Chapter 1. Guide for a project inquiry-based learning

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In this chapter we provide a guide for projects following the pedagogy of inquiry-based learning in the classroom. Teachers can make use of this guide in order to direct the execution of projects as described in the thematic chapters or for one's own theme. In this chapter we demonstrate how a project can be formed based on the seven phases of inquiry-based learning. The extent to which a teacher uses this guide as either a step-by-step instruction or as a source of inspiration is entirely dependent on the knowledge, experience and need of the teacher.

This guide is frequently adjusted and improved based on new insights. The most recent version will always be available online on the website www.wkru.nl/english. Often the text will refer to materials that can be found on our website. This website will be referred to by the following symbol: ◉

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1.1 Preparation of a project inquiry-based learning

A successful project inquiry-based learning should be prepared thoroughly. Here below we mention several key points that are associated with a good preparation.

Immerse yourself in the theme

A project inquiry-based learning starts with selecting a theme. In the chapters of the book series 'Scientific breakthroughs in the classroom!', several themes based on scientific breakthroughs are exhibited. In the first sections of these chapters, you will find substantive information on the theme and you will read how scientists conduct research with regard to the theme. These thematic chapters also explain the important terms used, so that you can then explain these to your students.

Know the pedagogy of inquiry-based learning

In order to properly guide students during their research, you require knowledge about the pedagogy of inquiry-based learning. It is, hereby, important to both know the seven phases that the students must proceed through, and to know how to guide the students through this process. Didactic knowledge is necessary in order to know how to guide your students during the execution of their research projects. When is a particular question a good research question? What should students pay attention to while setting up their research? How do you ensure that 'fair research' is performed, implying that only one factor is varied? How can students draw conclusions based on the information they have collected? In this chapter, we describe the entire process including instructions on how to guide the students. It is, therefore, recommended that teachers thoroughly read this chapter, in combination with a thematic chapter, prior to starting a project with the class. To teachers who desire more guidance, the WKRU offers courses [only in Dutch]. More information about these courses can be found on our website: www.wkru.nl.

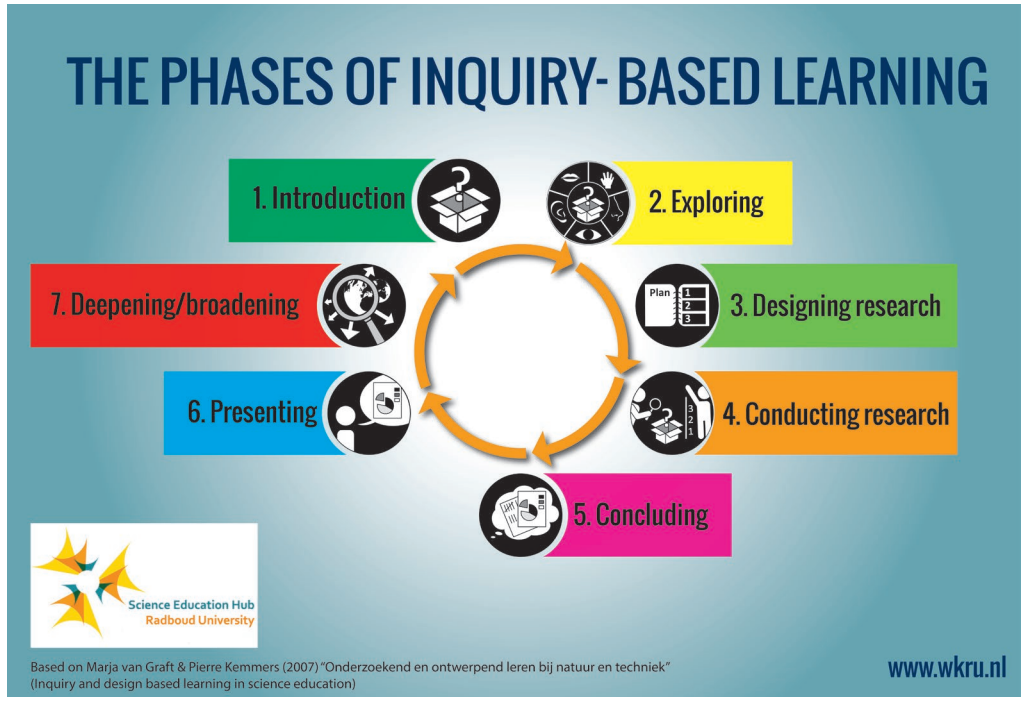
- Take a look at our website in part 2 of the video modules for a brief overview of the seven phases of inquiry-based learning. You will also get an idea of how it looks like in class.

Construct an overview of the entire project

How many lessons will you devote to the project? How many lessons do you require per phase? Do your students work only during the regular lessons on their project or do you give them extra time during independent work time? By answering these questions and creating a plan of the entire project you will avoid unfavourable surprises. Experience shows that if the teacher possesses a good overview of the project, then the students too will have a clear idea of what is required of them. The WKRU believes that the absolute minimum number of lessons for a project inquiry-based learning is fourteen.

- On the website you will find a lesson plan form that you can use when making a schedule. The amount of lessons per phase indicated is merely an indication. This is dependent on the theme, the amount of content you wish to handle and how extensive you wish to set up a project.

Guide for a project inquiry-based learning



The phases of inquiry-based learning

Keep your experience and that of your students in mind

For many teachers inquiry-based learning is a new way of teaching. A project inquiry-based learning can seem like a big step, especially for teachers who are not accustomed to giving students a lot of responsibility regarding their own learning. You should consider inquiry-based learning a learning process in which mistakes can be made and you should not set the bar too high at first. Naturally, not everything will run smoothly at first. When it comes down to the crucial skills, such as formulating a good research question, it might be useful to devote a lesson to those skills outside the domain of the students' research projects. Where applicable, we have stated this in the relevant phase.

In this chapter, we distinguish between the basic guide and the continuation that you can give it once you and your students are sufficiently familiar with the basics. The basic guide can be seen as the minimum knowledge and activities the WKRU deems necessary to carry out a complete project inquiry-based learning. For teachers who already know the basics and wish to go a step further with their students, the 'Go further' frameworks describe continuation tips and activities.

Both the experience of the teacher and the student determines the approach

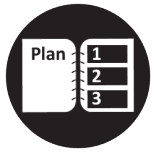
In this chapter, we distinguish between the basic guide and the continuation that you can give it once you and your students are sufficiently familiar with the basics. The basic guide can be seen as the minimum knowledge and activities the WKRU deems necessary to carry out a complete project inquiry-based learning. For teachers who already know the basics and wish to go a step further with their students, the 'Go further' frameworks describe continuation tips and activities.

1.2 The seven phases of inquiry-based learning

The pedagogy of inquiry-based learning that we use at the WKRU is based on the seven phase model by Van Graft and Kemmers (2007). The seven phases provide guidance to the project and the circle forms a parallel with research as conducted by scientists, because it is based on the (empirical) cycle that scientists proceed through. Research is, therefore, seen as a cyclic process: questions that are answered by research often generate follow-up questions leading to the reiteration of the process.

Below we extensively elaborate on the phases of inquiry-based learning. For every phase, we describe the goals, the activities for the students and how the teacher can provide guidance for this process. For experienced teachers and students, tips for continuation are listed under the frameworks 'Go further' at each phase.

Seven phases of inquiry-based learning (Van Graft and Kemmers, 2007)

Symbol	Phase	Student activities
	1. Introduction The teacher introduces the theme chosen by the students. In doing so the teacher should attempt to evoke feelings of wonder and curiosity in the students, with the goal of enticing them to want to understand and inquire more about the subject following the introduction. It is best to keep the introduction brief, fun and playful.	Observing Recognising Comparing
	2. Exploring The students explore the theme as broadly as possible. There is a broad exploration of reality. Doing so allows for the first questions to be answered, but this also creates new questions which will form the basis of the research that the students will set up.	Broad exploration Collecting data Asking questions Suggesting ideas
	3. Designing research The students form groups and design a feasible research plan based on their own research question. They think about how they are going to set up the research (with which subjects, what is to be measured, how are the results going to be displayed) and who gets what role. They collect or develop the necessary research materials and measuring instruments such as questionnaires.	Formulating the research question Setting up research Predicting Planning
	4. Conducting research The students carry out the research on the basis of their research plan. They record their observations. At the end of this phase, the students will have the results of their research.	Observeren Onderzoek uitvoeren Uitkomsten noteren
	5. Concluding The students organise their research results and draw conclusions based on these. In doing so, they answer the research question. The conclusion is then also reflected upon: Is the research question hereby correctly answered? Why was this the result? Does this coincide with our expectations (hypothesis)?	Analysing data Formulating conclusions Reasoning Reflecting
	6. Presenting The research question, the research plan and the results and conclusions are included in a presentation. The results of the research and thus the answer to the research question are presented to the rest of the class and preferably to the parents as well	Writing up a report Presenting
	7. Deepening/broadening Based on the discussions and presentations, the teacher has been given a picture of the level of understanding; he/she can further conceptualise the terms: apply the results to other contexts and establish connections with other concepts.	Reflecting Discussing Comparing (experiments of others) Asking follow-up questions

Phase 1. Introduction

Duration: 1 to 2 class hours

When it comes to inquiry-based learning, it is essential that a learning environment is created in which students can fulfil the role of a researcher and can conduct research. At the start of the project, you introduce the theme and the way in which the students should work.

Goals of this phase

- Students become curious about the theme.
- Students activate their prior knowledge.
- Students are introduced to (scientific) research.

Guidelines for the teacher

Introduce the theme with an activity

On the basis of one or more meaningful activities that match their experiences, you can pique their curiosity about the theme. This activity is not intended for them to gain knowledge, but rather to trigger their curiosity and raise questions. In the thematic chapters, activities have been described that can be implemented for this cause.

Activate prior knowledge

Before the content of the theme is explored, it is important to activate the prior knowledge of the students. One way of doing this is to have the students create a mind map to illustrate what they already know about the topic. If the students expand their mind map over the duration of the project, it can be used as a visible means of monitoring their increase in knowledge.

Encourage the asking of questions

Students often find it difficult to ask questions. Some perceive it as an embarrassing act, because by asking a question they display they do not know something. For scientists, however, wanting to know is more important than actually knowing. Whoever asks a question wants to know something and can conduct research. It's very simple; without questions there is no research. To achieve this state of mind in students, the act of asking questions should be appreciated and encouraged. As a teacher you should act as a good example by constantly being curious and wondering aloud. If no questions arise from the students, then it is your task to inspire them to ask questions. This can be achieved by asking them stimulating questions in order to get them thinking so that they too come up with questions. The teacher serves as an important role model here.

Construct a question wall in the classroom

During the project, you want to make sure that the students' questions about the theme are not overlooked or lost. Therefore, it is recommended to introduce a 'question wall'. Such a wall can be given shape and form in a variety of ways: for example, by hanging two large sheets of paper on the wall with at the top: 'What do we want to know?' and 'What do we already know?'. The students can then write down and stick their questions on there for the duration of the project. It is advised that the teacher also posts some questions on the wall to demonstrate how natural it is to pose questions.

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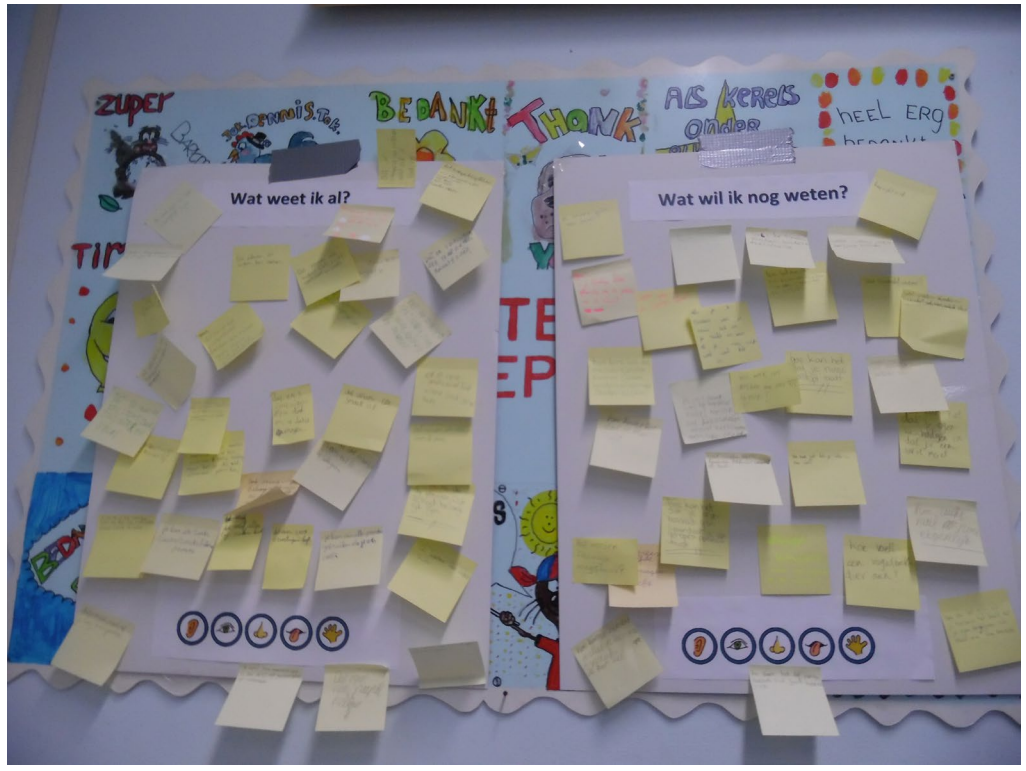
At every activity during phase 1 and phase 2, you should stimulate the students to think of questions, to write them down on a post-it and to paste it on the first sheet. These questions on the question wall will become an important basis for the formulation of research questions in phase 3.
In various classes, we noticed how stimulating it is to reflect on the questions on the question wall at the end of the lesson: which questions have already been answered in this lesson and can now move to the 'What do we already know?' sheet. As questions from the question wall's first sheet are answered during the course of the project, they will migrate to the second sheet.



Question wall at De Peppels

◉ Watch the following films to see how to get started with a question wall:

- Video module 3

Discuss what a researcher looks like and what he/she does
To acquaint students with research, you might want to have them first think about researchers. What does a researcher look like? Where does a researcher work? What does a researcher do? You can have the students draw or describe their thoughts (for example in a mind map).

Students often have a fairly stereotypical impression of a researcher. It is important to nuance this in the discussion. Researchers can be young or old, male or female. Some researchers conduct experiments in laboratories, but not all! Researchers conduct research in all sorts of places: on Antarctica, at sea (both above and below water), in the woods, in buildings, in archives, in museums and so on. Research is also conducted by talking with people, by observing people or by having people participate in tests. What all researchers have in common is that they read and write a lot, often behind the computer.

From researcher Asifa Majid, students can learn that research can also mean studying the cultures of people from distant lands

- To learn more about what science is, how scientists conduct research and how that applies to how children learn, watch video module 1.

Discuss what doing research includes
Once the students have a concrete idea of what a researcher is, you can establish a link to the students' research. Explain that the class is going to set up their own research. The poster 'The phases of inquiry-based learning' can be used as a visual aid to explain the phases the students will go through. Here you can make the comparison to the research of scientists.

- The poster of the seven phases can be hung in the classroom or displayed on the digiboard. In doing so, it serves as a tool for both yourself -the teacher- and the students in providing an overview of the project. The poster can be downloaded or ordered through the website.

It is important to keep in mind that the phases of research do not necessarily follow a strict order. There may be times where you find yourself stuck with the design of your research, for example when you cannot find an appropriate method to answer your question. In such an instance, you might be required to adjust your research question, implying that sometimes you need to take a step backwards in order to move forward again.

Additionally, you can explain that the cycle continues: it is not finished after phase 7. Every research leads to answers for particular questions, but it also leads to new questions. This is essentially how new knowledge is generated. Through research we continuously generate new knowledge.

GO FURTHER

Make a class mind map
In addition to the individual mind maps, you can also opt to make a class mind map in which you bring together all the information the students have gained. This method is often used in the research of Harry Stokhof (HAN Pabo, pre-service education). You start with displaying the central theme and place the subthemes in the main branches. Over the course of the project, the students add more knowledge. This way, the research project becomes a project of the class and not just that of individual groups. At phase 7, deepening/broadening, the class mind map can be used as a means to conclude the project. For further information regarding the use of a class mind map, please refer to Harry Stokhof's article (2016) [only in Dutch].

Phase 2. Exploring

Duration: 3 to 6 class hours

Following the introduction of the theme, the students will actively explore the topic. This is essentially when the substantive basis for the project is established. That is why this phase is of great importance: it is during this phase that ideas for research projects are generated by the students.

Goals of this phase

- Students activate their prior knowledge.
- Students expand their knowledge about the theme.
- Students acquire inspiration on ways of doing research on the theme.
- Students ask many questions about the theme.

Guidelines for the teacher

Ask many questions

Also during this phase is it important to address the prior knowledge of the students. Hence you should ask the students plenty of questions during this phase in an attempt to activate their prior knowledge. In addition, by questioning the students, their thought process maintains an active state so that they can get acquainted with the theme.

Explain the theme to the students

Before the students explore the theme through activities, it is good to provide them with a contextual framework. You can spend a lesson to explain the theme, possibly with the aid of films or other media. As a basis for this, the involved researchers in the thematic chapters provide a description of the theme and the research. It is important that the students not only get acquainted with the content of the theme, but also with the way by which research is conducted.

◉ There are video recordings of lectures of the researchers available online. These lectures are intended for teachers, but can also possibly be watched together with students. [Only in Dutch]

Choose a number of different activities

A theme is best explored by using a multitude of different activities. By using different activities, students acquire concrete experiences from different perspectives and gain knowledge about the theme and about the research that scientists conduct within that theme. In the thematic chapters, activities that you can employ during the exploration phase are described for each theme

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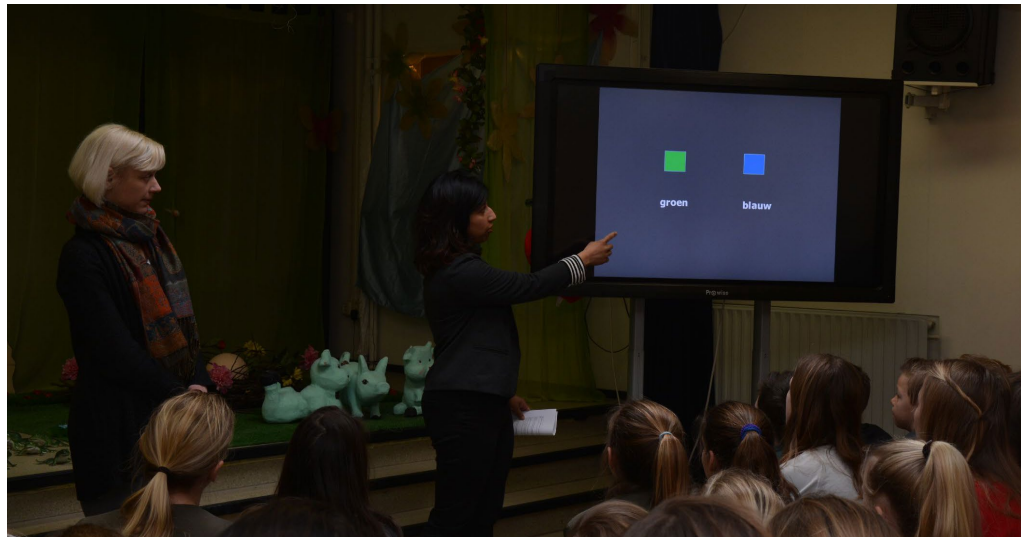

Researcher Asifa Majid tells the students of De Troubadour about her research

Establish the connection between activities and the theory

The goal of the activities is to gain knowledge about the theme. To ensure that knowledge is well received by the students, it is important to explain how the activity is related to the theme and what can be learned from the activity about the theme. This should be done prior to the activity. In chapter 5 of this book, it is described how each exploration activity is connected to the theme. In concluding an activity, you should always affirm what the students have learned about the theme, whereby you have the students identify the connection between the activity and the theme before telling them yourself. This way the knowledge learned becomes more embedded.

Have the students complete their mind map

In addition to the mapping of their prior knowledge, a mind map is very suitable for providing students with an overview of what they have learned and experienced in phases 1 and 2. By incorporating their knowledge and experience into a mind map, it becomes clear what they already know a lot of and what they are still curious about. Additionally, you can track what new knowledge has been acquired over the course of the project. A mind map can prompt new questions and can therefore be useful in choosing a research question.

GO FURTHER

Have the students research sources

In the exploration phase, the students expand their knowledge and go further into depth. Students often have a lot questions which are usually easy to answer with a quick search on the internet. It is best to have them search for the answer themselves. By having them briefly present their answers, the knowledge is shared with the rest of the class. In addition, this allows you to assess whether the answers are complete and whether the students properly interpreted and truly understand the information. If this is not the case, you can correct it for the entire class or request that the students search for additional information.

Phase 3. Designing a research

PREPARATION

Duration: 1 to 2 class hours

In phase 3, the students begin with their own research. They form a research group and decide together what question they wish to research and how they intend on doing this. Phase 3 consists of formulating a research question and a research plan. Because these are both rather large activities, we describe them here separately as phase 3a and 3b. Prior to this, you should have formed the research groups and discussed how the students are going to work together within the group.

Divide the class into groups
Experience dictates that a research project is best carried out when groups are no larger than four to five students. When forming the groups, it would be wise to take the interests, skills and characters of the students into consideration. Phases three to six of inquiry-based learning, which starts with coming up with a question to the ultimate presentation of the research, are all group based.

Assign roles within the group
When composing the groups, make sure that each student receives a different role within a group. This way the students learn to work together and learn to take on the accompanying responsibilities of their role. From experience, the following assignment of roles has proven to be successful:

- **The president** leads the meetings, ensures that everyone's opinion is heard, that clear agreements are made and makes the final decision if the group cannot collectively decide.
- **The secretary** writes everything down, keeps track of the agreements made, who participates in the experiments and records the results over the course of the experiment.
- **The head experimenter** is responsible for the proper execution of the experiment, says who does what and when during the experiment and takes care of the materials and subjects.
- **The controller** checks whether the others in the group are properly performing their tasks and whether everyone fulfils their obligations. In addition, he/she ensures that the research is on schedule and fills in for someone upon absence.
- **The source expert** (in groups of five students) searches for information when necessary (for example on the computer or in books) and consults an expert to acquire a better understanding and subsequently processes this information.

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Students of De Peppels work on their research as a group

Discuss and practice how to work well together
In a project inquiry-based learning, students have to work together as a group for an extensive period of time and this does not necessarily always work out. When asked what did not go well with the research, teamwork is the most-given answer. Therefore, it may be useful to make arrangements about working together, or, if these are already in place, to assess these arrangements before starting the research. Arrangements tend to be more successful when they come (partly) from the students themselves.

For inquiry-based learning, the following agreements are important:

- Share all information and ideas that you have with the rest of the group.
- Always clearly support your claims.
- Try to reach a consensus within the group before making a decision.
- Listen to the ideas of others and let everyone express their opinions. Try to ask questions about what the person has to say.
- Respect the opinions and ideas of others.
- Discuss and compare the ideas within the group. What are the pros and cons?

PHASE 3A. FORMULATING A RESEARCH QUESTION

Duration: 2 to 3 class hours

During this phase, the research question is determined. The research question is central to the entire research, making this particular phase a very important one. For students and teachers, this proves to be one of the more difficult components of the inquiry cycle.

Goal of this phase
Students learn to formulate a question that is researchable by them.

Guidelines for the teacher
Familiarise the students with the criteria of a good research question
Formulating a question that is researchable is, both for the teacher and for the students, one of the most difficult aspects of inquiry-based learning. If the students have no experience with research questions, we recommend devoting a separate lesson to familiarising the students with the criteria of a good research question. This can be done by practicing with example questions.

- On the website, a work sheet with examples of research questions is available.

Have the students fill in the worksheet either individually or in groups. Once completed, you can discuss with the class whether the students consider the example questions appropriate to research. It is not about answering the question : 'Can you or can you not research it?'. Rather the students should explain why they think or don't think the question is researchable. The examples on the worksheet were selected so that all of our criteria for a good research question are highlighted here (see framework). By conducting the exercise this way, the criteria are less 'imposed' on the students and the students better understand why these are the criteria.

Criteria for a good research question

- The question fits the **theme**. The question must be relevant to the theme to research.
- The answer should **not be searchable**. A searchable question is a question for which its answer can be looked up (for example fact questions). The intention is that research must be conducted in order to find the answer (The answer to searchable questions can of course be looked up during the project).
- The student **does not know the answer** to the question yet. The student is curious about the answer and can **learn** something from the question.
- The question is **singular.** Only one question is being researched. Multiple research questions should be split up into single research questions and answered separately.
- The question is **concise and clearly formulated** so you know exactly what is being researched.
- The question leads to **executable** research within the available school time and with the materials available.

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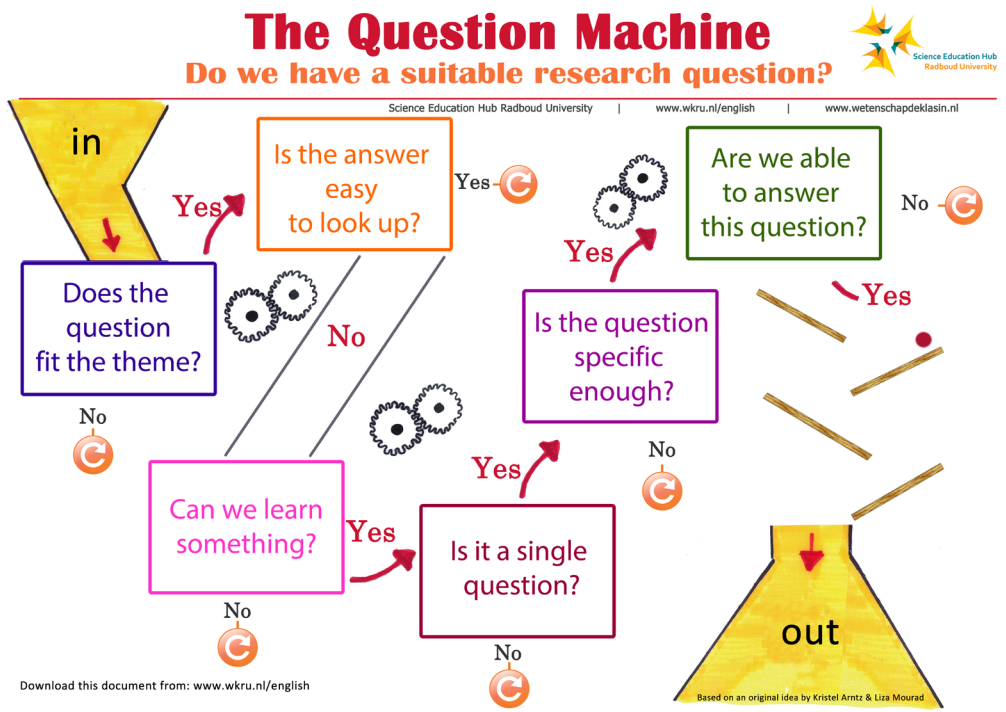
During previous projects of the WKRU, a tool was developed to assist students in learning the criteria of a good research question. Using the 'question machine', students can get familiar with the criteria of a good research question in a playful way. They can use the question machine to assess whether their research question fulfils the criteria. In a sense the question is 'processed' by the question machine. A question that falls out of the machine is considered unsuitable to research and requires adjustment.



The question machine

It is important to note that the question machine does not follow an all-or-nothing principle. It is intended as an instrument of feedback (see paragraph below). The question machine, as depicted above, contains a set of criteria that fit with experimental research. You may imagine that for other types of research, such as opinion polling, a different set of criteria are needed.

- The question machine is available online. A blank question machine without any criteria is also available.

- Watch video module 3 to see how a teacher discusses the criteria for a research question with the students.

Have the students formulate their own research question
Once the students are familiar with the criteria of a good research question, they can begin with formulating their own research question. The questions that first arise are often not yet directly suitable for research. Sometimes the questions are too large or abstract ('Is there a God?') or they refer to facts that are easy to look up ('What is the capital of Spain?'). The trick is to transform the unpolished and unsuitable questions into questions that can be researched. It is the task of the teacher to assist the students in this process.

◉ Watch the following films to see how a teacher formulates research questions with a group of students:
- Video module 3
- Video phase 3 : research question

A student of the Dr. Albert Schweitzer school works on his research with the question wall in the background

Start with the questions from the students
Start with the questions that have already been proposed in the first phases of the research. You can use the input from the question wall or mind map as a starting point for example. A good way to generate more questions is by holding a brainstorm session with the students. This method is suitable to encourage students to learn based on their own questions (demand-driven education) (Stokhof, 2015). Divide the students in groups of three or four, and have them take their mind maps. In turns, they call the first question that springs to mind about the theme. This question can pertain to anything; all questions are regarded as good. One student within the group writes down all the questions. The students continue asking questions until everyone has had a few turns. It's probably best to indicate when the groups can stop; normally when the groups cannot come up with any more questions. Following the brainstorm session, the questions are evaluated. Which questions does the group consider the most interesting to research? The students choose one to three interesting questions and rephrase these into good research questions using the question machine. You can choose to have groups pick a question from their own selection or collect all questions from the class and collectively decide which to research. The groups then choose which question they wish to research. This may be a question from another group. Doing so gives you a more collective project and with it, a greater diversity of questions.

Rephrase the original question into a good research question
Have the students assess their questions using the question machine. If the questions fall out of the question machine, there is nothing yet to worry about. Unsuitable questions do not necessarily have to be discarded immediately; after all, these represent the interests of the students. Most questions can actually be adapted into researchable questions.

Very often students pose why-questions, such as 'Why is the sky blue?'. Why-questions imply a search for an explanation. These questions are difficult to research, because in order to come to an adequate answer, you would have to research all possible causes, which, depending on the topic, could be very numerous. In essence, why-questions generally conceal multiplequestions which make them inappropriate for focused research. By rephrasing why-questions to 'what happens if...' questions, you limit the domain of the question to one possible cause or factor which you can then research.

Students of De Peppels are assisted in adjusting their research question

Let the groups exchange feedback on each other's research questions
By allowing the students to give feedback on each other's research question, they learn to assess things critically. As a result, you are effectively stimulating the formation of their critical and inquiry-based attitude. The students can make use of the question machine and a worksheet to assess each other's questions.

◉ On the website, you can find a worksheet with which the students can have their research question assessed by another group.

Use the question machine as a means to consult
If you think the question belonging to a group of students is not yet adequate or if you have your doubts, then visit each criterion of the question machine with the group and have them explain why they think their question is good. Use the questions from the question machine to further ask questions and to check if the question is researchable by the students.

GO FURTHER

Learn to recognise different types of questions
Students pose all sorts of different questions about the theme. It is interesting to take a closer look at the type of questions and to give the students insight into the different types of questions that exist. Can the students classify their own question? You can spur them on to come up with a different type of question using this knowledge.

Examples of different types of research questions (partly based on De Vaan & Marell, 2012):

- **Counting and measuring questions**: These questions look to keep track of amounts or measure something. Examples include 'How many students in our class are colour blind?' or 'How high is the tallest sunflower in our class?'.
- **Rating questions:** With these questions, you acquire insight in how people value things. Examples include 'What do the students in our class prefer to do in their free time?' or 'What smell do the students in our class consider the worst?'.
- **Comparison questions:** Here the focus lies in discovering the differences and similarities. Examples include 'Which paint is easier to apply to a sheet of paper: paint that has been heated, paint that has been chilled or paint at room temperature?' or 'Are the children from grade 1 more stressed when seeing or holding a mealworm?'.
- **Consequence questions:** These are questions whereby you manipulate something and research the consequences of the manipulation. Examples include 'What happens to your weight when in a moving elevator?' or 'What changes do you perceive in the pattern of colliding sound waves when you block the sound waves by placing a large object in the room?'.
- **Relationship descriptive questions:** Sometimes you want to know how two things are interrelated. Examples include 'What is the relationship between water temperature and the speed at which you can swim?' or 'What is the relationship between the frequency of washing your hands and the amount of bacteria present on your hands?'.
- **Experience questions (phenomenological questions)**: These questions look to understand how people perceive a certain situation. Examples include 'How would students in our class experience a four day period without internet and screens (tv, tablet, telephone)?' or 'When do people really feel part of a culture?'.
- **Opinion questions:** Here you ask about people's views and arguments. Examples include 'Do the students in our class think that the task of the teacher can be taken over by a robot?' or 'Do the parents of the students in our class think pictures and videos of their children can be distributed on social media without their permission? Why/why not?'.

The above list is not exhaustive; there are still other types of questions imaginable. Questions can often be a combination of different types.

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PHASE 3B. SETTING UP A RESEARCH PLAN

Duration: 1 to 2 class hours

Once the students have formulated a suitable research question, they can then begin creating a corresponding research plan. In drawing up the research plan, the students should thoughtfully consider the execution of their research. They should describe step-by-step what they want to research and how they are going to do it. Sometimes students prefer to start immediately with their research and do not see the purpose of coming up with a concrete research plan. Nevertheless it is important that they take the time to think about the details of their research and create a plan.

Goals of this phase

- Students properly prepare their research.
- Students develop their question into a research plan.

Guidelines for the teacher

Discuss what 'fair research' means
Knowing what 'fair research' comprises of is necessary for the design of experimental research. Fair research implies that only one variable within the research changes and the other variables remain constant. Imagine you want to research what determines the growth of a sunflower. The growth of a sunflower is influenced, for example, by the type of soil the flower is planted in, the amount of water the flower receives, the amount of light the flower captures and the ambient temperature. If you want to research which of these factors influences growth, then you would have to research each of these factors separately. If you change both the soil type and the amount of water the flower receives at the same time, then you won't be able to say whether the soil type or the amount of water was the deciding factor for the measured growth. That is why you choose to manipulate only one variable per experiment. For more information about fair research, please refer to the article by Mulder, Van Baren-Nawrocka and Peeters (2015). [only in Dutch]

◉ On the website, you can find a worksheet that you can use for fair research.

Students of the Dolfijn classes practicing fair research

Have the students set up a research plan
In the research plan, the students describe what needs to be done in order to answer the research question. Who are the students going to research? How are they going to approach it? Who is going to do what and when? How are they going to record the results? The students also make predictions about what the answer might be: they formulate the hypothesis.

- On the website, you can find worksheets that can be used to design the research plan.

The worksheet research plan provides guidance and structure in drafting the plan. Students sometimes get bored when required to think about the different components of their research plan and would rather begin immediately. But what will they do first? And do they know what exactly they have to do? From past evaluations, we noticed that students, in hindsight, understand the importance of creating a plan.

Students of De Peppels working on their research plan

Practice first together in designing the research plan
If the students have no experience in making a research plan, we recommend practicing first with the entire class. When picking a practice example, pick one whereby all students can somehow relate to it, but make sure that it does not fit in the theme of the project. This will prevent students from merely copying the example when it comes to making their own. You can fill in the worksheet together with the students, so that they see the different components of the plan. Make sure to inform the students that they cannot be the test subjects of their own research. After all, they know what they want to research and can use this knowledge to influence the results of their research.

Pose directional questions to assist students
In your role as coach, when you notice students are not progressing with their research plan, it is best to pose directional questions. Think of questions such as 'Have you already considered with who you wish to conduct this research and whether it is possible during school time?' or 'What needs to be prepared before you can conduct your research with students from grade 5 in the swimming pool?'. If you find your students stuck, provide them with a hint with which they can progress.

Have the research plan approved before the research is conducted
It is important to inform the students that they can only start the execution of their research after you have approved their research plan. Together with the students, discuss the different components of their plan and tick off the components if you approve of their research plan. Based on their research plan, you will have an overview of what their intentions are and what they have not yet considered. In this way, you remain one step ahead of them. Students that were not required to get their research plans approved commented that it would have been better if they had initially begun with a good research plan.

GO FURTHER

Introduction to different types of research
When you think of research, you quickly think of conducting experiments. However, experimental research is merely one of many types of research. If you review all the different types of questions students come up with (see framework 'Go further' at phase 3a), then it isn't hard to imagine that different questions each require their own approach and method. Not every research question can be answered with a test or measurement. Some question require that youconduct interviews, for example, to understand the motives or reasons of people. There may also be questions that require you to conduct accurate observations of people or objects (for example paintings or archaeological findings). Other cases might require source research, for example, in order to better understand history.

Together with the class, review the questions the students have come up with and discuss what type of research would be most suited to answer these questions. What type of question is most common? What research methods can the students think of? What research methods do the students consider most interesting? What would they like to try? Side effect: If the students know what possibilities exist for research, they might just come up with new questions.

Phase 4. Conducting the research

Duration: 2 to 3 class hours

During the execution of the research, students should work on their own accord as a group as much as possible. For a group that has properly completed the research plan, this should not be a problem. You must ensure that you have an overview of what the groups are doing and that you always remain one step ahead of them so that you can intervene promptly when necessary.

Goals of this phase

- Students learn to independently perform their own research.
- Students learn to work together as a group.

Guidelines for the teacher

Let the students start on their own

Once the research plan has been approved, the students are prepared to carry out their research. They know who they are going to research, how they are going to do it and what they need. You can now let the students work independently. By allowing the students to feel ownership of their own research, many groups may surprise you with their results. This does not imply that your supervision is not necessary, however. Simply watch from a distance how the process proceeds and consider the possible interventions you might need to commit in order to assist them.

A student of De Gazelle records the results of her research.

Be one step ahead of your students

Even though your students have to conduct the research themselves and are responsible for it, it is wise to anticipate potential problems. You can anticipate these problems by viewing their research plan and deducing possible factors they have not yet considered.

◉ Watch video module 2 to see how the class of teacher Jort gets started with their research.

GO FURTHER

Have the students keep a logbook

Doing research requires students to work in an organised fashion. Keeping a research logbook is one way of doing this. The logbook can be filled with descriptions of how the research is conducted and any unexpected events that may have occurred that could be of influence to the results. The groups should also record their experiences during the project, what they have learned, any questions they have, what obstacles or difficulties they encountered, the role each member fulfilled, the agreements that were made within the group and the data collected. The logbook will help them to reconstruct the phases of their research and may help them devise explanations for their results. Moreover, it is a convenient and useful reference that can be used for the presentation at the end of the research process (phase 6). In introducing the logbook, you can hold a class discussion, for example, about how to measure precisely and how to make good notes during the research. If you introduce a logbook, you can also ask students to write their research plan in it. The worksheet, which they already know, can be omitted then. It is, of course, important that all components are mentioned in the developed plan.

Students of the Dolfijn classes updating their logbooks.

Phase 5. Concluding

Duration: 1 class hour

With the completion of the execution of the research, the results must be clearly processed and displayed, for example in a table or graph. Based on the results, the students should then draw a conclusion: the answer to their research question.

Goals of this phase

- Students get an overview of the results they collected during the execution of their research.
- Students establish the link between the results of their research and their research question.
- Students can concisely articulate the results of their research (conclusion).

Guidelines for the teacher

Teach the students to distinguish between the results and the conclusion

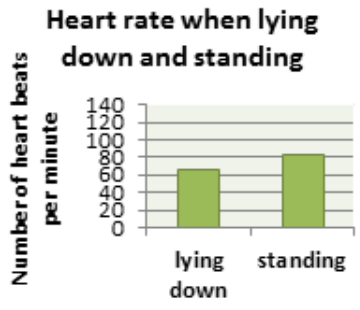
Results are slightly different than the conclusion. Because the distinction between results and conclusion is often difficult to make for students, we recommend devoting some attention to this in advance. In short, the results can be made comprehensive by displaying them in a graph, table or pie chart. In describing the results, you indicate which results stand out. The conclusion is essentially the answer to your research question. With the example below, we attempt to clarify this:

Example research question

When is your heart rate higher: standing or lying down?

Results

When 'standing', a heart rate of 82 beats per minute was measured on average. When lying down, an average rate of 63 heart beats per minute was measured.



Conclusie

The heart rate is higher when standing relative to lying down.

◉ Online you will find a worksheet and an instruction sheet to aid in drawing conclusions. These tools help students to distinguish between the results and the conclusion of their research.

Practice, practice, practice

Concluding is a difficult part of the research process. Even novice researchers often struggle with this. The aforementioned worksheets provide starting points, but the only way to really learn how to translate results into a conclusion is through practice. We recommend that teachers practice this a few times, so that you can better guide your students through this process.

Guide for inquiry-based learning

Students of De Peppels process their results into a pie chart

Have the students reflect on their conclusion

Once the conclusion has been reached, the students interpret and compare it to their hypothesis (the prediction). The worksheet presents a number of questions that are meant to assist the students in this process. Is the students' conclusion the same as their hypothesis? Why/why not? Why do the students think that these results and conclusion were found? Did any surprising elements come forth from the research? What would the students do differently if they had to redo it? The answers to these questions can be discussed with the entire class.

Have the students understand that conclusions are always temporary

Have students get familiar with the idea that the conclusion of a research is always temporary. There is always a possibility that subsequent research debunks the results or the interpretation of the results. This is simply how science works. Sometimes a conclusion can stand undefeated for tens or hundreds of years to ultimately be changed following new research. Hence the knowledge that we have is continuously changing! Research and knowledge are never finished.

GO FURTHER

Head back to the literature again: compare the results

If source research has been conducted during the exploration phase, then the conclusions of the students can be compared with the results found in literature. Do their findings during the execution of the research correspond to what was previously described in literature? Are they adding knowledge to an existing concept or are they confirming what is already known? And if it does not correspond, what do they believe to be the cause?

Phase 6. Presenting

Duration: 2 to 3 class hours

The presentation is an important part of research, because it gives an overview of the entire research process. It requires the students to look back on the entire process.

Goals of this phase

- Students learn to create an overview of their research as a process and of their results.
- Students reflect on the process, the results and the conclusion of the research.
- Students learn to explain the process and the results in a clear and structured way.
- Students learn to come to an agreement together about the form and content of the presentation.

Guidelines for the teacher

Tell the students what a presentation consists of

In the presentation, the students must clearly convey how they started from their research question and how they ultimately arrived to their answer. They do this by presenting their question, their approach, their conclusion and their reflection on the conclusion. You can ask the students what they think should be addressed during a presentation in order to provide the audience with a clear image of the research. In our opinion, at least the following components should be addressed in a presentation:

- Introduction
- Research question
- Predictions or hypothesis
- Research plan
- Execution of research: how was the research step-wise conducted?
- Results and conclusion
- Improvements and reflection on the research

Have students decide for themselves how to present their research

The students are usually strongly committed to their own research and are also very proud when given the chance to present their research. It is fun to let them do so in a creative way, for example in the form of a PowerPoint presentation,a poster, a demonstration of their research, a theatre piece, a film, an article in the school paper, a rap or song. By giving the students the autonomy to decide for themselves, you give them the possibility to come up with a multitude of creative ideas. That being said, the purpose remains that they present their research and its important components.

◉ Watch some inspiring examples of creative presentations online.

Guide for inquiry-based learning

Students of the Roncalli school presenting their research to the class.

Invite an audience to the presentation

Presentations by the students are a golden opportunity to give parents insight into what the students are doing in school and what they have learned. From past experiences, we noticed that students are more motivated to make a success of their presentation when knowing that their parents are present. Students and teachers from other classes can also be invited. It can also be fun to invite people for whom the research is relevant.

GO FURTHER

Have the students critically question each other

To ensure that students listen attentively to each other, you can have them critically question each other after the presentation. Give students the time to ask each other questions and give a good example when the discussion falters. When questions are asked about the presentation, it might inspire other questions in students and cause them to reflect on the presentation at the same time:

- Was it clear for the people who are not familiar with the research? Would questioning allow for a clearer idea of it all?
- Were all components addressed? What might you ask if a component was missing?
- Did the conclusions correspond with the results? What might you ask if this were not the case?

Good questions may also inspire further reflection by the students presenting their research. Do not worry if students do not ask good questions immediately. Asking good questions requires practice.

Discuss the presentations after

You can ask questions about the content of the presentation, but you can also review the form of the presentation together with the students, so that students can do even better next time. Was it clear what the presenting student wanted to convey? Were the presenting students enthusiastic? How was the collaboration during the presentation?

Phase 7. Deepening/broadening

Duration: 1 to 2 class hours

The last phase involves the deepening and broadening of the topic. This is an important phase, because the learning gains are solidified and enhanced. The learning gains are solidified by collectively reviewing the process and knowledge gained. In addition, possible follow-up questions are also addressed. The learning gains are enhanced at this stage by offering additional knowledge on the topic

Goals of this phase

- Students reflect collectively on their research process.
- Students solidify their learning gains by collectively reviewing.
- Students learn from each other by integrating learning gains.
- Students add prior knowledge with new knowledge together.
- Students end the project together.

Guidelines for the teacher

Integrate new knowledge with existing knowledge

It is good to reflect and think about the amassed knowledge after all research projects have been presented. What did we all know already (prior knowledge) and what have we learned since then by looking at existing knowledge (exploring) and through our own research? What have all the research projects provided? By discussing this with one another, the different learning gains are reviewed and the students are given the opportunity once more to learn from each other. The mind maps can be used to facilitate this.

Students of the Peppels work on their mind map

Guide for inquiry-based learning

Connect the results to the lives of the students

Try to create a link between the research and the significance of it for the students' lives. What do the results mean for you, your family and others? What do the conclusions provide and based on these conclusions what can we improve or adjust?

Identify the questions for a follow-up study

Research always generates follow-up questions. Researchers often find themselves with more questions than answers at the end of their research. By looking at possible follow-up questions with the students, you effectively consolidate the seven phases as a real cycle. Here you can make the connection to real researchers, who are also always busy with follow-up questions and further research. You can ask the students yourself what the continuation of their own research would be. Additionally, you can take a look at the unanswered questions on the question wall. If time allows it, you can have the students conduct one more round of research.

Add new knowledge

Now that students have actively immersed themselves in the theme and have conducted their own research, their knowledge can be further broadened by supplementing it with existing knowledge. This can be achieved by hosting an additional lesson on the theme, but students can also look up additional information on their own volition. You can choose to further explore a certain part of the theme based on the students' follow-up questions. You can also make this an opportunity to go on excursion with the students, such as visiting a museum or a place that is relevant to the topic, to further expand their knowledge.

Evaluate the project and end it together

Following the presentation, the different groups all reflected on their research process. By mentioning the phases once more and collectively looking at what went well and what can be improved for next time, the students can benefit from each other's learning moments. This applies to both learning moments where things went well and where things went less well. Some questions that you can ask at this point include: What went well? What can we do better next time? What was the most fun to do? How was working together? Would new agreements and arrangements have to be made if we were to repeat a project inquiry-based learning?

GO FURTHER

Supplement the class mind map

If you started with a class mind map in phase 2 (exploring), then you can use this to integrate knowledge during the deepening phase (Stokhof et al., 2016). By steadily supplementing the class mind map with new knowledge, an overview of the collective knowledge of the class is produced. At this stage, the mind map can be further supplemented and discussed: what knowledge was gained over the course of the project and what have we learned?

Individual end mind map as a measuring device

At the beginning, the student created a mind map based on their prior knowledge. At this stage, the students can create a new individual mind map. By laying the two mind maps side-by-side, you can see how the students have developed over the duration of the project.

1.3 The role of the teacher during inquiry-based learning

It is essential that teacher creates a favourable environment for inquiry-based learning. We provide the following advice in achieving this:

Display yourself as a coach
As a teacher, it is your task to provide the students with the necessary basis for inquiry-based learning. In addition to this, you should display yourself as a coach and facilitate the learning process of students where needed. You are not expected to know the answers to all the students' questions. It is more important that questions are actually being asked and that a collective effort is made to search for an answer.

As a coach, you should think together with your students, provide advice and assist students when necessary, so that they can continue onwards. This does not imply that the students can freely get started. From a distance you observe how the process of research and discovery is conducted, and which interventions might have to be made in order to help the groups progress with their research. You can support the students by engaging in dialogue or by implementing the resources that the WKRU has developed. Where necessary you provide help in adapting questions into researchable questions, in setting up the experiment, in organising the results or in the evaluation of the teamwork. It will not always progress smoothly and the students will be confronted with setbacks. However, these are important learning moments, because learning from mistakes and setbacks sets the stage for improvement. The challenge here for you is: how do I let students deal with setbacks? How do I inspire them to critically evaluate their work? How do I inspire them to conduct even more challenging research?

Dare to let go and allow students to be responsible for their own learning process
The transition to a role as coach requires that you dare to let go and to allow your students to work independently on their research. It is important that your students can acquire experience by themselves and attain a feeling of responsibility for their own learning process. This implies that you must be willing to hand over the control; you must dare to let go so that they can conduct research. Gradually you will have to retreat from your role as content expert and the students will continuously learn how to better collaborate. Doing this will allow students to continue becoming more independent.

A student of De Peppels records the results of the experiment that his fellow researchers are calling out.

Many teachers that have implemented a project inquiry-based learning have indicated that they found difficultly in giving their students so much freedom to work independently. They had to have faith in their own students, because ultimately the students have to be capable of doing it themselves. With that being said, they all understood the importance of letting go and allowing the students to gain control. By giving the students the freedom to operate, you simultaneously provide them with the opportunity to bear responsibility for their research. This implies that students must make and keep agreements with each other, and strive to conduct their own research.

Be a role model
The manner in which you convey your inquisitive attitude has great influence on that of the students. Based on research, it appears that young children show more interest in materials when an adult visually expresses his or her own curiosity about the materials (Engel, 2011). By questioning the world around you and acknowledging that you cannot know everything imparts you convey the message to to the students that it is alright to not know something. Provide a good example and adopt an inquisitive and critical attitude. It is more important to ask questions than to have the correct answers. The need to know and the search for an answer is the core of your teaching practice. If you display an inquisitive attitude, your students are bound to adopt it as their own. Research has shown that children are more curious when a teacher encourages curious behaviour by smiling and engaging in discussions in an inviting way (Engel, 2011). You could say that curiosity is contagious!

- Watch the following film in which teachers, who participated in previous projects, voice their experiences about the project and the tips they have to offer.

- Video module 4