

1 **Meaningful Learning Through Scientific Experiments: Its Impact on Learning Skills** 2 **and Information Processing Among Elementary School Students in Science Education.**

3 **Abstract**

4 This study investigated the impact of meaningful learning through inquiry-based scientific
5 experiments on the development of learning skills and information-processing abilities
6 among elementary school students in science education. The study was motivated by
7 contemporary educational trends emphasizing active learning, critical thinking, and
8 meaningful engagement with scientific concepts rather than traditional memorization-based
9 instruction.

10 A quasi-experimental design was employed involving 61 fifth-grade students from an
11 elementary school in Nazareth. Participants were divided into an experimental group (n =
12 30), which received instruction through inquiry-based learning and scientific experiments,
13 and a control group (n = 31), which received traditional instruction. Data were collected using
14 pre- and post-achievement tests designed according to Bloom's Taxonomy and measuring
15 multiple cognitive levels, including remembering, understanding, application, analysis, and
16 inference.

17 The findings indicated significant improvements in the performance of students exposed to
18 inquiry-based scientific experimentation compared with those taught through traditional
19 methods. Students in the experimental group demonstrated stronger academic achievement,
20 enhanced analytical abilities, improved scientific interpretation, and more effective
21 information-processing skills. Moreover, classroom observations revealed higher levels of
22 participation, motivation, and engagement among students in the experimental group.

23 The study concludes that meaningful learning through scientific experimentation represents
24 an effective pedagogical approach for enhancing science learning at the elementary level. The
25 findings support the integration of inquiry-based instructional practices into science curricula
26 and highlight the importance of providing teachers with professional development
27 opportunities related to active and experiential learning strategies.

28 **Keywords:** Meaningful Learning, Inquiry-Based Learning, Scientific Experiments,
29 Information Processing, Learning Skills, Science Education, Elementary Education

30 **1. Introduction**

31 Educational systems worldwide have undergone substantial transformations in response to
32 rapid scientific, technological, and social developments. Contemporary educational reforms
33 increasingly emphasize the development of higher-order thinking skills, problem-solving
34 abilities, and meaningful engagement with knowledge rather than the passive acquisition of
35 information. Consequently, educational researchers and practitioners have sought
36 instructional approaches that place learners at the center of the educational process and
37 encourage active participation in knowledge construction.

38 Meaningful learning, originally proposed by Ausubel (1968), is among the most influential
39 educational approaches supporting deep understanding and long-term knowledge retention.
40 Meaningful learning occurs when learners successfully connect new information with
41 existing cognitive structures, resulting in enhanced comprehension and application of
42 knowledge in various contexts. In science education, meaningful learning is particularly
43 important because scientific concepts often require learners to understand relationships,
44 analyze evidence, and apply knowledge to real-world situations.

45 Inquiry-Based Learning (IBL) represents one of the most effective applications of meaningful
46 learning. Through inquiry activities and scientific experimentation, students engage directly
47 in observation, investigation, hypothesis testing, and evidence-based reasoning. Such
48 experiences encourage learners to construct scientific knowledge actively rather than receive
49 it passively from teachers.

50 Despite the growing recognition of inquiry-based learning, traditional teaching methods
51 continue to dominate many science classrooms. These methods often emphasize
52 memorization and factual recall while providing limited opportunities for students to develop
53 critical thinking and information-processing skills. As a result, students may struggle to
54 transfer scientific knowledge to authentic contexts or develop the competencies required for
55 lifelong learning.

56 Accordingly, the present study seeks to investigate the effectiveness of meaningful learning
57 through scientific experiments in enhancing learning skills and information-processing
58 abilities among elementary school students. Specifically, the study examines whether inquiry-
59 based scientific experimentation can improve academic achievement and cognitive
60 development compared with traditional instructional approach

61 **2. Literature Review**

62 **2.1 Meaningful Learning in Science Education**

63 Meaningful learning is a fundamental educational approach that emphasizes the integration of
64 new knowledge with learners' existing cognitive structures. According to Ausubel (1968),
65 learning becomes meaningful when students actively connect new concepts with prior
66 experiences, leading to deeper understanding and long-term retention. Unlike rote
67 memorization, meaningful learning promotes conceptual understanding, critical thinking, and
68 the ability to transfer knowledge to new situations.

69 In science education, meaningful learning is particularly important because scientific
70 knowledge is built upon relationships among concepts, observations, and evidence-based
71 reasoning. Students who engage in meaningful learning are more likely to understand
72 scientific phenomena, analyze complex information, and apply scientific concepts to
73 everyday life. Research has consistently shown that meaningful learning environments
74 increase student engagement, motivation, and academic achievement while fostering higher-
75 order thinking skills.

76 **2.2 Inquiry-Based Learning**

77 Inquiry-Based Learning (IBL) is a learner-centered instructional approach that encourages
78 students to construct knowledge through investigation, questioning, experimentation, and
79 reflection. Rather than receiving information passively, students actively participate in the
80 learning process by exploring scientific questions and seeking evidence-based explanations.

81 The inquiry process typically involves identifying a problem, formulating hypotheses,
82 collecting data, analyzing evidence, and drawing conclusions. Through these stages, students
83 develop scientific reasoning skills and become more capable of independent learning.
84 Previous studies have demonstrated that inquiry-based learning enhances academic
85 achievement, critical thinking, problem-solving abilities, and scientific literacy.

86 Moreover, inquiry-based learning aligns closely with constructivist learning theory, which
87 views knowledge as actively constructed through interaction with the environment. This
88 theoretical foundation supports the use of inquiry-oriented activities as effective tools for
89 promoting meaningful learning experiences.

90 **2.3 Scientific Experiments as a Learning Strategy**

91 Scientific experiments represent one of the most effective instructional strategies in science
92 education. Experiments provide students with opportunities to observe scientific phenomena
93 directly, test hypotheses, and analyze outcomes through systematic investigation.

94 Practical experimentation contributes to transforming abstract scientific concepts into
95 concrete experiences, thereby enhancing conceptual understanding. Through participation in
96 experimental activities, students develop scientific process skills, including observation,
97 classification, measurement, interpretation, and evidence-based reasoning.

98 In addition to cognitive benefits, scientific experiments increase students' motivation and
99 engagement. Hands-on activities create interactive learning environments that encourage
100 collaboration, communication, and active participation. Consequently, scientific
101 experimentation is widely recognized as an essential component of effective science
102 instruction.

103 **2.4 Information Processing Skills**

104 Information-processing skills refer to the cognitive abilities that learners employ when
105 receiving, organizing, analyzing, interpreting, storing, and applying information. These skills
106 are fundamental for successful learning in modern educational contexts because they enable
107 students to engage critically with knowledge rather than merely memorize information.

108 Key information-processing skills include classification, comparison, analysis, interpretation,
109 inference, and decision-making. Students who possess strong information-processing abilities
110 are better equipped to solve problems, evaluate evidence, and make informed decisions.

111 Science education provides an ideal context for developing these skills because scientific
112 inquiry requires learners to collect data, identify patterns, interpret findings, and draw logical
113 conclusions. Consequently, instructional approaches that emphasize inquiry and
114 experimentation are particularly effective in enhancing information-processing abilities.

115 **2.5 Previous Studies**

116 Numerous studies have examined the impact of inquiry-based learning and scientific
117 experimentation on students' academic achievement and cognitive development. Khan et al.
118 (2021) reported that inquiry-based learning significantly improved scientific thinking and
119 academic performance among elementary school students. Similarly, Duran and Dökme
120 (2016) found that students exposed to inquiry-based instruction demonstrated superior
121 critical-thinking skills compared with those taught using traditional methods.

122 Ruiz-Mallén et al. (2020) emphasized the positive role of collaborative inquiry activities in
123 developing communication, analytical thinking, and critical reasoning. Furthermore, Andi et
124 al. (2023) demonstrated that scientific experimentation contributed significantly to students'
125 understanding of scientific concepts and increased classroom engagement.

126 Although previous research has established the effectiveness of inquiry-based learning in
127 various educational contexts, limited studies have specifically examined the relationship
128 between meaningful learning, scientific experimentation, and information-processing skills
129 among elementary school students in Arab educational settings. Therefore, the present study
130 seeks to address this gap by investigating the impact of meaningful inquiry-based learning
131 through scientific experiments on learning skills and information processing among
132 elementary school students.

133 **3. Methodology**

134 **3.1 Research Design**

135 This study employed a quasi-experimental research design to investigate the effectiveness of
136 meaningful learning through inquiry-based scientific experiments in enhancing learning skills
137 and information-processing abilities among elementary school students. The quasi-
138 experimental approach was considered appropriate because it allowed the researcher to
139 compare the effects of two different instructional methods within a natural educational
140 setting.

141 The study involved two groups: an experimental group that received instruction through
142 inquiry-based learning and scientific experimentation, and a control group that received
143 traditional teacher-centered instruction. Both groups completed a pre-test before the
144 intervention and a post-test after the intervention to measure changes in academic
145 achievement and cognitive performance.

146 **3.2 Participants**

147 The study sample consisted of 61 fifth-grade students enrolled in an elementary school in
148 Nazareth during the 2024–2025 academic year. Participants were divided into two groups:

Group	Number of Students	Instructional Method	
Experimental Group	30	Inquiry-Based through Experiments	Learning Scientific

149

150 The sample was selected purposively based on the availability of suitable educational
151 conditions for implementing the instructional intervention.

152 **3.3 Research Variables**

153 **Independent Variable**

154 The independent variable was the implementation of meaningful learning through inquiry-
155 based scientific experiments.

156 **Dependent Variables**

157 The dependent variables included:

- 158 • Academic achievement in science.
- 159 • Learning skills.
- 160 • Higher-order thinking skills.
- 161 • Information-processing abilities.

162 **3.4 Research Instruments**

163 **The present study sought to answer the following research questions:**

164

165 **1. What is the effect of inquiry-based scientific experiments on academic achievement**
166 **among elementary school students in science education?**

167 **2. To what extent does inquiry-based learning contribute to the development of learning**
168 **skills among elementary school students?**

169 **3. What is the impact of inquiry-based scientific experimentation on students'**
170 **information-processing abilities?**

171 **4. Are there statistically significant differences between students taught through**
172 **inquiry-based scientific experiments and those taught through traditional instructional**
173 **methods?**

174

175 **Research Hypotheses**

176

177 **H1: There are statistically significant differences in post-test achievement scores**
178 **between the experimental group and the control group in favor of the experimental**
179 **group.**

180

181 **H2: Students exposed to inquiry-based scientific experiments demonstrate higher levels**
182 **of learning skills than students receiving traditional instruction.**

183

184 **H3: Inquiry-based learning significantly improves information-processing abilities**
185 **among elementary school students.**

186

187 **Conceptual Framework**

188

189 **The conceptual framework of this study is grounded in meaningful learning theory and**
190 **constructivist learning principles. It assumes that inquiry-based scientific experiments**
191 **provide students with opportunities to actively engage in the learning process through**
192 **observation, questioning, investigation, and evidence-based reasoning. Such engagement**
193 **enhances learning skills, promotes deeper cognitive processing, and strengthens**
194 **information-processing abilities. Consequently, these improvements contribute to**
195 **higher academic achievement and better understanding of scientific concepts.**

196

197 **Enhanced Description of Research Instrument**

198

199 **The achievement test consisted of 25 multiple-choice items distributed across Bloom's**
200 **Taxonomy cognitive levels. Five items measured remembering skills, five assessed**
201 **understanding, five evaluated application, five measured analytical thinking, and five**
202 **focused on inference and interpretation. The total score ranged from 0 to 100 points.**
203 **The test was designed to evaluate both lower-order and higher-order cognitive skills**
204 **associated with science learning.**

205

206 **Validity of the Instrument**

207

208 **To establish content validity, the research instruments were reviewed by five experts**
209 **specializing in science education, curriculum development, educational measurement,**
210 **and instructional methodologies. Their recommendations regarding item clarity,**
211 **content relevance, and cognitive appropriateness were incorporated into the final**
212 **version of the instrument.**

213

214 **Expanded Discussion**

215

216 **The findings of the present study can be interpreted through the lens of Ausubel's**
217 **Meaningful Learning Theory, which emphasizes the importance of linking new**
218 **information to existing cognitive structures. Inquiry-based scientific experiments**

219 provided students with meaningful learning experiences that facilitated conceptual
220 understanding and long-term retention.

221

222 Furthermore, the findings align with constructivist theory, which views learning as an
223 active process of knowledge construction. Through experimentation and investigation,
224 students actively generated meaning from scientific experiences rather than receiving
225 information passively.

226

227 The results are also consistent with Piaget's theory of cognitive development, which
228 highlights the importance of active interaction with the environment in promoting
229 intellectual growth. Scientific experiments enabled students to explore, manipulate, and
230 interpret scientific phenomena, thereby supporting cognitive development.

231

232 Additionally, Vygotsky's social constructivist perspective helps explain the observed
233 improvements in learning skills and information processing. Collaborative inquiry
234 activities encouraged interaction, discussion, and shared problem-solving, which
235 contributed to deeper understanding and enhanced cognitive performance.

236 Achievement Test

237 A researcher-developed achievement test was used to assess students' learning outcomes
238 before and after the intervention. The test was designed according to Bloom's Taxonomy and
239 included items measuring:

- 240 • Remembering
- 241 • Understanding
- 242 • Application
- 243 • Analysis
- 244 • Inference

245 The test aimed to evaluate both basic cognitive skills and higher-order thinking abilities
246 related to science learning.

247 Inquiry-Based Instructional Unit

248 An instructional unit consisting of five inquiry-based science lessons was developed
249 specifically for the study. The unit incorporated:

- 250 • Scientific experiments
- 251 • Inquiry activities
- 252 • Active learning strategies
- 253 • Cooperative learning tasks

254 Students were encouraged to formulate questions, conduct experiments, collect data, analyze
255 results, and draw conclusions based on evidence.

256 **3.5 Validity and Reliability**

257 To ensure content validity, the research instruments were reviewed by specialists in science
258 education, curriculum design, educational measurement, and instructional methodologies.
259 Feedback provided by the experts was incorporated into the final version of the instruments.

260 Reliability was established through internal consistency procedures. The obtained reliability
261 coefficient indicated an acceptable level of consistency, supporting the use of the instruments
262 for educational research purposes.

263 **3.6 Procedures**

264 The study was conducted according to the following steps:

- 265 1. Reviewing relevant literature and previous studies.
- 266 2. Developing and validating research instruments.
- 267 3. Selecting participants and assigning them to experimental and control groups.
- 268 4. Administering the pre-test.
- 269 5. Implementing the inquiry-based instructional unit with the experimental group.
- 270 6. Teaching the control group using conventional instructional methods.
- 271 7. Administering the post-test following completion of the intervention.
- 272 8. Collecting and analyzing the data.
- 273 9. Interpreting the findings in relation to previous literature and theoretical perspectives.

274 **3.7 Data Analysis**

275 Data analysis was conducted using appropriate statistical procedures. Descriptive statistics
276 were calculated, including means and standard deviations. Comparative analyses were
277 conducted to examine differences between the experimental and control groups before and
278 after the intervention.

279 The level of statistical significance was set at $\alpha \leq .05$. Statistical analyses were performed
280 using standard educational research procedures to evaluate the effectiveness of the
281 instructional intervention.

282 **3.8 Ethical Considerations**

283 The study adhered to accepted ethical standards in educational research. Approval was
284 obtained from the school administration prior to data collection. Participants' information
285 remained confidential, and all collected data were used exclusively for research purposes.
286 Furthermore, the intervention posed no psychological or educational risks to participating
287 students.

288 **4. Results**

289 **4.1 Pre-Test Results**

290 To determine whether the two groups were equivalent before the intervention, descriptive
291 statistics were calculated for the pre-test scores.

292 **Table 1**
293 **Pre-Test Scores of the Experimental and Control Groups**

Group	N	Mean	SD
Experimental Group	30	64.21	6.34
Control Group	31	63.75	6.11

294
295 The results indicate that the mean scores of the experimental and control groups were very
296 similar prior to the implementation of the instructional intervention. This finding suggests
297 that the two groups were comparable at the beginning of the study.

298 **4.2 Post-Test Results**

299 Descriptive statistics were calculated for the post-test scores to examine the effectiveness of
300 inquiry-based scientific experimentation.

301 **Table 2**
302 **Post-Test Scores of the Experimental and Control Groups**

Group	N	Mean	SD
Experimental Group	30	87.43	5.28
Control Group	31	72.16	6.02

303
304 The results reveal substantial differences between the two groups following the intervention.
305 Students who participated in inquiry-based scientific experiments achieved considerably
306 higher post-test scores than students who received traditional instruction.

307 These findings suggest that meaningful learning through scientific experimentation
308 contributed positively to students' academic achievement and learning outcomes.

309 **4.3 Development of Learning and Information-Processing Skills**

310 In addition to academic achievement, qualitative classroom observations indicated notable
311 improvements among students in the experimental group. These improvements included:

- 312 • Enhanced analytical thinking.
- 313 • Improved scientific interpretation.
- 314 • Greater ability to organize information.
- 315 • Increased problem-solving competence.
- 316 • Higher levels of classroom participation and engagement.

317 Students exposed to inquiry-based learning demonstrated greater confidence in discussing
318 scientific concepts and applying scientific reasoning to unfamiliar situations.

319 Overall, the findings support the effectiveness of meaningful inquiry-based learning as an
320 instructional strategy for promoting both academic achievement and cognitive development
321 in science education.

322 **5. Discussion**

323 The purpose of this study was to investigate the effectiveness of meaningful learning through
324 inquiry-based scientific experiments in developing learning skills and information-processing
325 abilities among elementary school students. The findings revealed clear differences between
326 students who participated in inquiry-based scientific activities and those who received
327 traditional instruction.

328 The pre-test results indicated that both groups were comparable before the intervention,
329 suggesting that the differences observed in the post-test can be attributed primarily to the
330 instructional strategy employed during the study. This finding strengthens the internal
331 validity of the research design and supports the credibility of the results.

332 The substantial improvement demonstrated by the experimental group may be explained by
333 several educational factors. First, inquiry-based learning actively engages students in the
334 learning process. Rather than receiving information passively, students formulate questions,
335 conduct investigations, analyze observations, and draw evidence-based conclusions. Such
336 experiences promote deeper cognitive engagement and facilitate meaningful learning.

337 Second, scientific experiments transform abstract scientific concepts into concrete learning
338 experiences. This transformation enables students to construct knowledge through direct
339 interaction with scientific phenomena, thereby increasing understanding and retention. These
340 findings are consistent with Ausubel's theory of meaningful learning, which emphasizes the
341 integration of new knowledge with existing cognitive structures.

342 Third, inquiry-based learning promotes higher-order thinking skills. Students participating in
343 experimental activities were required to analyze data, interpret evidence, evaluate results, and
344 solve scientific problems. Consequently, they developed critical-thinking and problem-
345 solving abilities that contributed to their improved academic performance.

346 The findings also revealed noticeability improvement in information-processing skills among
347 students in the experimental group. Inquiry activities required learners to collect information,
348 organize observations, compare findings, identify relationships, and formulate conclusions.
349 These processes directly support the development of cognitive abilities associated with
350 information processing and scientific reasoning.

351 The results of the present study are consistent with previous research demonstrating the
352 effectiveness of inquiry-based learning in science education. Similar findings have been
353 reported by Duran and Dökme (2016), Ruiz-Mallén et al. (2020), and Khan et al. (2021), all
354 of whom found positive relationships between inquiry-based instruction, academic
355 achievement, and higher-order thinking skills.

356 Overall, the findings support contemporary educational perspectives advocating student-
357 centered instructional approaches that encourage exploration, experimentation, and active
358 participation in learning.

359 **6. Educational Implications**

360 The findings of this study have several important implications for educational practice.

361 First, science teachers should be encouraged to integrate inquiry-based scientific experiments
362 into classroom instruction to enhance students' understanding of scientific concepts and
363 improve learning outcomes.

364 Second, curriculum developers should design science curricula that emphasize meaningful
365 learning experiences and provide opportunities for scientific investigation and
366 experimentation.

367 Third, educational policymakers should support the implementation of active learning
368 approaches by providing schools with appropriate laboratory facilities, educational resources,
369 and professional development opportunities.

370 Fourth, teacher-training programs should focus on developing educators' competencies in
371 designing and implementing inquiry-based learning environments that promote critical
372 thinking and scientific literacy.

373 Finally, the findings suggest that meaningful learning approaches can contribute significantly
374 to preparing students for the challenges of the twenty-first century by developing analytical
375 thinking, problem-solving abilities, and lifelong learning skills.

376 **7. Limitations of the Study**

377 Despite the positive findings, several limitations should be acknowledged.

378 1. The study was conducted in a single elementary school, which may limit the
379 generalizability of the findings.

380 2. The sample size was relatively small and included only 61 students.

381 3. The study focused exclusively on fifth-grade students and therefore may not reflect
382 outcomes at other educational levels.

383 4. The intervention was implemented over a limited instructional period, which may not fully
384 capture long-term effects.

385 5. The study concentrated on science education and did not examine the applicability of
386 inquiry-based learning in other subject areas.

387 Future studies should address these limitations by including larger and more diverse samples,
388 multiple educational settings, and longer intervention periods.

389 **8. Recommendations for Future Research**

390 Based on the findings of this study, future research should consider:

391 1. Investigating the effectiveness of inquiry-based learning among middle and secondary
392 school students.

393 2. Examining the impact of scientific experimentation on learning outcomes in mathematics
394 and other academic subjects.

395 3. Conducting longitudinal studies to explore the long-term effects of meaningful learning on
396 academic achievement and cognitive development.

397 4. Exploring the relationship between inquiry-based learning and students' motivation, self-
398 efficacy, and creativity.

399 5. Comparing different models of inquiry-based learning to determine the most effective
400 instructional practices.

401 6. Investigating the role of educational technology in supporting inquiry-based scientific
402 learning environments.

403 **9. Conclusion**

404 The present study examined the effectiveness of meaningful learning through inquiry-based
405 scientific experiments in enhancing learning skills and information-processing abilities
406 among elementary school students in science education.

407 The findings demonstrated that students who participated in inquiry-based scientific activities
408 achieved higher levels of academic performance and exhibited stronger analytical,
409 interpretive, and information-processing skills than students taught through traditional
410 instructional methods.

411 The study highlights the importance of transforming science classrooms into active learning
412 environments where students engage in experimentation, exploration, and evidence-based
413 reasoning. Such environments promote meaningful learning experiences that contribute to
414 both academic success and cognitive development.

415 The results further support constructivist and meaningful learning theories, emphasizing that
416 students learn more effectively when they actively participate in knowledge construction
417 rather than merely receiving information passively.

418 In conclusion, inquiry-based scientific experimentation represents a powerful instructional
419 approach capable of improving science education and preparing students for the demands of
420 contemporary society.

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