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Research Article

REASONING IN STEAM EDUCATION: UNLOCKING THE POWER OF INDUCTION, DEDUCTION, AND ABDUCTION

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Abstract:

This article explores the significant role of reasoning within science education, examining three main process: deductive, inductive and abductive reasoning. It underscores the significance of these cognitive processes in facilitating comprehension of intricate scientific concepts and problem solving in different domains. It also explains how each mode of reasoning can be applied in real world contexts through practical examples obtained from various fields with the emphasis of their relevance and utility in fostering critical analysis and understanding. It explains all the reasoning with the balanced understanding of reader's effectiveness. The main aim of the article is ti equip the readers with the tools require to make informed decisions and navigate complex issues in both academic and professional spheres. Finally, the articles seeks to enhance the students reasoning proficiency, thereby bolstering their critical thinking abilities and contributing to their success in different intellectual pursuits.

Keywords: Reasoning; Science education; Critical thinking; Problem-solving; Cognitive process

Introduction

In the dynamic fields of science, technology, engineering, art , and mathematics (STEAM), the ability to reason remains a cornerstone of critical thinking and innovation Ideas are cognitive processes that enable individuals to explore analyze, draw conclusions, and find solutions. There are three distinct modes of reasoning on this theory: induction, deduction, and deduction. Each mode serves a different purpose in unraveling the complexities of STEM disciplines and stimulating growth. Reasoning is a fundamental component of human cognition. This cognitive process enables us to comprehend the world, solve problems and arrive at conclusions. Three principal types of reasoning exist: deductive, inductive and abductive reasoning. These different modes are crucial for critical thinking, intellectual development as well as problem-solving decision making activities that enable people to have an insightful perspective on things around them while responding efficiently when faced with challenges or problematic issues. Several studies have highlighted the significance of reasoning as a crucial aspect in science and mathematics education [1-3]. Reasoning skills are essential for students to comprehend and critically analyze scientific concepts relevant to modern society's technological advancements [4].

The study of human reasoning has been a subject that has garnered much attention since the era of Aristotle and continues to be an important area in theoretical, empirical and psychological research today. In contemporary society where there is immense pressure on us to manage huge amounts of information within shorter periods than ever before, both educational environments as well as workplaces heavily rely on effective reasoning skills[5]. Furthermore, Kwon and Lawson (2000)[6] found that the physical development and social experience of children affects their capacities for reasoning. Inductive reasoning, which is sometimes called generalization, allows us to draw overreaching conclusions from a small number of observations. By identifying patterns and forming hypotheses based on empirical evidence, we are able to explore the possibilities in our experiences. This type of logic drives scientific discoveries and serves as the backbone for common knowledge - where we believe that what has been verified before will remain true again later on. The mental process of drawing logical conclusions is referred to as deductive reasoning [7]. The highest form of logic and accuracy is represented by deductive reasoning. It follows a cause-and-effect association based on general premises that conclude in specific outcomes, adhering to strict principles. According to its theory, if the initial foundations are correct, then any resulting conclusion must be absolute and an undeniable fact. Deductive reasoning serves as the foundation for mathematical proofs, legal discussions/debates or structured logical thought processes.

Moreover, according to DeMichele (2018), [8] "**Deductive reasoning deals with certainty** and involves reasoning toward certain conclusions, **inductive reasoning deals with probability** and involves reasoning toward likely conclusions based on data, and **abductive reasoning deals with guesswork**, involves reasoning toward possible conclusions based on guesswork (a best guess), it is a type of reasoning that is used in formulating a hypothesis for further testing." When our observations are incomplete or uncertain, abductive reasoning acts as a detective for the cognitive world. This type of reasoning aims to produce the most plausible explanation based on available facts or observations. In an ambiguous and unpredictable setting, abductive reasoning is essential in identifying likely explanations even if there is insufficient evidence. It plays a vital role in scientific discovery and solving everyday puzzles effectively.

This article takes an exploratory approach by using real-life examples and practical insights to demonstrate how each mode of thinking can be applied across various fields including science, engineering, mathematics and everyday problem-solving activities. Through understanding these modes' strengths as well as limitations we can unlock their power for enhancing our critical-thinking capability enabling better decision making abilities too! Join us now as we explore the art behind both inducement/deduction/abduction strategies that shape our perceptions about this wonderful place called Earth - uncovering its secrets along every step taken with insightfulness into what makes it all run together harmoniously at once before finalizing any conclusion either small or large-scale analysis-wise

Objective:

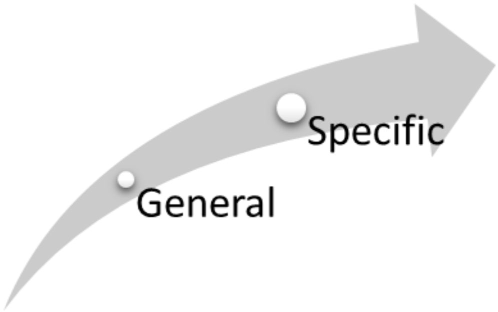
The aim of this article is to examine and clarify the importance of reasoning, specifically deductive, inductive and abductive types of reasoning. These forms of logical thinking are significant in science and engineering education as they help enhance critical thinking skills which can be applied across a wide range of disciplines. The focus is on providing examples that illustrate how each mode applies practically.

Methodology

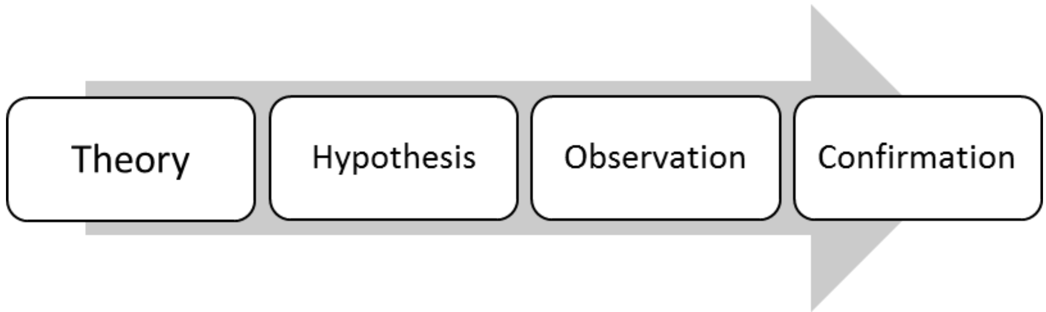
Adopting a qualitative and exploratory methodology, the article delves into the three main types of reasoning: deductive, inductive, and abductive. Drawing on real-life examples from areas such as science and engineering to illustrate their applications, this piece takes an approach that prioritizes practical insights. The use of tangible demonstrations helps solidify understanding surrounding these fundamental concepts for readers seeking to explore logic-based fields further.

Deductive Reasoning in STEM Field

Deduction a “valid” argument (piece of reasoning) is one in which the concluding explanation fundamentally takes from supportive articulation or propositions. Deductive thinking begins with the statement of a common principle or rule (an established truth) and continues to an ensured specific conclusion. Deductive reasoning moves from general to specific. Human knowledge cannot be raised since the result drawn by deductive thinking are iterative statements that remains within the site and for all intents and purposes self-evident. In science education, deduction is to arrive at a conclusion (or recognized rules, laws, theory or other widely accepted truths) which is believed earlier to be true. At the beginning, a hypothesis formulation of hypothesis is done and data or evidences are collected to support the hypothesis. The hypothesis is accepted, when the observation supports the statement, principle or truth. Whether a deductive explanation is genuine or correct can be evaluated by the degree of connectedness between premises and conclusion.



Hypothetical Deductive Approach



This starts with formulating theory which is narrowed down in to testable hypothesis, collect data through observations for addressing hypothesis and end up with testing the hypothesis with data collected from observation to confirm or prove the theory. Traditional science teaching is deductive, which starts with principles and succeeding to applications of those principles

The steps involved in Hypothetic Deductive reasoning approaches [9] are,

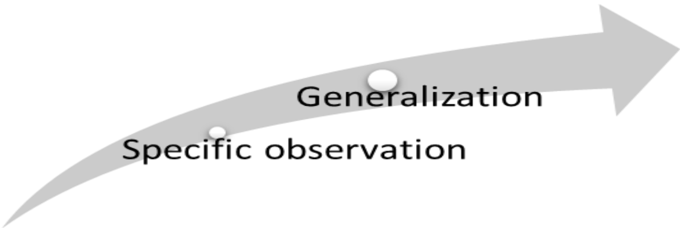
1. Identifying the broad problem area in which main problem is occurring to do a research project.
2. Defining the problem statement. It can be the scientific research with definite aim and general objective of the research.
3. Development of hypothesis which should be testable and falsifiable.
4. Measuring the theoretical framework and if it not measurable then it should be qualitative.
5. Collection of data is based on quantitative and qualitative data.
6. Analysis of data is done to check if the hypotheses generated were supported.
7. Interpreting data for finding out the meaning of the results.

Some practical example for Deductive Reasoning

Example 1	Example 2	Example 3	Example 4
X=Y	Body organs are made up of living cells	Carbonate minerals produce carbon dioxide when dilute hydrochloric acid dropped on it	Metals are solid at room temperature
Z=X	All humans have body organs	Mineral A is a carbonate mineral	Mercury is a metal
Therefore, Z is Y	Therefore, all humans are made up of living cells	Dropping dilute hydrochloric acid in mineral A causes carbon dioxide.	Mercury is solid metal

Inductive Reasoning in STEAM Field

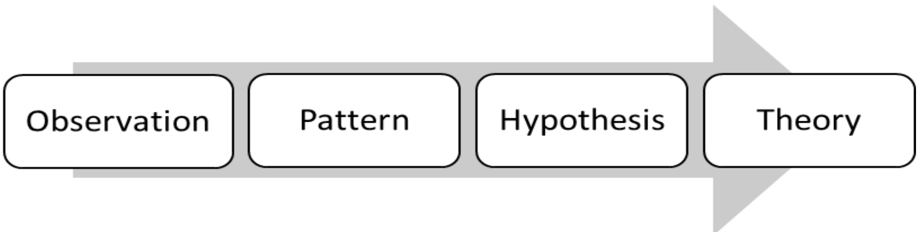
Kinshuk and colleagues (2006) identified inductive reasoning as one of the seven fundamental mental abilities that contribute to intelligence. Inductive reasoning involves collecting specific facts or instances to support a general conclusions from the previous studies [10,11]. Induction is learning from experience. Induction is a piece of reasoning that draws conclusions from observations or logic. In other way we can state induction as a reasoning which involves drawing inferences from observations. It is opposite of deduction. The purpose of deduction is to prove a conclusion or truth whereas induction aims to predict the theory, truth or a conclusion. Inductive reasoning moves with specific observations and proceed to a generalized conclusion. Most of the educationist and scientist carried out their research using inductive method. They gather evidences and formulate hypothesis or a theory (conclusion) to explain what they observed. Scientist measures the evidence or process under the study, which they analyzed to develop generalization or theory. Induction can be strong or weak. An inductive reasoning is either consider weak or strong depending upon whether its conclusion may be likely explanation for the premises.



Acquiring new evidence can affect inductive reasoning.

Specific observation → **Generalization (Broad conclusion)**

(Observation → pattern → probable(tentative)Hypothesis → Theory)



This starts with specific observation and measures, detect patterns, formulate probable hypothesis and finished with developing some theory or conclusions. Alternative teaching strategy in science follows inductive approach. The learning content is delivered through targeted observations, case studies or problem-solving exercises. Learners are then guided to identify relevant principles only after the need for understanding them has been established. . According to Prince and Fielder (2006)

[12]“Inductive teaching and learning is an umbrella term that encompasses a range of instructional methods, including inquiry learning, problem-based learning, project-based learning, case-based teaching, discovery learning, and just-in-time teaching”. Those strategies are related with inductive teaching, as in those strategy students are provided with opportunities to observe, experience, pose questions and develop conclusions or hypothesis. Students’ independent thinking skill, analyzing skill and higher order thinking skill are developed and students learn authentically through inductive approach.

Some practical application of Inductive Reasoning

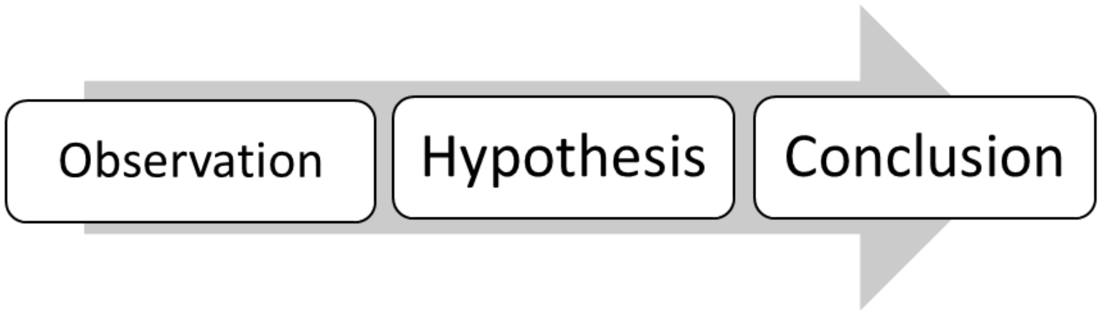
Example 1	Example 2	Example 3
Mineral A is a carbonate mineral.	Water boils at 100 degrees Celsius in this experiment	Fishes swims in water
Dropping dilute hydrochloric acid in mineral A causes carbon dioxide.	Water boils at 100 degrees Celsius under these conditions too	Whale swims in water
Carbonate minerals produce carbon dioxide when it is treated with dilute hydrochloric acid.	Therefore, water always boils at 100 degree	Whale is a fish

The examples 1 and 2 are correct but inference drawn in example 3 is wrong

Abductive Reasoning in STEAM Field

According to Hartshorne, Weiss and Burks (1958), the term abductive reasoning was originally introduced by Charles Pierce. He defined it as "the initial introduction of a hypothesis into one's thinking and its subsequent consideration, whether this occurs with only an exploratory intention or with greater confidence - which I suggest may be referred to as abduction." According to Thagard and Shelley (1997)[12,13], the process of abductive reasoning can be a sophisticated and imaginative way of thinking, involving the development of new hypotheses from innovative concepts. It is characterized by interrelatedness among various conjectures leading one hypothesis to inform another within this complex thought process. Nersessian’s (2002)[14, 15] conducted a historical analysis and discovered that scientists have made significant progress in their investigations by applying abduction to adjust their cognitive models of how things function. Abduction is a methodical thinking process that can facilitate the establishment of fresh aspects within mental frameworks. Additionally, it may help students construct substitute versions of intangible phenomena while studying science[16].

Abductive reasoning involves making probable inferences or explaining a hypothesis based on evaluation of evidence and observation. This type of reasoning often begins with an incomplete set of observations, which then leads to the most likely outcome. The argument relies heavily on observed facts, starting from limited data and arriving at conclusions that seem reasonable given those initial pieces of information. While abductive reasoning shares similarities with induction method, it is not always accurate as some possible alternatives may be incorrect [17]. For this reason, we should only use it when there is enough support by the theory [17]. In everyday life we all use this logic (abduction) frequently without necessarily realizing what were doing – piecing together diverse bits details into one bulky explanation. Overall Abductive Reasoning provides us practical methods obtaining new insights regarding unexplainable phenomena by filling gaps between observable effects serving stepping stone for scientific researches.



Example 1	Example 2	Example 3
Dropping dilute hydrochloric acid in mineral A causes carbon dioxide	In a pond ecosystem, the population of a particular aquatic plant species (Species X) has rapidly declined.	An experiment involving an electromagnet and a piece of iron shows that when an electric current passes through the coil, the iron piece becomes magnetized.
Carbonate minerals produce carbon dioxide when they drop dilute hydrochloric acid.	It is known that a new species of herbivorous fish (Species Y) has been introduced into the pond.	Iron is known to exhibit ferromagnetic properties.
Mineral A is a carbonate mineral.	The decline in Species X may be due to the introduction of Species Y, as herbivorous fish typically consume aquatic plants.	The observed magnetization of the iron is likely due to its ferromagnetic properties, as iron materials are known to become magnetic when exposed to an electric current in an electromagnet.

When a doctor observes a symptom in a patient he /she hypothesizes its possible causes based on his/her causes, based on her /his knowledge of the causal relations between diseases and symptoms. One of the report [18] suggested that these kinds of approaches are also equally important for the ICT integrated pedagogical applications.

Conclusion and Implications

To summarize, this article delves into the key cognitive processes known as deductive, inductive and abductive reasoning while underlining their importance to STEAM education. Reasoning remains an indispensable tool for comprehending our environment, addressing issues sensibly & making well-informed decisions. All three types of reasoning namely deductive, inductive and abductive perform unique roles that shape how we perceive reality around us. The importance of deductive reasoning is highlighted in science education as it helps move from general premises to specific conclusions. This serves as a base for proving established truths, laws and theories logically. Furthermore, inductive reasoning commences with particular observations and progresses towards generalizing conclusions, which is an inductive process. It plays a significant role in scientific discovery as it helps form hypotheses and generalize from empirical evidence. The expansion of knowledge always relies on induction, including developing new theories using this approach. By presenting concrete examples from science, this article has offered actionable guidance on how to utilize different modes of reasoning in diverse disciplines. By comprehending the advantages and constraints of each mode, individuals can harness their potential for thought processes that amplify critical thinking competence while also refining decision-making capabilities.

This article has significant implications for problem-solving and education across multiple fields. It is vital for educators to comprehend the various modes of reasoning in order to enhance education. By familiarizing themselves with deductive, inductive, and abductive thinking processes, teachers can adjust their methods of instruction accordingly and encourage students' development these cognitive skills. The result could be more successful learning outcomes as well as improved readiness for scientific or mathematical thinking tasks. Educators can cultivate critical thinking skills in students by acknowledging the significance of deductive, inductive, and abductive reasoning. By urging learners to adopt these modes of thinking when confronting obstacles, they are more likely to discover innovative solutions that are not immediately apparent. Researchers can enhance their knowledge in reasoning processes, which includes deductive reasoning for confirming established facts, inductive reasoning to make generalizations and hypotheses from observations, as well as abductive reasoning that enables exploration of alternative explanations when data is incomplete. This information will be valuable to scientists during scientific research.

Furthermore, effective problem-solving in daily life hinges on the ability to use reasoning modes. Knowing their strengths and limitations can improve decision-making, enabling individuals to solve complex problems across diverse situations. The article highlights the adaptability of these reasoning methods in different fields, emphasizing that utilizing deductive, inductive and abductive thinking can effectively connect diverse disciplines while promoting collaborative problem-solving approaches. The understanding and utilization of reasoning are crucial in a society that has become highly reliant on information processing as well as decision-making. This piece aims to demonstrate the significance of reasoning methods in education and how they could be powerful solutions for confronting challenges within an intricate world. By applying deductive, inductive, or abductive logic thoughtfully, individuals could continue discovering innovative ways while progressing through lifelong learning alongside their communities.

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