

Analysis and Design of a Multidirectional Scientific Inquiry Model (MSIM) Based on Existing Inquiry-Based Tasks (IBT)

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Abstract The emerging research and limited frameworks that define and evaluate scientific inquiry have led this study to develop a designed model, which aims to provide a structured framework for crafting tasks to enhance the scientific process of authentic inquiry. The study employed a mixed-methods convergent approach to investigate the qualitative and quantitative aspects of existing inquiry-based tasks found in learning modules. In the analysis and design of the proposed model, the study identified three essential inquiry trends (introduction, investigation, and communication), comprising 6 Phases and 16 Sub-phases. The study also reveals the process of scientific inquiry in iterative feedback loops, characterizing the implementation process of a complete task. Furthermore, the proposed model provides a structured yet flexible framework for conducting a dynamic and authentic inquiry.

Keywords: *Multidirectional Model, Scientific Inquiry, and Inquiry-Based Tasks*

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1. Introduction

Scientific literacy has become vital for addressing contemporary challenges, including technological advancements, environmental issues, and health concerns. By actively engaging in inquiry-based learning, students deepen their understanding of science and develop critical thinking skills essential for navigating real-world problems. Students' participation in science initiatives enhances understanding through hands-on learning, which emphasizes that targeted strategies for scientific literacy equip students to address societal challenges [2-30]. Technology's role in fostering scientific literacy is also significant. Early exposure to science and technology enables students to develop problem-solving skills and comprehend the impact of technology on society [21]. Teaching materials focused on sustainability further strengthen students' readiness to tackle environmental issues [3]. In health education, inquiry-based and computational approaches enhance students' ability to address health-related and technological challenges [16,17,18,19,20]. Ultimately, scientific literacy empowers students to become informed, engaged citizens capable of participating in civic discourse. Integrating scientific, technological, and societal perspectives in education fosters a well-rounded scientific literacy that empowers

students to make informed decisions in personal and societal contexts [25,26,27,28,29,30].

This study examines essential themes and qualities of existing inquiry-based tasks to propose a model. In science education, inquiry-based tasks face significant challenges, mainly due to the limited availability of inquiry-based materials. This shortage has led educators to seek more practical resources, with only 15% of class time dedicated to inquiry activities [1-32] [19-33]. Calls for curricular transformation emphasize the need for instructional materials that support inquiry learning [6]. However, the prevalent use of expository materials still limits the perception of science as an investigative process [15]. The evaluation process also presents challenges; the current assessment system lacks clarity and objectivity, with limited tools for evaluating the distinct features of inquiry-based learning [24]. Despite the benefits of this approach, limitations in assessing and implementing it remain a barrier to fully realizing its potential.

Moreover, research indicates that inquiry-based instruction can enhance student achievement; however, studies on teachers' actual implementation of scientific inquiry are scarce [11,12,13]. Teachers face challenges in adopting inquiry-based learning, including limited resources, lack of training, and practical constraints [7-19] [20,21,22]. Although inquiry-based methods are recognized for improving science teaching, teachers often revert to traditional approaches [5,6,7,8]. Moreover, few

teachers utilize this approach due to these challenges [27].

Additionally, research remains limited to frameworks that effectively define and evaluate scientific inquiry [17-24] [25,26,27]. Thus, the study addressed this gap through the proposed model, which aims to enhance the evaluation process, establish relationships among its core features, and provide a framework for the task construction that promotes authentic inquiry. The study has three specific objectives: (1) to identify distinct features and structural processes evident in learning module, (2) to determine how existing tasks adhere to quality and authentic inquiry, (3) to graph the key characteristics and features of inquiry-based learning that are necessary in a model, designed holistically for task construction to facilitate authentic inquiry. This study employed a mixed-methods convergent design to analyze existing inquiry-based tasks. Qualitative data included an analysis of inquiry tasks. In contrast, quantitative data were analyzed by dimension to dig into the qualitative information and determine the extent to which learning materials promote quality inquiry tasks. Integrating these findings provides a comprehensive understanding of scientific inquiry, offering valuable insights into tasks that can help improve scientific literacy. This study addresses key gaps in the implementation and evaluation of scientific inquiry, establishing a model for constructing inquiry tasks and processes to enhance understanding of scientific inquiry.

2. Theoretical Framework

In this study, the research methodology identified two key elements: philosophical assumptions and methodological procedures. These components collectively constitute the research approach, which serves as the study's blueprint. The research approach is grounded in a philosophical foundation, employs various research designs, and utilizes specific methodologies [10]. This conceptualization is illustrated in Figure 1, which depicts the relationship among these elements. It highlights the significance of a philosophical worldview, aligning it with the research design and implementing specific methodologies.

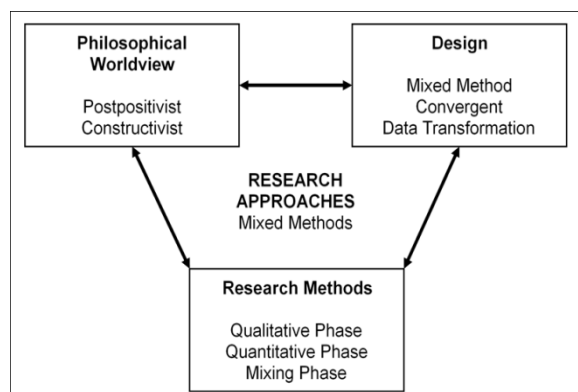


Figure 1. Research Approach

This study examines the components of scientific inquiry, focusing on existing inquiry-based tasks, while excluding related approaches, such as discovery learning,

game-based learning, problem-based learning, and project-based learning. This exclusion ensures the clarity and practical applicability of the study's outcomes. By reducing its scope, the study aims to create a designed model that provides actionable data for educators and instructional designers, thereby facilitating the development of inquiry-based activities and materials.

The proposed model centers on breaking down the scientific process into smaller, interrelated units known as inquiry phases. These phases guide students, emphasizing key aspects of scientific thinking in a cohesive inquiry cycle. The development process emphasizes the sequencing, interdependence, and necessity of its phases, with data analysis serving as its foundation. This analysis is based on essential inquiry tasks, including the application of scientific concepts.

Using an Input-Process-Output (IPO) model, the study follows a path from needs analysis and review of existing inquiry-based tasks to graphing essential features. The input phase captures scientific tasks; the process involves data analysis, and the output results in a designed model aimed at providing a scientific process for crafting tasks or task construction that helps promote authentic inquiry.

2.1. Qualitative Phase

Rooted in constructivist principles, scholars such as John Dewey advocate for student-centered approaches that prioritize active engagement. This philosophy informed the design of the proposed prototype model, which incorporates conceptual components, including the inquiry cycle and its phases. Each phase consists of sub-phases to guide inquiry activities [28]. The designed model aimed to promote students' engagement in inquiry tasks and dynamic teacher-student interactions, emphasizing Dewey's belief in sustained inquiry as a process of active questioning, exploration, and evidence-based conclusions [18].

2.2. Quantitative Phase

This study is grounded in a postpositivist philosophical perspective and adopts a deterministic approach, suggesting that causes likely determine effects, thereby justifying a systematic examination of causal influences. Reflecting postpositivism's reductionist approach, the study deconstructs the complexities of inquiry-based learning into specific variables for detailed analysis [4]. With an emphasis on objectivity and empirical measurement, quantitative methods are employed to assess the frequency of scientific tasks [29]. This deductive approach, anchored in hypothesis testing, supports the development of the proposed model by providing empirical evidence to reinforce the study's qualitative findings.

2.3. Merging Phase

The primary objective of this study is to design a model that includes the identified phases, sub-phases, structures, qualities, cycles, and pathways. The designed model is constructed based on qualitative and quantitative analyses of essential features and quality, as determined by existing tasks constructed.

The study examined the relationships among the components of scientific inquiry by employing the concept of Graph Theory [33]. In this context, the graphs consist of nodes and edges, where nodes represent phases and sub-phases of inquiry, and edges denote the connections between them. The direction indicates the flow from one node to another. These graphs illustrate the pathways and sequences of inquiry phases, highlighting the cyclical nature of the inquiry process.

3. Methodology

This study employed a convergent mixed-method design to collect and analyze quantitative and qualitative data separately and then compare the results to assess their consistency. This approach acknowledges that qualitative and quantitative data offer distinct types of information, and their convergence is essential for validating findings. The research design is illustrated in Figure 2. The data analysis process consists of three phases. First, the qualitative data were coded and organized into specific to broader themes. Second, the quantitative data was analyzed for statistical results. The third phase involved integrating the two datasets. The researcher then combined these transformed qualitative measures with the quantitative data for a comprehensive analysis [10].

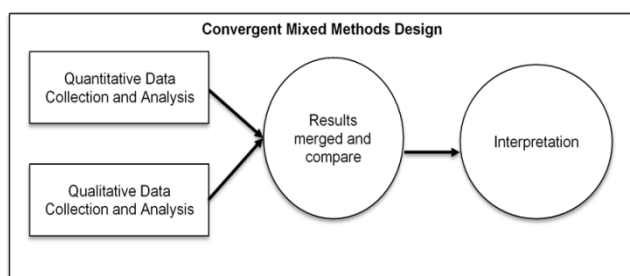


Figure 2. Convergent mixed-method design

3.1. Research Procedure

The study begins by concurrently collecting quantitative and qualitative data, treating each type of data collection as equally important and independent. Next, the researcher analyzed each data set using standard quantitative and qualitative methods. Once the initial results are obtained, the researcher proceeds to the merging phase, where the results are compared or transformed to facilitate further analysis. Finally, the researcher interpreted how the two sets of results converge or diverge, assessing their relationship and how they contributed to an enhanced understanding of the study's overall purpose [9].

3.1.1. Qualitative Procedure

The researcher employed qualitative data collection through document analysis [10]. The researcher focused on collecting qualitative data by analyzing existing inquiry-based tasks. The qualitative analysis aims to build substantial data needed to frame the scientific inquiry task process. The results were analyzed to identify the elements of phases, sub-phases, qualities, structure, paths,

and cycles. This was achieved by first analyzing the individual scientific tasks to isolate unique characteristics and then analyzing the scientific inquiry to generate an initial design of the prototype model based on the qualitative data. Unique characters must be established to create an elemental unit of phases, sub-phases, structure, and qualities, then knotting each unit to frame cycles and pathways.

3.1.2. Quantitative Procedure

The researcher aimed to quantify the qualitative data by measuring the inquiry-based tasks inherent in learning modules. The researcher analyzed Grade 7 chemistry learning modules to investigate how these tasks resemble scientific inquiry. This study utilized the Inquiry-Based Tasks Analysis Inventory (ITAI) to quantify the qualitative data from the analysis of learning modules, measuring the essential inquiry-based tasks. The instruments were adopted from the study of Liu and Yang (2016) [23].

3.1.3. Merging Procedure

Qualitative and quantitative data were collected simultaneously in the study's merging phase. The primary purpose of this phase is to guide the study and provide a secondary database that serves as a supporting role in the procedures. Given less priority, secondary quantitative data is embedded or nested within the predominant qualitative data. The collection and analysis of quantitative data were built upon the results of the initial qualitative data, with a focus on thorough analysis. Data mixing occurs when the initial qualitative results inform the secondary quantitative data collection. Thus, the two forms of data are separate but connected [9]. To frame the scientific inquiry, the data gathered were analyzed to identify the core elements of phases, sub-phases, structure, qualities, cycles, and pathways of the scientific inquiry. This process was used to build the model.

4. Results and Discussion

4.1. Qualitative Phase

Based on the analysis of existing inquiry-based tasks, 6 Phases were identified based on the inquiry tasks' structural sequence: orientation, conceptualization, exploration, experimentation, discussion, and conclusion; and 19 Sub-phases, namely contextual, directional, procedural, problem statement, guide questions, hypothesis generation, data gathering, data organization, data analysis, data interpretation, evaluation, reflection, prediction, synthesis, implication, and recommendation. All six phases were condensed into only three essential Trends (introduction, scientific investigation, and communication), as this approach facilitates the presentation of the entire inquiry-based learning more effectively and avoids complex and challenging learning processes for learners [12]. The initial list was reduced, not by eliminating any particular phase, but by conducting an in-depth analysis, as described earlier, to group similar phases together.

Table 1. Structure of Inquiry-Based Tasks

Introduction of Tasks						Scientific Investigation				Communication Of Results					
Orientation			Conceptualization			Exploration	Experimentation			Discussion			Conclusion		
Contextual	Directional	Procedural	Problem Statement	Guided Questions	Hypothesis Generation	Planning				Evaluation	Reflection	Prediction	Synthesis	Implication	Recommendation
						Preparation									
						Observation									
						Data Gathering	Data Organization	Data Analysis	Data Interpretation						

4.2. Quantitative Phase

The quality of existing inquiry-based tasks was evaluated based on three dimensions of Liu and Yang (2016) [23]: scientific concepts, scientific skills, and scientific inquiry.

Table 2. Structure of Inquiry-Based Tasks

Scientific Concept	Scientific Skills	Scientific Inquiry
Learning Objectives Core Ideas	Observing	Questions & Hypothesis No Single Set of Methods Questions Guide Procedure Scientists Influence Results Procedure Influence Results Conclusions & Data Data and Evidence Explanation
	Inferring	
	Measuring	
	Communicating	
	Classifying	
	Predicting	
	Controlling Variables	
	Defining Operationally	
	Formulating Hypothesis	
	Interpreting Data	
	Asking Questions	
	Formulating Models	
94%	33%	70%

The results indicate a high level of alignment in scientific concepts, with a scoring probability of 94%, demonstrating effective support for students in constructing and comprehending scientific principles. This strong coherence ensures systematic and consistent reinforcement of knowledge, promoting a deeper understanding of scientific concepts. However, the development of scientific skills presents a challenge, as the scoring probability is 33%, reflecting an imbalance in the use of inquiry process skills. Specific skills, such as observation and inference, may be overemphasized, while others are underutilized, leading to gaps in students' mastery of the scientific inquiry process. A more balanced instructional approach is necessary to ensure the comprehensive development of all essential skills. Additionally, the assessment of scientific inquiry reveals a 70% scoring probability, indicating that students have different opportunities to engage in a full spectrum of inquiry-based tasks. Learners are given valuable opportunities to engage in activities such as asking questions, planning investigations, analyzing results, and forming conclusions based on evidence. Overall, while learning modules effectively support the comprehension of scientific concepts, improvements are needed to foster scientific skills, thereby enhancing students' overall scientific literacy.

4.3. Merging Phase

The study revealed that the trends identified in Phase 1

are consistent with the three goals of an inquiry-based approach and principles [23]. Phase 1 emphasized the structural components and procedures necessary for task formation, while Phase 2 focused on the quality of well-designed tasks within learning modules, both of which were found to be crucial for practical task completion.

The convergence of the results from Phase 1 and Phase 2 has led to the discovery of a unidirectional trend in task construction. The trend is characterized by two components: quality and structure. The quality of inquiry-based tasks has three key elements: alignment, balance, and guidance. The second component comprises three elements: task introduction, scientific investigation, and communication of results. Each component flows in a zigzag pattern, illustrating a procedural process for crafting a task based on quality and structure, resulting in a complete and authentic task.

The unidirectional trend in task construction can serve as a process for crafting tasks that promote authentic inquiry with the necessary elements for independent design. The utilization of the mode flow in a zigzag pattern starts with the alignment of the lesson objectives to the learning competencies; second is the structures for orientation and conceptualization for specific learning targets; third is the arrangements of process skills for balanced mastery of skills, fourth is the scientific investigation that provides a learning environment that allows students to explore and experiment. Fifth, it includes pertinent and well-designed questions to guide the investigation. The guidance provided by these scientific questions enables students to communicate their results through discussion and conclusion, concluding the model.

Moreover, two unique inquiry-based paths (Path A & B) were found, each providing organized yet customizable sequences for scientific discovery. Path A prioritized exploratory learning, allowing students to repeatedly improve their study topic, whereas Path B took a hypothesis-driven approach that included structured experiments. The presence of feedback loops along these channels revealed that inquiry is a dynamic process with various entry points and iterative refinements. The study also revealed recurring patterns within these inquiry lines, emphasizing the cyclical nature of scientific exploration. Cycles A and B promoted ongoing knowledge development by recurrent data analysis, whereas Cycles C and D enabled systematic hypothesis testing. The emphasis on communication at all stages highlighted the significance of scientific discourse in knowledge creation. These findings demonstrate that organized yet flexible inquiry models enhance conceptual knowledge and scientific reasoning, making them a valuable foundation

for science education. Ultimately, the study developed a model that integrates these features into a practical framework for designing assignments that promote authentic inquiry, thereby ensuring that students actively participate in the scientific process rather than passively

receiving information.

Converging all results from qualitative and quantitative data paved the development of the Multidirectional Scientific Inquiry Model (MSIM).

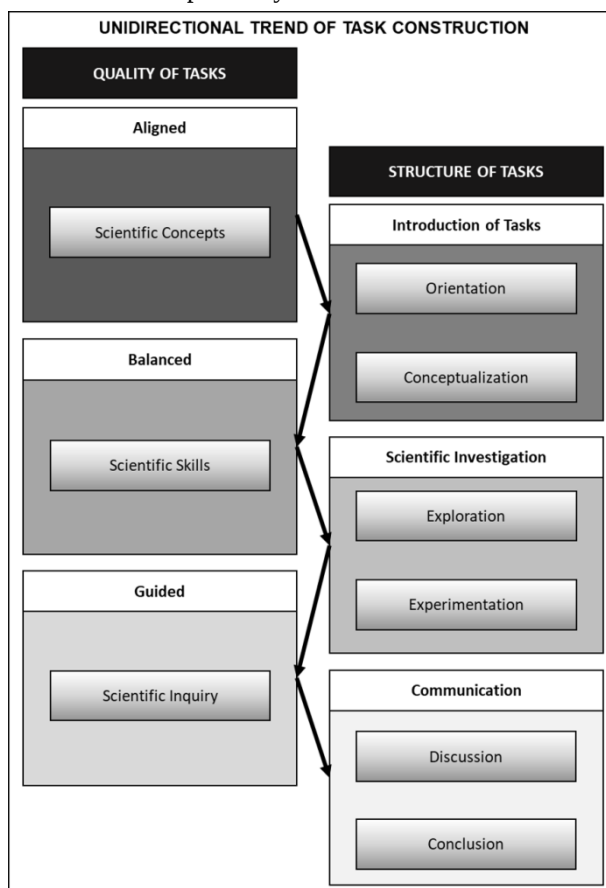


Figure 3. Illustrations of the Unidirectional Trends of Task Construction



Figure 4. Illustrations of the Multidirectional Scientific Inquiry Model

The model provides a structured yet flexible framework for conducting a dynamic and authentic inquiry. It establishes a structured yet dynamic model that transforms how scientific inquiry is conducted. At its core lie three interdependent structures: guided scientific inquiry, aligned scientific concepts, and balanced scientific skills. This triadic foundation arranges a continuous union of

knowledge, skill application, and investigative depth. Unlike traditional linear models, the designed model redefines scientific methodology with a nonlinear, cyclical, and multidirectional approach. It integrates key trends (introduction, investigation, and communication) while embedding iterative feedback loops that continuously refine the inquiry process. The bidirectional arrows and outward progression from phases to subphases ensure adaptability, responsiveness, and precision in scientific exploration and experimentation. By incorporating multiple pathways and multidirectional transitions, the model ensures a comprehensive, adaptive, and reflective scientific process, fostering deep understanding and promoting critical thinking.

5. Conclusions

The inquiry-based tasks subjected to analysis generally show a complete task from the orientation phase to the communication phase; however, based on dimensional scoring, there is less authentic inquiry. Thus, this study concluded that structure and quality must be considered in task construction. These two factors served as a building block for the design of the proposed model, a process designed to craft tasks that promote authentic inquiry with the elements necessary for independent design.

Furthermore, the value of a synthesized model lies in the possibility that it could form the basis for a general structure of inquiry-based tasks on learning materials.

Recommendations

The proposed model can be applied widely in designing inquiry tasks for science materials to facilitate investigation and learning. In this way, the inquiry-based learning model supports teachers and designers in analyzing what learners need as input at each stage and the expected output.

List of Abbreviations

Department of Education (DepEd)
 Inquiry-Based Learning (IBL)
 Inquiry-Based Tasks (IBT)
 Inquiry-Based Tasks Analysis Inventory (ITAI)
 Multidirectional Scientific Inquiry Model (MSIM)

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