With the support of the Erasmus+ Programme of the European Union

Inquiry-based learning pedagogical guidelines

eSTEM – Toolboxes for SuperFastLearning digital contents development in STEM is a Strategic Partnership for Higher Education project (2020-1-IT02-KA226-HE-095144). The European Commission support for the production of this website does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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1. Introduction

Figure 1 shows the practical flow to follow to create your own inquiry-based learning (IBL) sequence[1].

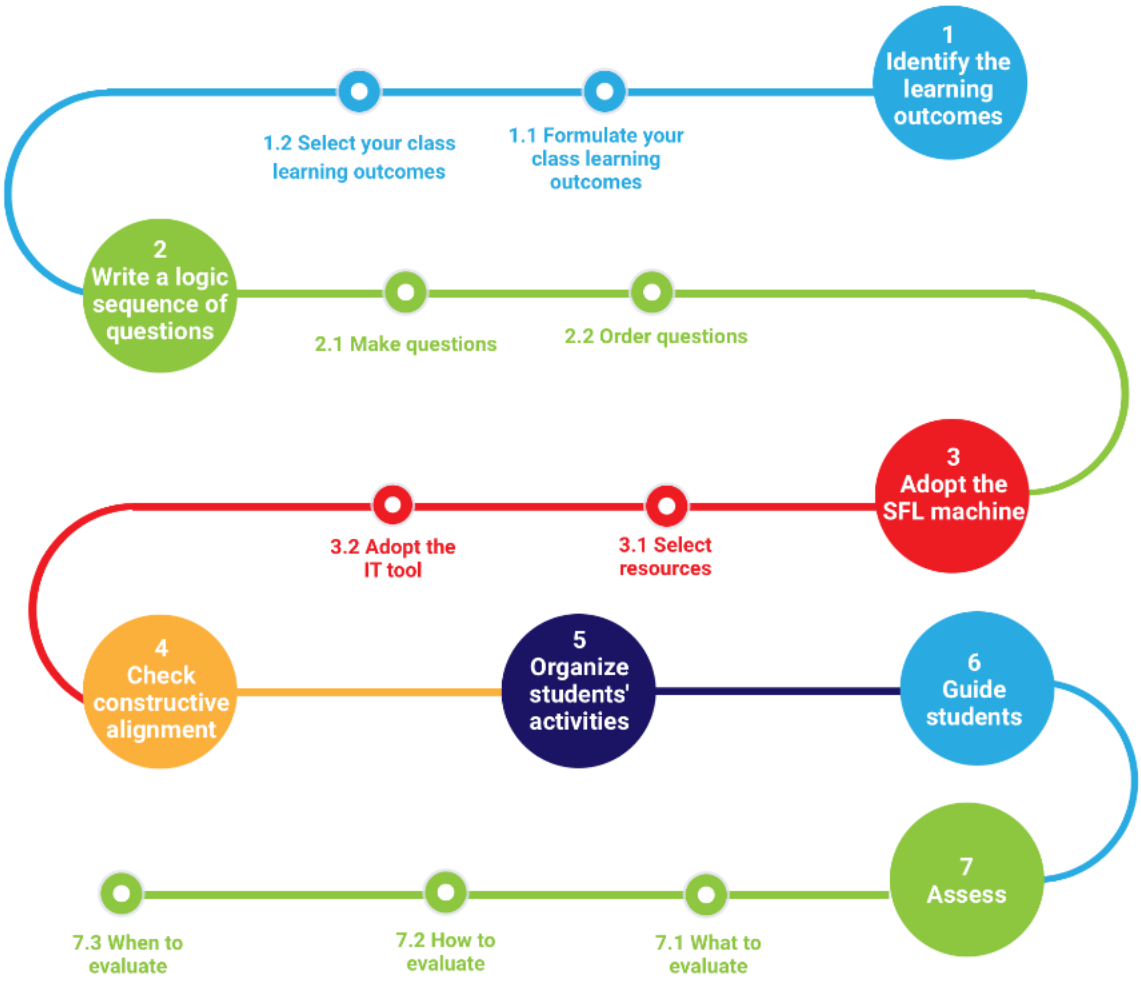

Figure 1: Flow to follow for creating your own IBL sequence

Phase 2 and phase 3 are interconnected: in fact, phase 2 is supported by the adoption of the SFL machine (phase 3). The next sections of the document clarify the interconnections of the two during the flow.

[1] The activities that are common to all methodologies (Formulate learning outcomes, Select learning outcomes and Check constructive alignment) are in a separated document.

2. Course scripting

Reminders

- Not all the topics could be addressed by a question
- Bloom's taxonomy could help in selecting relevant questions
- The selection of resources should be carried out considering the learning outcomes

2.1 How to create a logic sequence of questions?

2.1.1 How to make good inquiry questions?

- The question should be connected to real life to show their relevance to the students
- The question should be formulated in such a way that it doesn't predetermine the answer
- The question should focus on a researchable issue that could be deeply investigated by the students
- The question should be thoughtful and encourage a larger conversation (more good questions) and not a simple answer
- The question should be measurable
- The question should be accessible to all students

2.1.2 How to order inquiry questions based on my course context?

- The sequence of questions should be aligned to the desired learning outcomes
- The sequence of questions should take into consideration a defined time frame for being answered
- There is no formula for calculating the perfect number of questions, but 4-5 questions should be developed for grounding a course and then 2-3 questions should be added for each specific addressed topic
- Not all the topics and lectures should be addressed by a question

2.1.3 Example [1]

Let's suppose that the educator of Geography would like to change the lecture about land use in Canada from a content-oriented approach to an inquiry-based approach.

1. He could start with the question "What are the characteristics of land use in Canadian communities?" and then realize that this question only asks to remember the content and can be answered through internet or textbook research.
2. So, he can change the question to "What is the significance of land use in Canada?": but the question is too similar to the first one and so students' responses may not involve the expected level of critical thinking.
3. He changes the question again: "What are the key features that help create a liveable community?" Wondering whether the students will be engaged by this question, the question has potential as he can imagine some of the great sources of material and community hosts that would make the inquiry alive for the students and allow for deep thinking and feeling.
4. Finally, after much reflection and a discussion with a colleague, he decides on the question: "How can we create more livable communities?" The question is an invitation to think and act, not to simply remember, summarize or detail facts. The question also leads to other good questions. Think about the types of cases students might want to investigate to answer the question, such as current community land use issues.

2.1.4 Tool [2, 3]

Inquiry is based on questions: big questions open big spaces for information, while little questions open up little spaces. The size of the answer is predicted by the size of the question. The tool in Table 1 helps educators in recognizing simple to more complex questions, according to Bloom's taxonomy.

Question types	Answers on Bloom's Taxonomy
Do? Is?	Remembering
Who? What? Where? When?	Understanding
Why? How?	Applying Analyzing
Should? Would?	Evaluating Creating

Table 1: Tool for recognizing simple to more complex questions according to Bloom's taxonomy version 1

Following the table:

- Do- and be-verb questions often evoke yes-or-no answers. (Q: Is a spider an insect? A: No.)

- Who, what, where, and when questions often require discrete answers. (Q: What is your favorite insect? A: I like the praying mantis.)
- How and why questions often make space for deeper answers. (Q: How do wasps survive the winter? A: Most wasps in a colony die before winter, but fertilized wasps called queens survive to create all-new colonies in the spring.)
- Should and would questions reach even deeper. (Q: Should we reduce our use of pesticides? A: We should definitely track how the use of pesticides affects non pest insects as well as many other parts of the ecosystem. Even so-called pests like mosquitoes are food sources for birds, bats, and frogs…)

Another useful version of the tool is shown in Table 2.

Levels of Thinking	One Student's Questions
To remember, ask about facts. What happened? Who was involved? Where did it take place? When did it happen?	What happened in the Cold War?
To understand, ask about meaning. Why did it happen? What does it mean? How does it connect to other things?	Why did the Soviets build the wall?
To apply, ask how to use ideas. What can I do with this idea? How could I use it?	What modern codes could I break?
To analyze, ask about the parts. What are the parts? How do they fit? Why do they work? What is their purpose?	What was the goal of CIA?
To evaluate, ask about quality. What is the value of this? Does it fulfill its purpose? How could it be better?	What good was the Cold War?
To create, ask about making something. What new thing can I make? How can I combine two things? How can I use something in a new way?	How could I use this idea to make a poster?

Table 2: Tool for recognizing simple to more complex questions according to Bloom's taxonomy version 2

2.2 How to adopt the SFL Machine?

The SFL Machine is the tool supporting the phase of generation of good inquiry question (see 2.1) and, for this reason, can play a key role in the process.

The SFL Machine takes in input any kind of textual source considered relevant for the lecture to be carried out and gives back as output the list of questions contained within these sources. The tool extracts only interesting question (i.e. does not extract general question such as “what is it?” without any reference to the topic).

2.2.1 How to select resources?

The first task the educator should carry on is selecting the digital textual sources to be fed to the SFL Machine.

The sources should be selected according to the learning outcomes, considering that some sources are more likely to contain more complex questions (based on Bloom’s taxonomy) such as scientific/academic/conference papers, some others are more likely to contain more basic questions (based on Bloom’s taxonomy) such as exam papers.

The topic specificity of the sources should be the same the educator aims to obtain during the lecture he is developing.

To support the resource selection, the SFL machine offers the opportunity to define:

- the type of document the educator uploaded (scientific/academic/conference paper, book, etc.) and it automatically adapts the extraction to the specificity of the type of document;
- one or more keywords as topics of the lecture on which it bases the extraction.

2.2.2 How to adopt the IT tool for selecting and ordering the good inquiry questions?

The second task the educator should carry on is the most value-added one: using his own expertise for selecting the good inquiry questions from the output file provided by the SFL Machine and ordering them.

The SFL machine supports the educator for selecting and ordering the questions provided with two features:

- the relevance score (from 0 to 1) associated to each question: the higher the score, the higher the inherence of the question to the topic(s) selected in phase 2.2.1;
- the attribution of each question to one or more levels of the Bloom’s taxonomy.

In order to successfully achieve this task, the guidelines to be followed by the educator are those already explored in detail in section 2.1.

At the end of this phase, the educator should use the ordered questions to prepare the training material to be used for the lecture.

3. Course flow

Reminders

- Inquiry process is not always linear
- During the learning process, educators are not knowledge provider but part of the whole process

3.1 What are students' activities during the sequence?

After having prepared the training material to be used during the lecture, the educator should plan and organize the inquiry process of the lecture based on the activities' sequence of the students:

1. Understand the background of the topic: the educator should give to the students the general background of the topic he will address during the lecture to make students able to follow the lecture and to start the inquiry process. The information on the background (i) should be detailed according to the complexity of the topic (and of the questions selected in phase 2.1) and (ii) could be delivered at the beginning of the lecture (synchronously) or before the lecture (asynchronously, for example giving them some materials to read before the lecture).
2. Understand the questions: the educator should propose the questions to the students, that work on them in small groups.
3. Gather and organize: Students collect, organize, and record relevant data, evidence, and/or information from appropriate primary or secondary sources. They focus and clarify ideas, concepts, strategies, or relationships between topics or skills.
4. Interpret and analyze: Students interpret and assess data, evidence, and/or information, and analyze to identify patterns, relationships, currency, and bias; make connections; and potentially construct new knowledge.
5. Evaluate and draw conclusions: Students synthesize data, evidence, results, and/or information to make informed, critical judgments based on the reliability of the information and to explain the decision, choice, goal, or solution and its impact on themselves, others, and the world around them.
6. Communicate: Students consolidate and communicate observations, decisions, conclusions, goals, choices, strategies, and/or solutions clearly, logically, and effectively by using correct terminology and expressing information/results orally, in

writing, or through demonstration or performance tailored to audience needs. They collaborate with others to deepen learning.

7. Reflect: This phase is horizontal. Students reflect on initial questions, what they learned, what else they could investigate or try and what they could have done differently. They transfer learning to new situations and plan next steps.

The teacher should be aware that inquiry process is not linear.

3.1.1 Tool [4]

Table 3, 4 and 5 are useful tools to be given to the students for making them follow the sequence of IBL activities:

- gathering and organizing information, keeping track of the source
- interpreting and analyzing information, searching for patterns and relationships among the information they collected
- evaluating and drawing conclusion, searching further information and developing additional questions if needed and sketching final deductions

Gather and organize

Source	Information description

Table 3: Gather and organize

Interpret and analyze

Source	Information description	Patterns, relationships, etc.

Table 4: Interpret and analyze

Evaluate and draw conclusions

Source	Information description	Patterns, relationships, etc.	Additional information needed, new questions, etc.	Deductions

Table 5: Evaluate and draw conclusions

3.2 How to guide students during their learning activities?

- Teachers should choose among three different types of inquiry (guided, structured, and open) based on the level (in terms of knowledge, position in the learning path and experience) of the class (read more in the theoretical background of the methodology). For details, see inquiry-based learning theoretical background – long version
- Teachers should provide students with some background information about the topic necessary for starting the discussion
- Teachers should clarify the desired learning outcomes to the students, so that they can evaluate themselves and the others
- Teachers should engage the students encouraging reflection and giving them some hints (e.g., “do you think about the opposite situation?”)
- In case of group work, teachers should assign roles to the students (team leader, who draws up the minute, who makes photos, etc.)
- Teachers should question themselves (they are not knowledge providers but part of the whole learning process)
- Teachers should focus on encouraging the students to express their opinion and explain their thesis

4. After course

Reminders

- Evaluating the learning outcomes in IBL consists of evaluating practical skills, ability to work systematically, understanding the procedure and knowledge of the theory of science
- Evaluation could be performed before inquiry, during inquiry and at the end of inquiry

4.1 How, when and what to evaluate?

4.1.1 What to evaluate?

Kolstø, Bjønnes, Klevenberg & Mestad (2019) suggest that the assessment (evaluate learning outcomes) of an IBL project should address the following:

- Practical skills
- Ability to work systematically: e.g. to follow the plan, to keep notes/overview of the progress & challenges, to document data, to communicate results to audience target groups
- Understanding of procedure: e.g. what characterize a good research question or hypothesis, what it means to control variables, what can be measured, what data can be collected, etc.
- Knowledge of theory of science: e.g. can explain why argumentation and communication are important, can evaluate scientific experiments, can build lines of scientific/ technological reasoning and argumentation based on established knowledge and logical thinking, etc.

The evaluation system of the students gives the advantage to constantly adapt the content and ensure attractivity for the students (evaluate tutor activity and evaluate IBL sequence).

4.1.2 How to evaluate? [5]

There are different ways to evaluate IBL process:

- Observations
- Discussions
- Group tasks

- Demonstrations
- Projects
- Peer and self-assessments
- Self-reflection
- Exams/projects

4.1.3 When to evaluate? [5]

Evaluation should take place in the different phases of IBL:

- before inquiry, teachers should understand what students already know and can do
- during inquiry, teachers should observe and listen students (working on their own or in groups) while understanding, discussing, trying to find an answer to the questions
- during inquiry, teachers should ask students to regularly self-assess their learning and see where they may need help or where they are doing well
- at the end of inquiry process, students should share their analyses and progresses and their final outcomes: teachers should assess the IBL process evaluating presentations, project reports, oral exams, etc.

4.1.4 Example

- During inquiry, students work in small groups. The educator moves throughout the room observing student conversations, recording students, and taking notes
- During inquiry, the educator asks students how the work is going, failure and frustration, benefits, etc. to understand what students are thinking.
- At the end of inquiry, the educator evaluates the group presentation of the final outcomes

4.1.5 Tool

Table 6 shows a practical tool to be used by educators for evaluating students' activities in the different phases of IBL.

What is assessed?	Degree of mastery		
	Low	Middle	High
Finding/formulating research question	The question is relevant but unsuitable to be	The question is relevant but slightly suitable to be	The question is relevant, clearly formulated, and

	investigated scientifically and technologically	investigated scientifically or technologically	suitable for investigation, scientifically or technologically
Formulating hypotheses	The hypotheses are hardly connected to the research question and cannot be tested scientifically	The hypotheses are connected to the research question but are not explained/justified	The hypotheses are connected to the research question, are explained, and can be tested scientifically
Choice of variables	The variables are hardly relevant	The variables are to some extent relevant	The variables are relevant and are chosen based on knowledge (theory) and hypotheses
Presentation of results	The presentation method is either irrelevant or lacks substantial content	Appropriate presentation method is used, e.g. using illustrations, but there are some mistakes and the illustrations are not explained/justified	Appropriate presentation method is used, e.g. using illustrations and the method (and illustrations) are explained/justified
Critical discussion of empirical data	The data are hardly discussed in relation to the research question, and the solution is given without justification	The data are discussed in relation to the research question, but the discussion is lacking in depth, e.g. sources of error or uncertainty in measurements are not considered	The data are discussed in relation to the research question, and well critically discusses, e.g. sources of error or uncertainty in measurements are thoroughly examined and tackled
Discussion of results in relation to established knowledge	Relevant theory is used for discussion but with substantial lack	The discussion draws on relevant theory, and show connections, but some parts are missing	The discussion draws on relevant theory, connections, between different knowledge areas are explained, hidden assumptions are uncovered and discussed

Table 6: Tool for evaluating students in different phases of IBL

Glossary

Inquiry question: an inquiry question is the complex, open-ended question that frames learning in a unit[2].

Sequence: a sequence is a not time-defined session of IBL that can last hours, days, weeks or months.

[2] https://support.inquired.org/hc/en-us/articles/360044818453-What-is-an-Inquiry-Question

Sitography

[1] http://blogs.ubc.ca/stevemcg/files/2014/09/inquiry-questions.pdf

[2] https://k12.thoughtfullearning.com/blogpost/10-questions-inquiry-bigger-better

[3] http://thoughtfullearning.com/sites/default/files/downloads/Inquire_Sampler.pdf

[4] Ontario Ministry of Education. (2013). Capacity Building Series: Inquiry-Based Learning (Secretariat special ed. #32). Retrieved from http://www.edu.gov.on.ca/eng/literacynumeracy/inspire/research/CBS_InquiryBased.pdf

[5] https://www.edmentuminternational.com/blog/assessing-inquiry-based-learning/

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