Chapter 1
Inquiry-Based Learning:
Encouraging Exploration and Curiosity in the Classroom

Ahmad Qablan
https://orcid.org/0000-0002-2780-9796
United Arab Emirates University, UAE

Ahmed Alkaabi
https://orcid.org/0000-0001-7220-8087
United Arab Emirates University, UAE

Mohammed Humaid Aljanahi
https://orcid.org/0000-0001-9982-7179
United Arab Emirates University, UAE

Suhair A. Almaamari
Emirates Schools Establishment, UAE

ABSTRACT

Inquiry-based learning is an approach to learning that encourages students to engage in problem-solving through exploration and high-level questioning. It incorporates active participation of students by involving them in posing questions and bringing real-life experiences to them. The basis of this approach is to channelize the students' thought process through queries and help them in "how to think" instead of "what to think." This chapter begins by defining constructivism as the theoretical origin of inquiry-based learning, it then moves to talk about the benefits and advantages of this approach on students' learning. It also discusses the multiple forms of inquiry-based learning that have been documented in the literature to increase student involvement in their learning. The chapter demonstrates the various types of inquiry-based learning that can be implemented to drive the teaching process.

DOI: 10.4018/979-8-3693-0880-6.ch001

INTRODUCTION

The constructivist view of learning profoundly influences our understanding of teaching and learning. Tobin (1993) highlighted constructivism as a paradigm shift in educational thought, describing learning as a dynamic, social process where learners actively constructed meaning based on their prior knowledge. Social constructivism, further elaborated by Driver et al. (1994), emphasizes the essential role of social settings in learning, which suggests that knowledge is constructed through interactions in educational environments (Ullrich, 1999). Constructivists advocate for teaching methods that enable students to connect their prior knowledge with new information, while considering their diverse backgrounds and experiences in the process (Bullough, 1994; Ullrich, 1999). The adoption of constructivism and inquiry-oriented teaching is widely supported by educators (Abd-El-Khalick et al., 2004; National Research Council, 2000; Slavin, 1994; Stofflett & Stoddart, 1994). They argue that these methods stimulate students' conceptual understanding by encouraging them to build on their existing knowledge and actively engage with new information, applying their learning in real-life contexts.

Despite varying interpretations of inquiry in education, many educators agree on its core elements. As Howes et al. (2008) suggested, inquiry in the classroom involves "doing what scientists do." This view aligns with the National Science Education Standards (National Research Council, 1996), which defined inquiry as:

A multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze and interpret data; proposing answers, explanations, and predictions; and communicating the results. (p. 1)

The literature documents several benefits of inquiry-based teaching and learning. Lord and Orkwiszewski (2006) argued that it effectively improved students' content knowledge, scientific process skills (Deters, 2005; Hofstein et. al., 2004), attitudes toward learning, motivation (Tuan et al., 2005), and communication skills (Deters, 2005).

ESSENTIAL FEATURES OF INQUIRY TEACHING

The inquiry process adopts a scientific methodology, beginning with the formulation of questions about scientific phenomena and seeking answers to these queries. This approach enables learners to develop various skills, including scientific skills like critical thinking and problem-solving, as well as communication skills encompassing collaboration and idea sharing. The literature highlights five key features of science inquiry that aid students in understanding the methods scientists use to acquire knowledge (National Research Council, 2000).

Learners are Engaged by Scientifically Oriented Questions

Scientific questions often stem from observations of objects, organisms, and events in nature. These questions are central to inquiry, leading to empirical investigations and the use of data to explain investigated phenomena. Scientists typically recognize two primary types of inquiry questions: existence questions, which include many “why” queries (e.g., Why do objects fall towards Earth? Why do humans have chambered hearts?), and causal or functional questions that explore mechanisms, often phrased as “how” questions (e.g., How does sunlight aid plant growth?).

In educational settings, many “why” questions can be reframed as “how” questions to facilitate investigation and simplify answers. This refinement sharpens the focus of inquiry and makes it more scientific. Classroom questions should be robust and engaging, and spark curiosity and the desire to explore. These questions can arise from various sources, including learners, teachers, instructional materials, or digital platforms. The teacher’s role in refining and focusing students’ questions is crucial. Effective inquiries emerge from questions that are meaningful, engaging, relevant, and investigable at the students’ developmental and ability levels. Skilled teachers guide students in refining their questions, which leads to both interesting and productive investigations.

Learners Prioritize Evidence to Develop and Evaluate Explanations

Learners focus on evidence to construct and assess explanations for scientifically oriented questions. Credible scientific investigations hinge on empirical evidence as the foundation for developing valid explanations about specific phenomena. Scientists prioritize obtaining accurate data from observations, whether in natural settings like oceans or controlled environments like laboratories. They rely on their senses and instruments that measure otherwise undetectable characteristics, such as magnetic fields. Sometimes, scientists control conditions to gather evidence; other times, they observe under a variety of natural conditions over extended periods to infer the influence of different factors (Darawsheh et al,2023). The validity of evidence is ensured through repeated measurements and observations or by collecting different data types related to the same phenomenon. This evidence is then subject to further inquiry and scrutiny.

In classroom inquiries, students similarly use evidence to formulate explanations for the phenomena they study. They might observe natural elements like plants, animals, and rocks, or social, economic, and political phenomena, noting their characteristics and attributes. They measure temperature, distance, and time, observe chemical reactions, Moon phases, and chart progress, or gather evidence from various sources, including teachers, instructional materials, and the internet, to fuel their inquiries.

Learners Formulate Explanations from Evidence

Inquiry-based learning emphasizes the reliance on evidence to construct scientific explanations. These explanations, grounded in reason, seek to provide causes for effects and establish relationships based on evidence and logical argumentation. Consistency with experimental and observational evidence about phenomena is paramount. Explanations must respect rules of evidence, be open to criticism, and involve cognitive processes such as classification, analysis, inference, prediction, critical reasoning, and logic. Explanations aim to make the unfamiliar understandable by relating observations to existing knowledge. Thus, they extend beyond current understanding to propose new insights. In science, this involves building upon the existing knowledge base to comprehend unclear phenomena. For students, it means constructing new ideas based on their prior understanding, which results in new knowledge.

Learners Evaluate Their Explanations Against Alternatives

A key feature of scientific inquiry is the evaluation, and sometimes revision or rejection, of explanations in light of alternative views, especially those grounded in scientific understanding. Critical questions include questions like: Does the evidence support the proposed explanation? Is the question adequately addressed by the explanation? Are there biases or flaws in the reasoning linking evidence and explanation? Can other plausible explanations be derived from the evidence? As students engage in dialogue, compare results, and review their findings against teacher or instructional material suggestions, alternative explanations may emerge. An important aspect of this process is ensuring students connect their findings with accepted scientific knowledge at a level appropriate to their developmental stage. Student explanations should align with current scientific understanding.

Learners Communicate and Justify Their Proposed Explanations

In scientific communication, explanations are presented in a manner that allows for replication by others. This involves clearly articulating the question, methods, evidence, proposed explanation, and considering potential alternatives, which fosters critical review and further application or questioning by other scientists. Encouraging students to share their explanations allows others to pose new questions, scrutinize evidence, identify flawed reasoning, challenge unsupported assertions, and propose alternative interpretations. This exchange can either question or reinforce the links students have made between the evidence, existing scientific knowledge, and their explanations. Through this process, students can address inconsistencies and strengthen their arguments based on empirical evidence.

LEVELS OF INQUIRY LEARNING

Structured Inquiry

At this foundational level, students are given specific questions to investigate, following set procedures to collect and analyze data, which leads them to an answer for the initial inquiry question. Structured inquiry is commonly employed in elementary classrooms, where students benefit from additional support and direction in their investigations.

Guided Inquiry

In guided inquiry, the teacher plays an active role in steering students through their inquiry process. This involves assisting students in formulating investigable questions and contemplating appropriate experimental designs to address these questions. This approach offers students more autonomy in question formulation compared to structured inquiry and is typically used in middle school settings.

Open-Ended Inquiry

This advanced level of inquiry adopts a more flexible approach. Students are presented with a problem or phenomenon to investigate, encouraged to generate their own questions, and design experiments to collect and analyze data in response to these questions. Open-ended inquiry is often utilized in higher grade levels, where students are more independent and encouraged to explore their interests through self-guided investigations.

BENEFITS OF INQUIRY-BASED LEARNING

Encourages Engaged Learning

Inquiry-based learning actively engages students, stimulating their interest and thinking. This heightened engagement often leads to enhanced knowledge acquisition, skill development, and attitudinal growth.

Fosters Critical Thinking

This learning approach cultivates critical thinking skills as students engage in investigations. They are encouraged to present and critique their findings among peers, thereby honing their problem-solving and critical-thinking abilities.

Sparks Creativity

Inquiry-based learning nurtures students' creativity. Given the freedom to explore their interests independently, students frequently devise innovative solutions, especially in open-ended inquiry scenarios.

Enhances Problem-Solving Skills

The process of inquiry learning sharpens problem-solving skills. Confronting real-world problems, students learn to think innovatively and devise creative solutions, which are invaluable skills for future investigative endeavors.

Facilitates Understanding of Complex Topics

Inquiry learning aids in grasping complex subjects. Through unrestricted investigation of phenomena of interest, students achieve deeper and more meaningful comprehension.

Improves Communication Skills

Engagement in inquiry learning enhances communication abilities. As students work on problems or investigations, they often find themselves explaining their ideas, results, and analyses to others, which refines their capacity to articulate their thoughts effectively.

Links Learning to Real-Life Contexts

Inquiry learning connects learners to real-world situations. As students explore issues relevant to their environment, they perceive the applicability of classroom learning to real-world scenarios. This fosters a more profound understanding of the concepts they explore.

CLASSROOM INQUIRY MODELS

STEM Teaching Model

STEM is an interdisciplinary educational approach that emphasizes hands-on, experiential learning to prepare students for careers in science, technology, engineering, and mathematics (Ibrahim et al., 2023; Qablan et al., 2023). This methodology, highlighted by Bataineh et al. (2022), aims to cultivate inquisitive minds, logical reasoning, and collaborative skills. It often includes participation in university research programs that allow students to actively contribute to the development of new technologies and pioneering research (Khalil et al., 2023). To maintain student engagement and enhance their understanding of STEM subjects, educators are encouraged to employ a variety of teaching methods, each contributing uniquely to the learning experience.

Engineering Design Process

The Engineering Design Process (EDP) is a structured approach for planning STEM lessons, involving a series of steps for problem-solving in project-based learning. This method promotes open-ended designs, creativity, and practical solutions (Nguyen et al., 2021). The following are steps in the EDP problem-solving approach:

Ask. Students are presented with a problem or project and asked to develop a product/design solution. They start by asking critical questions about their task or desired creation.

Research. Students gather information about their project, utilizing resources like the internet, teacher or expert consultations, STEM volunteers, laptops for research, or relevant videos.

Imagine. In teams, students brainstorm potential solutions. This collaborative stage ensures every student contributes, with the teacher fostering a judgment-free environment for idea generation.

Plan. Teams select a solution and strategize its implementation, considering their initial questions, research findings, and brainstormed ideas.

Create. Students build a prototype based on their plans. This phase allows for creativity and practical application, which tests the functionality and adherence to original requirements.

Test. Students devise methods to evaluate their solutions' effectiveness, assessing whether they address the problem. Teachers can facilitate peer review discussions to promote deep thinking and collaboration.

Improve. The final step involves feedback and discussions on enhancements. Students then redesign and refine their products and repeat this cycle until satisfied with the outcome.

The Inquiry Cycle Model

The 5E model, developed by the Biological Sciences Curriculum Study (BSCS) (Bybee et al., 2006), represents a constructivist approach to inquiry teaching and learning. It enhances students' understanding through hands-on experiences and is designed in a cyclical format. This model has gained widespread adoption and adaptation among educators. The 5E instructional model is comprised of five phases: engage, explore, explain, elaborate, and evaluate. Throughout these stages, students collaboratively observe, investigate, analyze, and draw conclusions. With the teacher serving more as a facilitator than a lecturer, this model is particularly effective for integrated subjects like STEM. It encourages students to deeply engage with and critically examine new concepts and ensures meaningful learning experiences. Studies have shown that the 5E model is more effective in helping students acquire scientific concepts than traditional textbook-focused methods. The following sections detail the specific activities and objectives of each phase in the 5E learning model.

Engagement

This initial phase draws students into the learning task by focusing their attention on a phenomenon, object, problem, situation, or event. Activities connect to prior experiences and reveal misconceptions, which create cognitive disequilibrium. Engagement methods include posing questions, defining problems, presenting discrepant events, or simulating problematic situations. The teacher's role is to introduce the situation, define the instructional task, and establish rules and procedures. Successful engagement stimulates and motivates students, and involves both mental and physical activity.

Exploration

Following engagement, students feel a need to explore ideas and test hypotheses. Exploration activities provide common, concrete experiences for concept, process, and skill formulation. The cognitive disequilibrium from the engagement phase is leveraged here to help students regain cognitive equilibrium. Exploration aims to create experiences for later formal introduction and discussion of concepts, processes, or skills. Students actively engage in exploring objects, events, or situations, thereby establishing relationships, observing patterns, identifying variables, and questioning events. The teacher facilitates and coaches these efforts and initiates activities that allow students to investigate based on their interpretations of the phenomena.

Explanation

The explanation phase centers around students constructing answers to their inquiry questions using data analysis. Students and teachers utilize terminology relevant to the concepts or phenomena being studied. Here, the teacher first guides students to present their explanations and then introduces scientific or technological explanations in a clear, direct, and formal way. This phase orders the exploration experiences logically to respond to research questions. Teachers should build on students' explanations and link them to experiences from the engagement and exploration phases (Jandigulov et al,2023). The objective is to present concepts, processes, or skills in a brief, straightforward, and clear manner before progressing to the next phase. Various strategies are employed by teachers in this phase. They might use verbal explanations, videos, films, or educational software to aid students in constructing their explanations. This stage is crucial for organizing thoughts and providing terminology for explanations. Ultimately, students should articulate their exploratory experiences using common terms.

Elaboration

In the elaboration phase, students apply their newly developed explanations and terminology to extended learning experiences. This phase encourages the application of concepts, processes, or skills to new, closely related situations. Sometimes, students may retain misconceptions or understand concepts only in the context of their exploratory experiences. Elaboration activities offer additional experiences to reinforce learning. Students engage in group discussions and information-seeking activities during this phase. They present and defend their approaches, refine the task's definition, and identify necessary information for successful completion. Information sources include peers, teachers, printed materials, experts, electronic databases, and their experiments to form an information base. These group discussions enable students to elaborate on their task conception, information sources, and potential strategies. Group interactions are vital in this phase as they provide opportunities for students to express their understanding and receive feedback from peers at similar comprehension levels. Elaboration also involves introducing students to new situations and problems that require applying similar explanations, aiming to generalize concepts, processes, and skills.

Evaluation

The evaluation phase is where students assess their understanding using their acquired skills. They should also receive feedback on the adequacy of their explanations. Informal evaluation may occur throughout the 5E cycle, with a more formal evaluation following the elaboration phase. As part of practical educational practice, teachers assess learning outcomes during this phase, using various assessments to gauge each student's understanding level.

Gather, Reason, Communicate (GRC) Framework

The Gather, Reason, Communicate (GRC) framework is a student-centric instructional approach designed to help students comprehend phenomena across natural, social, economic, historical, and other domains through scientific and engineering practices. This framework can be integrated into the 5E instructional model's lesson planning.

Gathering Stage

At this stage, instruction is centered around phenomena, engaging students in various science and engineering practices such as questioning, investigation, qualitative observation, and quantitative data recording. Students explore observable phenomena or events to collect evidence supporting scientific explanations. Anchoring learning in observable phenomena aids students in making sense of real-world observations. Essential observation skills, including inferring, measuring, communicating, predicting, and classifying, are employed by scientists in their research. Students apply these skills to begin addressing their questions about the observed phenomena.

Reasoning Stage

The reasoning stage in the GRC framework involves critical thinking practices. Here, students engage in activities such as analyzing data, constructing evidence-based explanations, evaluating data collection techniques, employing computational thinking, and developing explanations grounded in collected evidence. They utilize key ideas and concepts from the previous stage to interpret data and construct reasoned arguments, using models to explain natural phenomena and support their explanations with evidence.

Communicating Stage

In this stage, students articulate their explanations and arguments, both written and oral, to demonstrate how their evidence substantiates their conclusions. They participate in a critical exchange of ideas, offering and receiving feedback on their explanations, and citing relevant evidence and reasoning. Additionally, students employ models to convey their thought processes and make their reasoning visible, which enhances communication and understanding of their scientific arguments.

LIMITATIONS AND CAVEATS

While the merits of inquiry-based learning are significant, it is equally important to recognize its limitations and challenges. These include practical difficulties in implementation, a deficit in specialized curricula and adequate teacher training, and the considerable psychological burden on educators (Khalaf & Zin, 2018). Moreover, unique cultural aspects of inquiry-based learning and varying stakeholder expectations (Dai et al., 2012) add to its complexity. The time-intensive nature of this approach may not always align with established academic assessment cycles, which poses additional logistical challenges for schools (Khalaf & Zin, 2018). Successful implementation is contingent upon comprehensive teacher training and adequate school investment (Alkaabi, 2023; Alkaabi et al., 2023; Alkaabi & Almaamari, 2020; Almaktoum & Alkaabi, 2024). This training might include mentorship programs where experienced teachers guide novices and formal training sessions, which are essential for teacher upskilling despite their costs. Inquiry-based learning will have a profound impact when it becomes a normative practice in the school, greatly influencing overall school performance. This norm can be established with the support of the administrative team and the school community staff (Al-Zoubi et al., 2023). Finally, the considerable psychological demands placed on teachers, who play a pivotal role in facilitating student inquiry and deep engagement, can lead to increased stress and a higher risk of burnout.

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