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Hierarchy of research study designs: a conceptual and illustrative approach for scientific education

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ABSTRACT

Aims: To present an educational conceptual framework for understanding research study designs, emphasizing their methodological relationships and educational value as tools to support scientific literacy and methodological understanding.

Methods: This conceptual and educational article was developed based on classical references in scientific methodology, evidence-based practice, and cognitive learning theories. International reporting guidelines and methodological frameworks, including CONSORT, STROBE, PRISMA, the Cochrane Handbook, and GRADE, were considered in the theoretical organization of the proposed models. Two visual representations were developed to illustrate the relationships among descriptive, observational, and interventional designs, as well as the distinction between primary and secondary studies. The figures were refined by consensus among the authors, prioritizing conceptual coherence and pedagogical applicability.

Results: The proposed visual models provide an integrated perspective on research study designs, highlighting their methodological characteristics, inferential potential, and complementary roles in knowledge production. Rather than reinforcing rigid hierarchical classifications, the models emphasize functional and conceptual relationships among different study designs. By promoting cognitive organization and reducing the complexity associated with abstract methodological concepts, these representations may facilitate critical reading and improve methodological understanding among students and novice researchers.

Conclusion: The proposed conceptual models complement traditional evidence pyramids by emphasizing methodological relationships rather than evidence hierarchy. As educational frameworks grounded in cognitive learning principles, they may facilitate the teaching of research methodology, strengthen methodological reasoning, and promote a more integrated understanding of evidence generation in dentistry and other health professions.

Keywords: Higher education, scientific methodology, evidence-based practice, decision-making, knowledge

INTRODUCTION

Scientific training in health sciences requires students not only to master technical and clinical competencies but also to develop the ability to critically understand, interpret, and apply knowledge generated by the scientific literature.[1,2] The exponential growth of academic publications over recent decades has transformed the information landscape into an increasingly complex environment,[3] in which multiple study designs coexist, each addressing distinct research questions and operating under different methodological assumptions.[4]

Within this context, research study designs play a central role in the generation of scientific knowledge,[5-7] as they provide the framework for the observational, comparative, analytical, and inferential strategies adopted by researchers.[2,3] A sound understanding of these methodological approaches is particularly important during academic training, as conceptual difficulties frequently observed among students may compromise both the critical appraisal of the literature and the development of scientific investigations.[8-10]

Evidence-based practice has emerged as one of the most influential paradigms in contemporary health sciences, advocating the integration of the best available scientific evidence with professional expertise and contextual factors relevant to decision-making.[10,11] Within this framework, different study designs have traditionally been organized into hierarchical structures,[12] such as evidence pyramids, which graphically represent relationships among methodological rigor, control of bias, and the potential for causal inference.[4-6,13]

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Although widely disseminated, these hierarchical representations have been the subject of considerable debate within the methodological literature. Classical studies have emphasized that scientific validity and relevance depend not exclusively on study design,[14] but also on the quality of study conduct, analysis, and interpretation.[10-13] Moreover, rigid hierarchical interpretations may promote reductionist views, obscuring the complementary nature of different research methodologies.[15,16]

Conceptual difficulties related to distinguishing observational from experimental studies, cross-sectional from longitudinal designs, and primary from secondary studies are frequently reported in health professions education.[1,10-12,16] These challenges highlight the need for pedagogical approaches capable of promoting conceptual clarity, cognitive organization, and an integrated understanding of methodological strategies.[17,18]

From an educational perspective, cognitive theories of learning suggest that visual representations can play an important role in the assimilation of abstract concepts and the organization of knowledge.[14-18] Well-structured graphical models may reduce cognitive load, facilitate the construction of conceptual schemas, and enhance understanding of the relationships among different study categories.[19]

Furthermore, the availability of educational resources in Portuguese deserves particular attention. Although most methodological literature is published in English, language barriers remain a significant challenge for students in training.[1] The development of educational materials in Portuguese may therefore broaden access to knowledge and contribute to strengthening scientific literacy.[20]

Despite the widespread use of evidence pyramids and other hierarchical representations of research study designs, there remains a gap in the development of visual models that integrate the methodological foundations of scientific research with cognitive principles of learning. This gap is especially relevant in health professions education, where students often experience difficulties in understanding the relationships among different study designs and their epistemological implications. Consequently, there is a need for approaches that move beyond rigid classifications and foster a more integrated, critical, and pedagogically oriented understanding of research methodologies.

Although several evidence pyramids and graphical classifications of research designs have been published, most were developed primarily to represent levels of evidence or methodological rigor. In contrast, the present proposal does not seek to establish a new hierarchy or replace existing frameworks. Instead, it introduces an educational model designed to integrate methodological concepts with cognitive learning principles, emphasizing the functional relationships among research designs and their complementary roles in answering different scientific questions. This pedagogical perspective represents the principal innovative aspect of the present work. Unlike conventional evidence pyramids, which primarily aim to classify research designs according to methodological hierarchy, the present models were intentionally conceived as conceptual educational frameworks. Their purpose is not to redefine levels of evidence but to facilitate conceptual understanding by explicitly illustrating the relationships among study designs and their complementary roles in scientific knowledge generation. The simplicity of the graphical organization was intentionally preserved to promote conceptual clarity and reduce unnecessary cognitive load, allowing learners to focus on methodological reasoning rather than on visual complexity.

In dental education, the ability to critically interpret scientific evidence has become increasingly important owing to the growing emphasis on evidence-based dentistry and lifelong learning. Dental professionals are continuously exposed to an expanding body of scientific literature addressing preventive, diagnostic, restorative, orthodontic, periodontal, and surgical interventions. Consequently, understanding the strengths and limitations of different research designs is essential for critically appraising evidence and translating research findings into clinical decision-making. Educational tools capable of facilitating this understanding may therefore contribute directly to improving evidence-based dental practice.

Accordingly, the present article proposes a conceptual and illustrative approach to the hierarchy of research study designs in health sciences. The aim is to present visual models conceived as educational tools to assist students and early-career researchers in understanding the methodological and epistemological relationships among different scientific study designs.

METHODS

Ethics

No ethics committee approval was required for this study because no human participants, patient data, photographs, or biological materials were involved. The investigation was conducted entirely using information retrieved from the literature. Therefore, according to institutional and international guidelines, ethical approval and informed consent were not necessary.

Conceptual Development and Construction of Visual Models

This study constitutes a conceptual article with an educational purpose, grounded in established theoretical frameworks from scientific methodology, evidence-based practice, and cognitive learning theories.[1-6,14-18] The development of the proposed framework was informed by classical references in health research methodology, international reporting guidelines, and epistemological perspectives on scientific knowledge generation.

The conceptual foundation of the study was based on three complementary domains: (1) methodological principles underlying research study designs and scientific inference,[5-9,21,22] (2) mechanisms of bias control and evidence appraisal in clinical and observational research,[10-13,23] and (3) cognitive theories emphasizing the role of visual representations in facilitating conceptual learning and knowledge organization.[14-18]

Widely adopted frameworks for the generation, reporting, and synthesis of scientific evidence, including CONSORT, STROBE, PRISMA, the Cochrane Handbook, and GRADE, were considered in the theoretical organization of the proposed models.[5-9] These references provided the methodological basis for distinguishing between descriptive,

observational, experimental, primary, and secondary study designs. No predefined graphical framework or previously published visual model was adopted during the design process. Instead, the proposed figures were developed as original conceptual representations intended to synthesize established methodological knowledge into an educational resource capable of facilitating conceptual understanding among students and novice researchers.

The development of the visual models followed an iterative three-stage process. Initially, the principal categories of research study designs were identified and organized according to classical methodological literature, evidence-based practice frameworks, and international reporting guidelines. Subsequently, preliminary conceptual diagrams were independently drafted to represent the methodological relationships among study designs, considering their investigative purpose, degree of bias control, inferential potential, and educational applicability. Rather than adapting an existing graphical template or previously published evidence pyramid, the figures were conceived as original educational models integrating methodological concepts with principles derived from cognitive learning theory. Finally, successive versions of the diagrams were critically reviewed by all authors through iterative discussions until consensus was achieved regarding conceptual organization, methodological accuracy, educational relevance, visual clarity, and internal consistency.

The figures presented were conceived exclusively as pedagogical tools. **Figure 1** was designed to illustrate the methodological relationships among descriptive, observational, and interventional studies, highlighting their distinct analytical approaches and investigative strategies. **Figure 2** represents an adapted conceptual pyramid aimed at clarifying the distinction between primary and secondary studies and their respective roles in knowledge generation and evidence synthesis. Unlike conventional evidence pyramids, the proposed models were intentionally designed to emphasize conceptual organization rather than hierarchical ranking, integrating methodological relationships with educational principles derived from cognitive learning theories.

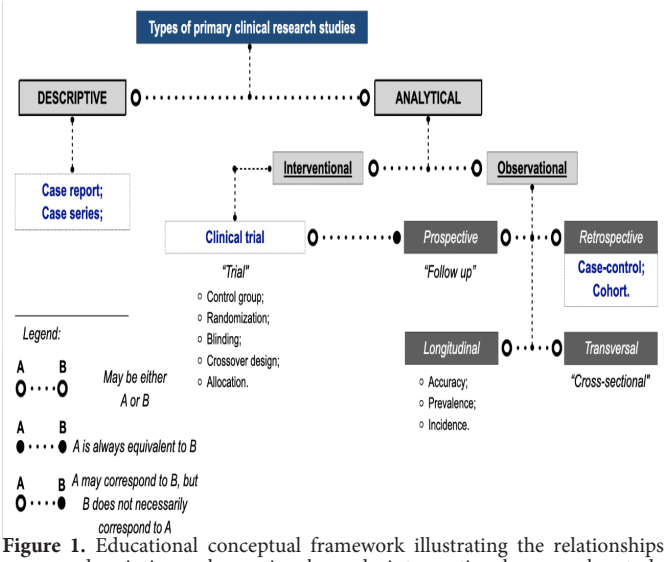

Figure 1. Educational conceptual framework illustrating the relationships among descriptive, observational, and interventional research study designs. The figure emphasizes the complementary methodological roles of each design and was intentionally developed as a simplified conceptual representation to facilitate learning and methodological understanding rather than to establish a hierarchy of evidence

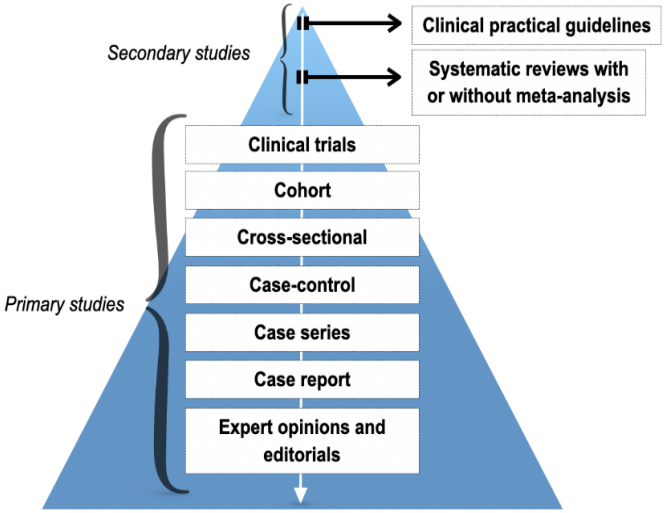

Figure 2. Educational conceptual framework illustrating the distinction between primary and secondary research. The figure emphasizes the complementary processes involved in evidence generation and synthesis and was intentionally designed to support conceptual understanding in research methodology education

RESULTS

Development of Conceptual Frameworks for Understanding Research Study Designs

The principal outcome of this conceptual study was the development of an educational framework composed of two complementary visual models and a structured summary table designed to facilitate the teaching and learning of research methodology. Together, these educational resources aim to improve conceptual organization, strengthen methodological reasoning, support critical appraisal of scientific literature, and promote scientific literacy among undergraduate students, graduate trainees, and early-career researchers. Rather than functioning as simple graphical representations, the proposed models were conceived as pedagogical tools to facilitate meaningful learning and evidence-based decision-making.

Two complementary visual models were developed to support the teaching and understanding of research study designs in health sciences. The originality of these models resides in their emphasis on conceptual integration rather than evidence ranking. By illustrating the relationships among study designs according to their methodological characteristics and investigative purposes, the framework encourages students to understand research designs as complementary methodological strategies instead of isolated hierarchical categories.

The first model (**Figure 1**) provides a conceptual representation of the relationships among descriptive, observational, and interventional study designs. Rather than emphasizing hierarchical rankings, the framework highlights methodological characteristics, investigative strategies, and the distinct roles played by each design in addressing specific research questions. This approach underscores the complementary nature of different methodological traditions and their contributions to scientific knowledge production.

The second model (**Figure 2**) presents an adapted conceptual pyramid intended to facilitate the differentiation between primary and secondary studies. The framework illustrates the progressive integration and synthesis of evidence while

emphasizing that the strength and applicability of scientific findings depend not only on study design but also on methodological quality and context of application.

The visual frameworks were developed to promote conceptual clarity and cognitive organization. By integrating methodological principles with educational theories of learning, the models aim to reduce the complexity associated with abstract concepts and provide a more relational understanding of research designs. In contrast to traditional hierarchical representations, the proposed models emphasize the interconnected and complementary roles of different forms of scientific evidence. The proposed models were intentionally designed using a simplified graphical structure to facilitate cognitive processing and avoid unnecessary visual overload. Rather than incorporating multiple visual elements, the educational emphasis lies in promoting conceptual organization and helping learners understand how different study designs relate to one another according to their methodological purpose.

In addition to the proposed visual models, **Table** presents a structured summary of the principal research study designs, highlighting their methodological characteristics, strengths, limitations, and educational relevance. Collectively, these educational resources provide an integrated framework that allows learners to distinguish research designs according to their methodological purpose rather than solely their position within traditional evidence hierarchies. This approach encourages deeper conceptual understanding and may facilitate the transfer of methodological knowledge to evidence-based clinical decision-making, particularly in dental education. Rather than emphasizing a rigid hierarchy, the table underscores the complementary roles of different study designs in answering specific research questions and generating scientific evidence. By integrating methodological and pedagogical perspectives, this resource aims to support the development of scientific literacy, critical appraisal competencies, and evidence-based decision-making skills. The table was conceived as an educational tool intended to facilitate meaningful learning and to provide students and novice researchers with a comprehensive framework for understanding the diverse approaches used in health research.

From an educational perspective, the frameworks were designed to support scientific literacy and critical appraisal skills among undergraduate students, graduate trainees, and early-career researchers. Their pedagogical purpose is to facilitate meaningful learning by providing a structured and visually accessible representation of the relationships among research methodologies. The proposed framework may be incorporated into dental research methodology courses, evidence-based dentistry modules, journal clubs, and scientific initiation programs, providing a practical educational resource to facilitate the interpretation of research evidence. In undergraduate education, the models may be used during introductory courses in research methodology and evidence-based dentistry to assist students in distinguishing among descriptive, observational, and experimental research designs. In postgraduate education, they may support journal clubs, critical appraisal activities, and discussions on research planning. At the doctoral level, the framework may facilitate advanced seminars on scientific methodology, evidence synthesis, and the selection of appropriate study designs for complex research questions.

Overall, the proposed educational framework represents a practical teaching resource that may support undergraduate and postgraduate curricula, journal clubs, scientific initiation programs, and evidence-based dentistry courses by improving students' understanding of research methodology and fostering more critical interpretation of scientific evidence.

DISCUSSION

The hierarchical organization of research study designs emerged historically as a pedagogical framework closely associated with evidence-based practice, aiming to guide the appraisal and interpretation of scientific literature.[2-6] Traditional evidence pyramids were developed to represent gradients of methodological rigor and inferential strength, thereby contributing to the systematization of scientific reasoning and evidence synthesis.[24] Nevertheless, methodological literature has consistently emphasized that these hierarchies should not be interpreted in a rigid or deterministic manner because the validity and applicability of scientific evidence depend not only on study design but also on methodological quality, risk of bias, statistical analysis, and the clinical context in which the findings are applied.[10-13]

From an epistemological perspective, scientific knowledge is generated through complementary methodological approaches rather than through a strictly linear progression of evidence.[19-22] Descriptive, observational, experimental, and evidence synthesis studies address distinct scientific questions and collectively contribute to a comprehensive understanding of health phenomena.[25] Consequently, educational strategies that encourage learners to recognize these complementary relationships may provide a more meaningful understanding of research methodology than approaches focused exclusively on evidence hierarchy.

The principal contribution of the present study is therefore educational rather than classificatory. Unlike conventional evidence pyramids, which primarily organize study designs according to levels of evidence, the proposed framework was intentionally developed to facilitate conceptual understanding by illustrating the methodological relationships among research designs. Rather than proposing a new hierarchy, these models encourage learners to understand why different

Table. Characteristics of major research study designs and their educational implications

Design	Category	Main purpose	Strengths	Limitations	Educational relevance
Cross-sectional	Observational	Prevalence	Simple	No causality	Understanding associations
Case-control	Observational	Risk factors	Efficient	Recall bias	Critical appraisal
Cohort	Observational	Incidence	Temporal sequence	Cost	Longitudinal thinking
RCT	Experimental	Causality	High internal validity	Expensive	Gold standard concept
Systematic review	Secondary	Evidence synthesis	Comprehensive	Quality-dependent	Evidence-based dentistry

RCT: Randomized controlled trial

study designs are appropriate for different research questions and how they collectively contribute to evidence generation. This conceptual perspective aligns with contemporary educational approaches that emphasize understanding relationships among concepts instead of memorizing isolated classifications.

Recent evidence in health professions education further reinforces the value of structured visual educational resources. A recent systematic review demonstrated that Visual Thinking Strategies enhance observation, analytical reasoning, communication, and reflective thinking among healthcare students, supporting the educational use of conceptual visual frameworks beyond their illustrative function.[26] Likewise, systematic reviews have shown that visual educational resources, including animations and other multimedia tools, improve learner engagement, knowledge acquisition, and retention when integrated into pedagogically structured activities rather than presented as passive instructional materials.[27] These findings support the rationale for developing simplified conceptual models capable of facilitating methodological reasoning during research training.

The intentionally simplified graphical organization adopted in the present framework is also consistent with cognitive theories of learning. Cognitive load theory and multimedia learning theory propose that reducing unnecessary visual complexity allows learners to allocate greater cognitive resources to essential conceptual processing.[14,15] Rather than incorporating multiple visual elements, colors, or directional arrows, the present models were intentionally designed to preserve conceptual clarity and reduce extraneous cognitive load. Their educational value therefore resides primarily in the explicit representation of methodological relationships rather than in graphical complexity.

The proposed framework may be incorporated into different educational settings throughout the continuum of dental education. During undergraduate training, the models may support introductory courses in research methodology and evidence-based dentistry by helping students distinguish descriptive, observational, and experimental study designs before critically appraising scientific articles. In postgraduate education, they may facilitate journal clubs, evidence-based dentistry courses, and research proposal development by encouraging methodological reasoning and study design selection. At the doctoral level, the framework may serve as a conceptual resource for advanced discussions on evidence synthesis, methodological decision-making, and research planning. These educational applications are consistent with learner-centered strategies such as flipped classrooms, collaborative discussions, and case-based learning, which have demonstrated positive educational outcomes in health sciences education.[28]

The increasing incorporation of digital educational technologies into health professions education further strengthens the relevance of concise conceptual learning resources. Recent analyses of digital teaching demonstrate that interactive visual materials have become increasingly important components of contemporary medical education, complementing traditional face-to-face instruction and supporting hybrid learning environments.[29] In this context, the proposed models represent a low-cost, easily reproducible educational resource that can be incorporated into classroom teaching, online learning platforms, journal clubs, scientific initiation programs, and continuing professional education.

Limitations

Some limitations of the present study should be acknowledged. Because this work represents a conceptual educational proposal, the visual models have not yet been empirically validated in formal educational settings. Furthermore, the interpretation of methodological relationships may vary according to disciplinary context and research objectives. Future investigations should evaluate the educational effectiveness of these conceptual models using objective educational outcomes, including knowledge acquisition, long-term retention, methodological reasoning, critical appraisal performance, and learner satisfaction. Comparative studies evaluating the proposed framework against traditional evidence pyramids may further clarify its educational value.

In summary, the present study proposes an educational framework that complements, rather than replaces, conventional evidence pyramids. By integrating methodological concepts with principles derived from cognitive learning theories and contemporary health professions education, the proposed models encourage a more relational understanding of research study designs. This approach has the potential to strengthen methodological reasoning, support evidence-based dentistry education, and promote meaningful learning among undergraduate, postgraduate, and early-career researchers.

CONCLUSION

The conceptual models proposed in this study complement existing evidence pyramids by shifting the educational focus from evidence hierarchy to the understanding of methodological relationships among research study designs. Grounded in cognitive learning principles, they provide an original educational framework designed to facilitate methodological reasoning, conceptual organization, and evidence-based learning through clear and simplified visual representations. Their potential application across undergraduate, postgraduate, and doctoral education, including research methodology courses, evidence-based dentistry, journal clubs, and scientific training, highlights their relevance as practical teaching resources for dental education. Although further educational validation is warranted, these models offer a novel pedagogical contribution that may promote meaningful learning and foster a more critical, integrated, and clinically relevant understanding of evidence generation in dentistry and other health professions.

ETHICAL DECLARATIONS

Ethics Committee Approval

No ethics committee approval was required for this study because no human participants, patient data, photographs, or biological materials were involved.

Informed Consent

As no biological material from humans or animals was used in the study, informed consent was not required.

Peer Review Process

This manuscript was subject to external peer review.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

Financial Disclosure

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Author Contributions

Concept: LSCB, ICS, CCAQ, LMDM; Design: LSCB, ICS, LMDM; Control: CCAQ, LMDM; Data Collection and/or Processing: LSCB, ICS, ROS; Analysis and/or Interpretation: LSCB, ICS, ROS, LMDM; Writing the Article: LSCB, ROS, LMDM; Critical Review: LSCB, ROS, CCAQ, LMDM.

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