ISSN 3025-2644

Scientific reasoning and objectivity in realia-based elementary science learning

Lilik Bangun Yunianto [1,*], Kartika Chrysti Suryandari [2], Septi Triyani [3]

Universitas Sebelas Maret, Surakarta, Indonesia
[1] bangoen_lb@student.uns.ac.id; [2] kartika77@staff.uns.ac.id*; [3] septitriyani@staff.uns.ac.id
* corresponding author

ARTICLE INFO

Article history
Received: May 21, 2026
Revised: June 10, 2026
Accepted: June 11, 2026

Keywords
Realia media
Scientific method
Scientific attitude
Science learning
Elementary school

ABSTRACT

The findings suggest that integrating claim-evidence-reasoning scaffolds into realia-based science instruction at the associating stage can strengthen students' objectivity and reasoning skills while fostering multiple scientific attitudes in the Indonesian elementary science curriculum. This study aims to (1) describe the preparation and implementation of realia media through the scientific method, (2) analyze fifth-grade students' scientific attitude profiles across five dimensions (curiosity, responsibility, independence, honesty, and objectivity), and (3) identify supporting and inhibiting factors. A qualitative-dominant mixed-methods case study was conducted at SDN 1 Wonogiri, a public elementary school in Wonogiri, Central Java, Indonesia. The participants included three classroom teachers and 297 fifth-grade students. Qualitative data from classroom observation and in-depth interviews were primary, complemented by descriptive data from a validated student response questionnaire, and were analyzed using the interactive model of Miles and Huberman. Four dimensions developed consistently, with positive responses from 88 to 100 percent, whereas objectivity remained the most vulnerable dimension, particularly at the reasoning stage. Supporting factors included the availability of authentic objects and material relevance to daily experience; inhibiting factors included limited instructional time and students' uneven reasoning capacity. The study provides a multidimensional profile of five attitudes, identifies reasoning capacity as strongly associated with objectivity, and reports a discrepancy between self-reported and observed objectivity. The findings imply that realia-based science instruction should incorporate claim-evidence-reasoning scaffolds at the associating stage to strengthen students' objectivity and reasoning skills while guiding teachers in designing learning activities that simultaneously foster multiple scientific attitudes within the Indonesian elementary science curriculum.

1. Introduction

Twenty-first-century elementary education places a premium on the development of scientific attitudes as the bedrock of scientific literacy and rational thinking. Scientific attitude encompasses curiosity, responsibility, independence, honesty, and objectivity as essential dispositions for learners when constructing knowledge about the natural and social world (Osborne et al., 2003). Within the curriculum in Indonesia, natural and social science is positioned as an integrative subject aimed at fostering the Indonesian student profile, particularly the dimensions of critical reasoning, independence, and faith in God Almighty (Faisal & Martin, 2019).

However, empirical observations indicate that natural and social science learning at the elementary level is still frequently dominated by lecture methods and abstract presentations of material that fail to engage students cognitively and affectively (Appleton, 2003; Kang & Keinonen, 2018). This condition is paradoxical given that fifth-grade learners are at the concrete operational stage and therefore require direct manipulation of authentic objects to construct scientific concepts (Piaget, 1972; Holstermann et al., 2010). Several studies have highlighted the gap between learning objectives that emphasize active processes and classroom practices that remain text-bound (Capps & Crawford, 2013; Roehrig & Kruse, 2005).

Realia media, defined as authentic objects from learners' surroundings, offer a strategic alternative for bridging concrete experience and abstract scientific concepts (Aiman et al., 2020; Braund & Reiss, 2006). The use of realia in science learning has been shown to enhance engagement, learning outcomes, and scientific literacy at the elementary level (Lalian et al., 2019; Belenky & Nokes, 2009). When integrated with the scientific method, namely observing, questioning, trying, reasoning, and communicating, realia media create authentic spaces for students to practice scientific processes (Minner et al., 2010; Zacharia & Olympiou, 2011).

Although the literature on realia and the scientific method has grown rapidly, most prior studies focus on one or two attitude dimensions, such as curiosity or learning outcomes (Parmiti et al., 2021; Rohaeti et al., 2020), and rarely examine the five dimensions simultaneously within the context of the curriculum in Indonesia. Comprehensive multidimensional studies that explore the interrelationships among curiosity, responsibility, independence, honesty, and objectivity are particularly scarce, especially for ecosystem topics in fifth grade. This gap creates room for novelty: not only describing each dimension separately, but also identifying which dimensions are strong, which are vulnerable, and what factors structurally differentiate them.

Equally important, accredited urban schools with diverse student backgrounds offer an instructive empirical setting that has been comparatively understudied. Many existing studies of scientific attitudes have focused on rural schools or schools with limited resources (Avery, 2013), so the dynamics of realia-based learning in urban schools with adequate facilities remain underexamined. SDN 1 Wonogiri, with the best accreditation and a history of pilot status for international standards, represents an ideal context for examining whether the alignment of facilities, teacher capacity, and student characteristics is sufficient to develop all dimensions of scientific attitude optimally. Preliminary observation and informal discussion with teachers at this school indicated that, despite adequate facilities and teacher capacity, natural and social science instruction on the ecosystem topic still leaned heavily on textbook exposition, and that students frequently stopped at describing observations rather than reasoning about the relationships among the components they observed. This locally grounded gap, rather than the literature alone, motivated the present case study and directed analytical attention to the reasoning and objectivity dimensions.

Prior studies have demonstrated the contribution of realia media to learning outcomes, but the objectivity dimension that requires advanced reasoning capacity has rarely been highlighted as a critical bottleneck. The novelty of this study lies in three contributions. First, a comprehensive multidimensional analysis of five scientific attitudes simultaneously across three parallel classes ($n = 297$). Second, the identification of a consistent association between objectivity and reasoning capacity that may serve as a leverage point for intervention. Third, the discrepancy analysis between self-report and observed behavior on the objectivity dimension, an issue rarely raised explicitly in earlier studies.

Consistent with the descriptive orientation of a case study, this study does not test the causal effect of an intervention but aims to (1) describe the preparation and implementation of realia media in natural and social science learning on ecosystem material through the scientific method, (2) analyze fifth-grade students' scientific attitude profiles across the five dimensions, and (3) identify the supporting and inhibiting factors of its implementation at SDN 1 Wonogiri. Accordingly, the study is guided by three research questions: (RQ1) How are realia media prepared and implemented through the five stages of the scientific method in natural and social science learning on the ecosystem topic? (RQ2) What are the profiles of students' scientific attitudes across the five dimensions, and which dimension is most vulnerable? (RQ3) What factors support and inhibit the implementation, and how are they related to the development of objectivity? The findings are expected to provide an empirical basis for designing reasoning-based realia teaching modules and to expand the literature on the implementation of the scientific method in the context of the Indonesian curriculum.

Ecosystem material was deliberately selected as the substantive focus for three reasons. First, ecosystem concepts are inherently relational and require students to reason about interactions among biotic and abiotic components, making them an ideal substrate for observing reasoning development. Second, ecosystem phenomena are readily accessible in the school environment through plants, soil, water sources, and small animals that constitute authentic realia. Third, ecosystem topics are prescribed in the phase C learning outcomes of the curriculum in Indonesia and thus carry policy relevance for fifth-grade natural and social science instruction (Faisal & Martin, 2019; Fensham, 2009).

2. Method

2.1. Research design

This study employed a qualitative-dominant mixed-methods case study design (Yin, 2018; Miles et al., 2014) aimed at exploring in depth the implementation of realia media through the scientific method and its relationship with students' scientific attitudes. More precisely, the study adopts an embedded single-case design in which a subordinate quantitative strand is nested within an overarching qualitative case, so that the numerical questionnaire results inform, rather than drive, the case interpretation. The design is qualitative-dominant because the core inferences are drawn from qualitative data (classroom observation and in-depth interviews), while closed-ended questionnaire data play an embedded, supporting role: they are used descriptively to profile attitude dimensions across classes and to triangulate, not to test hypotheses. This explicit framing resolves the apparent inconsistency between a case study orientation and the use of percentage-based questionnaire results, since the quantitative component is subordinate to and interpreted within the qualitative case (Yin, 2018). The research site was SDN 1 Wonogiri, an elementary school accredited A with a value of 97 and a history of pilot status as an international school. This urban institution was selected because it represents a school context with adequate facilities, a structured curriculum, and student heterogeneity that is relevant for examining the dynamics of realia-based learning.

2.2. Research subjects

Research subjects comprised three categories of informants: (1) the principal as a curriculum and policy informant, (2) three fifth-grade classroom teachers, namely the teachers of classes 5A, 5B, and 5C, as the main implementers of learning, and (3) 297 fifth-grade students (99 students per class) as primary subjects in the assessment of scientific attitude profiles. Informant selection used purposive sampling: the principal and the three teachers were chosen as key informants because of their direct role in planning and delivering the realia-based lessons, while the three intact fifth-grade classes were included in their entirety (a complete-enumeration approach within the case) so that the questionnaire profiled the whole fifth-grade cohort rather than a subsample. Inclusion criteria were direct involvement in natural and social science learning on the ecosystem topic during the observation period and willingness to participate, with informed consent obtained from teachers and parental assent for student participation.

2.3. Data collection and analysis

Data were collected through three principal techniques. First, non-participant classroom observation of fifteen natural and social science sessions across the three classes (five sessions per class), guided by an observation checklist focused on the five stages of the scientific method and the indicators of scientific attitude. Second, semi-structured in-depth interviews with the principal and the three teachers, covering planning, implementation, and constraints. Third, a closed-ended student response questionnaire comprising twenty statements (four per dimension) spanning the five dimensions of scientific attitude, completed by all 297 students. The questionnaire was adapted from validated elementary scientific-attitude instruments (Navarro et al., 2016; Wicaksono & Korom, 2023) and aligned with the observation checklist developed in line with observation-based attitude instruments for primary school (Kind et al., 2007). Consistent with the qualitative-dominant design, instrument trustworthiness was established through expert validation rather than statistical item analysis: the observation checklist, interview guide, and student response questionnaire were reviewed and validated by the supervising lecturers for representativeness, clarity, and alignment with the five attitude dimensions and the five stages of the scientific method. The credibility of the resulting data was then secured through source triangulation (principal, teachers, students) and method triangulation (observation, interviews, questionnaire), so that no single instrument carried the inferential weight alone. The mapping of variables, indicators, and instruments is presented in Table 1.

Table 1. Mapping of variables, indicators, and research instruments

Variable	Indicator	Instrument
Implementation Process	Five stages of the scientific method (observing, questioning, trying, reasoning, communicating)	Observation, interviews
Curiosity	Asking questions, exploring objects, seeking additional information	Questionnaire, observation
Responsibility	Completing tasks on time, taking care of media, accepting roles	Questionnaire, observation
Independence	Working without continuous instruction, taking initiative	Questionnaire, observation
Honesty & Objectivity	Reporting data as is, basing conclusions on evidence	Questionnaire, observation, interviews

The research procedure proceeded in four sequential phases. In the preparation phase, the researchers obtained school permission, developed and validated the instruments, and coordinated the observation schedule with the three teachers. In the implementation phase, the fifteen natural and social science sessions on the ecosystem topic were observed across the three classes while teachers delivered the realia-based lessons through the five stages of the scientific method. In the data-gathering phase, observation notes were recorded during each session, the questionnaire was administered to all 297 students at the end of the unit, and semi-structured interviews were conducted with the principal and the three teachers. In the analysis and verification phase, the data were reduced, displayed, and interpreted, and findings were confirmed with informants through member checking. Data analysis used the interactive model comprising four iterative activities: data condensation, data display, conclusion drawing, and verification (Miles et al., 2014). For the embedded quantitative component, questionnaire data were analyzed descriptively by calculating the percentage of positive responses per item and then aggregating them for each attitude dimension. To support interpretation, dimension percentages were categorized using a standard descriptive scale in which 85–100 percent denotes very high, 70–84 percent high, 55–69 percent moderate, 40–54 percent low, and below 40 percent very low; these categories are reported alongside the percentages to clarify what a given value indicates rather than to imply statistical inference. Data validity was strengthened through source triangulation (principal, teachers, students) and method triangulation (observation, interviews, questionnaires), and member checking was conducted by confirming findings with the three teacher informants to ensure interpretive accuracy. An audit trail of field notes, interview transcripts, and analytical decisions was maintained throughout the process (Nowell et al., 2017).

3. Results and Discussion

Teacher preparation began with the systematic development of teaching modules that integrated realia media into each stage of the scientific method. This preparation involved establishing learning objectives aligned with the Phase C learning outcomes, selecting ecosystem-related content that reflected the students' immediate environment, and identifying realia objects that satisfied the principles of authenticity, relevance, accessibility, and feasibility. The teachers also considered how the selected objects could be incorporated into learning activities to facilitate direct observation, questioning, evidence collection, and scientific reasoning. This finding is consistent with previous evidence indicating that well-structured teaching modules contribute significantly to the quality and effectiveness of concrete learning implementation at the elementary level (Davis & Krajcik, 2005; Bennett et al., 2007).

The preparation process emphasized coherence between the characteristics of the realia, the scientific learning stages, and the expected learning outcomes. Teachers could connect abstract ecosystem concepts with students' direct experiences, thereby creating opportunities for contextualized observation and evidence-based interpretation. The integration also provided a structured pathway for teachers to guide students from initial observation toward more systematic scientific inquiry, while maintaining alignment between instructional objectives, learning activities, and assessment. The conceptual framework is presented in Figure 1.

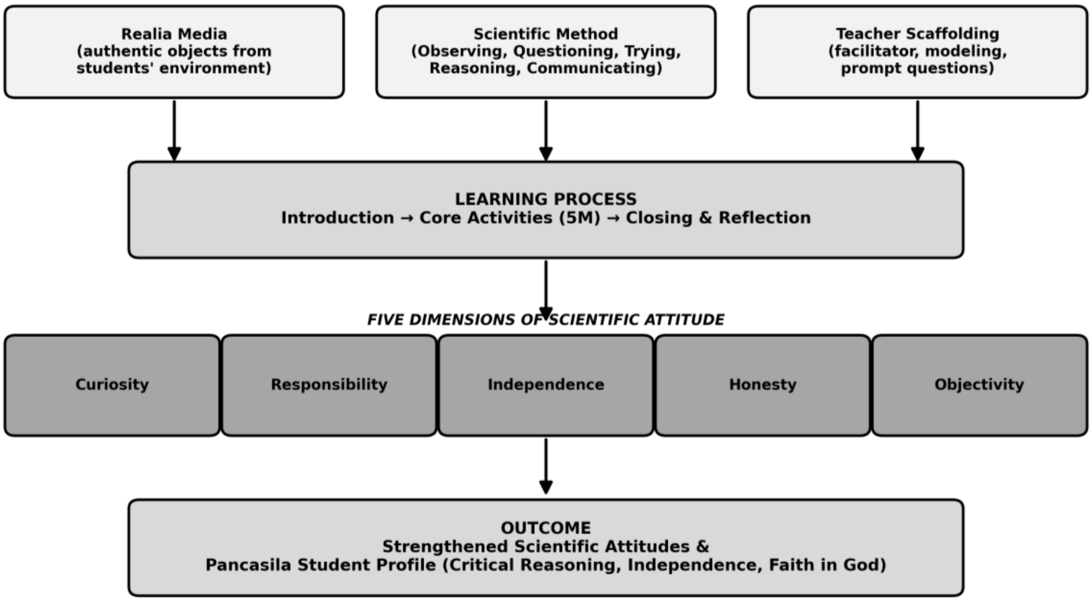

Fig. 1. Conceptual framework of realia integration with the scientific method

The learning process unfolded in three phases: introduction, core, and closing. In the introduction phase, the teacher provided apperception and posed prompting questions that linked students' daily experiences to the ecosystem concept. In the core phase, the five scientific activities were carried out sequentially with support from realia media. The observation results across the three classes are presented in Table 2.

Table 2. Observation results of realia-based scientific method implementation

No.	Learning activity	Class 5A	Class 5B	Class 5C
1	Actively observing realia objects in detail	✓	✓	✓
2	Asking questions based on observation results	✓	✓	✓
3	Collecting information and recording data	✓	✓	✓
4	Reasoning or associating relationships between data	✓	–	✓
5	Communicating results orally and in writing	✓	✓	✓
6	Reflection at the end of the session	✓	–	–
7	Responsible use of realia media	✓	✓	✓
8	Curiosity stimulation through real objects	✓	✓	✓
9	Facilitating independent task completion	✓	✓	✓
10	Distinguishing fact from opinion objectively	✓	–	✓

Note: ✓ = observed; – = not yet optimal.

Table 2 indicates that most realia-based scientific activities were observed in all three classes. However, the reasoning phase was not yet optimal in class 5B, while reflection at the end of the session was less than ideal in classes 5B and 5C. These findings are consistent with reports that the reasoning stage tends to be the most challenging in the implementation of the five-step scientific approach at the elementary level because it demands advanced cognitive capacity (Aiman et al., 2020; Capps & Crawford, 2013).

The questionnaire results from 297 students across three classes revealed substantial variation across the five assessed attitude dimensions. These variations indicate that students demonstrated different levels of responses across the dimensions measured in the questionnaire. The differences observed suggest that certain attitude dimensions were more strongly developed among students, whereas others may require further attention and reinforcement through instructional activities. Such variation provides an important basis for understanding the overall attitude profile of the students and identifying areas that may need greater pedagogical support. The complete results of the questionnaire, including the distribution of responses across the five dimensions, are presented in Table 3.

Table 3. Student scientific attitude questionnaire results (n=297)

Attitude Dimension	Class 5A (n=99)	Class 5B (n=99)	Class 5C (n=99)	Attitude Dimension	Class 5A (n=99)	Class 5B (n=99)
	Yes	No	Yes	No	Yes	No
Curiosity	97 (98%)	2 (2%)	87 (88%)	12 (12%)	87 (88%)	12 (12%)
Responsibility	98 (99%)	1 (1%)	93 (94%)	6 (6%)	99 (100%)	0 (0%)
Independence	96 (97%)	3 (3%)	93 (94%)	6 (6%)	81 (82%)	18 (18%)
Honesty	95 (96%)	4 (4%)	93 (94%)	6 (6%)	94 (95%)	5 (5%)
Objectivity	95 (96%)	4 (4%)	84 (85%)	15 (15%)	93 (94%)	6 (6%)
Mean	97.2%	2.8%	91.0%	9.0%	91.8%	8.2%

To complement the tabular data, the cross-class profiles are presented using complementary visual forms that facilitate a more comprehensive comparison of both the magnitude and distribution of the five attitude dimensions. The visualization allows the differences in students' positive responses across the three classes to be examined more clearly, while also highlighting which attitude dimensions tend to show relatively higher or lower response levels. The bar chart provides a straightforward basis for comparing the absolute frequency or proportion of positive responses across dimensions and classes, making variations in the students' attitude profiles more readily observable. Through this visual presentation, similarities and differences among the three classes can be identified without relying solely on the numerical values reported in the table. These comparative patterns are presented in Figure 2.

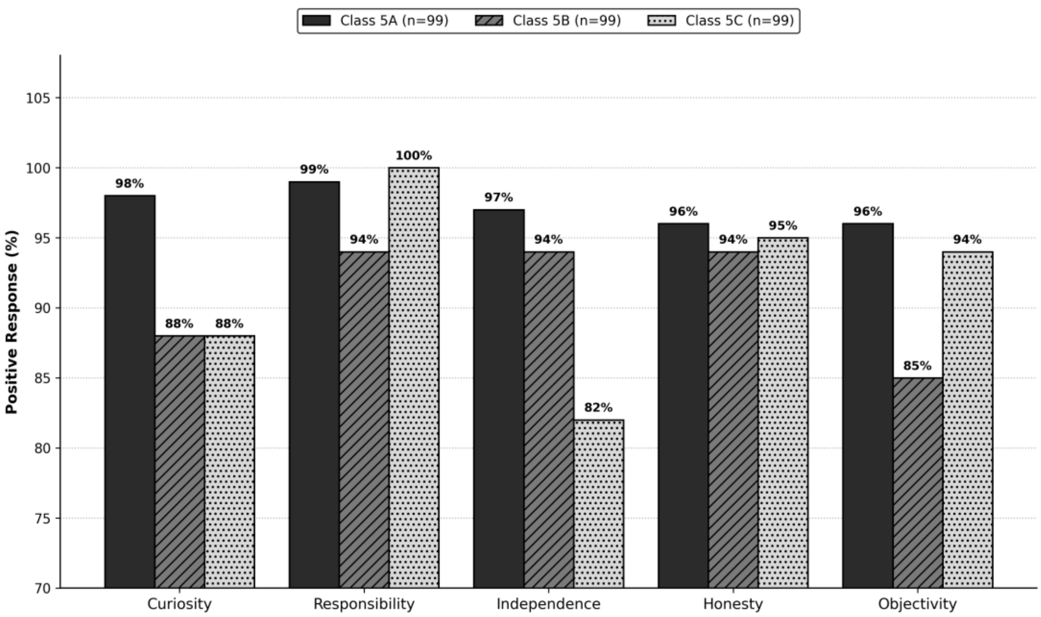

Fig. 2. Comparison of positive scientific attitude responses across three classes

Figure 2 illustrates the comparative scientific attitude profiles across the three classes. Class 5A demonstrates the highest scores on nearly all dimensions, with a range from 96 to 99 percent. Class 5C shows the highest score on responsibility (100 percent) but the lowest on independence (82 percent). Class 5B exhibits a more even profile but with the lowest score on objectivity (85 percent). Overall, the results indicate that Class 5A has the strongest and most consistent scientific attitude profile across the assessed dimensions. In contrast, the wider variation observed in Classes 5B and 5C suggests that the development of scientific attitudes is not uniform across all dimensions. The differences are particularly evident in the objectivity and independence dimensions, which show relatively lower scores in some classes compared with the other attitude dimensions. These findings suggest that each class has a distinctive pattern of scientific attitudes, although responsibility generally appears as one of the stronger dimensions across the classes. The overall distribution also indicates that differences between classes are more pronounced in specific dimensions than in the general attitude profile, providing a useful basis for interpreting students' scientific attitudes more comprehensively, as illustrated in Figure 3.

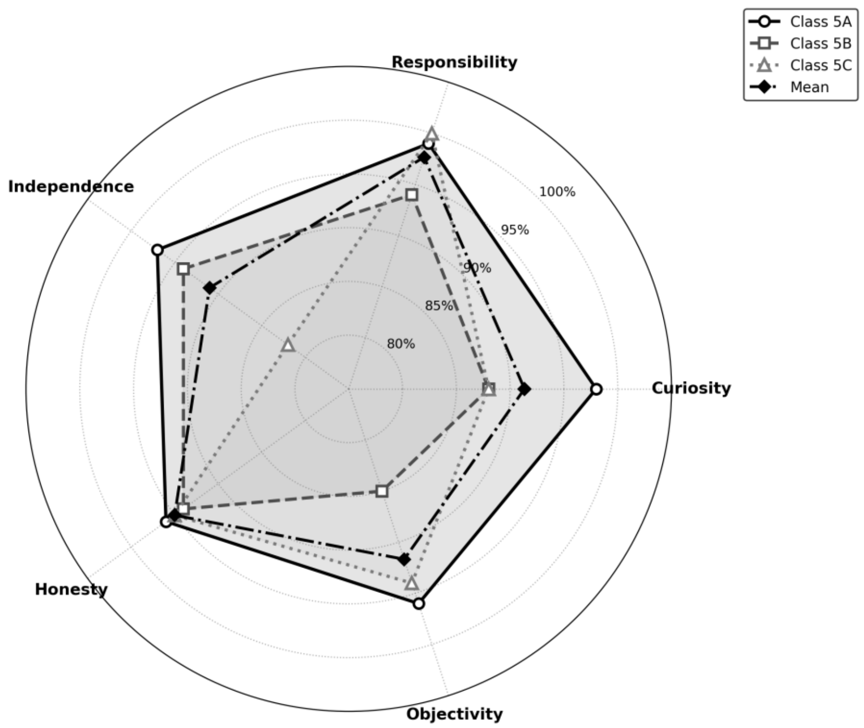

Fig. 3. Radar profile of scientific attitudes across the three classes

Figure 3 reveals that the cross-class mean (dashed line) forms a relatively balanced pentagon with a slight indentation on the objectivity dimension. This pattern indicates that, although all dimensions reach acceptable levels, objectivity remains the relatively most vulnerable dimension among the five. The curiosity dimension developed strongly with a mean of 97.2 percent positive responses. Direct interaction with realia objects, such as plant samples, soil, and small insects, stimulated students' natural urge to ask questions and explore further. This finding corroborates evidence that the physical presence of authentic objects in the classroom raises engagement levels through multi-sensory stimulation (Holstermann et al., 2010). Interview data with teachers revealed that the questions arising from realia interactions were often more probing and unexpected than those elicited by textbook content. Several teachers reported that students began bringing in their own specimens from home, indicating that curiosity extended beyond the classroom into the students' broader daily environment (Hidi & Renninger, 2006). This pattern was articulated directly by the teachers, as the following interview excerpt illustrates:

> *"When we used the realia, the children's curiosity became much higher. You could see it yesterday when the children were observing; they were competing, even scrambling over each other, and they took turns over the animals too" (Teacher, Class 5A, interview).*

The responsibility dimension reached the highest score, with class 5C attaining 100 percent. The responsibility for caring for realia objects, completing observation tasks, and presenting results to peers created an authentic learning experience that drew on students' affective investment. These findings are consistent with Swarat et al. (2012) and Belenky and Nokes (2009) on the contribution of hands-on activities to elementary students' responsibility character. The shared use of realia objects in small groups also fostered social responsibility through peer accountability, a pattern consistent with Vygotskian social constructivism in which collaborative engagement reinforces individual commitment to shared learning goals (Mercer & Howe, 2012).

The independence dimension showed greater variation, with class 5C scoring the lowest (82 percent). Interviews indicated that some students still required continuous teacher guidance when handling realia objects, particularly during the data-gathering stage. This highlights the importance of gradually withdrawing scaffolding to enable students to take initiative independently (Sasse et al., 2025; van de Pol et al., 2010). The variation across classes points to a pedagogical decision space: teachers must calibrate the degree of structure provided based on the developmental readiness of each class. Excessive scaffolding risks inhibiting independence formation, whereas insufficient support may overwhelm students and discourage exploration (van de Pol et al., 2010). Teachers described this calibration in their own terms during the interviews:

> *"In the process the children could observe directly, then actively ask questions, and also try things out; they even wanted to handle the media themselves, Sir. After that they reasoned, and then communicated by drawing on the objects around them" (Teacher, Class 5C, interview).*

The honesty dimension remained consistently high across all three classes (94 to 96 percent). Realia objects functioned as a natural reality check that made data manipulation socially untenable: peers could verify observations directly. This finding is consistent with accounts of scientific sense-making as a dialogic practice in which claims are made publicly accountable to evidence (Ford, 2012), and resonates with character-education programs that build honesty through authentic accountability rather than instruction alone (Althof & Berkowitz, 2006). The transparency afforded by physical objects reduces the cognitive and moral cost of accurate reporting, since fabricating data when evidence is publicly visible carries immediate social consequences. This mechanism aligns with the broader literature on character formation through experience-based learning rather than didactic moralizing (Berkowitz & Bier, 2004).

The objectivity dimension still requires attention, particularly in class 5B, where it reached 85 percent and, although categorized as very high on the descriptive scale, was the lowest value recorded among all dimensions and classes. Objectivity is the most cognitively demanding dimension because it requires the ability to distinguish observed facts from personal interpretation. This finding is consistent with the developmental premise that objectivity in primary school depends on a reasoning capacity that is still maturing (Piaget, 1972; Özden, 2020), since distinguishing observed facts from personal interpretation presupposes logical operations that consolidate only gradually during the concrete-operational stage. The discrepancy between self-report and observed behavior is concrete: in the questionnaire, 85–96 percent of students across the three classes reported that they distinguish fact from opinion, yet the observation data in Table 2 show that the reasoning (associating) activity and the activity of distinguishing fact from opinion objectively were recorded as not yet optimal precisely in class 5B, the same class with the lowest objectivity score. In other words, students consistently endorsed objectivity statements at the self-report level while the corresponding behavior was not consistently enacted at the reasoning stage, which is the clearest empirical illustration of the gap this study highlights. This converging pattern points to a consistent association, rather than a proven causal or structural link, between scientific reasoning capacity and the enactment of objective attitudes; given the descriptive case-study design, the relationship is best read as suggestive and warrants confirmatory study. An alternative explanation should also be acknowledged: the gap may partly reflect social-desirability bias in self-report on a valued item rather than a pure reasoning deficit, which is why triangulated and behavioral assessment is needed. Pedagogically, this gap can be addressed through structured claim-evidence-reasoning frameworks that make the inferential process visible, enabling students to evaluate the warrant for their conclusions explicitly (Suyanto, 2018; McNeill & Krajcik, 2008; Osborne, 2010; Erlina et al., 2018). The qualitative observation record makes this discrepancy tangible. During the reasoning (associating) stage in class 5B, the field notes captured the moment at which students stopped at description rather than proceeding to infer relationships among the ecosystem components they had observed:

> *The observation record noted that the scientific attitude that had not yet developed optimally was objectivity, specifically in distinguishing personal opinion from the results of observation, so that some students still conveyed views based on personal assumption rather than the facts they had found in the field (field observation, Class 5B).*

This converging pattern is consistent with the interview accounts, in which the teachers and the principal attributed the difficulty at the reasoning stage to limited instructional time and to the absence of structured prompts for guiding inference, factors examined further in Section 3.3. Read together, the questionnaire endorsement, the observation finding, and the teacher accounts triangulate on the same conclusion: objectivity is endorsed in principle but not yet consistently enacted at the reasoning stage, which is where the qualitative evidence locates the bottleneck.

Implementation of realia-based learning at SDN 1 Wonogiri was strongly influenced by a complex interaction between supporting and inhibiting factors, summarized in Table 4. On the supporting side, the availability of authentic objects in the school environment, the relevance of the material to students' daily experience, the active role of teachers as facilitators, and school policies that encouraged exploratory activities worked together to sustain the five stages of the scientific method. On the inhibiting side, limited learning time per session, students' uneven reasoning capacity, end-of-session reflection that was not yet routine, and the absence of structured prompting questions for reasoning constrained the depth of the associating stage in particular. Read together, these factors indicate that adequate facilities alone did not guarantee the development of objectivity, which depended more on how instructional time and reasoning support were deliberately structured.

Table 4. Supporting and Inhibiting Factors of Realia-Based Learning

Supporting factors	Inhibiting factors
Availability of authentic objects in the school environment	Limited learning time per session
Material relevance to students' daily experience	Students' uneven reasoning capacity
Active teacher role as facilitator and motivator	End-of-session reflection that is not yet routine
School policies that support exploratory activities	Lack of structured prompting questions for reasoning

Among supporting factors, the availability of authentic objects in the school environment and the relevance of material to students' daily experience were the most dominant. The school's location in an urban area with parks, gardens, and natural microhabitats facilitated teachers in obtaining realia objects without high logistical costs (Avery, 2013). The active role of teachers as facilitators also became a critical variable: structured prompting questions, demonstrative modeling, and adaptive support enabled most students to navigate the five stages of the scientific method (Sasse et al., 2025).

On the inhibiting side, limited learning time was the most frequently cited obstacle. The reasoning stage in particular requires sufficient time for students to internalize observation data and construct logical inferences. Suboptimal reflection at the end of sessions also weakened the consolidation of learning experiences into firm scientific attitudes (Sasse et al., 2025). The absence of structured prompting questions for reasoning at the teaching-module level forced teachers to improvise, leading to variation in the quality of reasoning across classes. This constraint recurred across the interviews with the principal and the three teachers.

As the principal explained, the main constraint was limited time, because applying realia media through the scientific method demands a great deal of time, leaving teachers short of it and obliging them to search for suitable media. The teachers of Classes 5A, 5B, and 5C added that the school's stock of realia was not yet complete, so they had to prepare some objects from home, and that using realia in the lesson took a long time, especially in the preparation stage (principal and teacher interviews).

The findings carry strategic implications for natural and social science learning practice at the elementary level. The central practical solution suggested by this study is to redesign the realia teaching module so that the reasoning (associating) stage is explicitly scaffolded rather than left to teacher improvisation. Concretely, this means embedding a claim-evidence-reasoning routine, fact-versus-opinion comparison sheets, structured observation logs, and short reflection prompts directly into the contextual realia module, an approach consistent with the development of context-based natural and social science teaching modules at the elementary level (Bennett et al., 2007). First, the development of realia-based teaching modules should explicitly incorporate prompting questions to support the reasoning stage. Such modules can include fact-versus-opinion comparison sheets, structured observation logs, and reflection guides that target the formation of objective attitudes. Second, teacher professional development should focus on the strategy of gradually releasing scaffolding so that learner independence develops in tandem with the maturation of their reasoning capacity (Sasse et al., 2025).

The contribution of this study to the literature is threefold, and in each case the advance over prior work is specifiable. First, it presents a comprehensive multidimensional analysis of all five scientific attitudes simultaneously, whereas prior realia and scientific-method studies at the elementary level (for example, Parmiti et al., 2021; Rohaeti et al., 2020) typically examine one or two dimensions or learning outcomes in isolation; profiling the five together is what makes the relative vulnerability of objectivity visible. Second, rather than treating all dimensions as equally responsive to hands-on learning, it identifies a consistent association between objectivity and reasoning capacity that functions as a candidate leverage point for intervention, refining the more general claim in the literature that authentic objects improve attitudes. Third, it provides a discrepancy analysis between student self-report and behavioral observation on the objectivity dimension, an issue rarely raised explicitly in earlier studies, and shows concretely where self-report and enacted behavior diverge. Given the descriptive case-study design, these contributions are best framed as well-evidenced patterns within one rich case rather than as generalizable causal laws.

Beyond these empirical contributions, the study extends the theoretical conversation on how constructivist learning environments shape character formation. The convergence of Piagetian concrete operations, Vygotskian scaffolding, and dispositional learning theory in a single elementary classroom setting provides a useful integrative case for science education scholarship. The finding that not all attitude dimensions develop in parallel under the same intervention pushes back on the assumption that hands-on learning automatically produces well-rounded scientific dispositions. Instead, dimensions tied to higher-order reasoning require deliberate instructional design, whereas dimensions tied to social and affective engagement develop more readily through the presence of authentic materials alone (Zacharia & Olympiou, 2011; Furtak et al., 2012).

Developing the five dimensions of scientific attitude has direct implications for achieving the Indonesian student profile, particularly the dimensions of critical reasoning, independence, and faith in God Almighty. Curiosity and objectivity attitudes underpin critical reasoning capacity, independence and responsibility undergird the independent dimension, while honesty about scientific evidence supports the formation of moral integrity that is an integral part of the religious dimension (Bybee et al., 2009; Berkowitz & Bier, 2004). This alignment is consistent with evidence that the implementation of the national curriculum in Indonesia contributes to the critical-reasoning dimension of the Indonesian student profile (Voogt & Roblin, 2012). The impact of this study can be projected at three levels. At the classroom level, the findings provide an empirical basis for teachers to design more reasoning-oriented realia-based learning. At the school level, the results can serve as a reference for supervision and pedagogical mentoring programs. At the policy level, the observed association between objectivity and reasoning can inform the orientation of natural and social science teaching-module revisions and elementary teacher continuing professional development programs (Desimone, 2009; Fensham, 2009).

Several limitations warrant acknowledgment for future research. First, the case study design at a single school site limits the generalizability of findings to broader elementary populations, particularly schools with different geographic, demographic, and accreditation contexts. Replication across multiple sites with varying characteristics would strengthen the external validity of the observed association between objectivity and reasoning identified in this study (Yin, 2018; Flyvbjerg, 2006).

Second, the use of student self-report questionnaires carries known limitations of social desirability bias, particularly on socially valued items such as honesty and objectivity (Krumpal, 2013). Although triangulation with observational data was employed to mitigate this bias, future studies should consider behavioral measures that more directly capture scientific attitudes, such as performance assessments at the reasoning stage or coded analyses of student argumentation (Sampson & Clark, 2008).

Third, this study did not measure long-term effects on the formation of scientific attitudes. Further research with longitudinal designs across an academic year or experimental quasi-comparative studies between realia-based and conventional approaches would provide stronger evidence regarding the durability of intervention impact. Such studies should focus particularly on the trajectory of the objectivity dimension as students enter the upper elementary phase, where formal operational reasoning capacity begins to develop (Piaget, 1972; Zimmerman, 2007).

4. Conclusion

This case study shows that the integration of realia media with the scientific method in natural and social science learning at SDN 1 Wonogiri proceeded systematically across the introduction, core, and closing phases, and that four of the five scientific-attitude dimensions, namely curiosity, responsibility, independence, and honesty, developed strongly, with positive responses ranging from 88 to 100 percent, while objectivity remained the most vulnerable dimension, particularly at the reasoning (associating) stage; its development was supported by the availability of realia objects, the relevance of material to daily experience, and the active role of teachers, and was constrained by limited learning time, students' uneven reasoning capacity, and reflection that is not yet routine. The principal contribution of the study is the identification, within this single rich case, of a consistent association, rather than a proven causal or structural law, between objectivity and reasoning capacity, which positions explicit teacher scaffolding at the associating stage, operationalized through claim-evidence-reasoning routines and fact-versus-opinion comparison sheets embedded in reasoning-oriented realia teaching modules, as the priority practical intervention and as a plausible entry point for advancing the critical-reasoning, independence, and integrity dimensions of the Indonesian student profile. Because these conclusions rest on a descriptive case study at one school, they should be read as well-evidenced patterns inviting confirmation rather than as generalizable effects, and future work using multi-site, longitudinal, and behavioral designs, including performance assessment and discourse analysis of student argumentation, is needed to test whether the reasoning–objectivity association holds and strengthens as learners progress toward formal operational reasoning.

Acknowledgment

The authors thank the Postgraduate Program of Universitas Sebelas Maret, the principal, teachers, and students of SDN 1 Wonogiri who supported the implementation of this research. Special appreciation goes to the supervisors for their direction and constructive critique during the research process.

Declarations

Autor contribution	:	LBY designed the research, conducted data collection, performed the primary analysis, and drafted the manuscript. KCS provided supervision on the research design and theoretical framework. ST provided supervision on instrument validation, data interpretation, and manuscript revision. All authors read and approved the final version of the manuscript.
Funding statement	:	This research received no specific external funding. All operational costs of the study were borne independently by the principal author as part of the master's thesis research at the Postgraduate Program of Universitas Sebelas Maret.
Conflict of interest	:	The authors declare no conflict of interest.
Additional information	:	No additional information is available for this paper.

References

Aiman, U., Hasyda, S., & Uslan, U. (2020). The influence of process oriented guided inquiry learning (POGIL) model assisted by realia media to improve scientific literacy and critical thinking skill of primary school students. *European Journal of Educational Research, 9*(4), 1635–1647. https://doi.org/10.12973/eu-jer.9.4.1635

Althof, W., & Berkowitz, M. W. (2006). Moral education and character education: Their relationship and roles in citizenship education. *Journal of Moral Education, 35*(4), 495–518. https://doi.org/10.1080/03057240601012204

Appleton, K. (2003). How do beginning primary school teachers cope with science? Toward an understanding of science teaching practice. *Research in Science Education, 33*(1), 1–25. https://doi.org/10.1023/A:1023666618800

Avery, L. M. (2013). Rural science education: Valuing local knowledge. *Theory Into Practice, 52*(1), 28–35. https://doi.org/10.1080/07351690.2013.743769

Belenky, D. M., & Nokes, T. J. (2009). Examining the role of manipulatives and metacognition on engagement, learning, and transfer. *The Journal of Problem Solving, 2*(2), 102–129. https://doi.org/10.7771/1932-6246.1061

Bennett, J., Lubben, F., & Hogarth, S. (2007). Bringing science to life: A synthesis of the research evidence on the effects of context-based and STS approaches to science teaching. *Science Education, 91*(3), 347–370. https://doi.org/10.1002/sce.20186

Berkowitz, M. W., & Bier, M. C. (2004). Research-based character education. *The ANNALS of the American Academy of Political and Social Science, 591*(1), 72–85. https://doi.org/10.1177/0002716203260082

Braund, M., & Reiss, M. (2006). Towards a more authentic science curriculum: The contribution of out-of-school learning. *International Journal of Science Education, 28*(12), 1373–1388. https://doi.org/10.1080/09500690500498419

Bybee, R., McCrae, B., & Laurie, R. (2009). PISA 2006: An assessment of scientific literacy. *Journal of Research in Science Teaching, 46*(8), 865–883. https://doi.org/10.1002/tea.20333

Capps, D. K., & Crawford, B. A. (2013). Inquiry-based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education, 24*(3), 497–526. https://doi.org/10.1007/s10972-012-9314-z

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34*(3), 3–14. https://doi.org/10.3102/0013189X034003003

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*(3), 181–199. https://doi.org/10.3102/0013189X08331140

Erlina, N., Susantini, E., Wasis, Wicaksono, I., & Pandiangan, P. (2018). The effectiveness of evidence-based reasoning in inquiry-based physics teaching to increase students' scientific reasoning. *Journal of Baltic Science Education, 17*(6), 972–985. https://doi.org/10.33225/jbse/18.17.972

Faisal, & Martin, S. N. (2019). Science education in Indonesia: Past, present, and future. *Asia-Pacific Science Education, 5*(1), Article 4. https://doi.org/10.1186/s41029-019-0032-0

Fensham, P. J. (2009). Real world contexts in PISA science: Implications for context-based science education. *Journal of Research in Science Teaching, 46*(8), 884–896. https://doi.org/10.1002/tea.20334

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry, 12*(2), 219–245. https://doi.org/10.1177/1077800405284363

Ford, M. J. (2012). A dialogic account of sense-making in scientific argumentation and reasoning. *Cognition and Instruction, 30*(3), 207–245. https://doi.org/10.1080/07370008.2012.689383

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research, 82*(3), 300–329. https://doi.org/10.3102/0034654312457206

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4

Holstermann, N., Grube, D., & Bögeholz, S. (2010). Hands-on activities and their influence on students' interest. *Research in Science Education, 40*(5), 743–757. https://doi.org/10.1007/s11165-009-9142-0

Kang, J., & Keinonen, T. (2018). The effect of student-centered approaches on students' interest and achievement in science: Relevant topic-based, open and guided inquiry-based, and discussion-based approaches. *Research in Science Education, 48*(4), 865–885. https://doi.org/10.1007/s11165-016-9590-2

Kind, P., Jones, K., & Barmby, P. (2007). Developing attitudes towards science measures. *International Journal of Science Education, 29*(7), 871–893. https://doi.org/10.1080/09500690600909091

Krumpal, I. (2013). Determinants of social desirability bias in sensitive surveys: A literature review. *Quality & Quantity, 47*(4), 2025–2047. https://doi.org/10.1007/s11135-011-9640-9

Lalian, O. N., Siregar, E., & Winarsih, M. (2019). The effects of using realia media on increasing science learning outcomes of elementary school students: A meta-analysis. *ACM International Conference Proceeding Series*, Part F1483, 1–4. https://doi.org/10.1145/3323771.3323775

McNeill, K. L., & Krajcik, J. (2008). Scientific explanations: Characterizing and evaluating the effects of teachers' instructional practices on student learning. *Journal of Research in Science Teaching, 45*(1), 53–78. https://doi.org/10.1002/tea.20201

Mercer, N., & Howe, C. (2012). Explaining the dialogic processes of teaching and learning: The value and potential of sociocultural theory. *Learning, Culture and Social Interaction, 1*(1), 12–21. https://doi.org/10.1016/j.lcsi.2012.03.001

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). SAGE Publications.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474–496. https://doi.org/10.1002/tea.20347

Navarro, M., Förster, C., González, C., & González-Pose, P. (2016). Attitudes toward science: Measurement and psychometric properties of the Test of Science-Related Attitudes for its use in Spanish-speaking classrooms. *International Journal of Science Education, 38*(9), 1459–1482. https://doi.org/10.1080/09500693.2016.1195521

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods, 16*(1), 1–13. https://doi.org/10.1177/1609406917733847

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science, 328*(5977), 463–466. https://doi.org/10.1126/science.1183944

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079. https://doi.org/10.1080/0950069032000032199

Özden, M. (2020). Elementary school students' informal reasoning and its quality regarding socio-scientific issues. *Eurasian Journal of Educational Research, 20*(86), 1–24. https://doi.org/10.14689/ejer.2020.86.4

Parmiti, D. P., Rediani, N. N., Antara, I. G. W. S., & Jayadiningrat, M. G. (2021). The effectiveness of local culture-integrated science learning through project-based assessment on scientific attitudes and science process skills of elementary school students. *Jurnal Pendidikan IPA Indonesia*, 10(3), 439–446. https://doi.org/10.15294/jpii.v10i3.31301

Piaget, J. (1972). *The psychology of the child*. Basic Books.

Roehrig, G. H., & Kruse, R. A. (2005). The role of teachers' beliefs and knowledge in the adoption of a reform-based curriculum. *School Science and Mathematics, 105*(8), 412–422. https://doi.org/10.1111/j.1949-8594.2005.tb18061.x

Rohaeti, E., Prodjosantoso, A. K., & Irwanto, I. (2020). Research-oriented collaborative inquiry learning model: Improving students' scientific attitudes in general chemistry. *Journal of Baltic Science Education, 19*(1), 108–120. https://doi.org/10.33225/jbse/20.19.108

Sampson, V., & Clark, D. B. (2008). Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. *Science Education, 92*(3), 447–472. https://doi.org/10.1002/sce.20276

Sasse, H., Weber, A. M., Reuter, T., & Leuchter, M. (2025). Teacher guidance and on-the-fly scaffolding in primary school students' inquiry learning. *Science Education*, 109(2), 579–604. https://doi.org/10.1002/sce.21921

Suyanto, S. (2018). The implementation of the scientific approach through 5Ms of the new curriculum of 2013 in Indonesia. *Jurnal Cakrawala Pendidikan*, 37(1), 22–29. https://doi.org/10.21831/cp.v37i1.18719

Swarat, S., Ortony, A., & Revelle, W. (2012). Activity matters: Understanding student interest in school science. *Journal of Research in Science Teaching, 49*(4), 515–537. https://doi.org/10.1002/tea.21010

van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher–student interaction: A decade of research. *Educational Psychology Review, 22*(3), 271–296. https://doi.org/10.1007/s10648-010-9127-6

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies, 44*(3), 299–321. https://doi.org/10.1080/00220272.2012.668938

Wicaksono, A. G. C., & Korom, E. (2023). Attitudes towards science in higher education: Validation of questionnaire among science teacher candidates and engineering students in Indonesia. *Heliyon*, 9(9), e20023. https://doi.org/10.1016/j.heliyon.2023.e20023

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE Publications.

Zacharia, Z. C., & Olympiou, G. (2011). Physical versus virtual manipulative experimentation in physics learning. *Learning and Instruction, 21*(3), 317–331. https://doi.org/10.1016/j.learninstruc.2010.03.001

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review, 27*(2), 172–223. https://doi.org/10.1016/j.dr.2006.12.001