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Introducing the ECEH model as a framework to support teachers in designing content-structured science educational infographics

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RESEARCH ARTICLE

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Abstract

Although infographics are used in science education, their design is rarely supported by explicit criteria for the pedagogical sequencing of scientific content. Responding to this gap, this methodology-design study introduces the ECEH model—Engagement, Concentration, Expansion, and Highlighting–Acting—as a framework for supporting teachers in designing content-structured science educational infographics. The study examines the model's perceived usefulness and practical applicability within the I.S.E. module (Infographics in Science Education), using a design-based action research approach with 12 teachers from Greece and France. Data included teacher-produced infographics, reflective texts, peer feedback, questionnaires, and observation notes. Findings suggest that the model offered a clear yet adaptable scaffold for organizing content, supporting confidence, and encouraging pedagogically purposeful design. Engagement and Highlighting–Acting were the most readily enacted dimensions, while Expansion proved more demanding, as it required teachers to connect core scientific content with additional cases, socio-scientific contexts, and opportunities for transfer. The paper discusses implications for professional development, infographic design, and future validation of the model.

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1 INTRODUCTION

Over the past two decades, the increasing presence of visual media in educational settings has significantly influenced both pedagogical practice and instructional design (Désiron et al., 2025; La Torre & Désiron, 2024). Diagrams, concept maps, animations, simulations, and other forms of visual representation are now widely used to support teaching and learning, particularly in response to the need for more accessible, engaging, and multimodal learning environments (McCrudden & Van Meter, 2021). Within this broader visual turn, infographics have gained particular attention. Commonly understood as visual syntheses that bring together textual, graphical, and data-based elements (Smiciklas, 2012), infographics appear especially relevant to science education, where learners are often required to interpret complex relations, processes, and forms of evidence.

This relevance is closely connected to the nature of science learning itself. Science education frequently involves phenomena that are abstract, systemic, microscopic, or otherwise difficult to communicate through verbal explanation alone (Treagust & Duit, 2008). Research in cognitive science and multimedia learning has shown that the coordinated use of visual and verbal representations can support conceptual understanding, provided that such representations are designed in ways that reduce unnecessary cognitive demands and make conceptual relations more explicit (Mayer, 2014; Schnotz & Bannert, 2003).

From this perspective, well-designed infographics may support learning by organizing scientific content in ways that are visually coherent, cognitively manageable, and pedagogically meaningful (Ozdamli & Ozdal, 2018). However, despite their growing use across STEM education, infographics are often designed through intuitive or aesthetic criteria rather than through systematic instructional principles. As a result, visual appeal may sometimes take precedence over conceptual accuracy, curricular relevance, and pedagogical coherence (Clark & Lyons, 2010).

Existing theoretical frameworks, including the cognitive theory of multimedia learning (Mayer, 2014) and approaches to visual literacy (Majooni et al., 2018), offer important insights into how learners process, interpret, and make meaning from visual information. Nevertheless, they do not fully address a more specific design problem: how scientific content should be selected, sequenced, organized, and pedagogically framed within educational infographics. This remains a critical gap. In the absence of explicit content-oriented criteria, science educational infographics may become visually attractive but instructionally weak. They may simplify complex ideas in misleading ways, overlook curricular aims, increase rather than reduce cognitive load, reinforce misconceptions, or fail to support learners' engagement with the nature of scientific knowledge.

The present study responds to this gap by proposing a structured, content-oriented model for the design of science educational infographics. The ECEH model, developed by the authors of this study, consists of four dimensions: Engagement, Concentration, Expansion, and Highlighting–Acting. Rather than treating infographics merely as visual products, the model positions them as pedagogical artifacts that require deliberate decisions about content inclusion, conceptual sequencing, representational form, and instructional purpose. In this sense, the ECEH model aims to support teachers in designing infographics that are not only visually engaging, but also scientifically accurate, conceptually structured, and aligned with the broader aims of science teaching and learning.

To examine the perceived applicability and pedagogical relevance of the model, the study adopted a design-based action research approach with a group of science educators. Through iterative cycles of design, reflection, feedback, and evaluation, participants explored the clarity, usability, and instructional coherence of the ECEH model in relation to their own infographic design practices. The significance of the study lies in its attempt to provide a methodologically grounded framework for integrating infographics into science education through explicit content-oriented criteria.

By articulating and examining the ECEH model through an action research process, the study contributes to bridging the gap between visual attractiveness and instructional rigor. It offers teachers a systematic way of selecting, sequencing, and representing scientific content, while also encouraging attention to conceptual understanding, epistemic engagement, and meaningful participation in the practices and discourses of science. To guide this investigation, the following research questions were formulated:

1. What are teachers' current practices, perceived benefits, and challenges in using science educational infographics?
2. How do teachers engage with the ECEH model when designing content-structured science educational infographics?
3. How do teachers describe the clarity, relevance, and instructional usefulness of the ECEH model after completing a design-based task?

2 LITERATURE REVIEW

2.1 The pedagogical potential and limitations of infographics in science education

The expanded role of visual media in contemporary educational practice has drawn increasing attention within science education, particularly as teachers and researchers search for more effective ways to support conceptual understanding, student involvement, and durable learning outcomes (Jaleniauskiene & Kasperiuniene, 2023; Navarrete-Muñoz et al., 2024). In this context, infographics have attracted considerable interest as a mode of representation capable of making complex scientific ideas more accessible without relying exclusively on extended verbal explanation (Alrwele, 2017; Elaldı & Çifçi, 2021). Their educational appeal lies partly in their ability to organize dense information, foreground key relations, and translate abstract or cognitively demanding content into visually interpretable forms (Lowe & Schnotz, 2014).

The theoretical justification for using infographics is commonly linked to Mayer's (2014) cognitive theory of multimedia learning. According to this perspective, learning can be strengthened when verbal and visual information are coordinated in ways that are complementary, coherent, and free from unnecessary duplication. Empirical findings provide some support for this claim. Alrwele (2017), for example, found significantly higher achievement among students who used infographics than among those in the comparison group. Ozdamli and Ozdal (2018) also reported favorable teacher and student evaluations of an infographic-based instructional design. In a broader synthesis, Elaldı and Çifçi (2021) found a large positive overall effect on academic achievement and qualitative evidence of cognitive contributions. Such findings suggest that infographics may operate as forms of cognitive mediation, helping learners connect existing knowledge with unfamiliar scientific concepts.

At the same time, the educational promise of infographics should not be treated as self-evident. Several scholars have warned that, when detached from sound instructional principles, infographics may become visually appealing but pedagogically weak artifacts (Clark & Lyons, 2010; Schnotz & Bannert, 2003). Their use may lead to excessive simplification, inaccurate representation of scientific processes, or the unintended reinforcement of misconceptions. In this sense, the very features that make infographics attractive, namely compression, clarity, and visual immediacy, can also become problematic if they flatten conceptual complexity or obscure the relational structure of scientific knowledge.

A further limitation concerns the lack of systematic and discipline-sensitive criteria for designing educational infographics. Although general visual-design guidelines and ready-made graphic templates are widely accessible, there remains limited methodological guidance on how teachers should select content, establish conceptual hierarchy, sequence information, or align infographic design with curricular aims. This gap is especially significant in science education, where representational accuracy, explanatory coherence, and disciplinary precision are essential (He et al., 2024). Consequently, many science-related infographics appear to rely more on aesthetic preference or intuitive judgment than on theoretically informed pedagogical reasoning.

The effectiveness of infographics also depends on how they are designed and embedded within instruction. Digital authoring tools can make infographic production more accessible and support flexible design exploration (Tyagi et al., 2022), but technical assistance alone does not ensure pedagogical quality. Infographics become more educationally meaningful when teachers use them to prompt questioning, interpretation, discussion, and active engagement with visual information. Without such pedagogical framing, they may remain static visual summaries rather than becoming resources for conceptual elaboration and metacognitive reflection.

The literature indicates that infographics offer considerable potential as multimodal resources for science teaching, but their value is conditional rather than automatic. Their contribution depends on the quality and intentionality of their content design, their alignment with the epistemic and curricular demands of science learning, and the instructional contexts in which teachers and students use them.

2.2 Conceptual and theoretical underpinnings of the proposed model framework

The proposed model is situated within socio-scientific inquiry-based learning (SSIBL), a framework that brings together inquiry-based learning (IBL) and socio-scientific reasoning (SSR). Rather than treating scientific knowledge as a closed body of facts to be transmitted, SSIBL approaches science learning as a process of investigation, interpretation, dialogue, and judgment within socially meaningful contexts. This orientation is particularly relevant to the design of educational tools that aim to support scientific literacy, reflective inquiry, and informed decision-making in situations where scientific knowledge intersects with ethical, environmental, and civic concerns.

Inquiry-based learning draws on Dewey's (1986) pragmatist view of education and has been further developed in contemporary research on inquiry processes and science learning (Pedaste et al., 2015). Its central premise is that learners develop understanding through active engagement with questions, evidence, investigation, and reflection. In this sense, IBL does not simply encourage activity; it introduces students to the ways in which scientific knowledge is produced, tested, revised, and justified. By engaging with authentic scientific practices, learners are invited to work with uncertainty, examine evidence, and construct explanations, thereby developing both conceptual understanding and the epistemic dispositions associated with scientific inquiry (Kuhn, 2005).

Socio-scientific reasoning extends this orientation by placing science education within real-world problems that are often complex, controversial, and value-laden. Through SSR, learners are encouraged to examine scientific evidence alongside ethical considerations, social consequences, and diverse perspectives. This shifts science learning beyond the acquisition of factual knowledge and toward the development of civic literacy, argumentative competence, and responsible participation in public issues involving science and technology (Zeidler & Sadler, 2023; Zeidler et al., 2005).

Within SSIBL, inquiry and socio-scientific reasoning are not separate pedagogical additions but mutually reinforcing dimensions of science education. Inquiry provides the investigative structure through which learners engage with evidence and explanation, while socio-scientific reasoning situates this engagement within broader questions of responsibility, uncertainty, and social relevance. This synthesis is also consistent with constructivist perspectives on learning, particularly Vygotsky's (1978) emphasis on the social, cultural, and discursive mediation of knowledge. From this viewpoint, learning is shaped through interaction with tools, language, peers, and culturally situated practices.

The ECEH model is also informed by complementary theoretical perspectives that clarify its design logic. From the standpoint of multimedia learning, Mayer's (2014) cognitive theory highlights the importance of coordinating verbal and visual information in ways that support meaningful processing rather than cognitive overload. This perspective is especially relevant to infographic design, where scientific content must be represented visually without losing conceptual accuracy or explanatory depth. In parallel, the notion of instructional scaffolding developed by Wood et al. (1976) informs the model's gradual movement from guided engagement toward more autonomous interpretation, allowing learners and teachers to work progressively with complex scientific content.

At an epistemological level, the model aligns with disciplinary literacy in science, understood as the capacity to read, interpret, evaluate, and produce the forms of language, evidence, and representation through which scientific knowledge is communicated (Shanahan & Shanahan, 2008). This perspective is important because science infographics are not merely decorative or communicative devices. They are disciplinary representations that require attention to accuracy, evidence, terminology, conceptual hierarchy, and the relationships among scientific ideas. Accordingly, the ECEH model treats infographic design as a pedagogical and epistemic practice rather than as a purely visual task.

Finally, the model is shaped by principles of culturally relevant pedagogy, which foreground the need for science education to be intellectually demanding, culturally responsive, and socially conscious (Ladson-Billings, 1995). Culturally relevant pedagogy rests on three interrelated commitments: supporting students' academic success, valuing their cultural knowledge and lived experiences, and fostering critical consciousness in relation to social inequities. Incorporating this perspective ensures that the design of science educational infographics does not address learners as a homogeneous audience, but instead recognizes diversity in experience, language, cultural background, and access to scientific knowledge. In this way, the ECEH model seeks to support infographic design that is not only cognitively and pedagogically coherent, but also attentive to issues of inclusion, equity, and meaningful participation in science learning.

The theoretical construction of the ECEH model can therefore be read as a translation of these perspectives into four design operations (Table 1). Engagement draws on inquiry, motivation, and culturally relevant pedagogy to connect the science topic with learners' interests and experiences. Concentration draws on multimedia learning, cognitive load theory, scaffolding, and disciplinary literacy to organize essential concepts accurately and coherently. Expansion draws on socio-scientific reasoning and inquiry to connect core content with additional cases, uncertainty, and transfer. Highlighting–Acting draws on reflection, scientific literacy, and socio-scientific engagement to consolidate key ideas and invite responsible interpretation or action.

TABLE 1
Conceptual alignment of ECEH dimensions with theoretical principles

ECEH dimension	Main theoretical basis	Pedagogical function
Engagement	Inquiry-based learning, culturally relevant pedagogy, motivation in multimedia learning	Connects the science topic to learners' interests, experiences, and questions
Concentration	Cognitive theory of multimedia learning, cognitive load, scaffolding, disciplinary literacy	Establishes the conceptual foundation and organizes essential scientific content
Expansion	Socio-scientific reasoning, inquiry, transfer of learning	Extends core content through cases, additional evidence, uncertainty, and broader contexts
Highlighting–Acting	Reflection; socio-scientific engagement, disciplinary literacy, action-oriented science education	Consolidates key ideas and invites interpretation, judgment, or responsible action

3 FRAMEWORK FOR DEVELOPING CONTENT-STRUCTURED SCIENCE EDUCATIONAL INFOGRAPHICS: THE ECEH MODEL

The ECEH model was therefore constructed as a sequence of pedagogical design decisions rather than as a purely visual template. Each dimension specifies a different function in the design of a science educational infographic: (a) attracting attention, (b) establishing conceptual focus, (c) extending understanding, and (d) consolidating reflection or action. The model is intended to help teachers move from intuitive visual design toward explicit decisions about content selection, conceptual sequencing, scientific validity, cognitive load, and socio-scientific relevance.

The ECEH model provides a structured framework for designing science educational infographics that guide learners through progressive stages of understanding while balancing socio-scientific engagement with scientific accuracy and validity (Figure 1). It scaffolds both cognitive and affective engagement, supporting the construction of knowledge and the development of socio-scientific reasoning.

Engagement: Learners are first introduced to the science topic in a context that sparks curiosity and motivates inquiry. Careful topic selection ensures alignment with curriculum goals and relevance for the target audience. At this stage, information is presented in concise, visually appealing ways to avoid excessive cognitive load and to capture attention without overwhelming working memory.

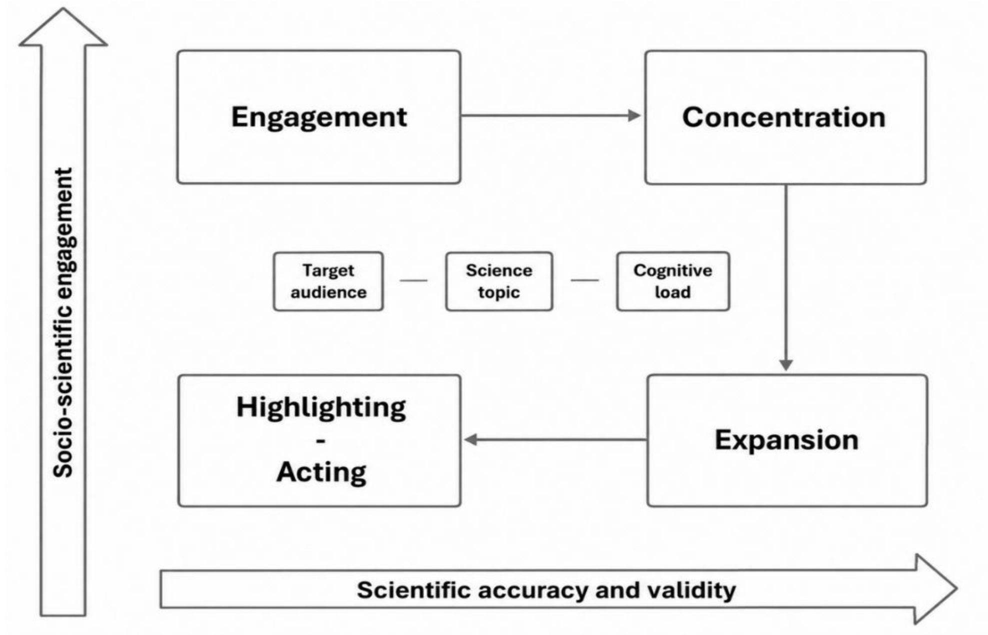
Concentration: This phase establishes the conceptual foundation by presenting essential facts, data, and guiding questions. The target audience informs the level of detail and choice of representations, while the design manages cognitive load through clear sequencing and the integration of text and visuals. These decisions allow learners to focus on core scientific ideas and begin critical analysis.

Expansion: Building on the initial understanding, learners encounter additional evidence, case studies, and alternative perspectives. The science topic is deliberately broadened to highlight complexity and uncertainty, but information is chunked and visually organized to maintain manageable cognitive load. Learners are challenged to apply their understanding in new contexts, promoting flexible reasoning and knowledge transfer.

Highlighting–Acting: The final phase consolidates key concepts and invites reflection and action. Prompts encourage students to evaluate implications, make informed decisions, and consider socially responsible responses. The needs and interests of the target audience shape the calls to action, while careful design ensures that even at this culminating stage the cognitive load remains balanced.

Throughout all four phases, the vertical axis of Figure 1 signals the increasing depth of socio-scientific engagement, while the horizontal axis underscores the continual requirement for scientific accuracy and validity. The three design considerations, target audience, science topic, and cognitive load, function as ongoing checkpoints, ensuring that each phase remains both intellectually rigorous and accessible.

FIGURE 1
The ECEH model for pedagogically grounded infographic design



4 MATERIALS AND METHODS

4.1 Research design

This study adopted a design-based action research approach to examine the perceived usefulness, practical applicability, and pedagogical affordances of the ECEH model for structuring the content of science educational infographics with a group of science educators. This methodology was chosen to ensure that the model was not only theoretically grounded but also examined in collaboration with practitioners within a realistic professional development context. By involving teachers as active participants in the design process, the study aligned with the participatory principles of action research and allowed for iterative refinement of the model's application.

The intervention was organized around four action-research moments: (a) planning, (b) implementation, (c) feedback, and (d) reflection. In the planning moment, the researchers introduced the pedagogical problem of infographic design and presented the ECEH model. In the implementation moment, teachers analyzed existing infographics and created their own products. In the feedback moment, participants received peer and facilitator feedback and compared their designs with the ECEH criteria. In the reflection moment, teachers evaluated the clarity, relevance, and instructional usefulness of the model. The intervention did not aim to prove general effectiveness, but to examine how the model functioned as a scaffold in this professional development setting.

The researchers acted as designers of the ECEH model, facilitators of the professional development module, observers of the workshop process, and evaluators of the teacher-created infographics. This dual role was necessary for a design-based action research study, but it is also treated as a methodological limitation because researcher facilitation may have shaped participants' engagement and positive evaluations.

The study was conducted within the framework of the UNI-T European Civic Academy, and specifically the blended learning module "I.S.E.: Infographics in Science Education," hosted on the CIVIS platform (https://moodle.civis.eu/course/view.php?id=275). The CIVIS initiative brings together partner universities, including the National and Kapodistrian University of Athens, Aix-Marseille Université, University of Tübingen, and Université libre de Bruxelles, to offer educators opportunities for professional learning through both online and face-to-face mobility programs.

Although the module offered both online and on-site components, the data reported here derive primarily from the face-to-face workshops, where participants engaged directly with the proposed ECEH model. The face-to-face format was intentionally selected because it allowed for real-time interaction, sustained dialogue, and immediate feedback among participants and the facilitator. Such immediacy was essential for observing teachers' engagement, design decision-making, and iterative application of the ECEH model**.** These processes benefit from spontaneous discussion and collaborative problem-solving and are difficult to replicate in purely online settings.

4.2 Sample

The study's sample consisted of 12 teachers from primary and secondary education in Greece and France. Participants were recruited through convenience sampling because they were accessible, voluntarily enrolled in the I.S.E.: Infographics in Science Education module, and were relevant to the exploratory purpose of the study. The sample is therefore treated as appropriate for generating context-rich qualitative insights into the model's perceived usefulness and practical applicability, rather than as a basis for generalizable claims about effectiveness.

The sample included science teachers from different disciplinary backgrounds: (a) four physics teachers, (b) two chemistry teachers, (c) two biology teachers, and (d) four primary teachers responsible for general science education. According to the participant profile, eight participants were based in Greece at the secondary level and four were based in France at the primary level. Table 2 presents the demographic and professional profile of the participants.

TABLE 2
Research sample

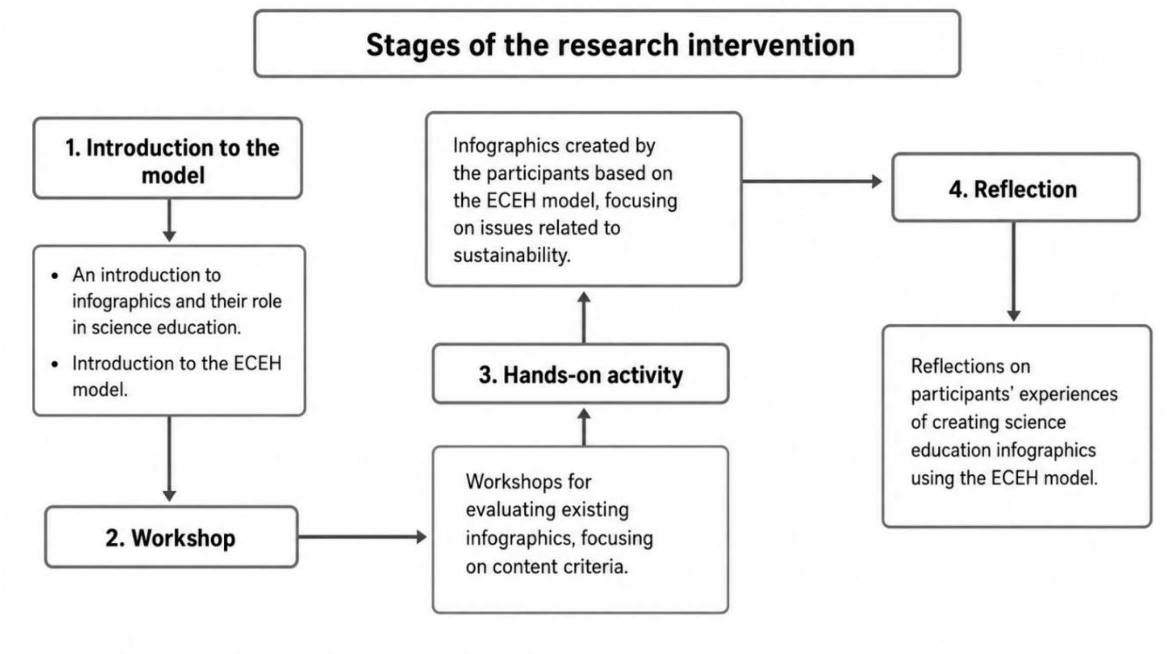
Participant	Country	Teaching level	Subject area
P1	Greece	Secondary	Physics
P2			Physics
P3			Chemistry
P4			Chemistry
P5			Biology
P6			Biology
P7	France	Primary	General science
P8			
P9			
P10			
P11	Greece	Secondary	Physics
P12			

4.3 Stages of the research

The research unfolded across two interconnected phases organized as a multistep design-based intervention (Figure 2). The first phase explored teachers' existing practices with science educational infographics and their perceptions of benefits and challenges. Data were collected through an online questionnaire (Google Forms), which provided baseline evidence for the first research question. The second phase implemented the ECEH model through introduction, guided analysis, hands-on design, peer feedback, and reflection. These stages corresponded to the action-research movement from planning to implementation, observation/feedback, and reflection.

During the implementation phase, teachers first participated in an introductory session on the pedagogical role of infographics in science education, followed by workshops in which they critically analyzed sample infographics using criteria derived from the ECEH framework. They then created and iteratively refined their own infographics, applying each of the four dimensions of the model. Evidence gathered during these activities addressed teachers' engagement with the ECEH model and their evaluations of its clarity, relevance, and instructional usefulness after the design-based task.

FIGURE 2
Stages of the research intervention



All activities were centered on the theme of sustainability, a contemporary scientific issue that is both cross-cutting and closely aligned with school curricula as well as broader societal concerns. Sustainability offers abundant opportunities to integrate scientific concepts with visual and narrative elements, making it an ideal context for exploring and applying the proposed infographic model.

5 DATA COLLECTION AND ANALYSIS

In this study, data collection and analysis are presented together to provide a cohesive account of both the methods used to gather information and the procedures applied to interpret it. For each type of data collected, the corresponding analysis approach is described, highlighting how the two processes were interlinked.

Multiple sources of data were collected to explore the application and adaptation of the ECEH model for content-structuring science educational infographics. Data were gathered over the duration of the I.S.E.: Infographics in Science Education module, delivered through the CIVIS platform from May 2024 to February 2025. The collection period spanned two one-month intervals, November 2024 and January 2025, each comprising four 2-hour sessions. Presenting data collection alongside the corresponding analysis for each source allows for a more organized and transparent account of how teachers' engagement with the ECEH model was examined throughout the module.

The types of data collected included:

1. Questionnaire responses that documented participants' prior experiences with infographics, perceived benefits, and challenges in using them in science teaching,
2. Teacher-created infographics, produced during hands-on workshops and submitted individually for

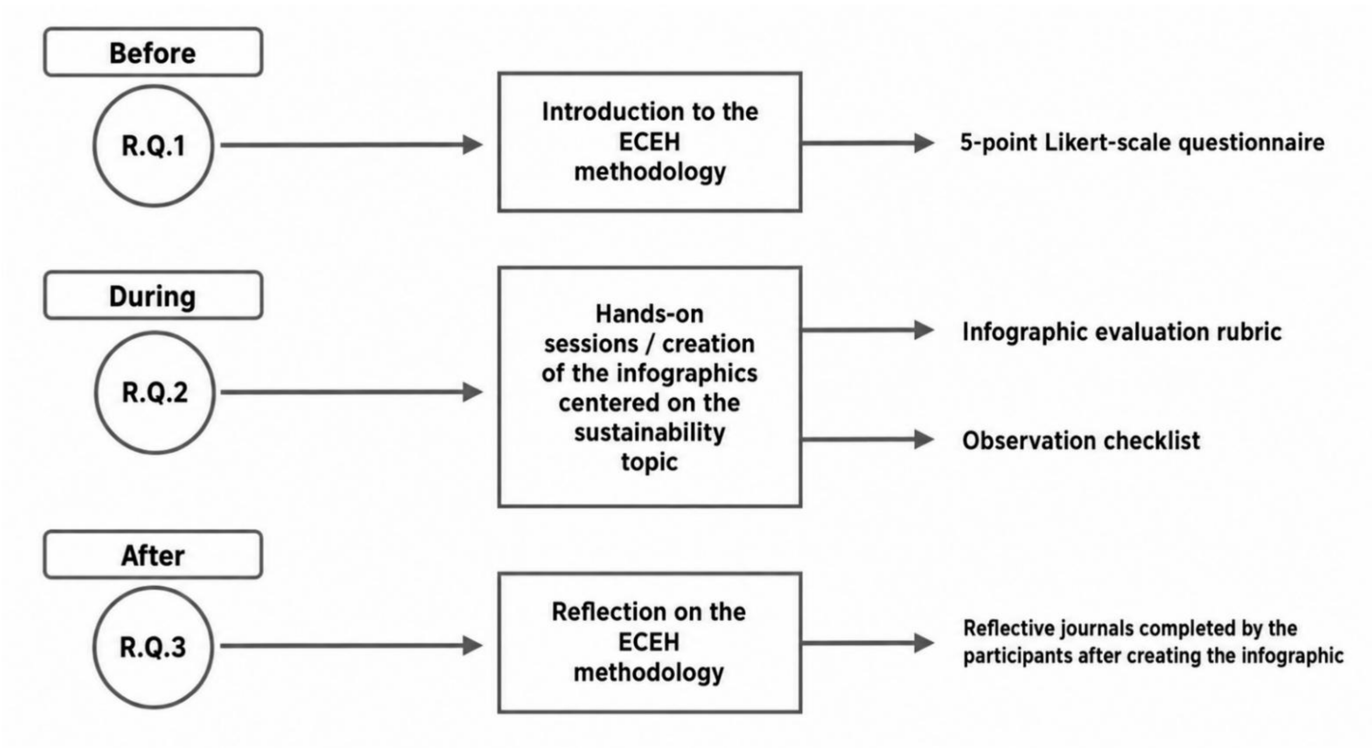
evaluation, reflecting the application of the ECEH model in practice,

3. Observation notes taken by the researcher during synchronous sessions, documenting teachers' engagement, problem-solving strategies, and collaborative interactions,
4. Workshop reflections and peer feedback, in which participants critically evaluated their own and their colleagues' infographics based on the established content criteria, along with the clarity, relevance, and instructional usefulness of the ECEH model.

The combination of these multiple data sources ensured triangulation, enhancing the credibility and validity of the findings (Patton, 2015). The questionnaire provided a baseline understanding of prior experiences and perceptions, while the teacher-created artifacts and reflections offered insight into how the methodology was enacted in practice. Observation notes provided contextual richness and allowed for interpretation of participants' experiences, contributing to both internal validity and trustworthiness of the study (Figure 3).

FIGURE 3

Research tools used at each stage of the intervention



5.1 Questionnaire

To investigate teachers' prior experiences with infographics, as well as their perceived benefits and challenges regarding their use in science education, we designed and administered a digital questionnaire. The questionnaire was directly aligned with the first research question and provided a descriptive baseline for the subsequent intervention.

The instrument comprised 10 items rated on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Items were generated from the literature on infographic use, visual representation, and science education, and were organized around three constructs: prior experience, perceived benefits, and perceived challenges. Reverse-coded items were included to reduce acquiescence bias and to encourage more careful engagement with the statements. Reverse-coded items were recoded before descriptive interpretation so that higher scores consistently reflected stronger agreement with the intended construct.

To ensure the appropriateness and clarity of the instrument, the questionnaire underwent expert review by two science education researchers familiar with visual representations and teacher professional development. Their feedback was used to refine item wording and confirm face validity, alignment with the study aims, and clarity for participants. The final version was administered through Google Forms, allowing secure and efficient data collection across the two countries.

5.2 Teacher-created infographics

To examine how participants applied the ECEH model in practice, teachers developed infographics during hands-on workshops and submitted individual products for evaluation. Upon completion, the researcher collected and systematically evaluated the infographics. This evaluation was not disclosed to the teachers. Following the evaluation, teachers engaged in workshop reflections and peer feedback activities, which were collected separately, as detailed below. An evaluation rubric was developed based on the four components of the ECEH model to provide structured criteria for assessing the quality and pedagogical effectiveness of each infographic (Table 3). The rubric assessed the extent to which each infographic oriented the audience to a science topic, presented essential concepts clearly, offered additional related information, and encouraged further reflection or action. Scoring was conducted on a four-point scale (1 = Poor, 4 = Excellent), allowing for consistent, comparative evaluation across all infographics.

TABLE 3
Infographic evaluation rubric based on the ECEH model

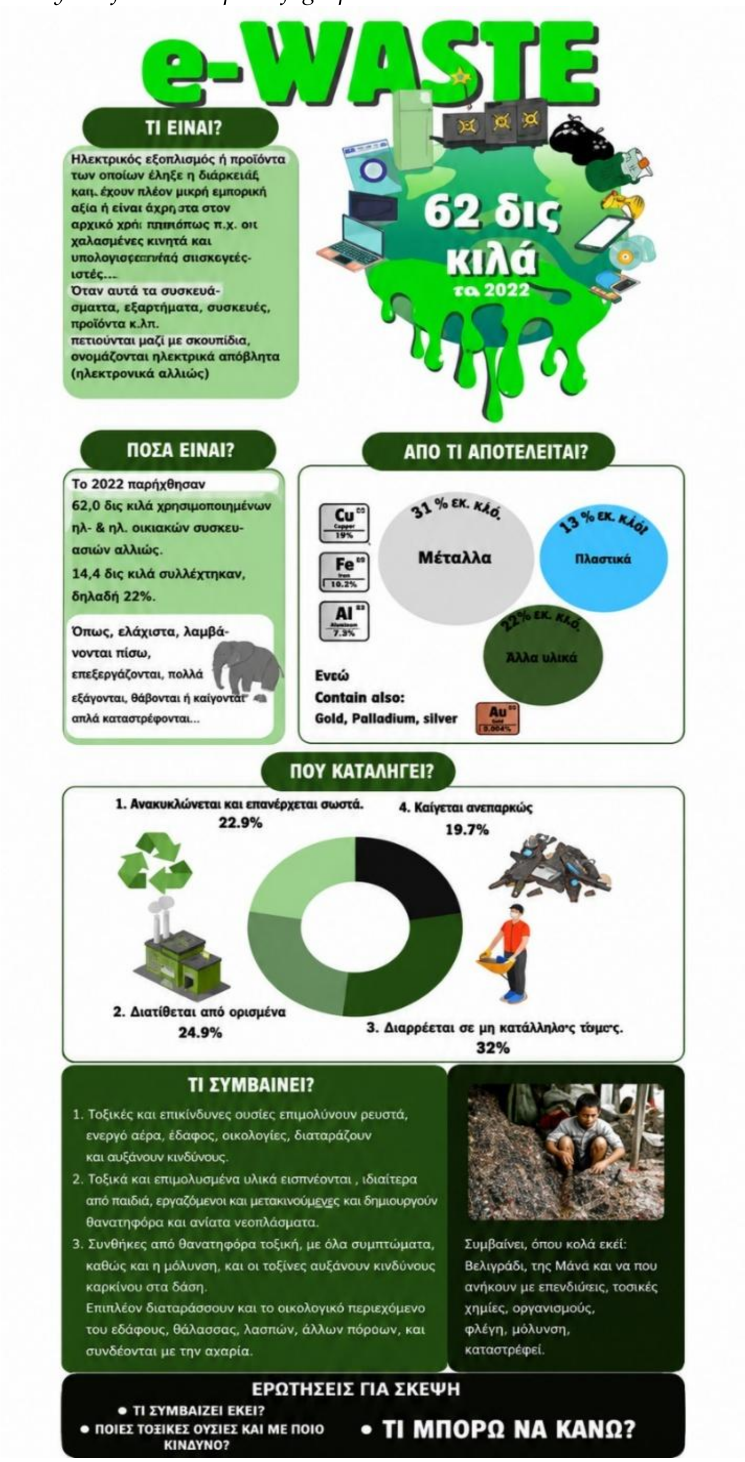
Criterion	Poor (1)	Fair (2)	Good (3)	Excellent (4)
Engagement	No clear orientation or challenging situation.	Weak or vague challenge; limited audience interest.	Topic is introduced with some challenge, but engagement is moderate.	Clear, challenging situation immediately orients and engages the audience.
Concentration	Core science concepts and guiding questions are absent or unclear.	Basic concepts or data are present but incomplete or confusing.	Concepts and data are mostly accessible; questions are present but may lack depth.	Essential concepts, data, and problem-centered questions are clear, accurate, and inquiry-oriented.
Expansion	No evidence of extension beyond basic content.	Limited additional cases, facts, or applications.	Some additional cases or applications are included, but links to the topic are partial.	Additional evidence, cases, and applications deepen exploration and support transfer.
Highlighting–Acting	No summary, reflection prompt, or call for further thinking/action.	Summary or action cues are weak, incomplete, or unclear.	Key points and some reflection/action cues are present but not fully developed.	Concise synthesis highlights key ideas and invites reflection, decision-making, or action.

The rubric was developed prior to evaluation and pilot-tested on two sample infographics that were not included in the dataset. The pilot test was used to check whether criteria were understandable, whether the four scoring levels were distinguishable, and whether the rubric could be applied consistently to different infographic designs. Minor wording refinements were made to clarify the distinction between partial and strong achievement in the Expansion and Highlighting–Acting dimensions. Although a single evaluator conducted the scoring, consistency was supported through systematic application of the rubric, analytic memos, and repeated checking of scoring decisions. Because inter-rater reliability could not be calculated, the rubric scores are treated as interpretive evaluative evidence rather than as objective measurement.

To illustrate the application of the rubric, one infographic produced during the workshops is presented. The e-waste infographic (Figure 4) depicts the environmental burden of discarded electronic devices, emphasizing the 62 billion kilograms of e-waste generated globally in 2022. The infographic categorizes waste by type (e.g., small devices, mobile phones, televisions), material composition (metals, plastics, other substances), and disposal pathways (recycling, company management, improper disposal, and general waste). A real-world case is illustrated through a photograph of a worker manually separating cables for metal recovery in China, highlighting both human and environmental dimensions of unsafe recycling practices.

FIGURE 4

Analysis of the example infographic "e-WASTE"



Note. The e-WASTE infographic was created by a participant in the I.S.E.: Infographics in Science Education module and is reproduced with the creator's written permission. Except for the third-party materials identified below, the participant's original contributions to the infographic, including its text, organization, and overall design, are reproduced under the Creative Commons Attribution 4.0 International (CC BY 4.0) license. Third-party photographs, icons, and other visual materials incorporated into the infographic are excluded from the CC BY 4.0 license and remain subject to their respective copyright terms and licenses. Third-party material credits: [Photograph/image: creator, source, license or permission], [icons/graphics: creator or platform, source, applicable license], [additional visual material: creator, source, applicable license].

Evaluation of this infographic according to the ECEH criteria indicates varying levels of achievement across the four dimensions (Table 4). In terms of Engagement, the infographic effectively attracted attention through bold visuals and a striking central statistic; however, the challenging situation was implied rather than explicit. Regarding Concentration, scientific content and quantitative data were clearly presented, with problem-centered reflection questions included, though explanation of toxic elements such as cadmium, mercury, and lead was limited. The Expansion component was less developed, offering only a single illustrative example with few references for further exploration. Finally, for Highlighting–Acting, key ideas and reflection prompts were clear, though actionable steps for reducing e-waste were not explicitly provided.

A second anonymized rubric profile was used to check the transparency of the scoring logic. In that case, the infographic introduced a sustainability problem clearly and presented core scientific information in a visually accessible way, but the Expansion dimension remained limited. The design relied on one main context, offered few comparative cases, and provided limited references or prompts for further inquiry. This pattern helped explain why Expansion produced lower and more variable scores across the sample.

TABLE 4
Evaluation of the e-waste infographic according to ECEH criteria

Criteria	Evaluation	Justification
Engagement	Good (3)	Strong visuals and statistics draw attention; challenging situation is implied rather than fully explicit.
Concentration	Good (3)	Clear definitions, data, and problem-centered questions; limited explanation of toxic elements.
Expansion	Fair (2)	Single illustrative example: lacks multiple case studies or references for further exploration.
Highlighting–Acting	Good (3)	Key ideas and reflection prompts are clear; actionable steps are not explicitly provided.

5.3 Observation notes

Observation notes were systematically recorded during all synchronous workshop sessions to capture participants' engagement with the design tasks and their collaborative interactions with peers. These notes served as a process-oriented tool, providing contextualized evidence of how teachers enacted the ECEH model in practice.

The analysis followed a structured content analysis approach. Notes were initially segmented according to the main phases of the workshops: introduction, group evaluation, and hands-on design. Within each phase, descriptive codes were applied to capture specific behaviors, including:

1. Engagement behaviors, such as attentive listening, questioning, and proposing solutions,
2. Problem-solving strategies, including trial-and-error approaches, reliance on peers, and application of prior disciplinary knowledge,
3. Collaborative practices, such as turn-taking, collective brainstorming, and division of tasks.

These codes were iteratively grouped into thematic clusters to reveal broader patterns in participants' engagement, problem-solving, and collaboration. To enhance the trustworthiness and transparency of the analysis, coding procedures were systematically documented in detailed analytic memos, including definitions, examples, and decision rules for each code. Furthermore, triangulation with participants' reflective texts and peer feedback was employed to cross-verify observed behaviors. This multi-source approach strengthened the credibility, reliability, and internal validity of the findings, ensuring that the observation notes provided a rich and trustworthy account of participants' processes during the workshops.

5.4 Workshop reflections and peer feedback

The reflective texts and peer feedback collected during the workshops were treated as qualitative data, providing evidence of how participants interpreted and applied the ECEH model in practice. The analysis followed a systematic, multi-step thematic coding procedure. First, all reflections and peer comments were transcribed into a common dataset. Next, two broad deductive categories were established, aligned with the study's aims: (a) perspectives on the clarity, relevance, and instructional usefulness of the ECEH model, and (b) evaluations of the design process and final products. Within these categories, inductive coding was used to identify recurring themes. Specific codes included: "ease of following the model", "difficulty expanding content", "student engagement potential", "clarity of problem framing", and "suggestions for improvement in highlighting/acting". Codes were iteratively refined and collapsed into broader themes such as: (a) clarity and structure, (b) challenges in expansion, and (c) perceived instructional usefulness.

For example, one participant wrote:

"The engagement section helped me structure the topic for students, but I struggled to include additional study cases in the expansion part."

This reflection was coded under "clarity of problem framing" for the positive evaluation of engagement, and "difficulty expanding content" for the challenge noted in the expansion dimension. Similarly, peer feedback stating,

"The infographic clearly presents essential concepts, but the call-to-action could be more explicit."

was coded as "student engagement potential" and "suggestions for improvement in highlighting/acting".

By iteratively comparing these codes across all participants, convergences and divergences were identified, supporting a detailed understanding of how teachers interpreted and applied the ECEH model. To enhance trustworthiness, representative excerpts like these are presented in the results section, thereby grounding interpretations in the participants' own words.

Finally, following the initial round of analysis, the data were organized and synthesized into narrative profiles that captured participants' engagement with the proposed ECEH model, highlighting trajectories of understanding, adaptation, and reflective practice. These profiles were organized around the main themes identified through the questionnaire, their crafted infographics, systematic analysis of reflective texts, peer feedback, and observation notes, providing an integrated view of how teachers enacted the model in practice. The profiles illustrate how the model guided participants' design processes, informed their critical evaluation of infographics, and supported the production of content-rich, visually coherent science educational materials.

6 RESULTS

6.1 Teachers' current practices, perceived benefits, and challenges in using infographics for science education

The questionnaire results illustrate teachers' prior experiences with infographics, their perceptions of the benefits, and the challenges they encounter (Table 5). Regarding prior experience, most participants reported limited use of infographics in their science lessons. Specifically, 3 participants strongly disagreed, 5 disagreed, 3 were neutral, and 1 agreed that they had previously used infographics as a teaching resource in their science lessons. Confidence in designing or adapting infographics was also limited: 8 participants selected disagree or strongly disagree, 1 was neutral, and 3 selected agree. Prior formal training was similarly limited: 7 participants selected disagree or strongly disagree when asked whether they had received such training, 4 were neutral, and 1 selected agree.

Teachers' perceptions of the benefits of infographics were generally positive. Regarding their potential to simplify complex scientific concepts, 3 participants strongly agreed, 2 agreed, 4 were neutral, and 3 disagreed.

Most participants reported that infographics increase student engagement: 3 strongly agreed, 4 agreed, 3 were neutral, and 2 disagreed. Support for student retention was recognized by 4 participants who strongly agreed, 5 who agreed, 2 who were neutral, and 1 who disagreed. Regarding the promotion of critical thinking and classroom discussion, 3 participants strongly agreed, 6 agreed, and 3 were neutral.

Challenges associated with infographic use were also reported. Five participants indicated difficulty in locating or creating high-quality infographics suitable for their students, while 3 disagreed and 4 were neutral. Time constraints were reported as a limiting factor by 7 participants; 3 were neutral and 2 disagreed. Concerns regarding the accuracy and reliability of online infographics were reported by 7 participants; 3 were neutral and 2 disagreed.

TABLE 5

Teachers' responses on prior experience, perceived benefits, and challenges of using infographics in science education

Survey question	Totally disagree	Disagree	Neutral	Agree	Totally agree
Q1. I have previously used infographics as a teaching resource in my science lessons.	3	5	3	1	0
Q2. I feel confident in my ability to design or adapt infographics for classroom use.	4	4	1	3	0
Q3. I have received formal training or professional development on the use of infographics in education.	5	2	4	1	0
Q4. Infographics help simplify complex scientific concepts for students.	0	3	4	2	3
Q5. Infographics increase student engagement and interest in science topics.	0	2	3	4	3
Q6. Infographics support students in retaining and recalling scientific information.	0	1	2	5	4
Q7. Infographics promote critical thinking and discussion in the science classroom.	0	0	3	6	3
Q8. I find it difficult to locate or create high-quality infographics that are suitable for my students.	1	2	4	3	2
Q9. Time constraints limit my ability to integrate infographics into my teaching practice.	0	2	3	5	2
Q10. I am concerned about the accuracy and reliability of infographics found online.	0	2	3	5	2

6.2 Teachers' engagement with the ECEH model for designing content-structured science educational infographics

To evaluate participants' application of the ECEH model in their infographic designs, a rubric-based analysis was conducted across the four dimensions of the framework: Engagement, Concentration, Expansion, and Highlighting–Acting. The distributions of scores for the 12 participants are presented in Figure 5 using box plots. The boxes represent interquartile ranges (IQRs), the whiskers show the observed ranges, and the dashed lines indicate means; medians are reported in the text below.

The Engagement dimension yielded the highest median score (3.0), with an IQR of 3–4. Only two participants scored at the lower bound (2), indicating that the majority effectively framed their infographics around compelling or contextually relevant challenges.

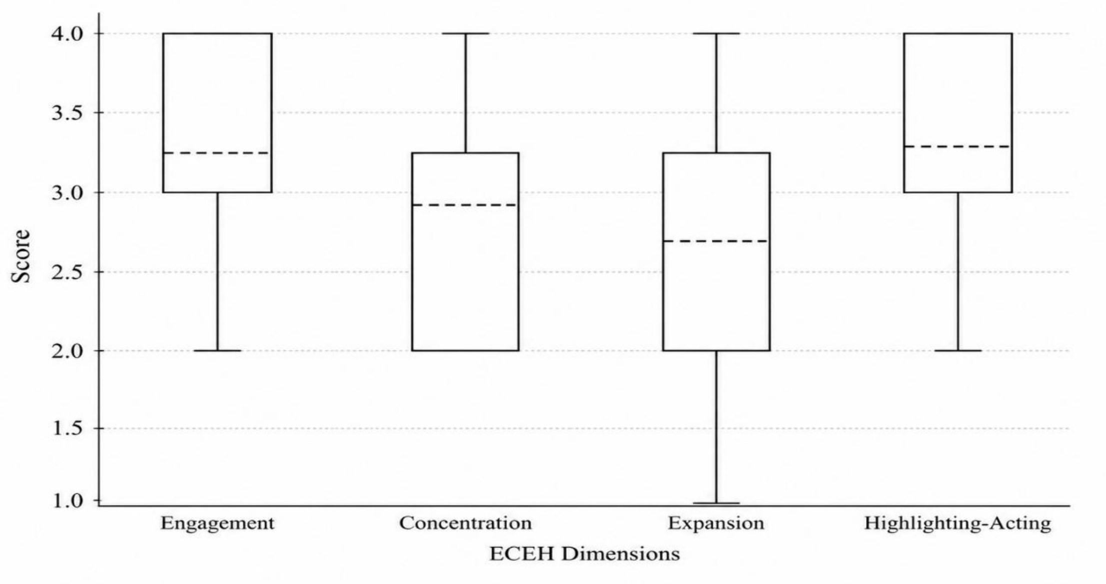
Concentration displayed slightly greater variability. While the median remained 3.0, the lower quartile dropped to 2, suggesting that some participants encountered difficulties in clearly articulating scientific concepts or formulating problem-centered questions. This variation reflects differences in the application of the model's scaffolding to support conceptual clarity.

Expansion emerged as the most variable and lowest-performing dimension. The median score was 2.5, with individual scores ranging from 1 to 4. One participant received the minimum score, indicating minimal elaboration beyond foundational content. This distribution suggests that extending core scientific content into additional cases, socio-scientific contexts, comparative examples, and opportunities for transfer was more demanding than attracting attention or summarizing key ideas.

In contrast, Highlighting–Acting demonstrated relatively strong outcomes. The median score was 3.0, with a narrower range and no scores below 2. Most participants concluded their infographics with effective summaries or calls to action, indicating competence in emphasizing key ideas and prompting reflection or action.

FIGURE 5

Rubric-based evaluation of participants' infographic designs across ECEH model dimensions



Analysis of the observation notes collected during the workshop sessions revealed three main thematic clusters related to teachers' engagement, problem-solving strategies, and collaborative interactions: (a) active engagement, (b) problem-solving approaches, and (c) collaborative practices (Table 6).

Active engagement. Participants generally demonstrated high levels of attentiveness and cognitive involvement, particularly during the group evaluation and hands-on design phases. Teachers actively listened to peers' presentations, asked clarifying questions, and offered suggestions for improving infographic content or structure. For instance, one observation noted: "P3 closely examined a peer's infographic and asked about the rationale behind the choice of visuals, suggesting an alternative to better illustrate the scientific concept." While engagement was broadly consistent, 2 of 12 participants were observed to hesitate before contributing during the introduction phase, reflecting a brief acclimatization period to the workshop format.

Problem-solving approaches. Participants employed a variety of strategies to address design challenges. Common approaches included trial-and-error experimentation, integrating peer feedback, and leveraging prior disciplinary knowledge to structure infographic content. One observation documented: "P7 experimented with color-coding different sustainability concepts after realizing the initial layout was visually confusing." Teachers also occasionally sought guidance from peers when confronting unfamiliar content or data visualization issues, indicating that collaborative problem-solving was a frequent and effective practice.

Collaborative practices. Teachers engaged in multiple collaborative strategies, including turn-taking, collective brainstorming, and division of tasks. Smaller groups often allocated responsibilities so that some participants focused on content accuracy while others refined the visual presentation. A representative observation stated: "During the hands-on design, P1 and P2 divided the infographic sections; P1 focused on embedding scientific data, while P2 concentrated on icons and layout." These interactions supported the integration of scientific content with engaging visual elements, though a few participants required prompting to fully participate in group discussion.

TABLE 6
Observation themes and representative excerpts

Theme	Description	Representative excerpt	Participants reporting theme
Active engagement	Participants actively attended, asked questions, and engaged cognitively during workshops.	"P3 closely examined a peer's infographic and asked about the rationale behind the choice of visuals."	10/12
Problem-solving approaches	Use of trial-and-error, prior knowledge, and peer support to address design challenges.	"P7 experimented with color-coding different sustainability concepts after realizing the initial layout was visually confusing."	12/12
Collaborative practices	Turn-taking, collective brainstorming, and task division facilitated group work.	"P1 and P2 divided the infographic sections; P1 focused on embedding scientific data, while P2 concentrated on icons and layout."	11/12

6.3 Teachers' descriptions of the clarity, relevance, and instructional usefulness of the ECEH model

The analysis of reflective texts and peer feedback from all 12 participants revealed three overarching themes regarding the application of the ECEH model in designing science infographics: (a) clarity and structure, (b) challenges in expansion, and (c) perceived instructional usefulness (Table 7).

Clarity and structure: Across the sample, participants consistently reported that the ECEH model provided a clear and systematic framework for structuring infographic content. Teachers highlighted that the four dimensions guided their sequencing of ideas and helped them frame topics in ways that would capture students' attention. For example, one participant reflected: "The engagement section helped me structure the topic for students and made it easier to introduce a real-world challenge." 9 of 12 participants indicated that following the model reduced uncertainty in organizing essential scientific concepts and enhanced the logical flow of their infographics.

The Expansion dimension emerged as the most variable aspect of participants' application of the model. Several teachers reported difficulties in including additional case studies, contextual examples, or extended applications beyond foundational content. One participant noted: "I found it difficult to go beyond the basic content, and including more examples felt time-consuming." Peer feedback frequently reinforced this point, with suggestions emphasizing the need for further support or scaffolding when extending infographic content. Four participants scored lower in the Expansion dimension according to rubric-based evaluation, aligning with their self-reported reflections.

Perceived instructional usefulness: Participants frequently recognized the potential of the ECEH model to promote student engagement, reflection, and critical thinking. Teachers emphasized the importance of including problem-centered questions, prompts for reflection, and actionable insights in their infographics. One reflection stated: "The model helped me think about how students could interact with the infographic and reflect on the implications of sustainability issues." 11 of 12 participants highlighted that the ECEH framework increased their confidence in designing pedagogically meaningful infographics that could support learning in science classrooms.

TABLE 7
Themes and representative excerpts from workshop reflections and peer feedback

Theme	Description	Representative excerpt	Participants (n = 12)
Clarity and structure	Model provides a clear framework for sequencing content and framing real-world challenges.	"The engagement section helped me structure the topic for students and made it easier to introduce a challenge."	9/12
Challenges in expansion	Difficulty including additional case studies, contextual examples, or extended content.	"I found it difficult to go beyond the basic content, and including more examples felt time-consuming."	4/12
Perceived instructional usefulness	Model supports student engagement, reflection, and critical thinking; improves pedagogical design.	"The model helped me think about how students could interact with the infographic and reflect on sustainability."	11/12

7 DISCUSSION

When examining how teachers engaged with the ECEH model, developed and proposed by the researchers for structuring the content of science educational infographics, both the strengths and challenges of the framework became apparent. Teachers consistently recognized the model as a clear and structured guide for organizing scientific content, yet they struggled with certain dimensions, particularly expansion. These results reveal not only how the researcher-designed model shaped teachers' design practices but also the ways in which professional development contexts mediate its enactment.

The questionnaire results provided the first layer of insight. Most teachers entered the study with limited experience in designing or using infographics and minimal formal training. This lack of prior exposure highlights the importance of structured scaffolds, such as the ECEH model, to support initial steps into visual design. Teachers, however, recognized the potential of infographics to simplify complex ideas, promote engagement, and stimulate discussion, while noting practical barriers such as time constraints and concerns about resource reliability. These perspectives formed the foundation upon which the model was introduced and enacted.

When teachers applied the ECEH model to their own designs, rubric-based evaluation revealed consistent strengths in Engagement and Highlighting–Acting, contrasted with challenges in Expansion. Most participants framed science topics around meaningful challenges and concluded with summaries or calls to action, suggesting that the model supported attention-capturing and reflective design. However, the Expansion dimension required teachers to move beyond core content toward additional cases, contextual applications, socio-scientific implications, and knowledge transfer. This made it more demanding because it depended not only on design skill but also on teachers' content knowledge, access to reliable resources, available time, and ability to connect scientific ideas with broader real-world contexts.

This interpretation also qualifies the positive findings. Teachers' favorable responses may have been influenced by the supportive workshop environment, the novelty of designing infographics, the collaborative atmosphere, and the presence of researchers as facilitators. These factors do not invalidate the findings, since they are part of the professional development ecology in which the model was enacted. They do, however, limit claims about the independent effectiveness of the ECEH model and support a more cautious interpretation in terms of perceived usefulness and practical applicability.

Reflective texts and peer feedback further illustrated that the model reduced uncertainty and increased teachers' confidence in structuring their designs. Yet, participants repeatedly noted difficulty in moving beyond the basics, highlighting a need for additional scaffolds, such as curated case studies, collaborative design strategies, or extended iterative design time. Observation notes confirmed that participants engaged collaboratively during synchronous sessions, experimenting with visual strategies, asking probing questions, and distributing tasks strategically within groups. These practices indicate that the ECEH model not only shaped individual design processes but also catalyzed collaborative professional learning, reinforcing its value in professional development contexts.

In aggregate, these findings indicate the methodological promise of the ECEH model. By providing a structured yet flexible framework, it supported teachers in creating infographics that were content-rich, pedagogically purposeful, and visually coherent within the specific context of the I.S.E. professional development module. The study also demonstrates that the enactment of such frameworks is mediated by prior experience, available resources, collaborative dynamics, and the structure of the workshop environment.

7.1 Implications for research

Building on these findings, future research should examine how the ECEH model can be adapted and extended across diverse educational levels, cultural contexts, and subject areas. The challenges identified in the Expansion dimension suggest the need to investigate how curated case banks, worked examples, digital tools, annotated infographics, and iterative peer-review protocols influence teachers' ability to enrich content beyond core material. Longitudinal studies could examine the sustained impact of using structured scaffolds like ECEH on teachers' design practices and student learning outcomes. Additionally, research could examine how methodological frameworks mediate the interplay between teacher agency, professional development environments, and instructional innovation.

7.2 Implications for theory

The study contributes to theoretical discussions in science education concerning the integration of disciplinary knowledge, pedagogical intent, and visual communication. The ECEH model demonstrates how structured yet flexible scaffolds can support teacher agency while ensuring coherent content design. Findings also reinforce the principle that methodological enactment is context-dependent, mediated by teacher experience, resources, and collaborative opportunities. The research thus extends theories of design-based professional learning, highlighting how methodological frameworks interact with teacher cognition and collaborative practices to shape educational innovation.

7.3 Implications for practice

Practically, the findings underscore the importance of structured scaffolds for professional development in science education. Introducing the ECEH model may enhance teachers' competence and confidence in designing instructional infographics while fostering reflective and collaborative practices. Professional development programs should provide targeted support for the Expansion dimension through curated examples, contextualization strategies, case-study banks, annotated models, and iterative peer-review opportunities. Collaborative engagement should remain central to training designs, because peer learning and co-construction of knowledge were important to model enactment. Infographics designed through the ECEH model may help teachers engage students with complex socio-scientific issues, promoting understanding, reflection, and action on sustainability and other real-world challenges.

8 LIMITATIONS

It is important to acknowledge certain limitations that frame the interpretation of this study. First, the number of participants was relatively small, as the research was based on a single professional development module and a convenience sample. While this limited the breadth of perspectives, it allowed for an in-depth exploration of teachers' engagement with the ECEH model across multiple data sources. The findings should therefore be read as contextually rich evidence of perceived usefulness and practical applicability, rather than as generalizable evidence of model effectiveness.

Second, the evaluation of teacher-created infographics was conducted by a single researcher, which may have introduced interpretive bias. To address this, a detailed rubric, systematic application procedures, repeated checking of scoring decisions, and analytic memos were employed to enhance transparency and consistency. Nevertheless, future research should include multiple evaluators, inter-rater reliability checks, and further validation of the rubric across a larger and more diverse set of infographics.

Third, the temporal scope of the study, spanning the duration of a single module, captured teachers' immediate engagement with the ECEH model but did not allow for tracing its longer-term impact on classroom practices or student learning. Longitudinal studies are therefore needed to examine whether and how the model influences teachers' instructional practices and student outcomes over time.

These limitations do not undermine the contribution of the study. Rather, they point to the specific contexts and conditions within which the findings were generated, offering a foundation for future studies to extend, adapt, and refine the ECEH model across broader settings and longer timescales.

DECLARATIONS

Author Contributions

All authors contributed equally to the conception and design of the study, data collection, analysis and interpretation, and the writing and revision of the manuscript. All authors have read and approved the final version for publication.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Ethics Committee Approval

The study was reviewed and approved by the Ethics and Deontology Committee for Research of National and Kapodistrian University of Athens (Επιτροπή Ηθικής και Δεοντολογίας της Έρευνας – Ε.Η.Δ.Ε.). Prior to participation, all participants received information about the aims and procedures of the study, the voluntary nature of participation, the types of data to be collected and used for research purposes, and their right to withdraw without consequence. Written informed consent was obtained from all participants before data collection. Participants were also informed that their questionnaire responses, reflective texts, peer feedback, observation data, and submitted educational materials could be analyzed and reported for research purposes. Participant identities were anonymized using identification codes (P1–P12), and identifying information was removed from the data and materials used in the analysis and publication. Where participant-produced materials are reproduced in the article, separate permission for publication was obtained where required.

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AI Declaration

The authors report that generative AI was not used in their research or preparation of this manuscript.

Data Availability Statement

This study did not generate new publicly shareable datasets. Due to ethical and privacy considerations, the data supporting the findings are not publicly available. Requests for access to the data may be directed to the corresponding author and will be considered on a case-by-case basis in accordance with institutional guidelines and participant confidentiality.

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