# Inquiry-based learning

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**Inquiry-based learning** (also **enquiry-based learning** in British English)[1] starts by posing questions, problems or scenarios—rather than simply presenting established facts or portraying a smooth path to knowledge. The process is often assisted by a facilitator. Inquirers will identify and research issues and questions to develop their knowledge or solutions. Inquiry-based learning includes problem-based learning, and is generally used in small scale investigations and projects, as well as research.[2] The inquiry-based instruction is principally very closely related to the development and practice of thinking skills.[3]

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## History

Inquiry-based learning is primarily a pedagogical method, developed during the discovery learning movement of the 1960s as a response to traditional forms of instruction—where people were required to memorize information from instructional materials.[4] The philosophy of inquiry based learning finds its antecedents in constructivist learning theories, such as the work of Piaget, Dewey, Vygotsky, and Freire among others,[5][6][7] and can be considered a constructivist philosophy. Generating information and making meaning of it based on personal or societal experience is referred to as constructivism.[8] Dewey's experiential learning pedagogy (that is, learning through experiences) comprises the learner actively participating in personal or authentic experiences to make meaning from it.[9][10] Inquiry can be conducted through experiential learning because inquiry values the same concepts, which include engaging with the content/material in questioning, as well as investigating and collaborating to make meaning. Vygotsky approached constructivism as learning from an experience that is influenced by society and the facilitator. The meaning constructed from an experience can be concluded as an individual or within a group.[8][9]

In the 1960s Joseph Schwab called for inquiry to be divided into four distinct levels.[11] This was later formalized by Marshall Herron in 1971, who developed the Herron Scale to evaluate the amount of inquiry within a particular lab exercise.[12] Since then, there have been a number of revisions proposed and inquiry can take various forms. There is a spectrum of inquiry-based teaching methods available.[13]

# Characteristics

Specific learning processes that people engage in during inquiry-learning include:[14]

- Creating questions of their own
- Obtaining supporting evidence to answer the question(s)
- Explaining the evidence collected
- Connecting the explanation to the knowledge obtained from the investigative process
- Creating an argument and justification for the explanation

Inquiry learning involves developing questions, making observations, doing research to find out what information is already recorded, developing methods for experiments, developing instruments for data collection, collecting, analyzing, and interpreting data, outlining possible explanations and creating predictions for future study.[15]

## Levels

There are many different explanations for inquiry teaching and learning and the various levels of inquiry that can exist within those contexts. The article titled *The Many Levels of Inquiry* by Heather Banchi and Randy Bell (2008)[15] clearly outlines four levels of inquiry.

**Level 1**: Confirmation Inquiry
The teacher has taught a particular science theme or topic. The teacher then develops questions and a procedure that guides students through an activity where the results are already known. This method is great to reinforce concepts taught and to introduce students into learning to follow procedures, collect and record data correctly and to confirm and deepen understandings.

**Level 2**: Structured Inquiry
The teacher provides the initial question and an outline of the procedure. Students are to formulate explanations of their findings through evaluating and analyzing the data that they collect.

**Level 3**: Guided Inquiry
The teacher provides only the research question for the students. The students are responsible for designing and following their own procedures to test that question and then communicate their results and findings.

**Level 4**: Open/True Inquiry
Students formulate their own research question(s), design and follow through with a developed procedure, and communicate their findings and results. This type of inquiry is often seen in science fair contexts where students drive their own investigative questions.

Banchi and Bell (2008) explain that teachers should begin their inquiry instruction at the lower levels and work their way to open inquiry in order to effectively develop students' inquiry skills. Open inquiry activities are only successful if students are motivated by intrinsic interests and if they are equipped with the skills to conduct their own research study.[16]

### Open/true inquiry learning

An important aspect of inquiry-based learning (and science) is the use of open learning, as evidence suggests that only utilizing lower level inquiry is not enough to develop critical and scientific thinking to the full potential.[17][18][19] Open learning has no prescribed target or result that people have to achieve. There is an emphasis on the individual manipulating information and creating meaning from a set of given materials or circumstances.[20] In many conventional and structured learning environments, people are told what the outcome is expected to be, and then they are simply expected to 'confirm' or show evidence that this is the case.

Open learning has many benefits.[19] It means students do not simply perform experiments in a routine like fashion, but actually think about the results they collect and what they mean. With traditional non-open lessons there is a tendency for students to say that the experiment 'went wrong' when they collect results contrary to what they are told to expect. In open learning there are no wrong results, and students have to evaluate the strengths and weaknesses of the results they collect themselves and decide their value.

Open learning has been developed by a number of science educators including the American John Dewey and the German Martin Wagenschein. Wagenschein's ideas particularly complement both open learning and inquiry-based learning in teaching work. He emphasized that students should not be taught bald facts, but should understand and explain what they are learning. His most famous example of this was when he asked physics students to tell him what the speed of a falling object was. Nearly all students would produce an equation, but no students could explain what this equation meant. Wagenschien used this example to show the importance of understanding over knowledge.[21]

# Inquiry-based science education

### History of science education

Inquiry learning has been used as a teaching and learning tool for thousands of years, however, the use of inquiry within public education has a much briefer history.[22] Ancient Greek and Roman educational philosophies focused much more on the art of agricultural and domestic skills for the middle class and oratory for the wealthy upper class. It was not until the Enlightenment, or the Age of Reason, during the late 17th and 18th century that the subject of Science was considered a respectable academic body of knowledge.[23] Up until the 1900s the study of science within education had a primary focus on memorizing and organizing facts. Unfortunately, there is still evidence that some students are still receiving this type of science instruction today.

John Dewey, a well-known philosopher of education at the beginning of the 20th century, was the first to criticize the fact that science education was not taught in a way to develop young scientific thinkers. Dewey proposed that science should be taught as a process and way of thinking – not as a subject with facts to be memorized.[22] While Dewey was the first to draw attention to this issue, much of the reform within science education followed the lifelong work and efforts of Joseph Schwab. Joseph Schwab was an educator who proposed that science did not need to be a process for identifying stable truths about the world that we live in, but rather science could be a flexible and multi-directional inquiry driven process of thinking and learning. Schwab believed that science in the classroom should more closely reflect the work of practicing scientists. Schwab developed three levels of open inquiry that align with the breakdown of inquiry processes that we see today.[24]

1. Students are provided with questions, methods and materials and are challenged to discover relationships between variables
2. Students are provided with a question, however, the method for research is up to the students to develop
3. Phenomena are proposed but students must develop their own questions and method for research to discover relationships among variables

Today, we know that students at all levels of education can successfully experience and develop deeper level thinking skills through scientific inquiry.[25] The graduated levels of scientific inquiry outlined by Schwab demonstrate that students need to develop thinking skills and strategies prior to being exposed to higher levels of inquiry.[24] Effectively, these skills need to be scaffolded by the teacher or instructor until students are able to develop questions, methods, and conclusions on their own.[26] A catalyst for reform within North American science education was the 1957 launch of Sputnik, the Soviet Union satellite. This historical scientific breakthrough caused a great deal of concern around the science and technology education the American students were receiving. In 1958 the U.S. congress developed and passed the National Defense Education Act in order to provide math and science teachers with adequate teaching materials.[15]

America's National Science Education Standards (NSES) (1996)[25] outlines six important aspects pivotal to inquiry learning in science education.

1. Students should be able to recognize that science is more than memorizing and knowing facts.
2. Students should have the opportunity to develop new knowledge that builds on their prior knowledge and scientific ideas.
3. Students will develop new knowledge by restructuring their previous understandings of scientific concepts and adding new information learned.
4. Learning is influenced by students' social environment whereby they have an opportunity to learn from each other
5. Students will take control of their learning.
6. The extent to which students are able to learn with deep understanding will influence how transferable their new knowledge is to real life contexts.

# In other disciplines/programs

Science naturally lends itself to investigation and collection of data, but it is applicable in other subject areas where people are developing critical thinking and investigation skills. In history, for example, Robert Bain in his article in *How Students Learn*, describes how to "problematize" history.[27] Bain's idea is to first organize a learning curriculum around central concepts. Next, people studying the curriculum are given a question and primary sources such as eye witness historical accounts, and the task for inquiry is to create an interpretation of history that will answer the central question. It is held that through the inquiry people will develop skills and factual knowledge that supports their answers to a question. They will form an hypothesis, collect and consider information and revisit their hypothesis as they evaluate their data.

## Ontario's kindergarten program

After Charles Pascal's report in 2009, Ontario's Ministry of Education decided to implement a full day kindergarten program that focuses on inquiry and play-based learning, called The Early Learning Kindergarten Program.[28] As of September 2014, all primary schools in Ontario started the program. The curriculum document[29] outlines the philosophy, definitions, process and core learning concepts for the program.

Bronfenbrenner's ecological model, Vygotsky's zone of proximal development, Piaget's child development theory and Dewey's experiential learning are the heart of the program's design. As research shows, children learn best through play, whether it is independently or in a group. Three forms of play are noted in the curriculum document, pretend or "pretense" play, socio-dramatic play and constructive play. Through play and authentic experiences, children interact with their environment (people and/or objects) and question things; thus leading to inquiry learning. A chart on page 15 clearly outlines the process of inquiry for young children, including initial engagement, exploration, investigation, and communication.[29] The new program supports holistic approach to learning. For further details, please see the curriculum document.[29]

Since the program is extremely new, there is limited research on its success and areas of improvement. One government research report was released with the initial groups of children in the new kindergarten program. The Final Report: Evaluation of the Implementation of the Ontario Full-Day Early-Learning Kindergarten Program from Vanderlee, Youmans, Peters, and Eastabrook (2012) conclude with primary research that high-need children improved more compared to children who did not attend Ontario's new kindergarten program.[30] As with inquiry-based learning in all divisions and subject areas, longitudinal research is needed to examine the full extent of this teaching/learning method.

# Misconceptions about inquiry

There are several common misconceptions regarding inquiry-based science, the first being that inquiry science is simply instruction that teaches students to follow the scientific method. Many teachers had the opportunity to work within the constraints of the scientific method as students themselves and figure inquiry learning must be the same. Inquiry science is not just about solving problems in six simple steps but much more broadly focused on the intellectual problem-solving skills developed throughout a scientific process.[25] Additionally, not every hands-on lesson can be considered inquiry.

Some educators believe that there is only one true method of inquiry, which would be described as the level four: Open Inquiry. While open inquiry may be the most authentic form of inquiry, there are many skills and a level of conceptual understanding that the students must have developed before they can be successful at this high level of inquiry.[26] While inquiry-based science is considered to be a teaching strategy that fosters higher order thinking in students, it should be one of several methods used. A multifaceted approach to science keeps students engaged and learning.

Not every student is going to learn the same amount from an inquiry lesson; students must be invested in the topic of study to authentically reach the set learning goals. Teachers must be prepared to ask students questions to probe their thinking processes in order to assess accurately. Inquiry-science requires a lot of time, effort, and expertise, however, the benefits outweigh the cost when true authentic learning can take place.

# Neuroscience complexity

The literature states that inquiry requires multiple cognitive processes and variables, such as causality and co-occurrence that enrich with age and experience.[31][32] Kuhn, et al. (2000) used explicit training workshops to teach children in grades six to eight in the United States how to inquire through a quantitative study. By completing an inquiry-based task at the end of the study, the participants demonstrated enhanced mental models by applying different inquiry strategies.[31] In a similar study, Kuhan and Pease (2008) completed a longitudinal quantitative study following a set of American children from grades four to six to investigate the effectiveness of scaffolding strategies for inquiry. Results demonstrated that children benefitted from the scaffolding because they outperformed the grade seven control group on an inquiry task.[32] Understanding the neuroscience of inquiry learning the scaffolding process related to it should be reinforced for Ontario's primary teachers as part of their training.

# Notes for educators

Inquiry-based learning is fundamental for the development of higher order thinking skills. According to Bloom's Taxonomy, the ability to analyze, synthesize, and evaluate information or new understandings indicates a high level of thinking.[33] Teachers should be encouraging divergent thinking and allowing students the freedom to ask their own questions and to learn the effective strategies for discovering the answers. The higher order thinking skills that students have the opportunity to develop during inquiry activities will assist in the critical thinking skills that they will be able to transfer to other subjects.

As shown in the section above on the neuroscience of inquiry learning, it is significant to scaffold students to teach them how to inquire and inquire through the four levels. It cannot be assumed that they know how to inquire without foundational skills. Scaffolding the students at a younger age will result in enriched inquiring learning later.[31][32]

Inquiry-based learning can be done in multiple formats, including:

- Field-work
- Case studies
- Investigations
- Individual and group projects
- Research projects

Remember to keep in mind...[34]

- Teacher is Facilitator in IBL environment
- Place needs of students and their ideas at the center
- Don't wait for the perfect question, pose multiple open-ended questions.
- Work towards common goal of understanding
- Remain faithful to the students' line of inquiry
- Teach directly on a need-to-know basis
- Encourage students to demonstrate leaning using a range of media

## Necessity for teacher training

There is a necessity for professional collaboration when executing a new inquiry program (Chu, 2009; Twigg, 2010). The teacher training and process of using inquiry learning should be a joint mission to ensure the maximal amount of resources are used and that the teachers are producing the best learning scenarios. The scholarly literature supports this notion. Twigg's (2010) education professionals who participated in her experiment emphasized year round professional development sessions, such as workshops, weekly meetings and observations, to ensure inquiry is being implemented in the class correctly.[10] Another example is Chu's (2009) study, where the participants appreciated the professional collaboration of educators, information technicians and librarians to provide more resources and expertise for preparing the structure and resources for the inquiry project.[35] To establish a professional collaboration and researched training methods, administration support is required for funding.

# Criticism

Kirschner, Sweller, and Clark (2006)[36] review of literature found that although constructivists often cite each other's work, empirical evidence is not often cited. Nonetheless the constructivist movement gained great momentum in the 1990s, because many educators began to write about this philosophy of learning.

Hmelo-Silver, Duncan, & Chinn cite several studies supporting the success of the constructivist problem-based and inquiry learning methods. For example, they describe a project called GenScope, an inquiry-based science software application. Students using the GenScope software showed significant gains over the control groups, with the largest gains shown in students from basic courses.[37]

In contrast, Hmelo-Silver et al. also cite a large study by Geier on the effectiveness of inquiry-based science for middle school students, as demonstrated by their performance on high-stakes standardized tests. The improvement was 14% for the first cohort of students and 13% for the second cohort. This study also found that inquiry-based teaching methods greatly reduced the achievement gap for African-American students.[37]

Based on their 2005 research, the Thomas B. Fordham Institute concluded that while inquiry-based learning is fine to some degree, it has been carried to excess.[38]

Richard E. Mayer from the University of California, Santa Barbara, wrote in 2004 that there was sufficient research evidence to make any reasonable person skeptical about the benefits of discovery learning—practiced under the guise of cognitive constructivism or social constructivism—as a preferred instructional method. He reviewed research on discovery of problem-solving rules culminating in the 1960s, discovery of conservation strategies culminating in the 1970s, and discovery of LOGO programming strategies culminating in the 1980s. In each case, guided discovery was more effective than pure discovery in helping students learn and transfer.[39]

It should be cautioned that inquiry-based learning takes a lot of planning before implementation. It is not something that can be put into place in the classroom quickly. Measurements must be put in place for how students knowledge and performance will be measured and how standards will be incorporated. The teacher's responsibility during inquiry exercises is to support and facilitate student learning (Bell et al., 769–770). A common mistake teachers make is lacking the vision to see where students' weaknesses lie. According to Bain, teachers cannot assume that students will hold the same assumptions and thinking processes as a professional within that discipline (p. 201).

While some see inquiry-based teaching as increasingly mainstream, it can be perceived as in conflict with standardized testing common in standards-based assessment systems which emphasise the measurement of student knowledge, and meeting of pre-defined criteria, for example the shift towards "fact" in changes to the National Assessment of Educational Progress as a result of the American No Child Left Behind program.

Programs such as the International Baccalaureate (IB) Primary Years Program can be criticized for their claims to be an inquiry based learning program. While there are different types of inquiry (as stated above) the rigid structure of this style of inquiry based learning program almost completely rules out any real inquiry based learning in the lower grades. Each "unit of inquiry" is given to the students, structured to guide them and does not allow students to choose the path or topic of their inquiry. Each unit is carefully planned to connect to the topics the students are required to be learning in school and does not leave room for open inquiry in topics that the students pick. Some may feel that until the inquiry learning process is open inquiry then it is not true inquiry based learning at all. Instead of opportunities to learn through open and student-led inquiry, the IB program is viewed by some to simply be an extra set of learning requirements for the students to complete.

## Additional scholarly research literature

Chu (2009) used a mixed method design to examine the outcome of an inquiry project completed by students in Hong Kong with the assistance of multiple educators. Chu's (2009) results show that the children were more motivated and academically successful compared to the control group.[35]

Cindy Hmelo-Silver reviewed a number of reports on a variety studies into problem based learning.[40]

Edelson, Gordin and Pea describe five significant challenges to implementing inquiry-based learning and present strategies for addressing them through the design of technology and curriculum. They present a design history covering four generations of software and curriculum to show how these challenges arise in classrooms and how the design strategies respond to them.[41]

## See also

- Action learning
- Design-based learning
- Discovery learning
- McMaster Integrated Science
- Networked learning
- POGIL
- Progressive inquiry
- Project-based learning
- Scientific literacy
- Three-part lesson

## References and further reading


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# External links

- Inquiry-based middle school lesson plan: "Born to Run: Artificial Selection Lab" (http://www.indiana.edu/~ensiweb/lessons/BornToRun.html)
- Teaching Inquiry-based Science (https://sites.google.com/site/inquiryschoolscience/)
- [2] (http://www.inquirypartners.com)

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