Time: 20 minutes

Aids: paper, pencil, questions

Goal: student maps co-students' opinions of assigned questions

Description: Divide the students to groups of 4-5. Prepare one interesting question for each group. At first, the students in a group write down their answer. Then, they decide who will be a recorder (stem) in each group, the rest become questioners (roots) inquiring the opinions of the other students in class. They have to remember them (they cannot use pencil and paper) and communicated them to their stem who writes them down. Finally, the stem summarizes the answers their group obtained.

Activity – What Can I Believe?

Time: 30 minutes

Aids: handout with texts and a table for students, paper, pencil, other texts, a PC if need be

Goal: student assesses the credibility of various information sources, or evaluates which sources are more reliable and which are less reliable

Description: Prepare short extracts on any topic using various sources. Choose easier texts for the students up to 11 years of age; it is possible to include a technical text along with citations and their meaning explained for older students. At first, the class works together. The teacher or selected students read all extracts aloud. Then, a group work assignment follows (groups of 3–5 students). Each group fills out a table:

Task 1: Add the names of sources to their text extracts

Task 2: Write down the grounds for your choice

Task 3: Evaluate the reliability of individual sources for the students

The reliability of information sources is assessed by a 1 – 5 “grade” according to how reliable the students think it is:

1 = very reliable

5 = insufficiently reliable

Check that the students understand the concept of reliability. Afterwards, the groups present their table completion and a short discussion can follow about why they think some information sources are more reliable than others.

Sample of a handout

Text samples: ...

Task: The following text extracts have a joint topic. Try to fill in the table:

- add information sources to the texts
- write why you have decided to do so
- evaluate how reliable the individual sources are for you, how much they can be trusted

INFORMATION SOURCES	TEXT NO.	WHAT MADE YOU DECIDE TO DO SO	RELIABILITY GRADE 1 = very reliable 5 = not reliable
Narration – what they say			
Quality Internet newspapers			
Tabloid Internet newspapers			
Thematically/branch-focused web pages			

5.3 Posing Questions

How to proceed when asking questions and selecting a research question

- The "question-asking" situation can be employed in any lesson (not only the inquiry lesson). Asking questions supports an inner motivation to continue working.
- Create a safe and creative atmosphere in which the students are not afraid or hesitant to come up with questions. It is important to maintain this openness also for sharing and that the students are not afraid to express their ideas. The teacher or anyone else does not assess whether or not an opinion is true.
- Motivate the students to try inventing diverse questions. Questions starting with "why" sometimes require difficult explanations and a related hypothesis is hard to create. It is also good when children come up with questions starting with "how, what, where, how long", etc. Such questions ask more concrete problems and a related hypothesis is easily created.
- Continue to work with the questions. Discuss them together with your students, sort them. Finally, jointly select those being inquired further.
- Keep the questions. Go back to them at the end of a unit and assess together with the students what they have revealed and discovered compared to what you had thought earlier.
- Choose a research question according to what the students are attracted by and what comes in useful for a learning plan; give reasons for possible limitations (e.g. the lack of time).
- Always select a research question together with the students. The opportunity to take part in the selection process increases the sense of responsibility for a question and the desire to continue to work on it; therefore, it increases the further motivation to work.

What to avoid

- Do not make students' investigations easier. You can point out a logical inconsistency or discrepancies that will surely appear in a class when collecting questions and opinions. However, avoid telling or assessing in any way correct or expected questions and solutions, even unwittingly non-verbally (gestures, grimaces). The issue is that the degree of happiness from searching and inquiring is lowered by a premature disclosure or indicating. Rather, entice the students by having them find out some answers already during a unit.
- Mind the group brainstorming with a large number of students. Usually, only fast and self-assertive students assert themselves. You can give them all time to think. A proven procedure is that a student thinks about a topic alone first, then in pairs and finally together within the whole group.
- Avoid the situation whereby students ask questions because they have to (they were assigned by a teacher).
- Do not assess and comment the questions or ideas immediately, nor let other students react in this way.
- Complicated questions not easy to answer unambiguously require more time for inquiring as well as for result analysis. When practicing an inquiry procedure, choosing simple questions that are likely to be answered based on the inquiring by the students is recommended.
- Often, a conflict develops between an inquiry orientation setup you have prepared and the questions the students come up with. You should consider your options to address these questions (time, aids, environment).

Activity – Picture Full of Questions

Time: 15–30 minutes

Aids: paper, pencil, pictures with unexpected, surprising content (e.g. <http://www.sarahderemer.com/>) – in groups or on an interactive board

Goal: students map and record questions coming to their mind when looking at a picture

Description: Select a picture that sparks curiosity. The picture should fit students' age. Give a copy of it to each group or show it to everybody. Ask them to write down the questions crossing their mind when looking at the picture (2 min). Students then share questions in threes or fours and choose the 5 best questions in each group. Sharing in the class follows; each group presents one question. Finally, discuss why students asked the particular questions.

Activity – Detective Plot

Time: 20–40 minutes

Aids: paper, pencil, detective story suitable for your class

Goal: students evaluate what they know thanks to the story and what they need to find out (what to ask about)

Description: Prepare a short story containing a plot with a topic you want to discuss with the students. The end of the story can be skipped to let the students investigate it. Ask them to read the story in groups or read it together aloud. The work of detective teams follows. At first, each detective writes a list of things they know and a list of questions to reveal. The detectives share their lists in pairs and then in the whole class. Joint discussion can be closed by a summary of how the detective team should proceed.

Activity – Balloon

Time: 30 minutes

Aids: paper, pencil

Goal: student writes questions for a topic and chooses 1–3 interesting ones they want to discuss

Description: Collect questions on the topic through brainstorming. Afterwards, the class agrees on 10 important questions. Then, everyone imagines they are flying in a balloon. The balloon goes down because it is heavy with questions. To make the balloon fly up, one question needs to be surrendered and thrown overboard and then another and another until everyone has only one question left. Sharing and comparing in pairs can follow, after that a full-class discussion of which question is both the most important and checkable. This would be the major one that remains. Another 1–3 questions that remained in most of the balloons can be discussed and researched in the following lessons.



Picture 3: Balloon ¹

5.4 Predicting (Formulating a hypothesis)

How to do it

There is no need to say the word "hypothesis" to young students. It is important to let them understand the concept of predicting the results based on the facts. Instead of creating a hypothesis, the students can be asked to guess, predict or formulate their opinion about the result.

Formulating a clear and consistent sentence is one of the most difficult activities the students will encounter during their school attendance; therefore, this rule stands: "Better to formulate an imperfect hypothesis than no hypothesis at all, being afraid of failure."

A correct “hypothesis” is

- unambiguous – i.e. it is either valid or invalid; it cannot be “half-way” valid
- verifiable – it can be verified or a way to verify it can be found
- widely applicable – it has to be possible to generalize it for a greater number of the same phenomena or objects
- measurable – it has to be possible to measure it or quantitatively describe it in another way
- specific – it has to be stated sufficiently in detail not to cause any doubts about its content

What to avoid

- Do not prefer hypotheses describing evident facts. It is important to realize that scientists in fact formulate hypotheses about the unknown.
- Do not prefer hypotheses that will be confirmed to those that will be disproved. It is important to realize that scientists in fact formulate hypotheses to be disprovable.
- Do not assess in advance whether or not a hypothesis is valid. Students should focus on formulating a formally correct hypothesis with proper content and wording. Whether or not it is valid is not the object of practice, but the inquiry itself.

Recommendations

- It is important to concentrate on the basic formal characteristics of a hypothesis as well. Make sure the students formulate the hypotheses in the simplest and the most particular manner.
- When creating a hypothesis, students should learn to pay attention to the thematic and formal correctness of their hypothesis. The thematic level means that a student creates a hypothesis truly connected to the content of a question. The formal level is connected to the criteria a hypothesis has to meet to enable us to start verifying it.
- We recommend increasing formal demands on a hypothesis step-by-step with regard to the age of the students.

Activity – Running Hypotheses

Time: 30 minutes

Aids: list of questions and hypotheses, space with marked start and finish lines

Goal: student adds hypotheses to questions according to a topic

Description: Prepare a set of questions and hypotheses, e.g.:

Question	Hypothesis 1	Hypothesis 2	Hypothesis 3
Is the volume of water changed when it freezes?	The volume of water is larger when frozen.	The volume of water is smaller when frozen.	The volume of water is not changed when frozen.
How are a fire and oxygen related?	The less oxygen there is the better a fire blazes.	A fire blazes based on how much wood there is; it is not connected to oxygen.	A fire will extinguish without oxygen.
What time does the sun rise at?	The sun rises at 4:30 am every day.	The sun rises at 9:15 am in winter and 4:30 am in summer.	The sun rises at different time each day.

Divide the students into 3 groups. Give each group a set of hypotheses (each group has them on differently coloured cards) and keep the whole table as a key for yourself. There is one hypothesis compatible with the question you assign in every set of hypotheses. The teacher says the question and the task of the groups is to choose a hypothesis belonging to the question as quickly as possible and send one student from the group to run on a track with the hypothesis on the card. When they reach

the finish line, they go back to the group. All group members should race. It is also possible to change the way of moving – running on all fours, backwards, on one leg...

After each individual race, the groups read the selected hypothesis they ran with. The fastest group wins 3 points, the second fastest 2 points, and the third 1 point. However, the points are awarded only if a group has run with a correct hypothesis, i.e. one belonging to the question. A group that runs with a non-compatible hypothesis does not get any points and the groups finishing after them improve their position by one. It is important to say that the hypotheses are only thematically added to the questions – their validity is not assessed at this phase.

The trick is that the physically best group does not necessarily win. First it is important to think about what hypothesis to run with. The same questions can be read repeatedly within one game.

If the conditions allow, it is suitable to work with the hypotheses further. E.g. choose one of them that the students try to confirm or disprove.

Activity – Family photo

Time: 20 minutes

Aids: picture of a Kalanchoe with a description (Annex 2)

Goal: student identifies “correct” and “wrong” hypotheses

Description: Students can see 4 plants of the same kind in the picture, but each of them is a little different. Based on the description, they should choose the hypotheses that could be confirmed using this family photo.

Solution

Hypotheses A, B, and E are related to the family photo and the situation arising therefrom in all age categories of the assignment.

5.5 Experiments / Field work + Data Analysis / Results

How to approach the planning, conducting and evaluation of experiment

The task of mentioned training activities is to practise the observance of individual “scientific rules” during the experiment itself. In a comprehensive inquiry unit, it is crucial that the experiment, if possible, be planned by the students themselves. While this approach may be perceived as very risky, the following tricks can lead the students onto the right path:

- Does your experiment aim for the confirmation or disproval of the hypothesis or somewhere else? To differentiate a direct link between an experiment procedure and a hypothesis is one of the fundamental abilities of the students that IBSE wants to develop.
- Is it feasible to manage the procedure suggested by you in today’s lesson regarding available aids/time/space? Keep the students within the limits you have for an experiment with these questions. Make them co-responsible for the observance of these limits.
- Inspiration box – a proven aid can be e.g. an “inspiration box”. The students still plan an experiment by themselves, but a part of the assignment is to use aids prepared in advance, located in the box.
- If you have a plan for an inquiry unit taking place in two phases with an interval of at least a day, you can plan the first part ending with the experiment-planning phase. Thus, the students have more independence in planning because they can get potential aids by themselves based on their possibilities in their free time.

Experiment recording

A good researcher has constantly in mind that they will discover something big, important and unique. That is why they thoroughly plan a way of recording their observations and experiment results. What if they wanted to go back to the experiment and didn't understand the records anymore? Writing the record thoroughly will not only save us work, but might avoid losing the big discoveries hidden inside them, waiting to be found.

We do not offer any special activity focused on the culture of keeping experiment results. Developing a habit of recording is necessary to cultivate in the students every day and with every opportunity.

Reflection on a performed experiment

Lead the students to constantly reflect on whether they are still on the path they set up. Taking this step at least once, after performing an experiment, should be a rule. Let the students think about whether they really confirmed or disproved a hypothesis with the experiment. Besides other interesting things, have they really found out the answer to their research question? Have they taken care of all circumstances which could have had an influence on the results when planning the experiment? Would they perform their experiment differently next time? Would they change any details? If they find some serious circumstances in this reflection, they should be mentioned in the research conclusion.

What to avoid and recommendations

- A wrong assessment of students' self-reliance: You know your class the best and you know their inquiry level. Initially, plan the procedure with the class. Give the responsibility for planning and performing experiments to the students gradually.
- Preferring one procedure at any cost: It is important to really think about each useful suggestion of the students. Does it lead to the confirmation or disproval of a hypothesis? Can you get needed aids for experiment realization; can you make it in terms of the time and space? If yes, accept the suggestion! Is it a completely different experiment than what you originally planned? Never mind, students' independent planning takes precedence over it!
- Do not refuse students' suggestion for no reason. If you do not accept some of their suggestions, explain why. Or better, try to make them revise their procedure, ask questions. Support the students in thinking. Appreciate them for their creative ideas, even though they cannot be performed right here and now.

Activity – Magic Flora

Time: 15 min. + length of the motivational extract

Aids: motivational extract (printed text, audio recording, video recording)

Goal: Student formulates an experiment procedure based on their own imagination.

Description: Firstly, listen to (watch) a short extract (from a film or a book dealing with the effect of some magic plant; e.g. a mandrake from *Harry Potter and the Chamber of Secrets*). The students' task is to come up with and draw their own magic plant you have just discovered in the Hogwarts greenhouse (or elsewhere, depending on the extract). They do not know its exact effects, but they would really like to try them. Therefore, they write what effects they expect the plant will have and plan when, where, how and under what conditions they will test these effects.

Activity – He Who Is Prepared Goes Without Difficulty

Time: 5 minutes

Goal: Student comes up with how to test a simple hypothesis using correct measurement.

Description: with young students, it is possible to practice experiment planning through common situations they encounter. For example, take the students through the following contemplation. It can be played as a scene.

Question

1. Who carefully prepared their schoolbag yesterday? – Thomas
2. Who didn't prepare their schoolbag yesterday and carries everything in it? – James

Hypothesis: I think that James will have a much heavier schoolbag than Thomas.

Question for children: do you have any idea how to find out the truth?

Anticipated students' answer: We will weigh both schoolbags.

Result: Thomas's schoolbag weighted 4.70 kg and James's 6.90 kg (the students have seen the decimal numbers for the first time). If you do not carefully prepare your schoolbag, you will carry 2–3 kg on your back in vain!!!

Activity – Find 5 Differences

Time: 10 min.

Aids: 2 pictures with 5 differences (Annex 3)

Goal: Student understands the importance of recording conditions during an experiment and their influence on results and hypothesis evaluation.

Description: The assignment in the annex contains 2 pictures describing an observation record. They differ in the experiment result and conditions. However, the evaluation forgets those differences that can be found in the picture and which the researchers did not take into account of or did not record.

Hypothesis: The tomatoes fertilized with TURBO fertilizer grow faster than those watered with ordinary water.

The depicted experiment disproves this hypothesis. What else should the students have recorded to make their results objective? Find 5 differences.

Solution:

- window – the sun supports the growth of the non-fertilized plant
- heating – the cold limits the fertilized plant
- large and small pot – the fertilized plant has less soil
- amount of watering – the non-fertilized plant was watered more
- experiment length – the non-fertilized plant grew a longer time

5.6 Conclusion – Decision Making

How to access the formulation of a conclusion and work with the hypothesis after finishing an experiment

- Find out actively whether the students understand the results of their inquiry. The students summarize what the output of their inquiring is, e.g. they write down the most important facts, result values, discovered relations and links
- The students go back to the hypothesis they proposed when starting the inquiry and compare it to the results. This step is a logical return to the very beginning of their inquiring. Lead the students to think about whether the results are truly connected to the hypothesis; discuss further the way of supporting its confirmation or disproof.

- An unconfirmed hypothesis is not a mistake, on the contrary. Remind the students that inquiry is not a contest of whose assumption will be confirmed and whose not. The unconfirmed assumption has often a higher value than the confirmed as it can direct another inquiry.
- The students write a clear conclusion. They state unambiguously whether their hypothesis is confirmed or not and based on what they arrived at the conclusion. Practise with the students continuously that a comprehensive, meaningful conclusion of their inquiry should have these basic features:
 - based on the results of the student's own inquiring or other inquiring
 - commenting on an assumption which was set at the starting of the inquiry by a student
 - comprehensible for others and the student if they go back to it after some time
 - posing new questions and problems to be solved
- The students discuss and pose new questions or problems that they discovered when inquiring and which can stimulate another inquiry.

What to avoid

- Avoid affirming that everything has worked out how it should have. The goal of the IBSE is not affirming; on the contrary, it is critically inquiring and thinking using one's own head. Do not be afraid of contradicting procedures or results the students give you, do not agree with them, you can try just "for appearance's sake".
- Pay attention to situations where the students formulate a conclusion without presenting evidence and providing reasoning. Without understanding the course and result of an experiment, the conclusion formulation is only a stylistic exercise, not thinking about inquiring.
- The students formulate their conclusion vaguely without any supporting arguments, e.g. in an "it worked out/failed" style. Insist on the conclusion being connected to an assumption (hypothesis) and supported by explanation.
- The students can perceive their unconfirmed assumption as a failure, as a poorly done work. Do not let them be skeptical when their hypotheses are not confirmed.

Activity – Cards

Time: 20 min.

Aids: pencil, paper, markers, skewers, tape, string

Goal: Student expresses verbally or visually the result of their inquiry, their assumption and other questions that have appeared during inquiry.

Description: This activity is not suitable as a practice itself, it is more suitable as a part of a unit where a student or a group have their own experiment they work on from the beginning to the end (e.g. sprouting plants in cotton wool, observing on a school garden, working with water, soil, etc. samples). The students create cards describing their experiment and place it near the place of experiment – put it into a pot, stick it, hang it somewhere. The card includes this information: assumption, evaluation of results, reasons given, assumption confirmation or disproof, other questions. Younger students can draw the card.

How to approach searching for links

- The realization of why exactly "this" is important and what the research was good for can be the hardest part of their inquiry. Therefore, it is suitable for a teacher to prepare examples in advance in which a topic appears in day-to-day life. Firstly, give the students an opportunity to come up with their own ideas.
- Linking it to daily life needs to be emphasized during the entire course of inquiring. This step serves only to summarize, putting the inquiry into the context of everyday life of a student, family or community and to set off to practice.

- When searching for links, it is necessary to leave some space for the students to use their imagination. Often, they can find an original use of gained knowledge which never would have crossed our mind.
- This step can be done in two ways: only theoretically (hypothetically), i.e. find out how and when “it” can be used; or practically, when the students do something where or during which they can use the experience from inquiring e.g. within a different subject or as a home assignment (e.g. testing if all plants at school have enough light).
- It is possible to assign as homework the students getting suggestions from their parents, from media, etc.

What to avoid

- Prevent the students from thinking only in a limited context, e.g. in “I really do not know what it is good for” or “We do not have any plants at home” style. Provide them with a lot of impetuses, motivate them to create, model hypothetical roles and situations in this phase, e.g. “If you were to help a gardener grow some tomatoes...”, “If a flood came...”
- Avoid evaluating whether an example a student gave is relevant or not. It is better to let the students come up with wrong conclusions than discourage them from thinking. Unreasonable suggestions can be eliminated later, e.g. by asking other students if they think all that is realistic and if they do, but you do not agree, point out directly: “And you think that this ... is relevant? I do not share this opinion, why do you think it is so?”
- The students are often not motivated as they lack an opportunity to use their experience from inquiring. We should always aim to have the students “doing” something rather than only talking about it.

Activity – Brainstorming

Time: 15 min. (possible to practice in language lessons)

Aids: paper, pencil, possible to use an interactive board

Goal: Students come up with associations coming to mind in connection to their inquiry and practical results and new knowledge use. They write these ideas down, sorting them logically and interconnecting them.

Description: Students write “my inquiry” or the name of the experiment, observation or topic in the middle of a sheet of paper (A3 size minimum). Then they think about the associations related to their life. The rule is to write down everything and chain the associations in the way they coming to mind (arrows). Using up all ideas, the diagram can be even more interconnected, uniting the entries into groups, marking them colorfully, emphasizing them by underlining, etc.

5.7 Presentation

How to present inquiry

- Since the start of a task, the inquiry needs to be documented (record, take photos, make drawings). It is possible to inform about inquiry during a long-term experiment by making use of a notice board, blog, ... The important thing is also that the students are keeping records of the source of information (literature sources are mentioned at the end of a computer presentation and in articles).
- A crucial thing is to practice natural communication about inquiring, give the students a space to share what they are doing and what they have discovered with others, and encourage them to communicate and reason. The goal is not only to practice various kinds of presentations to manage them technically, but mainly to consciously plan what to say and why this is important, to react to questions and not to be afraid of presenting to a group.
- Initially, it is good to introduce a discussion on the topic of “why it is good to tell others about inquiring”, “why the results are presented”. If the experiment and the results are not published, nobody knows about them and all of the work has to be done all over again maybe by somebody else. Also the experiment can be repeated if described properly, so the results can be proved and of course proper documentation allows follow-up studies to be based upon the findings of previous research.
- The students themselves think up the way to present their experience to others and who it needs to be presented to, who to discuss it with and why. The students gradually try out the methods of presentation. It is possible to recommend as practice that they all present in the same way in accordance with the same criteria they received in advance (it is simpler to assess and the students learn mutually). Later, the groups can choose a presentation form and present differently.
- When presenting, it is useful to make maximal use of technology, giving space to IT lovers who may not be good speakers. They can process everything on a computer, creating a presentation, a photo story, a poster.
- Assigning any presentation, always provide the students with the criteria and outline. Do not be content with the instruction of “draw a poster for next class”.
- The activities should be interconnected with media education, informatics and Czech language.

What to avoid

- Presentation learnt by heart, by drilling. Sometimes, the students do not have an opportunity to talk enough in class. Guide them in presentation skills so that they learn to talk naturally and decrease the fear of talking or performing in front of a class.
- Inappropriate form of presentation. Different forms are suitable for different inquiries, age or target group. Plan it well.
- The teacher uses only the presentation form they already have done with the students or which they are used to. Do not be afraid to try something new, everything can be trained. Most importantly, do not forget that today’s students belong to a “digital” generation.
- Presentation is regarded as fun, not learning. However, presentation has its rules, too! Prepare the criteria and feedback for the students. Moreover, presenting and being able to quickly summarize one’s own ideas is very important and an art in this fast-moving world.
- Students focus on one aspect of a presentation, e.g. visual or verbal. The presentation is a practice of many skills, not only the communicative ones. It also includes the art to sound

convincing, eliminate stage fright, answer questions, choose what is substantial, organize thoughts, the technical skills to use a projector or an interactive board...

Hints for various kinds of presentation

Up to 10 years of age

rather creative methods, i.e. visual and graphic, limit the methods based on solely written language

- a poster, collage, labelled drawing
- theatre
- a photo story or comic
- a school magazine or a blog

11–13 years

- the above-mentioned forms
- a presentation-creating computer program
- a simple scientific poster

13–15 years

- the above-mentioned forms
- an article for a local newspaper
- a presentation for school management, local office
- a simple scientific article or an abstract from the student's inquiry
- a photo report or a short film processed on a PC
- an article for one's own or school blog
- a publication on the cause via social media (Facebook, Twitter, YouTube...)
- a class or school scientific conference on the occasion of finishing projects or e.g. Earth Day, Water Day, Tree Day, etc.

Activity – Results Advertising

Time: 10 min. for preparation, 3 min. for each group's presentation

Aids: different based on selected type of advert and topic the students are processing

Goal: Students attractively present the course and results of their inquiry.

Description: Instruct the students to prepare a presentation of their inquiry results in groups for others in a way so as to make the highest number of persons possible interested in it – tell them to try advertising their inquiry and results. The form of the advert can differ, e.g. a scene that students play as a TV commercial, recorded advertising slogans for radio, newspaper advertising, billboard advertising, advertising mail, leaflet, etc. Encourage the students to use typical advertising features: a moment of surprise, comparison, exaggeration, emotions, stories, colour, music, etc. In a final discussion, talk about what else is used in adverts and that some of them should not be used when presenting the inquiry. Surely, we should not deceive the listener and offer our findings as the only true ones.

Activity – Poster Presentation

Time: 10 minutes minimum, based on difficulty

Aids: sheets of paper, coloured pencils

Goal: Students design a poster to introduce the course and results of their experiment.

Description: Poster extent, quality and processing technique depends on the age of the students. Younger ones can draw what they like about a topic, the older ones can play scientists presenting their posters at a conference. At first, discuss with the students what a poster should look like. To whom

and in what kind of conditions they will present the poster always matters, it should definitely catch one's attention. Based on this, the amount of text, photo sizes, diagrams and language used for written communication on the poster should be chosen. It is good to make a poster special using something unusual to attract attention. A joke, original or provocative name, interesting art process (e.g. a silhouette of the inquired object in the background) or 3D elements hanging or pasted on a poster can be used to do so.

How to evaluate students' posters?

A proven procedure is a combination of appreciation and recommendation given by co-students as well as the teacher.

Activity – Comic

Time: 10 minutes minimum, based on selected difficulty

Aids: sheets of paper, art equipment

Goal: Students depict the course and results of their inquiry in a comic – they process them into a story.

Description: Instruct the students to create a comic about how they inquired and what they discovered. According to students' age and skillfulness, they can draw or make the comic using the slides of a computer program for creating presentations. They can use photos and other real documentation from their experiment. Then, the presentation can be simply projected as a story.

6. Hands-on lessons

Part of this document is nine exemplary science lessons. The lessons represent different scientific topics – chemical, biological, physical and geographical, and at the same time contain environmentally related topics. These lessons are intended for students between the ages of 6-14 and they are prepared so that they are easy to implement and present various options of implementation of IBSE.

An overview of the lessons including basic information and a short description is in the table below.

Lesson name	Intention	Length (min.)	Target group (years)	Lesson objectives	Benefits for young students
A Creek or a Sewer	chemical, environmental	90	13 - 14	Students name factors that contribute to water pollution. They describe related problems, measure several indicators of the purity of surface water and evaluate them.	The lesson focuses on a topic related to students' everyday life. Students do practical research in a locality that they well know.
Blushing Plants	biological, ecological	90	9 - 11	Students explain why water is indispensable for plants. They describe how water circulates in plants. They realize the influence of substances that a plant absorbs into its body on our own health.	The lesson contains an easy experiment. There is a clear connection between the results and everyday life.
Climate Refugees	biological, ecological, chemical	240	13 - 14	Students understand that carbon is a natural element which flows between four major sinks through natural processes. They understand that human activities enter the circle and disrupt the balance of carbon. They understand that CO ₂ emissions are associated with the phenomenon of climate change and realize the impact of climate change on human life.	
How Do They Live	geographical, environmental	90	12 - 14	Students learn about the differences in climate within different climate zones. The lesson introduces the topic of climate change and its impact on nature and human life.	Students work with pictures and stories of children from various countries, which help them to better understand the topic and realize global differences.
How to Insulate Your Classroom	physical, environmental	320	10 - 11	Students are expected to gain basic scientific knowledge regarding heat transmission and insulation of material.	

It's Raining Cats and Dogs	geographical, environmental	90	6 - 10	Students learn causes of erosion and its impact on nature and human. They realize how it is possible to influence erosion.	The lesson contains a simple experiment, which demonstrates the natural phenomenon of erosion.
Natural Gas: a Curse or Blessing?	chemical, ecological	200	13 - 14	Students are expected to gain basic scientific knowledge regarding natural gas.	
Pond Skaters without Skates	physical, biological	90	11 - 13	Students name several species of organisms that move on the water surface and explain how they move. They explain the effect of surface tension of water.	The lesson contains research that is partly conducted in nature and involves living organisms.
Researching the ecological pyramids. Who is the unknown organism X?	biological, ecological	480	14 - 15	Students understand basic ecological terms, the structure and function of an ecosystem, describe the consequences of various environmental factor changes and the consequences of human activities on nature. Students understand the flow of energy and material in a food chain. They perform sampling, collect, present and interpret the data collected and use them to develop predictions.	

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Annexes

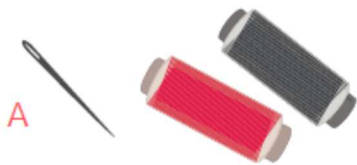
Annex 1

To make a science notebook, each student will need¹:

6 sheets of paper of A4 size

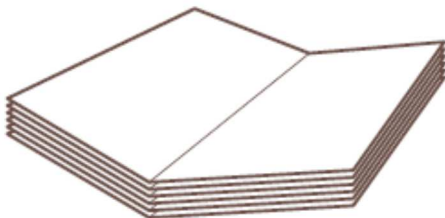


A needle and a thread



Work steps:

Fold the papers in half



Use the needle to punch holes for sewing

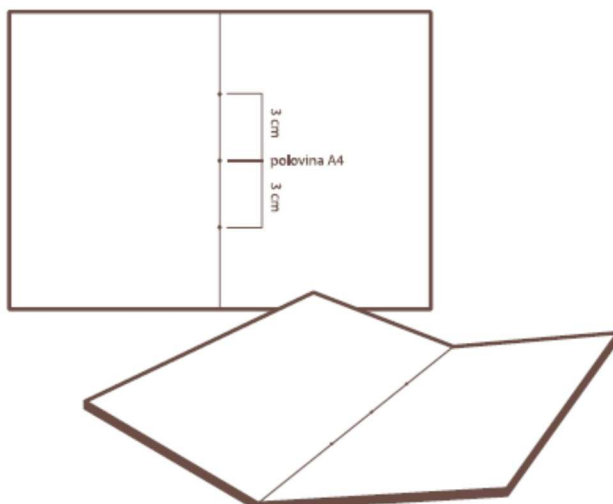
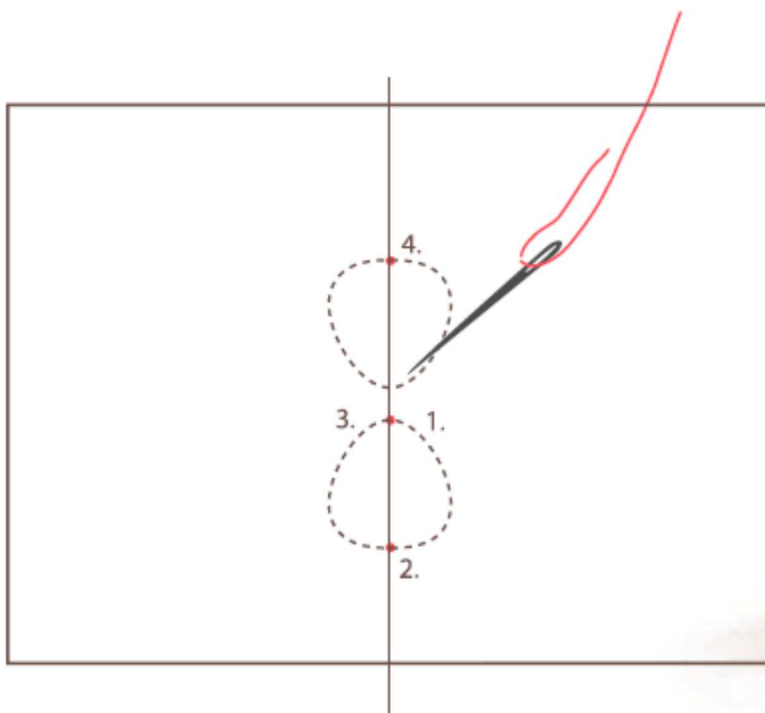
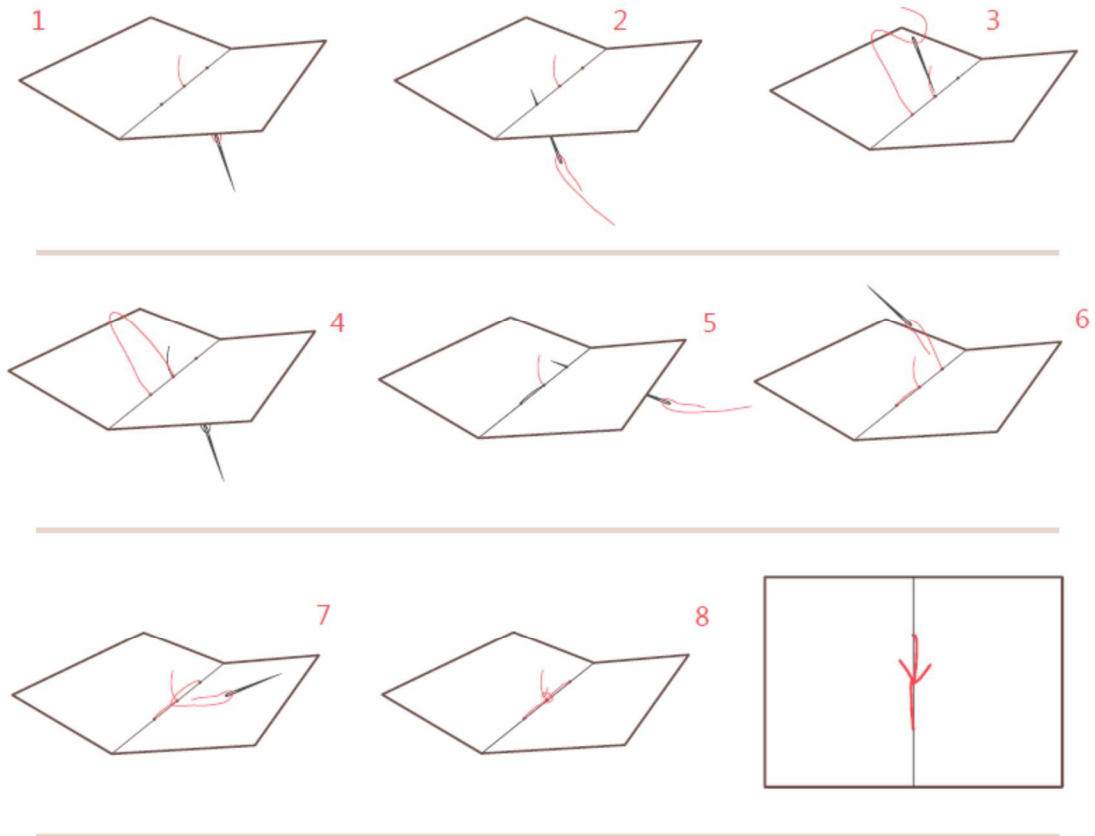


Diagram of sewing



Annex 2

Initial situation

Although it does not look like it, we can see 4 completely same plants! It is a kind of Kalanchoe. There is one planted in a garden and 3 others potted in front of our cottage. We cut them all for the winter and the potted ones move to a cellar. The cellar is very damp and there is no light. We had an idea in the spring to make an experiment to confirm a theory we had. We put the pots out one by one and then made a joint plant family photo.



Picture 4: Family picture ¹

1. I have been outside for quite a while; they put me out 14 days ago.
2. I was carried out of the cellar a week ago. I looked like my brother on the right, but I am getting some colour already...
3. I was carried out of the cellar today, right in front of the photographer!
4. I was also cut for the winter, but they left me outside...

Your task is to choose from the following hypotheses those that could be confirmed by the “family photo” according to you.

9–11 years

- A. A plant is only green if it has access to the light.
- B. A plant grown in the dark has longer stems and shorter leaves than a plant grown in the light.
- C. A plant gets a green colour when it is replanted from a pot to a garden.
- D. A plant is green when it has access to oxygen.
- E. A plant grown in the light has shorter stems and larger leaves than a plant grown in the dark.

11–13 years

- A. A plant's green colour is produced only when there is access to light.
- B. A plant grown in the dark makes its stems longer and its leaves shorter.
- C. A plant gets a green colour when it is replanted from a pot to a garden.
- D. A plant's green colour is produced only when there is the access to oxygen.
- E. A plant grown in the light has shorter stems and larger leaves than a plant grown in the dark.

13–15 years

- A. A plant's green colour is conditioned by plant's access to the light.
- B. A plant grown in the dark makes its stems longer and suppresses leaves growing in width.
- C. A plant's green colour is conditioned by growing it in a garden; it is lost when repotted.
- D. A plant's green colour is conditioned by a plant's access to the oxygen.
- E. A plant grown in the light has shorter stems and larger leaves than a plant grown in the dark.

Annex 3

Find 5 differences ⁵

