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Scientific Inquiry: Five Essential Features in Bahraini Primary School Textbooks and Workbooks

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Abstract

This study examined the Bahraini primary school science textbooks and workbooks from grades 1 to 6, focusing on how they incorporate the five key features of scientific inquiry. These features are: (1) engaging students in scientifically oriented questions, (2) prioritizing evidence in responding to questions, (3) guiding students to formulate explanations based on evidence, (4) connecting these explanations to scientific knowledge, and (5) enabling students to communicate and justify their explanations to others. A rubric was used to classify these features into four inquiry levels, ranging from teacher-centered (teacher-driven and teacher-guided) to student-centered approaches. The analysis found that 95.9% of the activities in the textbooks and workbooks included these essential features. However, most were concentrated at the lower inquiry levels (teacher-centered and teacher-driven). As students advanced through the grades, the inclusion of higher-level inquiry activities (teacher-guided and student-centered) increased. When broken down by scientific disciplines, the features were largely emphasized at the teacher-driven levels. The study concludes that science textbooks and workbooks should offer more opportunities for higher levels of inquiry (levels 3 and 4). These findings provide valuable insights for educational leaders and policymakers in developing the science curriculum.

Keywords: Curriculum analysis, inquiry, scientific inquiry, textbook evaluation

1. Introduction

Inquiry is an active learning process encompassing question formulation, information gathering, data analysis, and result communication. It is crucial for understanding scientific concepts and is widely utilized in scientific research [6], [12]. Engaging in inquiry enables students to think critically, assess evidence, and effectively communicate their findings. This pedagogical approach enhances student engagement and deepens comprehension of complex subjects [1], [7]. It is closely tied to scientific literacy as it imparts an understanding of the scientific method, vital for students' success in an evolving world.

Inquiry-based education is essential in science instruction, promoting skills such as critical thinking and problem-solving [6]. This method encourages student engagement by linking scientific principles to real-life contexts [2]. Furthermore, it fosters collaboration and creativity as students work together on investigative tasks. Integrating inquiry in education is crucial for preparing students for the 21st century, where scientific literacy is increasingly important [5].

Globally, science curriculum standards stress the necessity of conducting scientific inquiries to elucidate various concepts [14], [15]. Scientific inquiry entails the process scientists use to explore the natural world, which in education translates to students posing questions, forming hypotheses, and drawing conclusions based on evidence [13]. Developing inquiry skills is fundamental for students' educational growth [14], [15].

The National Research Council [17] has identified five essential inquiry features that promote effective science education. These features include student engagement with scientifically oriented questions, evidence prioritization, evidence-based explanation formulation, evaluation of explanations, and communication of findings.

2. SIGNIFICANCE OF THE PROPOSED STUDY

The proposed study highlights the critical role of scientific inquiry in fostering students' scientific literacy, which is a primary goal of science education [10], [19], [21]. Understanding how curricula represent scientific inquiry is essential for guiding instruction and developing students' inquiry and critical thinking skills.

Scientific inquiry skills are closely aligned with 21st-century competencies, emphasizing critical thinking and creativity. These skills encompass formulating questions, gathering and evaluating information, and communicating findings effectively. Scientific literacy involves grasping scientific concepts and assessing the reliability of scientific information, requiring a robust foundation in inquiry skills and an understanding of the scientific method.

Moreover, inquiry skills are linked to other essential competencies such as problem-solving, communication, collaboration, and innovation. The National Science Foundation underscores the importance of these skills for success in STEM fields, which are increasingly in demand [8].

Examining science textbooks is vital, as they serve as key educational resources that structure scientific concepts and principles. They not only provide foundational knowledge but also stimulate curiosity and engage students in active learning [7], [4]. Textbooks should encourage independent research and critical thinking, allowing students to apply their knowledge through projects and experiments [9].

Ultimately, science textbooks should encompass all essential inquiry features and facilitate student-centered learning. This study aims to provide insights into how inquiry-based features are integrated into primary science textbooks, enhancing teacher training and curriculum development to better prepare students for the challenges of the 21st century.

3. Conceptual Framework of the Study

The study employs a conceptual framework essential for analyzing textbooks, focusing on their content from various perspectives [4], [7]. This framework highlights that many science textbooks emphasize memorization over genuine inquiry, presenting activities that resemble formulaic laboratory experiments rather than fostering independent scientific exploration [11]. Effective scientific inquiry should prioritize student engagement, promoting open-ended activities that encourage hypothesis formulation, experiment design, and result communication. Incorporating scientific inquiry in teaching materials is crucial for developing students' reasoning and inquiry skills, preparing them for competencies needed in the digital age [23]. Thus, the study aims to assess how well science textbooks and workbooks facilitate the development of essential scientific inquiry skills among students.

4. Literature Review

Science education is shifting from rote memorization to teaching science as a process, emphasizing the integration of scientific inquiry into curricula [20]. Inquiry can be approached as "content" or "technique," but gaps exist between theory and practice in its implementation. Globally, standards like NGSS in the USA and the National Curriculum Board in Australia emphasize inquiry skills, but variations in implementation remain [1]. Inquiry-based instruction enhances student learning, achievement, and attitudes towards science, with research showing positive outcomes for both general and special needs students.

Despite support for inquiry, debates persist on its effective implementation. Different frameworks categorize inquiry activities based on student and teacher roles, ranging from structured to open-ended inquiry. Research indicates that guided inquiry often yields better results for achievement, especially among low-attaining and special needs students, while open-ended inquiry fosters deeper understanding and critical thinking. Textbooks shape science education significantly, providing resources for teachers and influencing student learning. Analyzing textbooks reveals how well they promote inquiry and support teaching practices [7]. Research shows that many textbooks focus on low-level inquiry tasks and lack opportunities for higher-order thinking.

In the GCC, studies have identified a need for more student-centered inquiry in science materials. This study uniquely examines Bahraini primary school science textbooks, categorizing their inquiry features and offering specific recommendations to enhance inquiry-based learning. It addresses gaps in previous research by focusing on practical improvements tailored to the Bahraini context, aiming to better equip students for future challenges.

Purpose of the Study and Research Questions

This study aimed to examine how well primary school science textbooks and workbooks cover scientific inquiry skills, utilizing the five essential features of inquiry rubric [17]. The research sought to address the following questions:

1. To what degree are scientific inquiry features represented in primary school science textbooks and workbooks?
2. What levels of inquiry features are present in both the textbooks and workbooks?
3. How do the levels of inquiry features vary across different science subjects (Physics, Chemistry, Earth Science, and Biology)?
4. Which types of activities are most effective in promoting inquiry among primary school students?
5. Are the levels of inquiry in current primary school science textbooks consistent with the recommendations of the NSES?
6. How are the levels of scientific inquiry features emphasized from first grade to sixth grade?

5. Methodology

This study employed document analysis, a qualitative research method, to evaluate the representation of scientific inquiry skills in primary school science textbooks and workbooks, using the five essential features of inquiry rubric [17]. Document analysis involves systematically reviewing and interpreting documents to extract meaningful information (Bowen, 2009).

5.1 Data Collection

Data were collected from 12 primary school science textbooks and 12 workbooks (Arabic Edition), adapted from McGraw-Hill, targeting students aged six to twelve across grades one to six. A total of 581 practical activities were analyzed. After excluding activities lacking multiple inquiry features, 533 activities remained for evaluation—161 from textbooks and 372 from workbooks, categorized into various types such as open inquiry and lab experiments.

5.2 Data Analysis

The analysis employed the NRC's inquiry feature rubric, categorizing activities into four levels of inquiry, ranging from teacher-centered to student-centered approaches. Each level specifies the degree of student autonomy in formulating questions and conducting investigations. The activities were coded based on these features, and frequency and percentage analyses were conducted for each inquiry feature across all grade levels.

5.3 Validity of Analysis

The study utilized the US National Science Standards as a framework for analyzing Bahraini science materials, ensuring conceptual integrity through careful translation of the evaluation rubric from English to Arabic. The accuracy of this translation was verified through back-translation and expert review.

5.4 Reliability of Content Analysis

To ensure reliability, two science education instructors independently analyzed the materials, with inter-rater reliability calculated using Cohen's Kappa. The Kappa values ranged from 0.75 to 0.94, indicating strong agreement between raters regarding the inquiry features in the materials, comparable to findings in similar studies.
Overall, the methodology provided a comprehensive assessment of how effectively Bahraini primary school science textbooks and workbooks support inquiry-based learning.

6. Results

We provided a comprehensive analysis of the representation of scientific inquiry features in primary school science textbooks and workbooks, focusing on data from 533 activities across grades 1 to 6. Here are the key details:
Overview of Inquiry Features
The analysis investigates five essential features of scientific inquiry:
Feature 1: Learner engages in scientifically oriented questions

Representation: 82.7%
Details: This feature is the least included in activities, suggesting limited engagement with student-generated questions. Most activities fall under the explore and quick activity types, where questions are primarily provided by teachers.
Feature 2: Learner gives priority to evidence in responding to questions
Representation: 100%
Details: All activities include this feature, indicating a strong emphasis on evidence-based responses, albeit often in a teacher-directed manner.
Feature 3: Learner formulates explanations from evidence
Representation: 99.2%
Details: This feature is prominently represented, with many activities requiring students to derive explanations based on provided evidence.
Feature 4: Learner connects explanations to scientific knowledge
Representation: 98.5%
Details: Activities often guide students to relate their findings to established scientific concepts, reinforcing a teacher-centered approach.
Feature 5: Learner communicates and justifies explanations
Representation: 99.1%
Details: While communication is emphasized, the structure of activities tends to limit students' ability to devise their own communication methods.
Levels of Inquiry
We categorized the levels of inquiry from teacher-centered to student-centered learning:
Levels 1 to 4 indicate the degree of student autonomy:
Level 1: Strongly teacher-centered
Level 4: Strongly student-centered
The overall mean for the inclusion of features across activities is 1.538, indicating a predominant focus on teacher-centered learning.
Comparison by Discipline
The analysis also explores the representation of inquiry features across different scientific disciplines (Biology, Chemistry, Earth Science, Physics):
Feature 1: Ranges from 82.2% (Biology) to 83.9% (Chemistry), all at Level 1.
Feature 2: 100% representation across all disciplines, also at Level 1.
Feature 3: Nearly all disciplines reach high percentages (98.8% to 100%) but remain at Level 1.
Feature 4 and 5: Similarly high representation, indicating a consistent trend towards teacher-directed inquiry.
Types of Activities
The document identifies six types of activities in the textbooks and workbooks:
Explore Activities: Most frequent, engaging students but primarily at Level 1.
Quick Activities: Limited representation, mostly teacher-directed.
Work Like a Scientist: Generally Level 1, emphasizing teacher oversight.
Lab Experiments: Fully teacher-centered.
Scientific Skills Activities: Mostly Level 1, lacking student agency.
Inquiry Activities: These show potential for student-centered learning, with many at Levels 3 and 4.
The findings indicate that while the inquiry features are present in the curriculum materials, the implementation tends to favor teacher-centered approaches, limiting student engagement and inquiry. The document suggests a need for more student-centered practices to better align with educational standards for scientific inquiry, encouraging students to generate their own questions, analyze data independently, and develop their explanations. Improvements are recommended to enhance the effectiveness of science education in fostering genuine inquiry among primary school students.

7. Discussion

The study investigates the coverage of five essential features of scientific inquiry, as outlined by the US NSES Standards, in primary school science textbooks and workbooks in Bahrain. The findings highlight several key points:
Teacher-Centered Approach:
The first feature, where students engage with scientifically oriented questions, is included in all activities but only at 82.7%, indicating a predominantly teacher-centered approach. This means students are often presented with questions rather than being encouraged to formulate their own.

Similar Findings in Other Studies:
Previous research confirms that inquiry in textbooks often lacks balance and fails to fully engage students in the inquiry process, emphasizing the need for better representation of inquiry types that foster student engagement.
Evidence-Based Learning:
The second feature, prioritizing evidence, is included at 100%, but primarily in a structured, teacher-directed manner (mean = 1.61). Students do not collect or analyze data independently, limiting their ability to engage with scientific inquiry.
Formulating Explanations:
The third feature, where students formulate explanations from evidence, is included at 99.2% with a mean of 1.72, indicating a moderately teacher-centered approach. Activities often provide specific evidence and guided questions.
Connecting to Scientific Knowledge:
The fourth feature is included in 98.5% of activities (mean = 1.82), showing that connections are often guided by the teacher, which restricts students from exploring concepts independently.
Communication Skills:
The fifth feature, communicating and justifying explanations, is high at 99.1% but remains teacher-directed (mean = 1.58), limiting students' opportunities to develop their communication skills effectively.
Grade-Level Variations:
While all grades (1-6) mostly reflect a teacher-centered approach, higher grades (4-6) show some activities at levels 3 and 4, indicating a gradual shift towards more student-centered inquiry.
Discipline-Specific Findings:
Overall, biology textbooks include inquiry features more frequently than physics and chemistry, with Feature 1 being the least represented across disciplines.
Recommendations for Improvement:
The study calls for a balance between teacher-centered and student-centered approaches in curriculum materials. Textbooks should include open-ended questions and prompts that encourage critical thinking and evidence-based reasoning.
Role of Teachers:
Teachers play a crucial role in facilitating a student-centered inquiry process. While textbooks can provide guidance, they cannot replace the nuanced understanding that teachers develop about their students' needs.
In conclusion, the study underscores the necessity of enhancing inquiry-based learning in primary science education in Bahrain, advocating for materials that support higher-order thinking, independent investigation, and a more balanced approach to teaching scientific inquiry.

8. Conclusion and Recommendations

The study analyzes the coverage of five essential features of scientific inquiry skills in primary school science textbooks and workbooks in Bahrain, as aligned with the US National Science Education Standards (NSES). Key findings and recommendations include:

Teacher-Centered Approach:
The analysis of 12 science textbooks and workbooks shows a predominant teacher-centered approach, where students are often provided with questions, procedures, and expected outcomes, limiting opportunities for developing scientific inquiry skills.
Guidance for Inquiry:
Primary school students need varying levels of guidance depending on their grade. Younger students (grades 1-3) require more structured support, while older students (grades 4-6) can engage in more independent inquiry, although teacher guidance remains important.
Effective Teaching Strategies:
Teachers should provide clear guidelines, gradually shift responsibility to students, encourage collaboration, and incorporate diverse resources and technology. This approach helps enhance understanding and fosters critical thinking skills.
Supplementing Resources:
Teachers are encouraged to design additional inquiry-based activities that align with the essential features of scientific inquiry. Revising existing textbooks to include more open-ended questions and higher-level inquiry opportunities is also recommended.

Curriculum Improvement:
The current science curriculum requires continuous evaluation and improvement to better align with inquiry-based learning principles. This includes regular reviews of instructional materials to ensure they support higher-order inquiry skills.
Professional Development:
Providing professional development opportunities for teachers can enhance their understanding and implementation of inquiry-based instruction, facilitating a more conducive learning environment.
Future Research Directions:
Future studies should explore the implementation of scientific inquiry from teachers' perspectives, analyze middle school resources, and assess the alignment of various science disciplines with inquiry standards.
In summary, the study emphasizes the need for a shift towards more student-centered approaches in Bahraini primary science education, along with ongoing curriculum evaluation, teacher training, and the incorporation of higher levels of inquiry in educational materials. This will better prepare students for scientific literacy and engagement in the modern world.

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