Supporting science teachers in the use of Inquiry Based Learning

- A hybrid approach for teacher professional learning

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Introduction and Course Aims

This coursebook details a hybrid approach to supporting teachers in their use of Inquiry Based Learning (IBL) pedagogies to enrich student learning in science. In particular, the course is aimed at teachers who are new to adopting (IBL) in their teaching. The coursebook will be of interest to teacher leaders, teacher educators, pedagogical coaches and others who support teachers in their professional learning. It should also be of interest to practising teachers as this coursebook will detail activities and their related rationale which teachers can review and adapt for their teaching. It may also be of support to science departments who want to access a resource that they can use internally as a focus for pedagogical enhancement. On completion of this course, teachers will be able to:

1. Understand inquiry based learning and how to adopt this approach in their classroom.
2. Design inquiry based learning activities.
3. Facilitate student learning in an inquiry based learning classroom.

The coursebook is designed to be accessible to all readers. It outlines our proposed approach to delivering this course with teachers. In this outline, the rationale and design approaches will be discussed. Where relevant, reference to other outputs from the RISE project will be signposted. These will include reference to a collection of IBL units, an overarching methodology for delivering remote courses, a collection of teacher IBL examples and to a coursebook on IBL and Practitioner Inquiry which is focused on supporting teachers with experience of IBL and who want to systematically investigate the impact of their teaching approaches on their students.

The coursebook has been developed by partners from four European Universities from Belgium, Ireland, Poland and Slovenia as part of the Remote Inquiries in Science Education (RISE) project which was funded by Erasmus + KA2, project number 2020-1-SI01-KA226-SCH-093576. The coordinator of the RISE project was the University of Ljubljana (UL), Faculty of Education (PEF).

University of Ljubljana is the oldest and largest higher education and scientific research institution in Slovenia. University with its rich tradition was founded in 1919. It has approximately 40,000 undergraduate and graduate students and employs approximately 6,000 higher lecturers, researchers, assistants and administrative staff in 23 faculties and three arts academies. The UL PEF educates and trains teachers and other professional workers in the field of education. It is the fourth largest Faculty at the UL with about 2600 students and close to 200 lecturers and researchers. The UL PEF trains all kinds of professionals, from preschool and primary teachers to teachers who are specialists in teaching two subjects or subject areas in primary school, as well as in certain secondary schools. In addition to the traditional teachers' programmes, the UL PEF trains specialists for inclusive education and the education of children and young people with special needs. The faculty executes seven first cycle study programmes (BA/BSc) and twelve second cycle study programmes (MA/MSc) and the PhD programme entitled Teacher Education and Educational Sciences. The PEF regularly organises professional courses for in-service teachers and collaborates with in-service teachers on a regular basis, as they are supervisors and mentors to students at practice.

Dublin City University is one of Ireland's youngest universities founded in 1981 and comprises over 19,000 students. DCU Institute of Education is the newest faculty of Dublin City University. It has a staff of more than 125 full-time academics and a student body in excess of 4,000. The Institute brings together students of education across all sectors from early childhood, to primary and post-primary, and further education and training. As well as providing a range of

undergraduate programmes in education, the Institute offers a rich menu of taught and research-based postgraduate programmes, at doctoral, masters, diploma and certificate levels. DCU's research Centre for Advancement of STEM Teaching and Learning (CASTeL) is Ireland's largest research centre in STEM Education with a focus on curriculum and pedagogy, assessment, teacher education and policy at all levels.

Artevelde University College Ghent, member of the Ghent University Association, is one of Flanders' largest university colleges (13,000 students). It offers study programs in teacher training, business management, communications, graphic education, health care and social work. Artevelde University College Ghent is a knowledge centre for education, research and services, where students, staff and strategic partners co-operate and develop their talents in a stimulating and internationally oriented environment. Artevelde University College (AHS) has got a strong research policy relying on an explicit choice for practice-based scientific research with concrete applications. The practice-based research strongly connects teaching practice with educational research focused on educational design, so curricula remain up to date, are ensured by innovation and professionalism and result in offering services to schools, policy makers, etc. AHS disposes of solid expertise with regard to research, education, counsel and consultancy.

Uniwersytet Jagiellonski (UJ), Jagiellonian University is a public institution founded in 1364. It is organised in 16 Faculties, including among others the Faculty of Physics, Astronomy and Applied Computer Science. The University is well recognized for its experience in Higher Education. The present number of students is approx. 42 000 (including 3000 PhD students), studying in 94 fields of studies. More than 7000 people are employed at UJ, including almost 4000 academic staff members. Within the university the Teacher Training Centre has been developed to provide generic courses in the areas of pedagogy and psychology for pre-service teachers, while the faculties are responsible for training in the methodology of the individual subjects and organisation of the teaching practice. The Faculty of Physics, Astronomy and Applied Computer Science of the Jagiellonian University provides courses for pre-service science and physics teachers.

The approaches adopted in RISE are authentic in that all activities discussed have been trialled and tested with practising teachers in a two stage process. Initially, a number of IBL activities were examined and discussed with professional learning communities (PLCT) of teachers in Slovenia, Poland, Belgium and Ireland. These activities were then adapted based on this PLCT feedback and were then incorporated into a pilot course for further testing and development. This coursebook thus represents the accumulated learning gathered from the pilot workshops and pilot course.

The partners from the RISE project have extensive experience supporting teachers in learning about Inquiry Based learning (IBL) and Practitioner Inquiry (PI). All four partners had previously collaborated on the ERASMUS+ project Three Dimensions of Inquiry in Physics Education (3DIPhE). Many ideas developed in 3DIPhE were realised and adapted to remote conditions in the RISE project. The outputs of the 3DIPhE Project including coursebooks are available at https://www.3diphe.si/ In the latter stages of the 3DIPhE project, the COVID-19 global pandemic struck and the partners had to adapt and deliver final aspects of the project remotely. Indeed the final conference of the 3DIPhE project which involved about 100 teachers including more than 80 teachers was delivered fully remotely. This conference was a great success and involved more teachers than would have been the case if it were delivered in person. The success of this conference spurred the development of the RISE project. We witnessed the opportunities that an online format could achieve, teachers were given a platform where they could share and develop new ideas linked directly to their classroom practice. The conference reached more teachers and generated a great interest and motivation towards the use of IBL that was both palpable and exciting.

Course Outline

Getting started with Inquiry Based Learning

Inquiry is a natural process of wondering about the world, experiencing it with all senses, and building human being's own attitude towards the miracle of its existence and the beauty of its structure. Inquiry starts any adventure and keeps the pace of any learning endeavour without giving up. Inquiry-based learning (IBL) can be described as a process of constructing knowledge through direct experience in authentic circumstances by the involvement of one's creativity (McLoughlin and Sokolowska, 2022). This instance comprises the ideas and works of the precursors of two pedagogical streams: constructivism and progressivism. Constructivists were confident that learning is an act of students who construct knowledge out of their experiences. For them, repeated exercises of building knowledge needed creativity, and at the same time, enhanced it. Progressivists argued that doing is more valuable than the result of doing. For them the process combining thinking, trying out, reflecting, and redesign - applied to the unknown, triggered motivation and engagement, and resulted in natural learning.

An inquiry learning cycle consists of several stages and RISE adopted an inquiry cycle with nine stages of an inquiry, as shown in Figure 1. This inquiry learning cycle has been adapted from the 3DIPhE – Three Dimensions of Inquiry in Physics Education project funded by ERASMUS+ Programme (2017-2020) and described in Sokolowska, 2020 p.12.

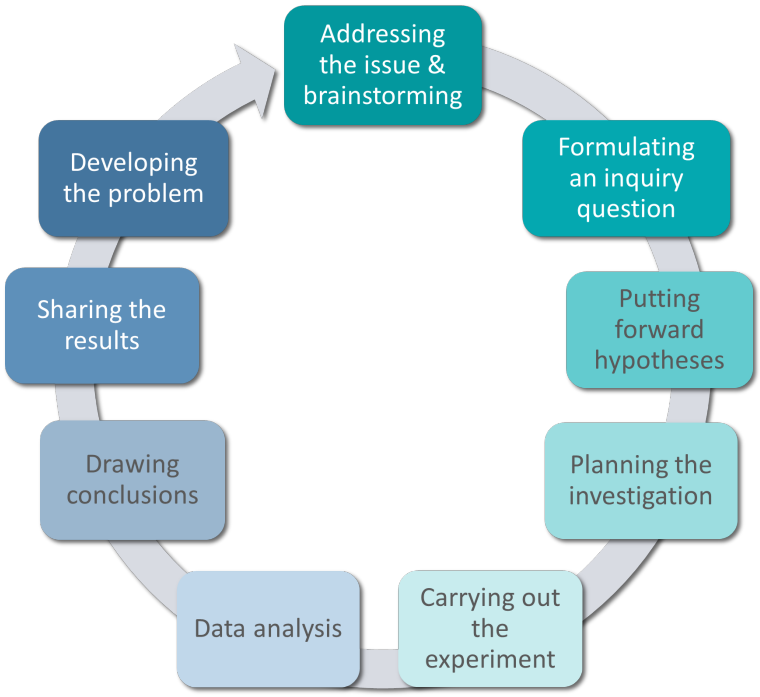

Figure 1. Nine stages of inquiry learning cycle, adopted from 3DIPhE project.

Course Design

The challenge of designing and implementing effective professional learning programs that influence both teachers (teachers' individual characteristics and their teaching skills) and student learning outcomes are widely debated (McLoughlin and Sokolowska, 2023). Professional learning communities (PLCs) within the school context have been promoted as an effective model to support teacher professional learning by facilitating teachers to collaborate and learn from their own practices to improve teaching quality and student learning outcomes (Dana and Yendol-Hoppey 2015).

We propose that in order to meet the aims of the RISE course - to support science teachers in the use of Inquiry Based Learning, a hybrid approach for teacher professional learning should be adopted. In this regard, the course is designed so that the teachers meet in person for 12 hours of workshops and then engage in a further 12 hours of workshops online using a meeting software, in our case Zoom. The decision to adopt this approach was borne out of the experiences working with PLCs in the earlier stages of the RISE project and indeed from our extensive experience providing science teaching professional learning (e.g. 3DIPhE project). We know that to create a successful PLC, it's important that the teachers feel part of the community and understand each other's context and reasons for engaging in the workshops. This is especially important given the community works online for the latter half of the course. This approach should encourage teachers to be more open, value peers' opinions and want to work with each other when engaging in the virtual space. I think most reading this coursebook will have experienced some online workshops or meetings where teachers don't turn on their cameras and/or are unwilling to comment or engage in discussion. For this course to be successful, it's important that this situation doesn't arise!

A feature of the course design is that the online workshops should be scheduled with a minimum of two weeks between each session. This will ensure the teachers have time to reflect on the workshop activities and test out some aspects they have learned when back in school. This reflective element and authentic input from the teachers based on their classroom practice is core to the course. It allows for rich discussions where teachers can share their and through this dialogue develop a deeper understanding of IBL and how to incorporate it into their practice. The shared experience also supports the PLC.

Course Schedule

In this section a suggested course schedule is provided. This outlines activities that should be used in each section and indicates the general purpose of the activity. A more detailed rationale for this structure and the specific activities used is explained in the next section. Detailed descriptions of the specific workshop activities used are found in our outer RISE output - *Inquiry-Based Learning in Remote Setting*. Any additional workshops not included in that book are found in the appendices of this coursebook.

The details of sessions and timings shown in Tables 1 and 2 are provided to give an *indication* of how this course could be run but they are adaptable to each individual context. The main consideration here is that teachers engage in 12 hours of in person workshops before starting 12 hours of online 'spaced' workshops. Ideally, Session 1 and Session 2 would take place on consecutive days, followed by a short break (1-2 weeks) before beginning the online sessions. We would recommend a minimum of two weeks separation between online sessions.

Table 1 : Overview of Course Schedule

Session 1	Session 2	Session 3	Session 4	Session 5
In Person	In Person	Online	Online	Online
5 hours	8 hours	4 hours	4 hours	4 hours

Table 2: Detailed Schedule of workshop activities

Session 1: In Person (5 hours)		
The overall purpose of session 1 is to: - Introduce teachers to Inquiry based learning and professional learning communities. - Support teachers in forming IBL questions - Supporting teachers to get to know each other and different contexts		
Time (mins)	**Activity**	**Purpose**
60	Spectroscope	Introduction to learning through IBL (structured inquiry vs. guided inquiry)
60	Teacher Introductions Consensogram	Introduction to Professional Learning Community (PLC) teachers gain an understanding of each others contexts
15	Coffee (during activity)	Sustenance but also PLC Building time
60	Ice Balloons	This activity aims to develop the skill of raising questions around an interesting phenomena. The focus of this activity is to develop teacher's awareness of the role of inquiry questions in the investigation process and facilitate them to distinguish between questions that are investigable or non-investigable. Teachers develop criteria for investigatable questions and collaborate to turn non-investigable questions into investigable ones.
15	Discussion on course and PLC	To set the context and expectations for teachers engaging in the course. This also allows for sharing of contexts so teachers learn to understand and value each other's expertise and contributions.
60	Bridge Building	There are two focuses of this activity. The first is the design of the experiment, which tests different shapes of cross sections

		regarding their load capacity. The second is the design of the measuring procedure which allows the control of variables and the correct comparison of the load capacity of different bridges.
30	De-brief, discussion, introduction the inquiry cycle and skill development	To make explicit the links between the activities explored and the inquiry cycle. To discuss how the learning can be applied in the classroom and to reinforce intended take home messages.

Session 2: In Person (8 hours)

Time (min)	**Activity**	**Purpose**
90	Measuring Speed	This unit was designed and implemented so that the teachers gain personal experience of open and guided inquiry activities. In this way it was hoped that they gain a real appreciation of what their own students' experience was when completing IBL activities.
30	Coffee	PLC building time for teachers to discuss activity in their context
110	Chemical Reactions	To introduce the inquiry continuum from structured to open using the same scientific concepts but taught in different ways. To learn that you can achieve different learning outcomes from doing the same experiment in different ways.
60	Lunch	Sustenance and PLC building
90	Boat Competition	Floatability of aluminium boats Introduction to measurement Experimental design, fair experiment, control of variables To model how to facilitate an IBL activity that focuses on experimental design considering fair testing and controlling variables.
30	Coffee	Sustenance and PLC building
50	Subtle shifts	To model an example of guided inquiry and to demonstrate how small changes “subtle shifts”to teaching instruction and lesson design can lead to different student learning on the concept of light shadows.
20	De-brief, discussion and Finish	To reflect on the in-person workshops and to establish the purpose and ways of working for the remainder of the course.

Session 3: Online (4 hours)

Time (mins)	Activity	Purpose
60	Brainstorming	To model different strategies regarding the first step of the inquiry cycle i.e. addressing the issue and brainstorming
80	Double Shadow	Developing hypotheses on cause and effect and how to test those hypotheses.
20	Coffee	Sustenance and PLC building
80	Indians, bells and whistling bottles	To model an extended example of the processes of brainstorming, data collection and drawing conclusions.

Session 4: Online (4 hours)

Time (mins)	Activity	Responsible
60	Raising inquiry questions	To model how teachers can support their students to formulate inquiry questions.
75	Cooking Spaghetti	To plan and carry out an investigation to cook the perfect spaghetti. Students are asked to consider what factors will affect the cooking of the spaghetti and what variables they should measure and record. Students must also discuss and agree how they will determine when they have cooked the perfect spaghetti.
20	Coffee	Sustenance and PLC building
85	Melting Ice cubes	To explore how modelling can be used to support students to reason and make conclusions about experimental observations

Session 5: Online (4 hours)

Time (mins)	Activity	Purpose
90	Concept Cartoons	Learn to make hypotheses and change them during a small inquiry.
15	Coffee	Sustenance and PLC building
135	Teaching sharing of practical ideas/activities from their practice	Sharing practice and PLC Building. This allows teachers to discuss IBL activities they have used to get advice on any questions they may have. It also serves as a motivating session to encourage all to want to test ideas in their classroom and continue to engage when the course moves online

Course Facilitation

This course is specifically designed for teachers who are new to using IBL. From our experience it's often the case that teachers have heard about inquiry but have seldom experienced learning through this approach. In this regard it's very difficult to expect someone to teach using a pedagogical approach they've not experienced. It can also add to questions about the merits of the approach where teachers may be sceptical about the effort and time needed to develop activities and teach using IBL. With this in mind, a core aspect of the course involves modelling of an IBL approach in workshops with teachers. This gives the teachers opportunities to experience IBL activities as a learner so they can reflect on the approach but also demonstrates ready-to-take examples which they can use in their own practice. This is a motivating factor for course teachers as they have something they can take away with them immediately.

Through our experience in RISE and other projects, we have learned that teachers benefit from experiencing and developing activities for each element of the inquiry cycle instead of trying to explore each element at the same time. This experience supports teachers to develop a thorough understanding of each element of the inquiry cycle. Of course, the end goal of this course is to enhance classroom practice and student learning. Hence we also model this approach so teachers can reflect on strategies which they can use to develop their own students' inquiry skills. We know that while students can engage in IBL activities that use different elements of the inquiry cycle, it is very helpful to focus on one element of the inquiry cycle at a time in order to scaffold their learning and understanding of the inquiry process.

We have previously discussed the rationale for the hybrid approach adopted in this course. Given the remote nature of the second half of the course, the design of this aspect of the course requires a lot of consideration. Before we discuss this further, it's important to remember the aims of the course, namely, to develop teachers' understanding of the Inquiry cycle, to develop their capacity to employ IBL approaches in their own teaching, and to develop a productive professional learning community. With this in mind, the choice of IBL activities used in the course had to meet a number of criteria i.e. they had to be safe to conduct at home, had to utilise basic equipment that is readily available and had to meet our purpose of developing teachers IBL skills as well as allowing for modelling of how it could be used in the classroom. In this section we will discuss each session, identifying the purpose of each workshop, choice of activity and key take home messages. This discussion will focus on both IBL and PLCs. If adapting this coursebook it's important to consider why these IBL and PLC activities were chosen so that any alternatives still allows for the intended purposes of the workshop to be achieved. While we will provide a detailed description here, if you are interested in further exploring our methodological approach, please refer to the *Inquiry-Based Learning in Remote Setting* output from this RISE project.

Session 1 Facilitation Guide

Spectroscope

The purpose of the Spectroscope unit is to model how to introduce students to the topic of refraction and splitting of light, as well as atomic spectrometry. The unit is organised in three parts (the last is optional), adaptable for different age groups. The first part is designed at the level of structured inquiry, the second is at the level of guided inquiry, the last can be organised as a challenge between the groups. The unit is particularly suitable for development of the skills of planning the inquiry (choosing the sources of light) and data collection from observations.

Teacher Introductions

Teachers are asked to briefly introduce themselves and provide some background to what school they are teaching in. This context is very important to help develop a community and create an atmosphere that all teachers feel happy to engage in.

Consensogram

The purpose of the Consensogram (Appendix A1) is to give teachers on the course an opportunity to learn about and understand each other's contexts some more. It is quite likely that teachers on the course will be coming from a range of different backgrounds, and each individual school context will be quite different. This activity gives everyone a chance to first of all get to know each other a little better, and for all teachers in the course to discuss the opportunities and challenges they face in their schools. One of the most important elements of this activity is to provide time for teachers to look at the responses and to discuss them. Having run this activity with several groups we have found that teachers value this opportunity to share what works well and doesn't work well for them in their schools in relation to collaboration, recognition and reflective dialogue. In the context of the RISE international course teachers also found it very helpful to hear that internationally many of the rewards and challenges of teaching were the same.

Ice Balloons

This inquiry unit aims to develop the skill of raising questions around an interesting phenomena. In this case we use ice balloons - water filled balloons that have been frozen and then peeled, to reveal a ball of ice. The purpose of this workshop is to generate questions. As we get older, we are sometimes less surprised by things happening around us. This workshop aims to bring back wonder and turn it into daring to ask different questions. These questions are then divided into investigatable and non-investigable questions. Strategies are provided on how to turn the non-investigable questions into investigatable ones. The ice balloons are an excellent subject of inquiry due to their unusualness in everyday life, not to mention their highly intricate structures. This activity is adopted from the Exploratorium Fundamentals of Inquiry Facilitator's Guide Workshop III: Raising Question.

Discussion on course and PLC

It is important to take time to outline the context and expectations for teachers engaging in the course. This also allows for sharing of contexts so teachers learn to understand and value each other's expertise and contributions. It is essential to give this so teachers will engage with each other between and during remote online sessions.

Bridge Building

The purpose of building the bridge is to establish a friendly and creative atmosphere at the beginning of the course.
Teachers receive a single piece of A4 paper and are asked to make a bridge that carries the largest possible load. The bridge should span across 28 cm, and should carry the load without breaking. The rest is left to teachers. If teachers want to test new shapes of the bridge, they use new A4 papers, but only one at a time. This content actually focuses on two important questions relevant for science learners: How to design a testing experiment, which will disprove or corroborate the idea, and how to perform the measurement correctly, that measurements are comparable and that the ultimate best shape is found. After the first trials, teachers aim to enlarge the load by changing the shape of the paper, which is the only variable left. The testing experiment should clearly show that the new shape carries a larger cargo than existing ones. Therefore the teachers have to agree upon methodology to measure the cargo and all of them have to apply the same method. The final outcome of the activity is the shape of the paper that carries the largest load. The competition mode of this activity has a strong motivation effect to achieve the best result, and positively encourages creating ideas and the collaboration within competing groups.

De-brief, discussion, introduction of the inquiry cycle and skill development.

At the end of this first session, some time is given for reflection and discussion on the activities carried out and how these are aligned to the RISE inquiry cycle. Again, this reflection time is essential as it allows teachers to reflect on the learning from the session. This can be overwhelming during a full day, so providing opportunities to explicitly discuss and call out the take home messages will enhance the outcome of the course.

Session 2 Facilitator Guide

Measuring Speed

This unit is concerned with the physical concepts of distance, time, the absolute value of velocity and its distinction from the concept of speed. The purpose of this activity is to provide learners with personal experience of open and guided inquiry activities. In this way it was hoped that they gain a real appreciation of their own students' experience while completing IBL activities. Teachers complete two inquiry investigations - firstly as an open inquiry and then as guided inquiry. They discuss and compare both approaches in terms of what inquiry skills are developed and the differences between teacher-led versus student-led inquiries. They also reflect on how comfortable and confident they were in planning and carrying out both activities. The facilitation approach adopted in this activity is adapted from the SAILS EU Project on Speed.

In the first part of this activity, two teachers collaborate to complete their inquiry investigation according to their own written plan for inquiry activities A and B.

Activity A: How fast can you walk in 5 seconds?
Activity B: how much time does it take to walk 5 metres?

They will investigate the influence of how far they walk and what time it takes to determine what their speed is. They should tabulate data and draw graphs to interpret their data and draw conclusions. A third teacher is assigned to observe the pair of students and pay close attention to how closely students execute their own written plans. In the secondary part of the activity, teachers are asked to carry out two (guided inquiry) plans provided by the teacher to address the same two inquiry activities A and B. Teachers use the same equipment as before. They should tabulate data and draw graphs to interpret their data and draw conclusions as per given plans. Teachers reflect on their experiences of carrying out activities A and B according to their own plan and following the plan provided. They are asked to consider what were differences in the the role of the teacher and student in the first 'open' inquiry approach and the second 'guided' inquiry approach. They also identify and discuss what scientific skills they have used while carrying out the open versus guided inquiry activities.

Chemical Reactions

The purpose of this activity was to model different approaches to teaching through inquiry using the same activities from the IBL unit Chemical reactions. As this course is designed for those with limited experience of inquiry it is suggested that the teachers should have the opportunity to experience inquiry as learners. In that regard the teachers should look at the three different approaches described in the inquiry unit. The facilitation approach adopted in this activity is adapted from the Exploratorium workshop 1: Comparing Approaches to Hands on Science.

It's recommended that the teachers should be divided into groups of 3-4 persons. Half of the group cohort should complete alternative activity 1 and the remainder should complete alternative activity 2 - If you have additional time you could ask all teachers to complete all approaches. The facilitator should circulate and pose questions outlined in the unit to the teachers as if they were students in a lesson. On completion of the activities, teachers should be asked to reflect on their experience - they should reflect as school level learners and consider how they approached the task and how they felt about the experience. A plenary discussion sharing their different experiences can be held at this stage. Normally you will see differences between the groups, some planned their approach whilst others jumped straight in and played with the equipment but most got to the same endpoint. It's important to keep observations during the facilitation so you can use examples from what happened during the activity to help with this discussion. For example, you might point to a group and ask how they record their data - it could be that they tabulated their data and another group might reflect that they just wrote it on scraps of paper. You could also pose questions on whether they felt comfortable not

having instructions on how to do the experiment, some might talk about being overwhelmed and others might say they preferred this approach. You can ask them to hold any more ideas they may have at this point and ask all teachers to complete the main inquiry unit parts 1-3. This should be facilitated as in the unit description.

On completion of this activity, the teachers should complete a worksheet where they are asked to compare the three different approaches based on three questions relating to the locus of control for the different approaches - (1) Who controlled the question being posed; (2) who had control over the procedure or experimental design and (3) who had control over the outcome of the investigations. This discussion will allow the teachers to explicitly appreciate the differences between the different approaches. The conversation can be extended to discuss what learning and skills were developed through the different approaches and when they would use each approach. A core take home message from this activity is that there are many approaches to teaching and that each approach leads to different learning so it's important to match the teachers intention with the lesson design.

If you're following our proposed schedule for the day, the teachers are certainly ready for a lunch break. This is a good time for them to reflect and process the messages from the activities they've engaged with.

Boat Competition

Aluminium boats is organizationally similar to the Building the bridge activity, however it has more open potential for further explorations. Teachers receive a rectangular piece of aluminium foil, from which they are asked to cut nine equal squares with length of the sides defined in advance. They also get a tray with water and a number of small and relatively light objects of the same size and shape and the most important, the same weight, for example paper clips, paper pins or similar. The competition rules are simple, make a boat from aluminium foil that carries the largest cargo. The cargo is measured in a number of small objects. The activity lasts for about 40 minutes, when the number of objects on a still floating boat does not increase any more. The cargo, that is, the number of objects, is the measure for the property called floatability. Finally, when the winner is already known, the properties that affect the floatability are discussed. The most evident is the shape of the boat. One should discuss effects of different dimensions relevant for the boat, like its volume or similar. It is also valuable to discuss the accuracy of the measuring method due to its discreteness and what are alternatives that allow for continuous measurement of the cargo. There are many other properties that affect the floatability. A careful observer can notice the shape of the water surface and link them to effects of the surface tension or conditions for stability of the boat. These effects can be further explored in separate open inquiries.

Subtle shifts

The main idea behind the subtle shits activity is to model how to change the focus or purpose of an activity by making small instructional changes. In this session, teachers experience different versions of the same activity. This is done so they have an opportunity to see how the same activity can be modified to lead to different learning and different expectations on the teacher/students. After completing the first activity the teachers are asked to reflect on their learning experience. They are asked questions: *who determined the question, problem, who determined the procedure/design and who determined the results/analysis.* The idea here is that the teachers reflect on the design of the activity and the relative autonomy of the student/teacher in the task. The teachers then repeat the task but with a modified instructional approach. On completion of the second approach, the teachers reflect on the difference between the approaches and the related learning. Teachers will discuss how one approach is more open than the other and that the students have more choice and decisions to make in this open version. For example, students have to decide what to investigate, how to collect and analyse their own data whereas in the more teacher led approach, these decisions are controlled by the teacher. Discussion is held on the relative merits of each approach and when they would be helpful to use in the classroom

De-brief, discussion and Finish

This is an important aspect of the workshop. This is an opportunity to reflect on the learning from the two days of workshops. It's a great opportunity for teachers to also note what they learned from each other which will support their PLC relationships. In this discussion we used a Zones of Comfort Protocol, where teachers were asked to express their relative comfort about understanding the RISE inquiry cycle, teaching through inquiry and engaging in a PLC. The final part of the debrief is to talk about the future and expectations regarding the online sessions. This is necessary to encourage future engagement in the project. For example, we used this as a chance to select the times and dates that suited most of the teachers. Giving them a voice in the design of the course also leads to increased engagement.

Session 3 Facilitator Guide

This is our first online session. A short re-introduction and overview of how the session will run is important. It's recommended that you are online early as some teachers will log-on early too. Should this be the situation, you can use this opportunity as a chance to check-in and see how they have been progressing with inquiry since the face to face workshops. This helps break the ice and builds a rapport between the teachers and facilitators. This is also an opportunity for the teachers to reconnect with each other. Finally, it's recommended to go through some housekeeping in terms of expectations and address any technology issues.

Brainstorming

Subsequent steps of the inquiry cycle require teacher attention and their specific skills to implement the IBL method successfully in the classroom. So during the course we propose that teachers get involved not only in practical activities based on IBL units but also in activities designed to develop specific skills essential to teach by inquiry.

Brainstorming is the first in a sequence unit aimed to develop teachers' skills to run an inquiry lesson. The first step of the iBL cycle plays an important role in motivating students by giving them floor and benefitting from their own context and prior experiences from everyday life, as well as their prior scientific knowledge. This is the moment of stimulating students' curiosity and developing in them the ownership of learning. All learners can be equally included, even those generally perceived as low achievers or misbehaving students, since all of them have their own (valuable) experience and can speak spontaneously, providing the teacher learns how to manage and conduct the brainstorming. This unit is organised around the Brainstorming protocol (Appendix A2).

Double Shadow

The instructions to carry out the Double shadow inquiry is published in VOLUME 1: Inquiry Based Learning to enhance teaching, the output of the Erasmus+ project Three dimensions of inquiry in physics education. It was adapted to remote conditions, and it focuses on testing ideas, that is, to design an experiment to test the tentative explanation of the phenomenon observed by students.

As a brainstorming, shadows are discussed. Shadows are a phenomenon observed every day. They appear when an object absorbs the light from the light source. Although shadows are very common, there are several phenomena worth observing and studying related to them, one is a double shadow. If the object is placed on the mirror or on the other reflective surface, and is illuminated by light, a bright light spot with two mirrored shadows of the object are seen, if the screen is set perpendicularly to the mirror/surface.

The introduction to the experiment begins with demonstration of the setup. Participants have to assemble the same experiment. When they are able to observe the double shadow, they are asked to investigate conditions under which the phenomenon is observable. In the next step they are asked to provide an explanation, why one shadow is oriented in the same directions as the object and the other shadow appears below in the opposite direction. When tentative explanations are offered, participants are asked to design an experiment, which can test their idea, predict the outcome of the experiment and the meaning of the outcome for the tentative explanation, does the outcome disprove it or not.

And, of course, participants have to show and carry out the experiment, and share the reasoning to the others, which also considers reporting part of the cycle.
Equipment for the experiment is available in every household and consists of a mirror, a small object that lacks the mirror symmetry, like a construction from a few lego bricks, a screen, which could be simply a wall, and a torch, the torch from the mobile phone is perfect.

Indians, bells and whistling bottles
This unit aims to introduce the learners to the concept of sound frequency, sound propagation in matter, and the resonator. The module is embedded into the IBL cycle at the level of guided inquiry. An extension to the open inquiry level is possible. Students experience different aspects of playing and calibrating non-standard instruments: spoons, glass bottles, and wine glasses. The unit consists of four units, which can be used alternatively or in a sequence, depending on the curriculum purpose, and the age of students. Parts 2-4 contain an ICT component.
The unit is particularly suitable to practise an extended brainstorming at the beginning of the lesson and to show teachers how to develop a storyline.

Debrief and close
As in the face to face workshops, it's recommended to give time for reflection on the session learnings, to thank the teachers for their engagement and to outline the expectations for the next session.

Session 4 Facilitator Guide

Introduction
Again, it's advised to start with an informal check-in and give the teachers time to talk to each other while everyone is logging on and getting settled for the session. This is important to build relationships and create an environment where the teachers are motivated and feel safe to share their classroom experiences whether positive or negative. If this is done well, you might find some teachers asking the community for advice and ideas which can be a wonderful sharing and learning opportunity.

Raising inquiry questions
This is the second in a sequence unit aimed at developing teachers' skills to run an inquiry lesson. When designing an IBL module for students, teachers need to remember the principles in formulating inquiry questions. Raising an inquiry question is asking one or a series of questions related to the issue selected in the first point. This is where the topic narrows down and becomes more specific. The question may be qualitative or quantitative, but in principle, it should be structured in such a way that it cannot be answered directly: "yes" or "no". It should also be formulated so that the answer can be obtained as a result of a study conducted in specific conditions created during classes, i.e., taking into account class time, availability of materials, classroom conditions, and student safety. Usually, the question is related to trends, the extent of influence of one (independent) variable on another (dependent) variable. Teachers (and students) should bear in mind that the question must be formulated in such a way that a fair test should be applicable to answer it. This unit is organised around the Raising Inquiry Questions protocol (Appendix A3).

Cooking Spaghetti
Teachers are asked to consider what factors will affect the cooking of the spaghetti and what variables they should measure and record. Teachers must also discuss and agree how they will determine when they have cooked the perfect spaghetti. These activities are adopted from the SAILS EU Unit on Cooking Food.

Teachers are facilitated to collaborate in small groups to firstly plan an investigation for the inquiry question: How to cook the perfect spaghetti? In planning their investigation, teachers are prompted to consider the following questions: What do you see (observe) happening to spaghetti when it is cooked? What is your method for cooking the perfect spaghetti? What changes to the spaghetti are you going to record or measure & how? What factors do you think could affect the spaghetti during cooking? Teachers debate and write a clear definition of what is the "perfect spaghetti", e.g. the perfect spaghetti should be slightly al dente, not soft or gummy, it will be sticky enough to hold sauce, but not so sticky that it sticks to itself.

Teachers are provided with a packet of uncooked spaghetti and a selection of measurement devices and prompted to identify and consider what variables they can measure and record. The facilitation of a whole group discussion to identify variables that could be measured/controlled during their investigations is an important step in this activity. Teachers collaborate in small groups to write an agreed plan for how they will carry out their investigation. Teachers carry out their investigation according to their agreed plan and compare their findings with other groups. They are facilitated to reflect on their plans and if/how they have controlled and measured variables.

Melting Ice-cubes

Many of the teachers who've engaged in this project have noted that their students often struggle with articulating their reasoning and in particular writing their explanations of scientific phenomena. They can sometimes explain it verbally but cannot translate this to paper. In this activity the teachers are introduced to the idea of using causal explanations and modelling to support students to explain their thinking and to provide opportunities - through analysis of student drawings - for the teacher to get more insights into student thinking and ask probing questions. This part of the session should be conducted as described in the Inquiry unit melting ice-cubes. It's important that the teachers experience this as learners first. On completion of the unit (parts 1-3), discussion should be held that reflect on the key take home messages namely, how the approach just experienced supports eliciting of student ideas, provides opportunities for teacher questioning, supports students use of evidence to make claims and how it holds students accountable for any claims they are making. If there is time, the extension activity on racing candles can be conducted. It's expected that this time, the teachers should be able to make improved drawings of the phenomena being investigated.

Debrief and close

At the end of this session teachers need to be advised of the plan for the final session where they will be asked to share their ideas and practical experiences to the group. Some teachers might be nervous about this especially where English isn't everyone's first language. This is the time to ensure all feel comfortable presenting to each other. If the PLC activities have been successful in the previous workshops the teachers should be open to this opportunity.

Session 5 Facilitator Guide

Introduction

As before, the introduction should be the time where the facilitators set the tone of the session where everyone feels relaxed, engaged and looking forward to the session. Some informal discussions and humour can settle the group.

Concept Cartoons

Concept cartoons are based on students' own thinking, which corresponds to known 'alternative thinking' or student Thinking.

The learner's thought images should not be viewed as mere common mistakes but require a specific didactic approach. Concept cartoons are a possible solution to this. In summary, concept cartoons invite students to think, formulate arguments and reduce the threshold for discussion. *Scientific concepts can incorporate familiar everyday situations, each of which can be equally valid but may conflict due to different perspectives. These concepts frequently lack a single correct answer and offer an excellent foundation for additional research. In this workshop we think about a specific topic for which we develop a concept cartoon. We first research what student mindsets are prevalent among the students and then we create a slide in PowerPoint to shape the concept cartoon.

Teaching sharing of practical ideas/activities from their practice

This session should be the culmination of all of the work completed during the course. This is teachers' chance to share their experiences of trialling IBL activities in their classrooms. In our experiences this was one of the most rewarding aspects of the course. It was a great opportunity to learn what the teachers had taken from the course and how they adapted it for their own teaching. This really should be a learning experience for teachers and facilitators and all should take away new ideas.

Debrief and close

The final debrief is a chance to thank everyone for their engagement throughout the course and to reflect on the full experience. This can be a time to get feedback on how the course could be improved for future implementations and also to encourage the teachers to continue to engage with each other through the PLC should they wish to do so.

Practicalities and Logistics and Digital Tools

In this section additional advice regarding the design and implementation of the course are provided. These relate to general practicalities, logistics and digital tools. This information is arranged in Tables as it's felt it is most accessible for the reader. It could be used as a checklist to refer back to when designing your sessions and as a final checklist before implementing any session.

Table 3 : Considerations for Practicalities and Logistics

Recruitment of teachers	The issue of recruitment is very context dependent. In our situation we used an open call through our teacher networks and to persons from previous courses who had indicated they were willing to be contacted again about future courses. We found it necessary to specify the full expectations, time commitments and days which the course would run at this point so teachers would know if they could commit. We also found that it is important to select the same day for the online sessions so all can commit and clear their diary if necessary. In previous projects we've used different days and asked teachers to identify days they were available. This led to problems of not being able to suit everyone and some teachers only engaged for some sessions. We believe that knowing what days and highlighting them at the start leads to a more engaged teacher group.
Communication	Depending on your region it's important that you follow all policies such as GDPR when communicating with teachers. For example, you need to be clear that you will be storing their email addresses for future correspondence. Do not request any information that is not necessary

	for your course. You will want to share information such as equipment lists, travel arrangements, links to access online sessions etc. Ensure that teachers are willing to be contacted about this and that you close copy (bcc) all correspondence so you are not sharing personal information. It is recommended that you send ongoing reminders about upcoming sessions, and outline clear expectations regarding communication, use of cameras during online sessions and engagement in sessions.
Trialling activities, Equipment and Resources	It's advised that you trial run every activity in advance of running your course. You need to ensure that the activities work in the modality that you are using i.e. face to face or online. You should consider aspects of health and safety and complete any required risk assessments. At this stage you can make a list of all equipment and resources that are required. Once you've compiled this information it will allow you to ensure you have everything you need for your face to face sessions. It will also allow you to send equipment lists for the online sessions at least a week in advance so teachers have enough time to collect what they need. For the online sessions, In some cases it's advised to send pictures of what's expected. For example when we used the chemical reactions activity, teachers had different types of Vitamin C tables which affected how the task could be completed. If you know the full list of equipment and resources you require, you could make this available at the start but still send pre-session reminders.
In Person facilities and considerations	Our course is designed to be delivered through hybrid delivery as already discussed. There are a number of considerations for the in-person sessions. Firstly, it's important to check if the space you are using is appropriate for the activities you are conducting. We chose a laboratory as it had all of the necessary requirements of sinks, sockets, safety stations and was arranged in a pod format so it was easy to facilitate individual and small group work. We were fortunate that we were also able to book a room beside the laboratory where we could set up a tea and coffee station and food where the teachers could socialise at different points during the sessions.
Online tools/apps	In your online sessions you will use a range of digital tools. It's recommended that these are all tested in advance and that they are device agnostic. Each facilitator should be comfortable and experienced using the various functionality of the tools that you intend to use in the workshops. In Table 4, we have listed the digital tools we used but more importantly the functionality that the tools offered. We advise using the same link for online sessions to reduce confusion and issues when teachers are logging on. For our online sessions we shared all resources through Google Drive. This was shared in advance and emails were sent in advance of sessions so teachers could access the resources in advance of

	the session. Again, the same link was used throughout so there was no confusion where resources resided. If using an app such as Google Drive for sharing resources, it's important that you check sharing access, ensure the format is consistent for each workshop so teachers know where to find information, show the filing system at the end of the in-person meeting so they know what to expect in advance of the online sessions.
Introductions and debriefs	The beginning and end of each session are very important. You will have read some notes regarding these in the description of the sessions. In general, we advise that the introductions are used to set the tone for the workshop. These should support the creation of an enjoyable and productive session where all teachers feel comfortable and want to engage with the materials and each other. There are a lot of new ideas addressed in the sessions. We encourage you to have a debrief where teachers can reflect on these ideas and have a final opportunity to discuss what they have learned and to check for any clarifications or misunderstandings. The debrief is also an occasion where you can outline expectations for future workshops and address any logistics.
teacher groups	We suggest that you use group formation as a way to support the development of the PLC. In our situation we were working with an international group. We ensured that there were different nationalities in each group. This encouraged mixing and learning about each other's contexts. It also reduced the chance of some people being isolated if teachers were tempted to speak in their native language.
Coffee breaks	It is essential to provide adequate time for coffee breaks throughout sessions (both for face to face and online) to support the development of a professional learning community. In face to face sessions, teachers have time to discuss key ideas and questions they may have on activities, make connections and foster relationships with other teachers. This can be replicated online by grouping teachers in breakout rooms to chat over coffee.
Course Facilitators	If you are in the fortunate situation to be delivering this course with colleagues like we were, we would advise to change facilitators regularly so the teachers are hearing different perspectives on the course aims. However, if you are adopting this approach it's important that the other facilitators either observe the sessions they are not engaged in or you build in time for each some debriefing before the next session. This is important for coherence and consistency in the workshops and also to support the development of the PLC. For example, if a teacher shares something about their context that is relevant in a later session it would be good if the facilitator was aware of this and could make reference to it.
Language	The language used depends on whether this is an international course or not. Clear communication and instructions are required so all information can be understood by all teachers. teachers' language abilities may influence how you set up your groups and could impact teacher

	confidence and engagement. There needs to be a supportive and patient environment where teachers don't feel uncomfortable if they are not fluent in the chosen language.

The online 12 hours of this course are delivered remotely. The rationale for this has been previously discussed. In this section a brief overview of the tools that we have used and trialled are discussed. Given that technology is ever changing, you may find different tools to use. The important aspect to note, is *why* the tools were selected and how their use supported the aims of the course.

Table 4 : Considerations for Choice of Digital Tools

Example of Digital Tools	**Main purpose**
Zoom Microsoft Teams	*Online Communication Platform* The purpose of these tools is to provide a stable platform for facilitating remote (or hybrid) learning workshops. For whatever tool is selected it is important that it provides appropriate functionality for smooth facilitation. This should include an ability to annotate the screen, to have breakout rooms for subgroups of teachers, and to facilitate easy communication to breakout rooms even while the host is not in the rooms. More generally it should be easy for all teachers to use chat, camera and sound functions from various devices (mobile, tablet, laptop). As noted previously, we recommend that you generate one access link for the remote workshops and use the same link for all workshops.
Google Drive	*File Management System* It is important to have a file management system that facilitates easy sharing of selected files and folders, and is easily accessible for all workshop teachers. It is preferable that course teachers do not have to pay for access to any file management/sharing system that you use. The RISE programme used Google Drive for the management and sharing of all course files. It is easily accessible for all teachers, provides easy sharing options and supports a variety of file types. It was also very easy for teachers to collaborate on working documents throughout the course.
JamBoard Padlet	*Collaborative Learning Tools* Specialised collaborative tools offer teachers the opportunity for real time collaboration. While this is also possible through more general tools (e.g. Google Docs, Office 363) some specialised tools provide additional functionality. They also allow for real time monitoring of group activity, and course teachers can easily explore what others are doing while continuing to work in their own group. In addition to collaboration, Padlet is an example of a tool that can be used for gathering ideas for discussion and for quickly collecting and recording of ideas from groups
Mural Miro	*Information Management Tools* Mural and Miro are powerful tools that allow you to collate all information in one place, modelling a digital practice that could be used in the classroom

Building and sustaining a Professional Learning Community

It is extremely important that you build a community during your course. This will encourage teacher engagement, collaboration and motivation to attend all workshops. In our context, this was a key consideration. We needed to ensure we could sustain a professional learning community of teachers from three different countries. We have outlined the specific activities that supported this above. It is important to emphasise that the idea of collaboration and community was central to many of the decisions we made in the design of the course. Our implementation of the course was hybrid; we brought together teachers for two days in person, before the online sessions that took place over a six week period. We found that having the in-person workshops first allowed our teachers to get to know each other, and overcame a lot of the Zoom unease that can often happen in a purely online course. When we moved online, we were sure to allow sufficient time for introductions, breakout-room discussion, informal coffee discussions and reflections during closing debrief activities.

Conclusions and Recommendations

This coursebook has been written based on our extensive experiences in supporting teachers to understand and engage in IBL practices. While there is no one way to achieve this, we have found our approach to be successful in delivering international hybrid courses that have led to changes and impact in teachers' classrooms as evidenced by their presentations and posters in our final project conference.

As noted, it is intended that on completion of this course, teachers will be able to:

1. Understand inquiry based learning and how to adopt this approach in their classroom.
2. Design inquiry based learning activities.
3. Facilitate student learning in an inquiry based learning classroom.

We understand that your context may be different to ours, however, we feel that if you consider the rationale and sequence of our course you should be able to adapt the main principles of our course to your situation. We strongly believe in the importance of creating a functioning and engaged PLC. In our experience we have found that a hybrid approach where teachers have an opportunity to meet first leads to more successful remote workshops. This face to face meeting allows for the fostering of relationships and friendships that lead to positive remote environments where teachers engage deeply and are open to sharing their concerns and ideas about their practice. We also believe that it is imperative that teachers experience the different aspects of the inquiry cycle in order to be able to understand it and develop inquiry activities for their own practice. We have found that paying specific attention to the inquiry cycle is more productive than discussing inquiry in generalities. We highly recommend you consider the nature and sequence of the workshops as we have described. These have been specifically selected to scaffold and support an understanding of the inquiry cycle.

We hope that you have found this coursebook information helpful. We wish you well in your endeavours to support teachers to engage in Inquiry Based Learning Practices.

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Appendices

This appendices presents the additional descriptions of workshops that are not included in the *Inquiry-Based Learning in Remote Setting* output from this RISE project.

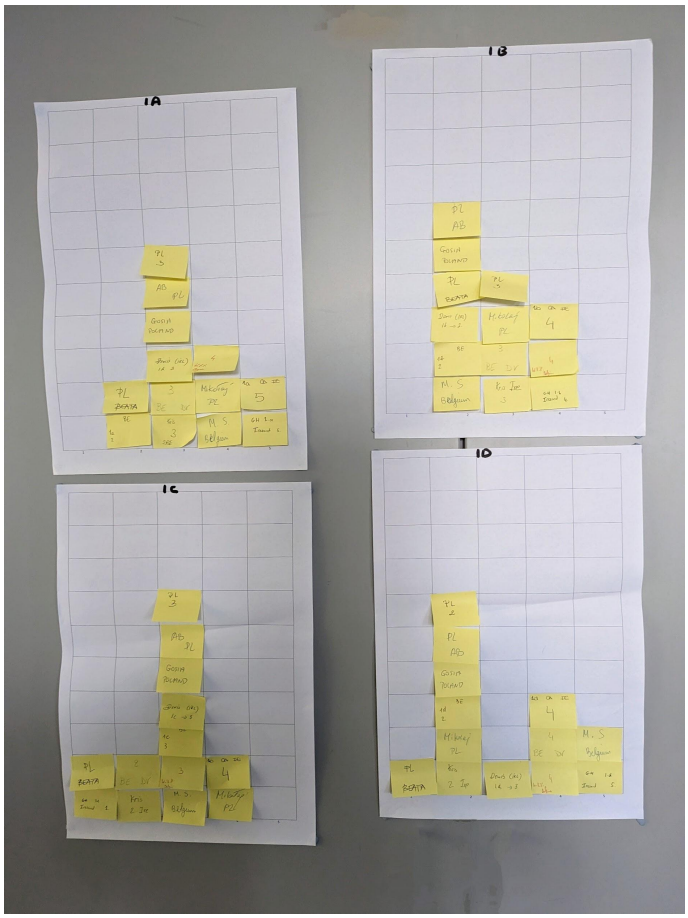
A1 - PLC Building: Consensogram

This protocol provides an opportunity for teachers in the course to find out more about each other's contexts. It also allows the facilitators of the course a chance to understand the group better, and to learn more about the different contexts that the teachers come from. Facilitators can use it to identify problems that course teachers are confronted with in their schools. The Consensogram, as implemented in this course, was adapted from the Consensogram used in the 3DIPhE – Three Dimensions of Inquiry in Physics Education ERASMUS+ project.

A consensogram can be used to determine the opinion of the teachers about an issue and to structure discussions. A consensogram helps to get a better understanding, to formulate the opinion of the teachers and to share their opinions. A consensogram gives the facilitator immediate information and data to work on. A consensogram makes sure that all teachers are involved in the issue and that their prior knowledge is taken into consideration.

teachers are presented with 12 questions regarding the context in which they work. teachers first read all of the questions, before indicating their responses. teachers then note their responses to each question on post-its and place these on charts placed on the wall of the room. When all of the post-its are placed on charts (see figure below), a professional conversation is facilitated using the following following process:

- The facilitator asks the teachers **to look** at the charts and to note what they see. (the facilitator makes sure that the teachers don't interpret yet); (8 min.
- The teachers deliberate in groups of 4 on what they **see**. The groups share their findings.(the facilitator makes sure that the teachers don't interpret yet); ((8 min.)
- The facilitator asks each teacher to **analyse** individually what they see on the graphs.(8 min.)
- The teachers deliberate in groups of 4 on their **analysis**. The groups share their analysis. (8 min.
- The facilitator asks each group to draw conclusions based on the results of their analysis. The groups share their **conclusions.** (5 min.)



Professional Learning Communities Consensogram

The consensogram below is design to allow teachers reflect on and discuss three themes:

- Reflective Dialogue
- Teacher Recognition
- School Structure

Part 1 Reflective Dialogue

1a. Staff members talk with each other about their teaching and the specific challenges they face

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

1.b Teachers share, observe, and discuss each others' teaching methods and philosophies

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

1.c Teachers assume that all students can learn at reasonably high levels and that teachers can help them

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

1.d Teachers not only work together to develop shared understandings of students, curriculum and instructional policy, but also produce materials and activities that improve instruction, curriculum and assessment

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

Part 2 Teacher Recognition

2.a Teachers take risks in trying new techniques and ideas and make efforts to learn more about their profession

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

2.b Teachers feel honoured for their expertise within the school as well as within the community of parents and other significant groups

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

2.c Within the school there are formal methods for sharing expertise among staff members so that marginal and ineffective teachers can improve

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

2.d The school leadership keeps the school focused on shared purpose, continuous improvement and collaboration

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

Part 3: School Structure

3.a Teachers have common spaces, rooms or areas for discussion of educational practices

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

3.b There are recurring formal situations in which teachers work together (team teaching, integrated lessons etc.)

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

3.c There are structures and opportunities for an exchange of ideas, both within and across organisational units such as teams, year levels, subject departments

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

3.d Teachers have autonomy to make decisions regarding their work guided by norms and beliefs of the professional community

Not at all	Somewhat	50%	To a large degree	To a great extent
1	2	3	4	5

A2: Brainstorming

Generating ideas usually begins with brainstorming around an issue formulated at the beginning of this first stage. This is the phase of communication of associations, examples from life, as well as reference to existing knowledge. If the teacher decides not to disclose the chosen topic just from the beginning, then at this stage, s/he guides the students about the classes, using a question-interwoven story, to which s/he expects spontaneous student responses resulting from their life experiences. This stage is important for three reasons. First of all, it is supposed to introduce two very important factors **motivating** students to continue working - to stimulate their **curiosity** and at the same time, embed the issue itself **in the context** they are familiar with. Secondly, it is a moment when all learners, including those generally perceived as low achievers (on the basis of the content-knowledge-based tests), **can speak spontaneously**. Thirdly, this is the phase in which **the teachers learn** the level of their students, thanks to which they can adequately select elements of the further process - e.g., by avoiding proposing experiments whose result is already known to learners or diversifying experiments due to different level of knowledge and experience of learners in the selected topic. So for the teacher, this is the moment for reflection and the last moment for adjusting the subsequent process.

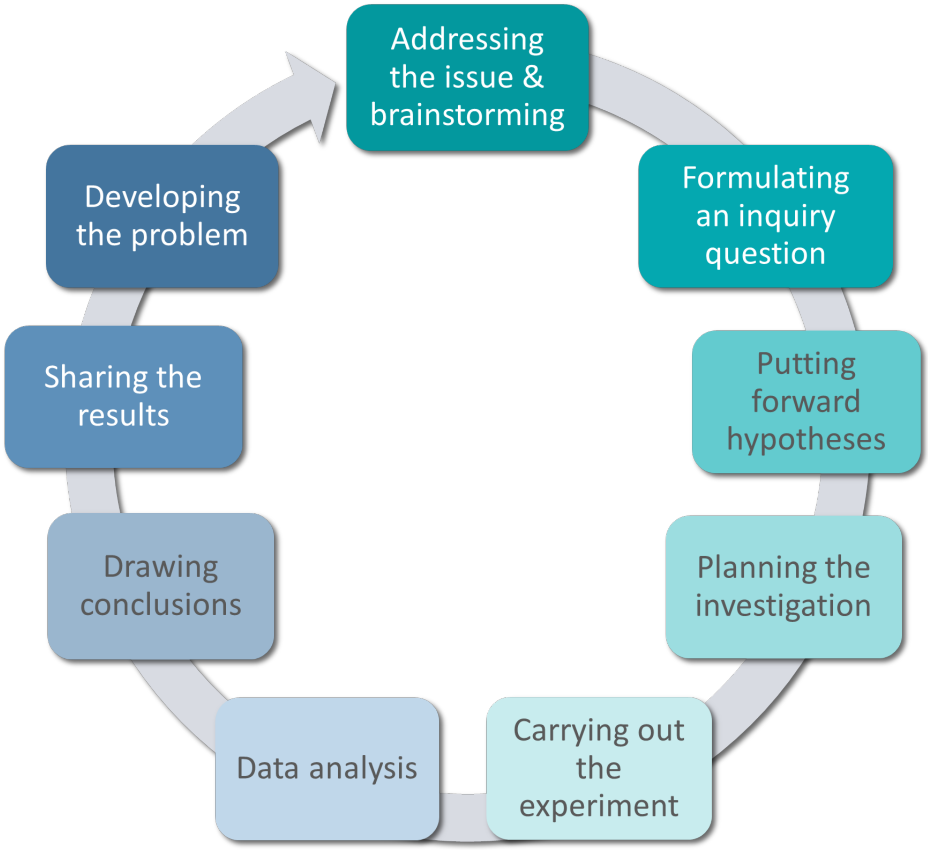


Figure 1. IBL cycle

Features and conditions of implementation in class. Generating ideas (brainstorming)
1. Method: brainstorming, group discussion 2. Based on students' daily experience or previous school experiences (recall situations, images, events) 3. Necessity of moderating the discussion (students may have a discussion in an unexpected direction) 4. Conducting elements in class management. 5. The art of returning to the topic the teacher is aiming at during the lesson.
Formats of implementation. Generating ideas (brainstorming)
Brainstorming is organised as a class discussion. It can be based on different clips: 1. an intriguing photo 2. a short video 3. a simple experiment conducted by the teacher or students 4. a storyline initiated by the teacher and developed through the participation of all students Brainstorming should refer to the topic of the IBL indirectly, especially at the beginning, so as not to reveal the aim of the lesson too early but rather allow the students to get to it by the discussion.

IBL protocol - Generating ideas

Groups	N groups of 2-4 persons	
Duration	(15 + 10* N) min	
Course	15-20 min in groups	Establishing in groups an introductory storyline about the issue, including examples and questions to students (including a number of paths to which students can direct the discussion and ways to return from these paths to the topic set by the teacher). When preparing the storyline teachers need to think about: (1) the general story, (2) the turning points which will allow them to come back to the main stream of the discussion whenever it becomes scattered or waving, (how to include all learners into the discussion (e.g. low achievers, shy students) and how to hold on those who have a lot of ideas and are loud.
	8 - 10 min for each group	Take over the role of teacher by the group and lead the ***Generation of Ideas***, by moderating discussions with all the other teachers who come into the classroom as students
Additional remarks	Depending on how advanced the groups are: ● all groups should be asked a predetermined issue (e.g. friction, gravity, etc.) - preferred in case of 1. iteration ● allow groups to choose the issue - preferred in the 2nd iteration	

A3: Rising inquiry questions

This protocol is aimed at developing teachers' skills to run an inquiry lesson. When designing an IBL module for students, teachers need to remember the principles in formulating inquiry questions. Raising an inquiry question is asking one or a series of questions related to the issue selected in the first point. This is where the topic narrows down and becomes more specific. The question may be qualitative or quantitative, but in principle, it should be structured in such a way that it cannot be answered directly: "yes" or "no". It should also be formulated so that the answer can be obtained as a result of a study conducted in specific conditions created during classes, i.e., taking into account class time, availability of materials, classroom conditions, and student safety. Usually, the question is related to trends, the extent of influence of one (independent) variable on another (dependent) variable. Teachers (and students) should bear in mind that the question must be formulated in such a way that a fair test should be applicable to answer it.

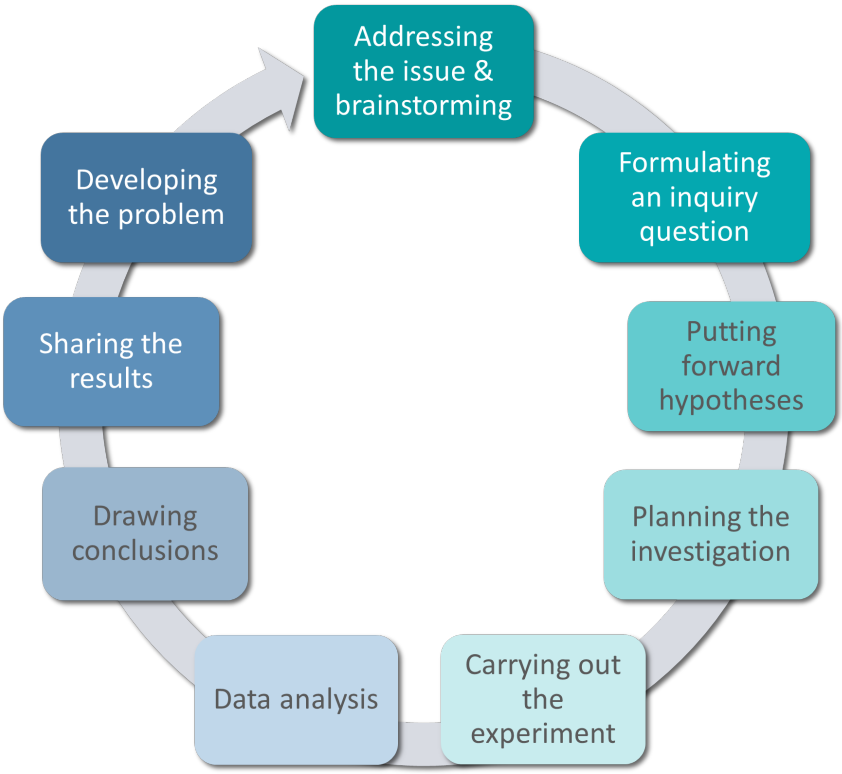


Figure 1. IBL cycle

Features and conditions of realisation in class. Formulation of the research question
1. The teacher's determination of the level of advancement of students and selection of the IBL level to the level of advancement of students (structured, targeted, open). 2. Method: whole-class discussion (low level of student independence) or individual work and group discussion (higher level of student independence) 3. Objective: to determine what we want to know 4. Necessary conditions to be determined: What resources do we have? How much time do we need? 5. Features of the research question: ● No simple answer is possible: YES/NO to the question asked ● The possibility of conducting a classroom study, the results of which will lead to conclusions allowing to answer this question ● Ensuring implementation through a test or cycle of tests in which the control of variables will be ensured (in one test, only one variable can be changed at a time, the others must be controlled, the so-called *fair test*)

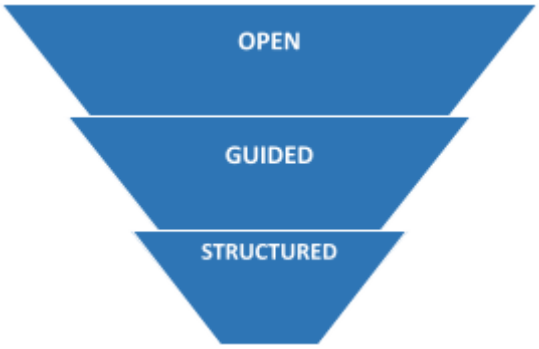


Fig. 2 Levels of inquiry

Teaching IBL - protocol- Raising inquiry questions

Groups	N groups 2-4 people	
Duration	(17 + 5* N) min	
Course	3 min in groups	Identify the issue for raising the inquiry questions (general issue, e.g., friction, gravity)
	7 min individually	Individual work on research questions with an outline of module implementation on three different levels
	7 min in groups	Establishing three common research questions, one for each of the three levels
	4 - 5 min for each group	Presentation of your three research questions together with an outline of your students' idea of implementation
Additional remarks	Depending on how advanced the groups are: ● all groups should be asked a predetermined issue (e.g., friction, gravity, etc.) - preferred in case of 1. iteration ● allow groups to choose the issue - preferred in the 2nd iteration	