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Toward a Pedagogically Driven Framework for Designing a Socioscientific Inquiry-Based Learning (SSIBL) Digital Platform

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Abstract: Socioscientific Inquiry-Based Learning (SSIBL) requires instructional continuity across contextual exploration, scientific inquiry, evidence construction, argumentation, and assessment. However, existing digital learning environments often support these activities in isolation, resulting in fragmented pedagogical processes. This study proposes a pedagogically driven framework for designing a Socioscientific Inquiry-Based Learning (SSIBL) digital platform through the systematic identification of instructional needs, synthesis of cross-phase instructional functions, derivation of system-level design requirements, and development of an architectural framework. A design-oriented requirement elicitation approach was employed involving 45 senior high school students and six physics teachers. Data were collected using structured questionnaires covering six phases of the SSIBL workflow and analyzed through descriptive analysis, cross-phase pattern identification, instructional function synthesis, requirement translation, and architectural framework development. The findings revealed consistently high instructional needs across all SSIBL phases and identified four cross-phase instructional functions: Epistemic Structuring, Evidence Construction, Deliberative Anchoring, and Orchestration Visibility. These functions informed the derivation of system-level design requirements and the development of an architectural framework that preserves instructional continuity throughout SSIBL. The study contributes a transparent pedagogically driven framework that bridges instructional theory and educational technology design, providing a conceptual foundation for future platform development and design-based research.

Keywords: Educational technology; Instructional design; Pedagogically driven framework; Requirement elicitation; Socioscientific Inquiry-Based Learning (SSIBL)

Introduction

Socioscientific Inquiry-Based Learning (SSIBL) has been widely recognized as a pedagogical approach that integrates scientific inquiry with socially relevant issues (Levinson, 2018). Within this framework, students are expected not only to investigate scientific phenomena but also to deliberate on their social implications, evaluate conflicting perspectives, and justify decisions using empirical evidence. By integrating inquiry with authentic societal contexts, SSIBL has been shown to enhance scientific literacy, argumentation, and evidence-informed decision-making (Dewi et al., 2023; Muntari et al., 2024; Purnamasari et al., 2025; Putra et al., 2023).

Despite its pedagogical potential, implementing SSIBL in classroom practice remains challenging (Amos et al., 2020). Inquiry activities frequently emphasize procedural experimentation, whereas socioscientific deliberation is often positioned as a separate discussion rather than as an integral component of inquiry (Kilinc et al., 2017). Similarly, although students are encouraged to express opinions, instructional support for constructing evidence-based arguments is often limited.

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Assessment practices also tend to emphasize final answers instead of documenting how students develop and refine their reasoning throughout the inquiry process (Abate et al., 2020; Romine et al., 2017). These discontinuities suggest that the challenges of implementing SSIBL extend beyond teachers' pedagogical competence and are closely related to the absence of an instructional infrastructure capable of maintaining continuity across the successive phases of learning.

Digital learning environments have considerable potential to support more coherent implementation of inquiry-based learning (Nguyen et al., 2023). Mobile technologies and smartphone-based experimental applications enable students to collect empirical data efficiently in authentic learning contexts while reducing many logistical constraints associated with conventional laboratory activities (Carroll & Lincoln, 2020; Liunokas & Asbanu, 2023; Pusch et al., 2021; Raharja et al., 2024; Staacks et al., 2018). Nevertheless, existing digital learning tools predominantly support isolated instructional activities, such as data collection, experimentation, or visualization. They provide comparatively limited support for connecting contextual problem framing, evidence transformation, socioscientific deliberation, structured argumentation, teacher orchestration, and assessment within a single coherent instructional workflow. Consequently, digital support often mirrors the fragmentation already observed in classroom practice rather than helping teachers orchestrate the complete SSIBL process.

Previous studies have consistently demonstrated that effective inquiry learning depends on more than successful experimentation. Inquiry requires learners to transform raw observations into meaningful representations before scientific reasoning can occur (Yaman & Hand, 2025). Likewise, research on scientific argumentation has emphasized the importance of explicitly connecting claims with supporting evidence to maintain epistemic rigor (Duncan & Chinn, 2025; Forsythe & Chan, 2025; Lin & Hung, 2025; Nesbit & Liu, 2025; Wei et al., 2021). Within socioscientific contexts, learners must additionally evaluate alternative viewpoints, consider societal consequences, and integrate scientific evidence into responsible decision-making. Collectively, these studies suggest that effective SSIBL implementation requires continuity across contextual framing, inquiry execution, evidence transformation, socioscientific deliberation, structured argumentation, and assessment rather than treating these activities as independent instructional events.

While numerous studies have examined the effectiveness of SSIBL interventions or investigated the educational benefits of individual digital learning technologies, considerably less attention has been given to identify the instructional conditions that should guide the design of an SSIBL digital environment before platform development begins. Existing studies generally evaluate completed instructional interventions or introduce technological features intended to support particular learning activities (Eriyanti et al., 2023; Rahmat et al., 2023; Tullah et al., 2025; Utami et al., 2023). As a result, the relationship between pedagogical workflow and system architecture often remains implicit, making it difficult to ensure that technological development faithfully represents the instructional logic of SSIBL. This indicates the need for a systematic requirement elicitation process capable of translating instructional workflow into coherent system-level design requirements.

Accordingly, this study proposes a pedagogically driven framework for designing a Socioscientific Inquiry-Based Learning (SSIBL) digital platform. The proposed framework comprises four interrelated components: instructional needs, cross-phase instructional functions, system-level design requirements, and an architectural framework. Rather than evaluating the effectiveness of a technological intervention, the study establishes a pedagogical foundation that can guide subsequent platform prototyping and design-based research.

Method

Research Design

This study adopted a design-oriented approach to develop a pedagogically driven framework for designing an SSIBL digital platform. The framework was constructed through a sequential process involving instructional need identification, cross-phase pattern analysis, instructional function synthesis, derivation of system-level design requirements, and architectural framework development. These sequential procedures operationalize the four components of the proposed pedagogically driven framework.

The research process began with identifying key instructional phases of SSIBL based on literature, followed by collecting input from classroom stakeholders. These inputs were then analyzed and systematically translated into a set of system-level design requirements and an initial architectural framework. The overall procedure is illustrated in Figure 1, which outlines the progression from instructional analysis to architectural synthesis.

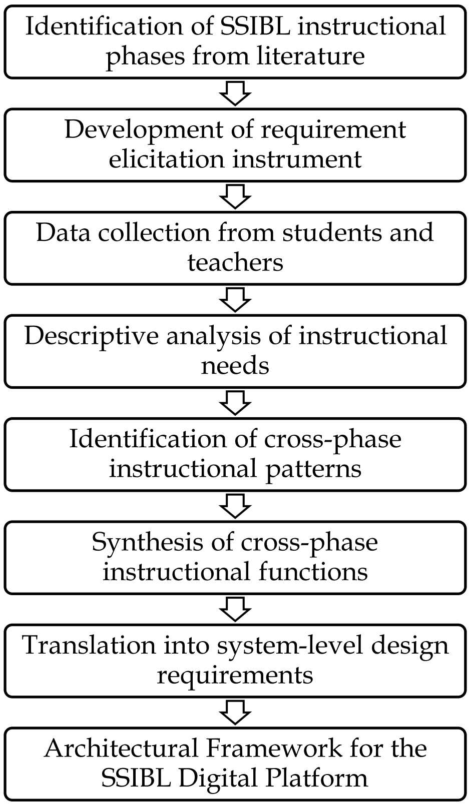

Figure 1. Procedure of the research

Participants and Context

The study involved 45 senior high school students and six physics teachers selected through purposive sampling. The participating teachers had at least five years of teaching experience and were familiar with inquiry-based science instruction. Students were included as they represent the primary users of the proposed digital platform.

Participants were selected to capture a range of perspectives related to the implementation of SSIBL in classroom settings. Their responses were used to inform the identification of instructional needs across different phases of the learning process.

Instrument Development

The instrument used in this study was developed based on the instructional phases of SSIBL identified through literature analysis. The learning process was organized into six phases: contextual framing, socioscientific deliberation, inquiry execution, evidence transformation, structured argumentation, and assessment and reflection (Amos & Levinson, 2019; Kyza, 2025).

Each phase was translated into a set of instructional situations that reflect typical classroom activities within SSIBL. The questionnaire asked participants to indicate the extent to which each instructional condition was needed to support effective learning, using a five-point scale ranging from "Not Required" to "Highly Required". Separate versions of the questionnaire were prepared for students and teachers to accommodate their different roles, while maintaining consistency in the instructional aspects being assessed.

Data Collection

Data were collected during regular classroom sessions. Participants completed the questionnaire individually after receiving a brief explanation of the study. All responses were recorded anonymously. The data captured perspectives from both students and teachers. Student responses reflected their experiences and expectations as learners, while teacher responses provided insights into instructional planning and classroom management. Together, these perspectives contributed to a more comprehensive understanding of instructional needs within SSIBL.

Requirement Translation and Data Analysis

Requirement translation refers to the analytical process through which synthesized instructional functions were transformed into system-level design requirements. Data analysis was conducted through a structured process to translate participant responses into design requirements. First, responses were summarized within each SSIBL phase using descriptive statistics to identify general patterns of perceived instructional needs. These patterns were then examined across phases to identify recurring themes and relationships among instructional activities. Next, related instructional conditions were grouped and interpreted as broader instructional functions. This step aimed to capture common pedagogical purposes that extend across multiple phases of SSIBL.

These instructional functions were subsequently translated into system-level design requirements by identifying the types of technological support needed to facilitate the intended learning processes. Finally, the resulting requirements were organized into interconnected platform components, forming an initial architectural framework. Throughout this process, attention was given to maintaining coherence between instructional practices and technological design, ensuring that the resulting framework reflects the structure and flow of SSIBL implementation.

Result and Discussion

Descriptive Analysis of Instructional Needs

The first stage of analysis aimed to describe participants' perceptions of instructional needs across the six phases of the Socioscientific Inquiry-Based Learning (SSIBL) workflow. Responses from students and teachers were analyzed separately to provide an overview of the relative level of perceived instructional support required for each phase. The descriptive analysis served as the empirical foundation for the subsequent identification of cross-phase instructional patterns. Table 1 presents the mean scores and standard deviations for each instructional phase as reported by students and teachers.

Table 1. Mean of perceived instructional needs across the SSIBL workflow

SSIBL Phase	Students M	Teachers M
Contextual framing	4.32	4.33
Socioscientific deliberation	4.28	4.42
Inquiry execution	4.19	4.08
Evidence transformation	4.61	4.58
Structured argumentation	4.54	4.75
Assessment & reflection	4.02	4.67

Overall, participants assigned high ratings to all six instructional phases. Both students and teachers consistently perceived each phase as requiring instructional support for SSIBL-based learning, with mean scores remaining within the upper range of the response scale. This pattern suggests that respondents viewed instructional support as important throughout the learning process rather than concentrating on only a limited number of activities.

Although the mean scores varied slightly across instructional phases, the observed differences were relatively small. For example, while some phases received marginally higher average ratings than others, all phases were consistently perceived as important components of the SSIBL process. Therefore, the descriptive statistics primarily indicate differences in the relative emphasis assigned to instructional support rather than differences in the overall importance of the instructional phases themselves.

Teacher responses exhibited somewhat greater variation than student responses across several phases. As the present study was intended to identify instructional requirements rather than to estimate population parameters, these descriptive statistics are reported to characterize participants' response tendencies and to facilitate the subsequent analysis of recurring instructional patterns.

Figure 2 illustrates the distribution of mean scores across the six instructional phases for both respondent groups. The figure provides a visual representation of the overall response pattern and highlights the consistently high level of perceived instructional needs throughout the SSIBL workflow.

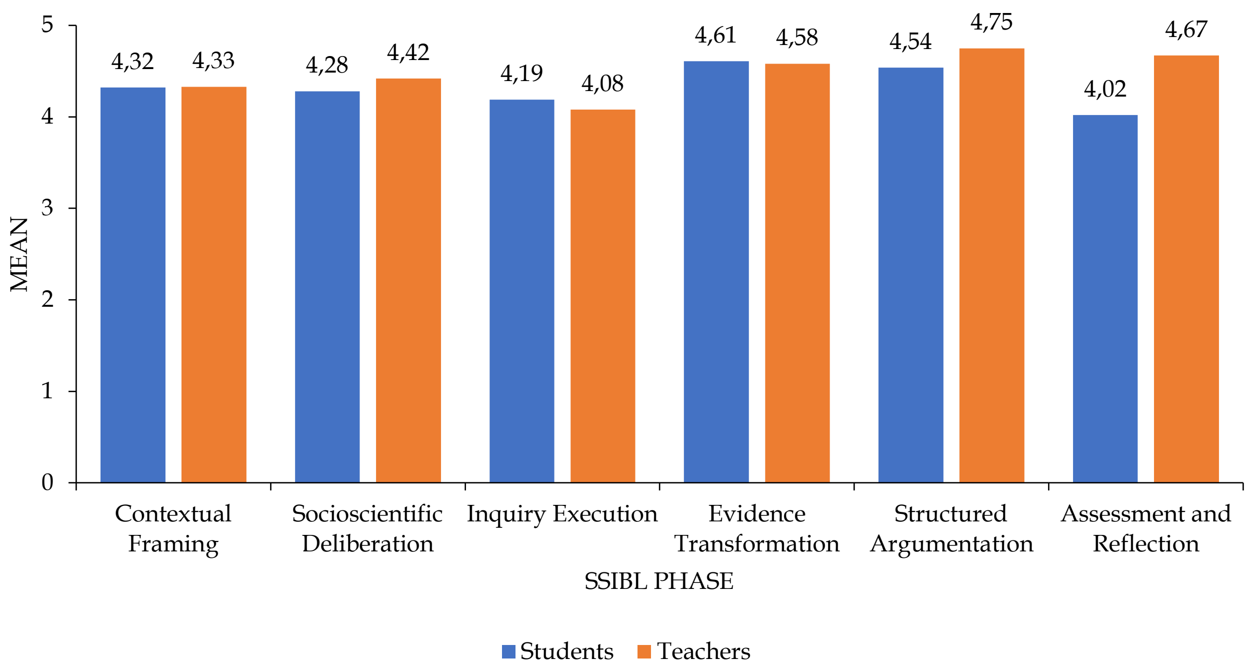

Figure 2. Comparison of mean perceived instructional needs across the six SSIBL phases

The descriptive analysis presented in this section establishes an overall picture of participants' perceptions of instructional needs. However, descriptive statistics alone do not explain how individual instructional phases interact to support coherent implementation of SSIBL. To address this question, the following section examines recurring relationships among the six instructional phases in order to identify cross-phase instructional patterns that can inform subsequent requirement synthesis.

Identification of Cross-Phase Instructional Patterns

The descriptive analysis provides an overview of participants' perceptions across the six instructional phases of SSIBL. However, the objective of this study extends beyond describing individual phases. To inform the development of a digital learning environment, it is necessary to examine how instructional needs are distributed across the entire learning workflow and to identify recurring relationships among successive instructional phases.

Analysis of the descriptive results revealed that participants did not perceive the six phases as isolated instructional events. Instead, responses consistently reflected a sequence of mutually connected learning activities in which each phase supports and extends the learning processes initiated in preceding phases. Three recurring instructional patterns were identified from the aggregated responses.

The first pattern links Contextual Framing with Socioscientific Deliberation. Participants consistently assigned high levels of instructional importance to activities that establish authentic contexts, introduce socioscientific issues, and encourage learners to examine multiple perspectives before beginning scientific investigation. This pattern suggests that effective inquiry is perceived as beginning with meaningful contextual framing rather than with experimentation alone.

The second pattern connects Inquiry Execution and Evidence Transformation. Participants emphasized not only the importance of conducting inquiry activities but also the need to organize, interpret, and communicate empirical observations. The close relationship between these phases indicates that the value of inquiry is closely associated with learners' opportunities to transform observational data into evidence that can subsequently support scientific reasoning.

The third pattern integrates Structured Argumentation with Assessment and Reflection. Responses from both students and teachers consistently highlighted the importance of constructing evidence-based arguments while simultaneously monitoring learning progress throughout the inquiry process. Rather than representing independent instructional activities, these phases appear to function together in supporting learners as they justify conclusions, evaluate alternative explanations, and reflect upon the quality of their reasoning.

Taken together, these recurring patterns indicate that instructional support is required not only within individual learning phases but also across transitions between phases. Participants consistently perceived instructional continuity as an important characteristic of SSIBL implementation, suggesting that effective learning depends on maintaining coherent connections from contextual understanding through inquiry, evidence construction, argumentation, and reflection.

The identification of these cross-phase relationships does not yet constitute system design requirements. Instead, the patterns represent recurring instructional structures derived from participants' perceptions of instructional needs. In the next stage of analysis, these recurring structures are synthesized into broader instructional functions that provide a pedagogical basis for translating instructional needs into system-level design requirements.

Synthesis of Cross-Phase Instructional Functions

The cross-phase patterns identified in the previous section reveal recurring relationships among instructional activities throughout the SSIBL workflow. While these patterns describe how instructional phases are connected, they do not yet provide an operational basis for system design. Consequently, the next stage of analysis synthesized related instructional patterns into broader instructional functions that represent common pedagogical purposes spanning multiple phases of learning.

This synthesis was guided by two complementary considerations. First, instructional activities that consistently occurred together across successive phases were examined as potentially serving a common educational purpose. Second, these recurring relationships were interpreted in light of established principles of inquiry-based learning, scientific argumentation, and socioscientific reasoning to ensure that the resulting functions reflected pedagogical processes rather than isolated technological features.

The synthesis resulted in four cross-phase instructional functions that collectively describe the pedagogical support required for coherent implementation of SSIBL. Table 2 summarizes the relationship between the observed instructional patterns and the corresponding instructional functions.

The first instructional function, Epistemic Structuring, represents the pedagogical process of establishing an epistemic context in which learners recognize why an issue is worth investigating and how scientific inquiry relates to broader societal questions. Rather than introducing socioscientific issues as isolated discussion topics, this function emphasizes the continuous integration of contextual understanding and socioscientific deliberation.

The second instructional function, Evidence Construction, captures the transition from inquiry activities to scientific reasoning. Participants consistently perceived that collecting empirical data alone was insufficient without opportunities to organize, interpret, and represent observations as meaningful evidence. This function therefore highlights the importance of supporting learners in transforming raw observations into evidence that can inform subsequent reasoning.

Table 2. Synthesis of cross-phase instructional functions

SSIBL Phase	Dominant Instructional Needs Identified	Recurring Pedagogical Focus Across Phases	Synthesized Cross-phase Instructional Function
Contextual Framing	Understanding the socioscientific issue, activating prior knowledge, identifying inquiry questions	Establishing a shared conceptual foundation before inquiry	Epistemic Structuring
Socioscientific Deliberation	Planning investigations, identifying information sources, organizing inquiry activities	Supporting systematic inquiry preparation and evidence generation	Evidence Construction
Inquiry Execution	Collecting, documenting, and interpreting evidence	Supporting systematic inquiry preparation and evidence generation	Evidence Construction
Evidence Transformation	Connecting evidence with explanations and scientific claims	Transforming evidence into scientifically justified reasoning	Deliberative Anchoring
Structured Argumentation	Constructing arguments, evaluating alternative perspectives, justifying claims	Transforming evidence into scientifically justified reasoning	Deliberative Anchoring
Assessment & Reflection	Monitoring learning progress, providing feedback, reflecting on inquiry outcomes	Maintaining instructional continuity through monitoring and regulation	Orchestration Visibility

The third instructional function, Deliberative Anchoring, reflects the instructional process of grounding socioscientific argumentation in empirical evidence. The recurring relationship between evidence transformation and structured argumentation suggests that learners require explicit support in linking scientific evidence to claims, evaluating alternative viewpoints, and constructing well-justified arguments.

The fourth instructional function, Orchestration Visibility, emphasizes the need for continuous awareness of learning progress throughout inquiry. Rather than restricting assessment to the end of instruction, this function highlights the importance of providing both teachers and students with opportunities to monitor evidence development, argument quality, and learning progression as inquiry unfolds.

Taken together, these instructional functions represent a higher level of abstraction than the individual SSIBL phases. They do not replace the instructional phases themselves; instead, they capture the pedagogical purposes that recur across multiple phases of the learning process. These synthesized functions subsequently provide the conceptual basis for translating instructional needs into system-level design requirements for the proposed digital platform.

Translation into System-Level Design Requirements

The synthesized instructional functions provided the conceptual foundation for translating instructional needs into system-level design requirements. At this stage, the analysis shifted from pedagogical interpretation to technological specification by identifying the digital capabilities required to support each instructional function during SSIBL implementation.

Table 3. Cross-phase translation matrix underlying the proposed system-level design requirements

Cross-phase Instructional Function	Corresponding System-level Design Requirements
Epistemic Structuring	Support contextual understanding of socioscientific issues; Support prior knowledge activation; Support inquiry question formulation.
Evidence Construction	Support inquiry planning; Support evidence collection and organization; Support evidence interpretation across inquiry activities.
Deliberative Anchoring	Support evidence-to-claim linkage; Support argument construction and justification; Support deliberation based on scientific evidence.
Orchestration Visibility	Support learning progress monitoring; Support formative feedback; Support instructional orchestration across the SSIBL workflow.

Each instructional function was examined to determine the minimum technological support required to sustain the intended learning processes across successive phases of SSIBL. Consequently, the resulting requirements represent pedagogically driven system specifications rather than collections of independent software features. Table 3 summarizes the relationship between the synthesized instructional functions and their corresponding system-level design requirements.

The translation demonstrates that each instructional function requires a distinct set of technological capabilities while remaining pedagogically interconnected with the others. For example, Epistemic Structuring requires digital support that enables learners to explore authentic socioscientific issues, organize inquiry questions, and establish meaningful investigative contexts. These capabilities prepare learners for subsequent inquiry activities and therefore serve as the pedagogical entry point of the digital learning environment.

Similarly, Evidence Construction emphasizes technological support that enables learners to document observations, organize empirical information, and construct evidence from inquiry activities. Rather than functioning merely as a data storage facility, the system should facilitate the transformation of raw observations into meaningful representations that can support scientific reasoning.

The instructional function of Deliberative Anchoring requires tools that explicitly connect empirical evidence with scientific claims. Digital support at this stage should facilitate collaborative discussion, argument construction, and evidence-based justification so that learners can critically evaluate alternative explanations and socioscientific positions using documented evidence.

Finally, Orchestration Visibility requires system capabilities that enable continuous monitoring of learning progression throughout the inquiry process. Such capabilities provide teachers with information regarding students' inquiry activities, evidence development, and argumentation processes while simultaneously supporting learners' reflection through ongoing formative feedback.

Taken together, these system-level design requirements demonstrate that technological specifications emerge from instructional functions rather than from isolated user requests or software preferences. This translation establishes an explicit connection between pedagogical intentions and technological design, providing a systematic basis for developing an SSIBL digital platform.

Development of the Architectural Framework

The final stage of analysis integrated the system-level design requirements into a coherent architectural framework for an SSIBL digital platform. Rather than representing independent technological components, the architecture was organized to preserve the instructional continuity identified throughout the previous stages of analysis. Consequently, each platform module was designed to support one or more instructional functions while maintaining explicit connections with adjacent phases of the SSIBL workflow.

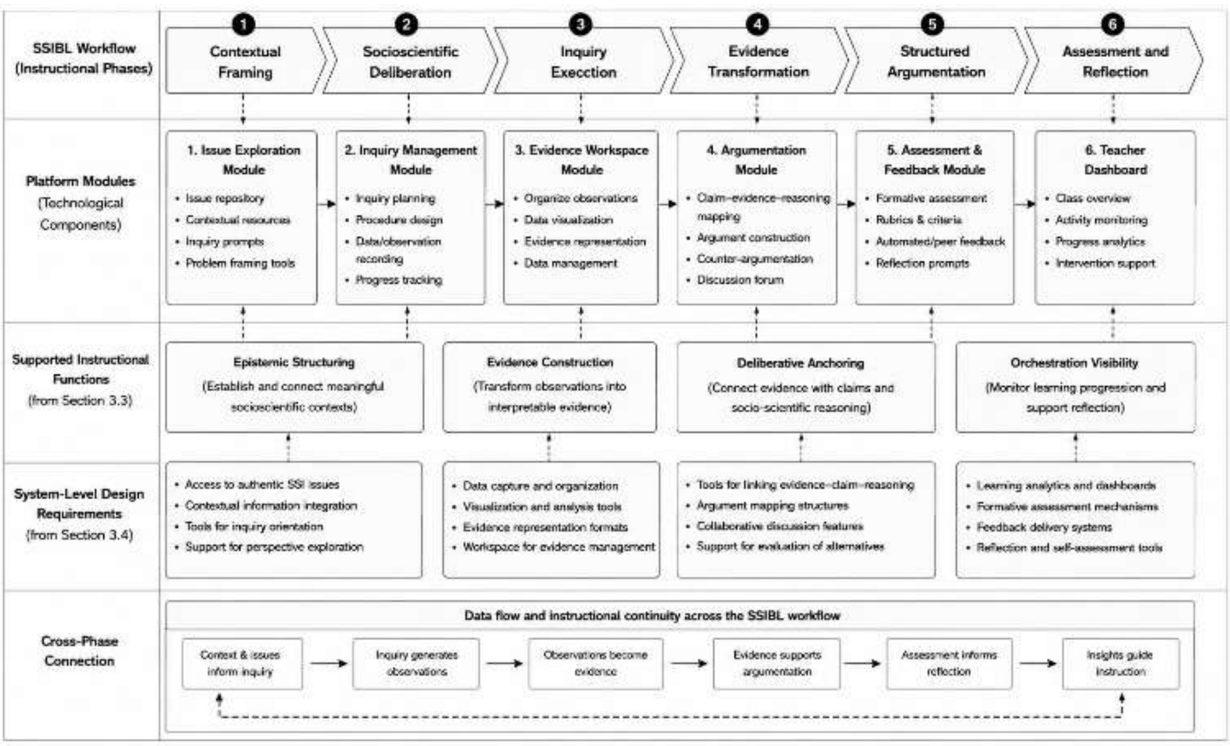

Figure 3. Architectural framework of the proposed SSIBL digital platform

Figure 3 presents the resulting architectural framework. This figure visualizes the proposed pedagogically driven framework by organizing the synthesized instructional functions and their corresponding system-level design requirements into an integrated architectural representation.

The architectural framework comprises six interconnected modules that collectively support the implementation of SSIBL from contextual exploration to assessment and reflection. Each module corresponds to a distinct instructional role while remaining functionally integrated with the overall learning process.

The Issue Exploration Module supports Epistemic Structuring by providing access to authentic socioscientific issues, contextual resources, and inquiry prompts that help learners establish meaningful investigative contexts. This module serves as the instructional entry point of the platform and facilitates learners' initial engagement with scientific and societal problems.

The Inquiry Management Module supports the planning and documentation of inquiry activities. Learners can organize investigation procedures, record observations, and document experimental progress, thereby providing a structured environment for scientific investigation.

The Evidence Workspace Module operationalizes the instructional function of Evidence Construction by enabling learners to organize empirical observations, develop evidence representations, and prepare information for subsequent reasoning and discussion. This module establishes continuity between inquiry activities and argument development.

The Argumentation Module supports Deliberative Anchoring by facilitating the construction of evidence-based arguments. Through explicit connections between claims, evidence, and reasoning, the module encourages learners to justify conclusions, compare alternative perspectives, and participate in collaborative socioscientific discussions.

The Assessment and Feedback Module supports Orchestration Visibility by providing formative assessment tools that document learning progression throughout the inquiry process. Rather than functioning solely as an end-of-unit evaluation system, the module enables continuous monitoring of evidence development, argument quality, and reflective learning.

Finally, the Teacher Dashboard provides an integrated overview of classroom activities by consolidating information generated across all instructional modules. The dashboard is intended to support instructional orchestration by presenting learners' progress, participation, and assessment information in a unified interface, thereby assisting teachers in monitoring classroom implementation without interrupting the inquiry process.

Collectively, these modules form an architectural framework in which pedagogical functions determine technological organization. Instead of treating contextual learning, inquiry, evidence construction, argumentation, and assessment as isolated digital features, the proposed framework maintains instructional continuity by preserving the relationships identified during the requirement translation process. In this way, the resulting architectural framework provides a systematic representation of how instructional needs can be translated into a digital learning environment for SSIBL.

Discussion

From Instructional Needs to Pedagogically Driven Platform Design

The primary contribution of this study lies in proposing a pedagogically driven framework for designing an SSIBL digital platform rather than a completed technological product. The present study adopted an instructional perspective in which system-level design requirements emerged from recurring pedagogical needs identified across the SSIBL workflow (Schoenherr et al., 2024). This approach establishes an explicit connection between educational objectives and technological design, thereby reducing the risk of developing digital environments that prioritize technical functionality over instructional coherence (Nesbit & Liu, 2025; Forsythe & Chan, 2025; Lin & Hung, 2025).

The analytical process revealed that participants consistently perceived instructional support as necessary throughout the entire SSIBL workflow. More importantly, the subsequent pattern identification and instructional function synthesis indicated that these needs were not confined to individual learning phases. Instead, the findings suggest that effective implementation of SSIBL depends on maintaining continuity across contextual framing, inquiry, evidence construction, argumentation, and reflective assessment. The resulting architectural framework therefore emphasizes pedagogical integration rather than the accumulation of independent technological features.

This perspective is consistent with contemporary views of educational technology that position digital platforms as mediating environments for learning rather than repositories of instructional resources. Previous studies have similarly argued that technology is most effective when it supports the orchestration of learning processes, facilitates meaningful interactions, and preserves coherence across successive learning activities (Amarasinghe et al., 2024; Rivera et al., 2024; Wang & Fan, 2025). From this perspective, instructional functions provide a more stable foundation for system design than individual software functions because they remain closely aligned with pedagogical intentions.

An important implication of the present study is that requirement elicitation can serve as a bridging mechanism between instructional theory and educational technology design. By systematically identifying instructional needs, examining recurring patterns, synthesizing pedagogical functions, and translating those functions into system-level requirements, the proposed framework offers a transparent design pathway that can guide future development of SSIBL digital learning environments. Rather than viewing pedagogical design and software development as separate activities, the framework illustrates how both processes can be integrated through a structured requirement translation procedure.

Accordingly, the proposed architectural framework should be interpreted as a pedagogically driven design specification rather than a finalized technological solution. Its primary value lies in providing a conceptual foundation that can support iterative prototyping, usability evaluation, and subsequent design-based research aimed at refining digital support for SSIBL implementation. Unlike previous studies that primarily evaluate completed digital interventions (Arifin et al., 2024; Kusumawati et al., 2022; Laudia et al., 2025; Nirwana & Octavia, 2025), the present study contributes a pre-development design framework that systematically derives technological specifications from pedagogical requirements.

Implications for SSIBL Implementation

The architectural framework proposed in this study has implications beyond the development of a digital platform. More fundamentally, it offers a structured representation of how pedagogical processes within SSIBL can be supported through coherent technological design. The findings suggest that digital learning environments should not be viewed merely as collections of instructional tools but as integrated environments that sustain continuity across successive phases of inquiry.

One notable finding is that participants consistently emphasized instructional support throughout the entire SSIBL workflow rather than within isolated learning activities. This observation reinforces the view that effective socioscientific inquiry depends on maintaining meaningful connections between contextual understanding, scientific investigation, evidence construction, argumentation, and reflective assessment. Previous research has similarly highlighted that inquiry-based learning becomes more effective when learners are supported in connecting these processes rather than experiencing them as separate instructional events (Hinostroza et al., 2024; Sam, 2024). Consequently, digital environments intended to support SSIBL should be designed around instructional continuity rather than independent technological functionalities.

The instructional functions synthesized in this study further suggest that learners require support not only in completing inquiry tasks but also in navigating transitions between different forms of reasoning. For example, contextual understanding provides the foundation for meaningful inquiry, while evidence construction creates the conditions necessary for scientific argumentation. Likewise, formative assessment becomes more valuable when it is embedded throughout the inquiry process rather than positioned solely at the conclusion of learning. These relationships reflect the interconnected nature of socioscientific inquiry and reinforce the importance of maintaining coherence across instructional phases.

From a design perspective, the proposed framework illustrates how pedagogical intentions can guide technological specification. Instead of beginning with available digital features, the framework first identifies instructional purposes and subsequently derives technological capabilities required to support those purposes. Such an approach aligns with learner-centered educational design, in which technology functions as an enabler of pedagogical processes rather than as the primary driver of instructional innovation.

The framework also provides practical guidance for future platform development. Because the proposed modules are derived from synthesized instructional functions rather than isolated feature requests, they offer a coherent structure that can be extended or refined as instructional needs evolve. This flexibility is particularly important for educational technologies intended to support complex pedagogical approaches such as SSIBL, where learning activities involve iterative inquiry, collaborative reasoning, and continuous reflection.

Contextual Considerations for Implementation

Although the proposed architectural framework is grounded in instructional requirements identified through this study, its implementation should be considered within the broader context of school environments. Educational settings differ considerably in terms of technological infrastructure, digital readiness, and classroom practices. Consequently, the effectiveness of an SSIBL digital platform depends not only on its pedagogical design but also on its adaptability to diverse implementation contexts.

One important consideration concerns the availability and reliability of digital infrastructure. Schools may differ in terms of internet connectivity, device availability, and access to digital learning resources. These variations do not diminish the relevance of the proposed instructional functions; rather, they suggest that platform implementation should be sufficiently flexible to accommodate different levels of technological readiness. For example, asynchronous data synchronization, mobile-friendly interfaces, and modular deployment strategies may enable schools with varying technological capacities to adopt the platform progressively.

Teacher readiness represents another important consideration. The proposed architectural framework is intended to support instructional orchestration rather than replace teachers' pedagogical decision-making. Successful implementation therefore requires professional development that enables teachers to integrate digital tools into inquiry-based instruction while maintaining the pedagogical principles of SSIBL. In this regard, the platform should be viewed as an instructional support system that complements teachers' expertise instead of prescribing fixed teaching procedures.

The framework also provides opportunities for contextual adaptation. Socioscientific issues are inherently influenced by local environmental, cultural, and societal conditions. Consequently, the contextual resources incorporated into the platform should remain adaptable so that teachers can select or develop learning scenarios that reflect issues relevant to their own educational settings. Such flexibility enables the platform to preserve the pedagogical structure of SSIBL while accommodating diverse curricular priorities and local contexts.

These considerations reinforce the importance of viewing the proposed framework as a flexible architectural specification rather than a fixed technological product. The instructional functions identified in this study are expected to remain stable across different learning environments, whereas their technological implementation may be adapted to available infrastructure, institutional priorities, and classroom characteristics. Such adaptability is essential for ensuring that pedagogically driven digital environments remain applicable across diverse educational contexts.

Conclusion

This study proposed a pedagogically driven framework for designing an SSIBL digital platform through the systematic identification of instructional needs, synthesis of cross-phase instructional functions, derivation of system-level design requirements, and development of an architectural framework. The resulting framework preserves instructional continuity across the SSIBL workflow by explicitly aligning pedagogical processes with system-level design. Rather than focusing on isolated technological features, the proposed pedagogically driven framework emphasizes the alignment between pedagogical processes and digital system design. The principal contribution of this study lies in demonstrating a transparent requirement translation process that connects instructional theory with educational technology development. The proposed framework illustrates how stakeholder-identified instructional needs can be systematically transformed into pedagogically meaningful system specifications and subsequently organized into an architectural framework. This process contributes a conceptual foundation for the development of digital learning environments that support coherent implementation of SSIBL while maintaining explicit relationships between contextual inquiry, evidence construction, scientific argumentation, and formative assessment. This study has several limitations that should be acknowledged. First, the framework was developed based on stakeholder perceptions of instructional needs rather than empirical testing of a functional system, and therefore does not provide evidence of actual instructional effectiveness. Second, the data were collected from a limited group of teachers and students, which may not fully represent the diversity of educational contexts in which SSIBL is implemented. Third, the proposed architectural framework has not yet been implemented or evaluated in real classroom settings, limiting conclusions regarding its usability and practicality. Future research may extend the present work by developing functional prototypes based on the proposed architectural framework and evaluating their usability in authentic classroom settings. Iterative design-based research may further examine how the platform supports scientific inquiry, evidence-based argumentation, and socioscientific decision-making across diverse educational contexts. Such investigations will contribute not only to the refinement of the proposed architectural framework but also to a broader understanding of how pedagogically driven digital environments can effectively support SSIBL implementation.

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Author Contributions

Conceptualization, M.Y. and H.A.; methodology, formal analysis, writing—original draft preparation, project administration, M.Y.; software, visualization, D.A.; validation, M.Y., H.A., and M.; investigation, M., D.A., and D.; resources, supervision, funding acquisition, H.A.; data curation, D.A. and D.; writing—review and editing, H.A., M., D.A., and D. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
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