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## Guided Models for Teaching Students Research in Science and Engineering

### Modelos guiados para la investigación en ingeniería y ciencias básicas

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#### Abstract

**Context:** This article presents the arguments that support the formulation of a research model from the idea of “guided models,” which allows the designing of routes and methodologies for the approaching, formulating, and solving problems in the training of technologists and engineers.

**Method:** The methodology used was based on grounded theory, which allows solving problems and develop innovative research through theoretical and methodological categories.

**Results:** It was possible to organize the model with a special emphasis on the generation of monitoring and contrasting matrices as a control mechanism and guide for the researcher.

**Conclusions:** The implications of the incorporation of this model are analyzed in relation to the training purposes of engineering and technology professionals, articulated through a progression hypothesis as a reference every researcher will be able to get when analyzing and reviewing their own research processes regardless of the methodology developed.

**Keywords:** models, methodology, informed theory, investigation, training.

#### Resumen

**Contexto:** En este artículo se presentan los argumentos que fundamentan la formulación de un modelo de investigación desde la idea de “modelos guiados,” que permite el diseño de rutas y metodologías para el planteamiento, formulación y resolución de problemas en la formación de tecnólogos e ingenieros.

**Método:** La metodología utilizada se basa en la teoría fundamentada, la cual permite por medio de categorías teóricas y metodológicas resolver problemas y desarrollar investigaciones innovadoras.

**Resultados:** Se obtuvo la organización del modelo, con especial énfasis en la generación de matrices de seguimiento y contrastación, como mecanismo de control y guía para el investigador.

**Conclusiones:** Las implicaciones de la incorporación de este modelo se analizan en relación con los propósitos de formación de profesionales de la ingeniería y de la tecnología, articulándose mediante una hipótesis de progresión como referencia que puede tener todo investigador al momento de analizar y revisar sus propios procesos de indagación, independientemente de la metodología que se desarrolle.

**Palabras clave:** modelos, metodología, teórica fundamentada, investigación, formación.

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## INTRODUCTION

This work aims to contribute to research training in initial and continuing teaching of methodological processes in three main areas. First, by formulating guided models for the construction of theories both in the practice and implementation of strategies, as well as in routes for the resolution of research problems (Gallego-Badillo R., 2004). Secondly, with the foundation of methodological designs that help guide research in engineering and science with the purpose of understanding scientific research processes. Third, by formulating the bases for the constitution of methodological guides, specifically dedicated to the training of researchers (Giraldo, 2011) (Gangoso, 2016).

From this perspective, this work is based on four guidelines. In the first place, the need to start from the construction of guided models, in other words, the methodological definition of the models as part of the construction of knowledge, which could be applied both in the training of researchers and for school science. Second, an epistemological foundation from the formulation and construction of theoretical categories. Third, a methodological proposal in accordance with said paradigm from grounded theory, whose starting point is the approach of a guided model of the phenomenon under investigation. This proposal is especially operative when it comes to building master's theses. And finally, methodological routes and hypothesis of progression to conclude with an example of construction and application of the proposal.

## METHODOLOGICAL PERSPECTIVE IN RESEARCH TRAINING

Throughout the history of natural science, the importance of formulating models that explain everything from natural phenomena to the structure of the universe itself has been widely documented. From this perspective, we propose a work oriented to research processes. This work is developed from two strategies: formulating models and establishing methodologies that allow configuring a work route

in order to generate new and better ways of building knowledge (Niaz, 2016) (Da Rocha, 2019).

From the importance of science education and model-based teaching arises the need to build a proposal of guided models for research training in Technology, Engineering, and Basic Sciences. Therefore, a guided model is proposed accompanied by a systematic review of both theoretical references and scientific production (Gómez and Garduño, 2020), in order to establish a solid support for the system (Chamizo-Guerrero & Ríos-López, 2017) (Arraiz, 2014). In other words, it is necessary to generate conceptual structures in students within a system framed in a model that would grant them several advantages. For example, the model will allow them both to understand the problem and to postulate hypothetical scenarios for the solution; that is, it will give them tools for the construction of innovative methodological designs that give them a guide to solve the problem and generate new ways of approaching science and technology education (Acevedo-Díaz & al, 2017) (Bosque-Pérez & al, 2016) (Sánchez-Robayo & Torres-Duarte, 2017). Additionally, it allows them to construct a representation of the degree work within an epistemological framework.

This proposal is based on the concept of model proposed by Ingham and Gilbert (1991). They argued that a model is a simplified representation of a system that focuses attention on specific aspects of it (Peralta, 2016). Furthermore, models allow aspects within the system (i.e. objects, events, or ideas) that are complex or that are on a different scale than the system itself. Models are important for scientific research in the formulation of hypotheses to be tested, as well as in the description of scientific phenomena (Ingham & Gilbert, 1993).

In summary, this proposal seeks to contribute to the development of the next generation of researchers. In particular, the objective is to help the development of skills that allow them, on the one hand, to pose problems and evaluate them, and on the other, to provide solutions with an emphasis on the construction of models to guide research and innovation processes.

## FROM GROUNDED THEORY TO THE ESTABLISHMENT OF MODELS IN RESEARCH AS A WORK ROUTE

In order to formulate a theory of guided models for research training, we turn to what is stated by Strauss and Corbin called "Grounded Theory," understood as the possibility of innovating with the generation of models that allow explaining a phenomenon (Glaser & Strauss, 1967). In particular, this research focuses on two types of phenomena related to the natural sciences and technology (Weiss, 2017) (Ovalle, 2019): on the one hand, those phenomena linked to the daily action of human beings; on the other, to those generated by nature itself.

Finally, it is important to take into account what is called "the four phases of all hermeneutical research." These phases are a) instrument validation; b) implementation; c) methods and tools for the collection and systematization of information; and d) the qualitative or quantitative analysis of the information (i.e. triangulation and analysis) (Carrero, 2012).

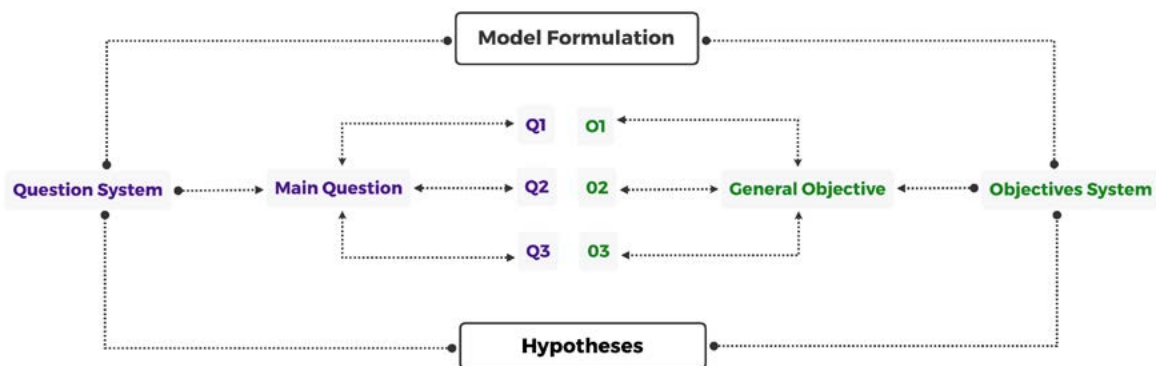
### Grounded theory

The grounded theory was initially defined by Glaser and Strauss, who in 1967 published a book called "The Discovery of Grounded Theory" where they developed it (Glaser & Strauss, 1967). After this

publication, many researchers have adopted this proposal whose purpose is to construct concepts that are derived from the registered and systematized information of experiences in which social researchers live experiences with communities (Hernández, Herrera, Martínez, & Páez, 2011). Grounded Theory (or "research training" in this case) adopts a mixed methodological paradigm (Medina, Arguello & Gómez, 2017) that allows the construction of guided models, which is the modeling of research proposals according to the intentions of every investigation. In this way, the conceptualization becomes an abstract and simplified perspective, as knowledge of the lived world and that the researcher wants to represent through the construction of models that, in the case of this investigation, is applied to the teaching of science (Arraiz, 2014) (Bonilla-García & López-Suárez, 2016).

Our proposal to work on guided models based on grounded theory for the training of researchers is structured around five moments:

1. Formulation of the model: systems of questions, objectives, and hypotheses posed as a system.
2. Presentation of theoretical categories by induction as a guide for mapping bibliographic information and conceptual foundation of research (Contreras Accounts, 2020). As many categories as concepts that are formulated in the problem will be proposed.



**Figure 1.** Formulation of the model.

Source: Own.

**Table 1.** Category matrix.

RESEARCH PROBLEM	GENERAL OBJECTIVE	SPECIFIC OBJECTIVES	CATEGORIES	CATEGORY DEFINITION	SUBCATEGORIES

Source: Own

3. Design of the methodological route: Construction of methodological designs, and the validation process of the instruments and activities that constitute the researcher's field work (Cisterna, 2005). This validation is carried out by entities, which are three differentiated actors, in order to give ownership and reliability to the research. These three actors are: a) academic peers of the researcher, b) experts, and c) a similar population group (Paramo-Bernal, 2018).
4. Implementation: The proposed designs are applied, the data obtained is systematized, and the information is triangulated (Richards, 2018). The systematization process can be qualitative or quantitative, with the need to go through writing techniques and semantic codes configured in the interpretation of the validated instruments (phase two). In this sense, it is important to use specialized software for the qualitative and quantitative analysis of information (e.g. MAXQDA®, Atlas-Ti®, N-Vivo®, SPSS®) (Chandra & Shang, 2019)
5. Modeling and Analysis. In this last phase, the researcher validates his hypotheses and tests the solution to the problem from the initial model. This process allows either a reconfiguration of the initial model or the reconfiguration of the initial approach and conclusions (Campeón, Becerra, & Villa, 2018).

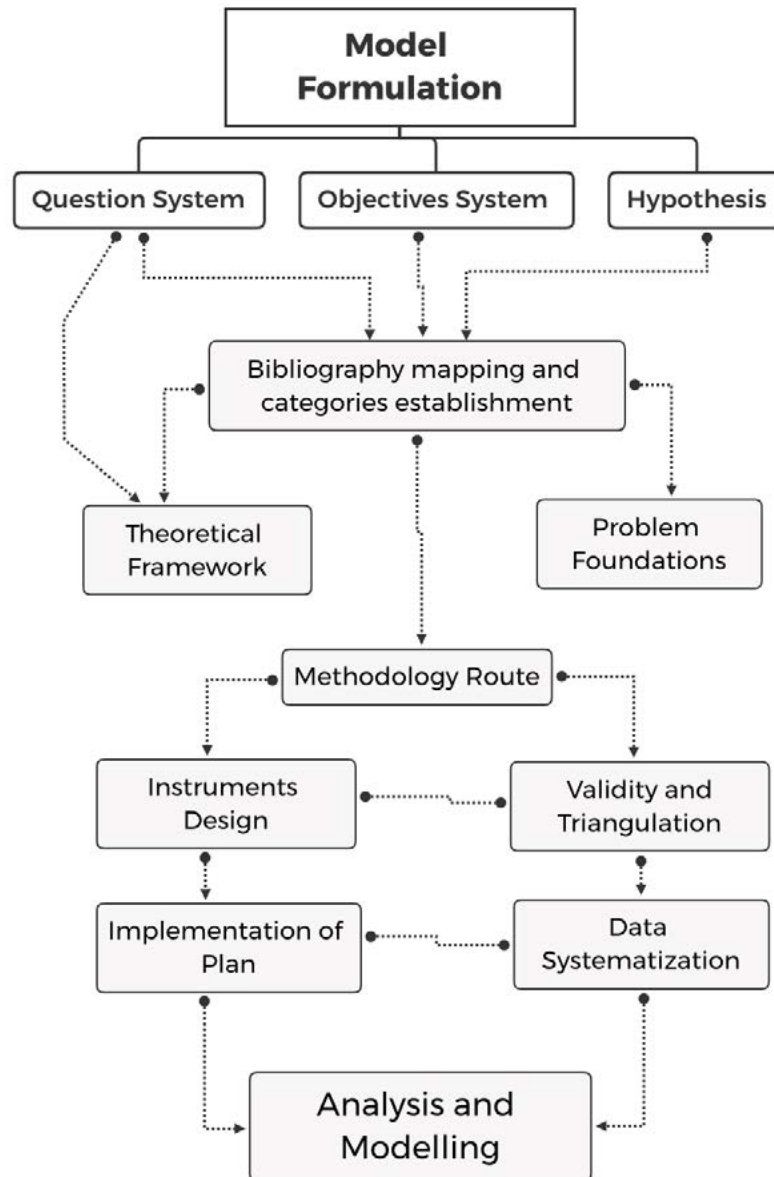
The follow-up to this methodological process, shown in Figure 2, secures the development of a systematic and reliable work, which will guarantee that the obtained results contribute to the scientific community dedicated to education. This greatly

benefits future researchers who pursue a hermeneutical education.

## THE DESIGNING AND IMPLEMENTING OF GUIDED MODELS IN THE INVESTIGATIVE PROCESS

In this section we will address an interpretive approach to the idea of guided models for research training in a dynamic and reflective sense. Thus, the concept of model is presented in association with factors that enhance its dialogic-reflective character. These factors also serve to structure a trajectory as a form of argued representation of the methodological route, via specific representations of maps of the process (Gutierrez, 2016). A generic example of representation of models and methodological maps is distinguished.

This organization helps to consolidate a new look at what is done when researching in science education because it questions the monitoring of phases (stages) and the mechanical use of techniques (methods), without reflecting on the events of the research process. Additionally, this option positions the conception of the reflective researcher, who is epistemologically aware of the differences between the application of research methods (from their various enunciations) and the design and implementation of problem-solving routes. This awareness of the difference applies even in cases in which mixed-cut methodological alternatives that dialogue with the construction of models and progression hypotheses are developed (Gallego-Badillo, Pérez, & Gallego-Torres, 2020).



**Figure 2.** Guided Model for Research Training.

Source: Own.

## Guided Models for Research Methodologies

The concept of “guided model” in research acquires relevance insofar as it allows understanding the process of solving the research problem from a dynamic, active, reflective, and also changing and complex approach. However, these characteristics do not

imply that the process is difficult or impossible. Another characteristic feature of the concept is the validation of the research in a praxiological sense; this favors the construction of meaning in actions, based on the reflection over the experiences of researchers and their work team (Arango-Londoño, 2016). For this reason, the guided model is enriched by the



contexts of reflection, the researcher's learning and the validation and feedback processes from experts.

Consequently, when the research process is beginning, the design of methodological models from the aforementioned approach is appropriate for the case of epistemological and hermeneutical perspectives. This is due to the constructive nature of knowledge that is produced and is applicable, for example, in the field of science education.

### Factors that enhance the guided model

According to the researcher's reflected experience on his own inquiry processes, research actions are consolidated as elements or factors of the investigative process. For the first case, the researcher can assume that the methodology consists of considering relevant aspects that are added or achieved as they solve their research problem question. For the second case, it can be assumed that the aspects associated with the methodology are like turning points in their maximum potential, that is, they are capable of reconstructing different paths to follow; these alternatives are proposed from a qualification perspective, not a denial, of those initially proposed. Thus, in the case of methodological trajectories, it is necessary to consider dynamic factors rather than disconnected elements.

A guided model can be designed with the following factors in mind:

1. *The epistemological perspective on the nature of knowledge that is produced.* It is necessary to consciously assume whether the knowledge that is produced obeys the researcher's particular philosophical views (e.g. realism or relativism), since this also gives value to the researcher's own knowledge.
2. *The organization of threads.* These are usually understood as phases of the investigation and are designs of possible routes of inquiry associated with the objectives of the investigation.

3. *The constitution of meaning for the threads.* What are they developed for? What do they contribute? Why are they necessary?
4. *The progressive approach to the process through the threads.* The researcher's actions must be continually reflected in such a way as to build a progressive awareness of the process. Therefore, it is not about developing the threads like a recipe in which predetermined steps are followed; on the contrary, each reflected investigative action contributes to the indicated meaning. Thus, the reconstruction processes of the corresponding methodological experiences are facilitated.

It is worth noting that this description does not refer to specific investigative techniques. This is because the techniques are selected or constructed to the extent that their characteristics enhance particular actions of the researcher. Although this is not an obstacle to consider them in the planning of the sub-processes, it should never be assumed in a dogmatic sense as it would be contradictory with the dynamic approach that we have presented.

### Guided models and progression hypotheses as a reference map

When organizing the research design from guided models, it is possible to establish a progression hypothesis as a reference map. In this sense, the progression hypothesis acquires relevance to contrast and reflect on the coherence of the methodological path (Figure 2). The factors are considered as criteria and in each of these it is convenient to analyze the "places" of reference. As a synthesis, it is possible to deduce a map that reveals a state of the guided model; In addition, it is possible to make maps at the beginning, during, and at the end of the investigative process. In this way, not only would there be evidence of the methodological transformation route as a product, but also the progression hypothesis would be fed back.

**Table 2.** Reference progression hypothesis for the representation of methodological routes.

Progression hypothesis in a guided model			
	A	B	C
<b>[E]</b> <b>Epistemological perspective of the knowledge that is produced</b>	A1: mainly positivist, A2: realistic approach associated with the explanation of the subject-object relationship.	B1: transitional, in process of reflection, B2: argues with positivism in the construction of explanations.	C1: a perspective of construction of reality is assumed for the object of study, C2: analyze the role of epistemological relativism.
<b>[SP]</b> <b>The organization of threads</b>	A3: isolated steps of the process are distinguished, A4: phases are listed as steps to develop.	B3: some thread relationships are built, B4: some factors distinguished (dynamic perspective of some threads).	C3: Consistent relationships are established between threads C4: factors are characterized C5: Threads are related to the research question C6: dynamic perspective of threads is displayed
<b>[ADV]</b> <b>The constitution of meaning for the threads</b>	A5: sense associated with following plans or recipes (mainly positivist approach).	B5: sense in relation to some threads, B6: reflective approach in negotiation with the alternative epistemological gaze.	C7: sense of thread in correspondence with the alternative epistemological gaze, C8: the dynamic sense is evidenced in the reflective processes developed.
<b>[PRG]</b> <b>The progressive approach to the process through the threads.</b>	A6: an additive perspective of progression prevails	B7: a thoughtful look at the progression for some threads B8: reflective tendency to maintain additive focus in some cases	C9: reflective-critical approach to the progression of all threads, C10: factor qualification complex approach C11: development of enrichment processes for research categories.

Source: Own

## Examples of Guided Model as Synthesis

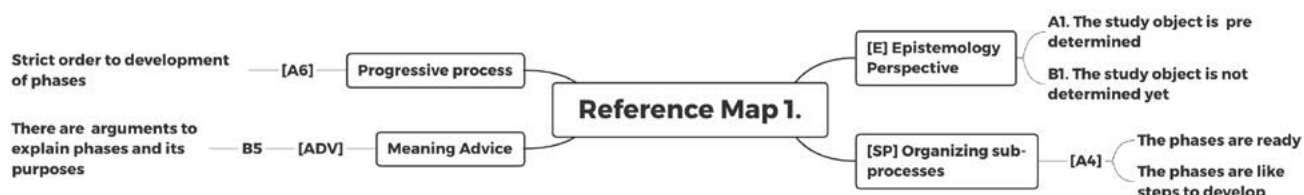
Regardless of the stage of development of the methodological process, it is possible to construct a representation as a reference map (Figure 3). This allows identifying the state of the process or reflecting and redirecting actions in order to qualify the methodological route as such. Thus, the route acquires meaning for the researcher and her work team (a dynamic, critical and reflective sense) instead of being addressed as a set of instructions or rigid steps.

When representing the guided model from the elaboration of reference maps based on the hypothesis of progression, consider the following example. Figure 3 shows the organization and state of

reflection on the design and development of a hypothetical methodological process. From this, it is possible to recreate a way to orient ourselves in our own methodological path.

From the categories of the progression hypothesis, levels A, B, and C have been selected. In these, the researcher has reflected and is in a moment of reflection both personally and with his team. This yields the representation of maps (Figure 4) that are represented as a methodological route given that the process is dynamic and reflective. As shown, the example has three maps corresponding to three moments (review, reflection, discussion), based on the factors of the progression hypothesis. With this, it is possible to give an account of the methodological route developed.





**Figure 3.** Reference Map.

Source: Own.

MAP 1 METHODOLOGICAL ROUTE			
	A	B	C
[E]	A1	B1	
[SP]	A4		
[ADV]	A6		
[PRG]		B5	

MAP 2 METHODOLOGICAL ROUTE			
	A	B	C
[E]			
[SP]			
[ADV]			
[PRG]			

MAP 3 METHODOLOGICAL ROUTE			
	A	B	C
[E]			
[SP]			
[ADV]			
[PRG]			

**Figure 4.** Methodological routes.

Source: Own.

## CONCLUSIONS

The guided model is an alternative for the collective and autonomous monitoring of inquiry processes, and it requires the construction of conceptual references such as progression hypotheses.

It is worth highlighting that this is the first of several works that have been prepared within the line of emphasis on research, and we hope to continue deepening and presenting results to the community of specialists.

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