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Systematic analysis of instructional models in science: towards the development of an instructional model

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ABSTRACT

Instructional models are essential for addressing the learning sequence of learners. They provide a series of activities intended to attain the learning outcomes while developing prerequisite skills. They are able to develop holistic skills in learners while adhering to learning standards. This systematic literature review discusses the different instructional models used in science. Selection criteria were used to identify articles considered essential for the review. Some of the criteria include being within a 10-year span, written in English, containing keywords such as "development" or "instructional design" focusing on science, and displaying a methodology for developing the model. After thorough analysis, the review narrowed down to 15 articles shedding light on the research problem of methodologies used in developing science instructional models. The analysis revealed three common themes: origins (grounds) of the model, essential elements or variables used in obtaining the models, and supreme guidelines outlining the procedures undertaken to develop the model. Six common methodologies were identified among the analyzed articles, synthesized and presented in this review. In light of these results, the review concludes that some models do not properly display methodological procedures for science instructional model development. This review can contribute to model developers by providing insight into how models should be developed using proper methodologies. The outlined methodologies resulting from the review can be adopted in developing science models for instructors, teachers, and other instructional leaders involved in designing learning models.

Keywords: *methodology, Science Instructional model, systematic review*

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INTRODUCTION

Instructional models are important in providing well sequenced lessons in a systematic manner enabling the process of learning development that are essentials in nurturing critical thinking among learners (Vong & Kaewurai, 2017). To improve the procedures, it is recommended for educators to choose an approach that posters the process and instructions whose goal is to instill critical thinking to students. These models of instructions as emphasized by Hubell and Goodwin (2019) and Chukwuemeka et al. (2020) help teachers in creating learning instructions catering to the recognized learning needs of students making the teaching-learning process more effective. Moreover, according to Ghani and Daud (2018) A wide range understanding of different models anchored to particular contexts is a key ingredient in the effectiveness of learning. In such, problem-based learning models in science class help students in applying critical thinking and solving real world problems, thus scientific understanding is applied.

In their 2020 review, Chukwuemeka et al. examined 15 popular teaching models and found that none of the developed models are suitable for streamlining classroom instructions. However, these models can provide ideas to teachers to enhance the teaching and learning environment, making it more engaging and effective (Chukwuemeka et al., 2020). The creation of instructional models can be traced back to numerous ideas related to teaching and technology integration in e-learning, as demonstrated in Byrne's study (2020) on using a model for e-learning. Dewi et al. (2018) explored an instructional model in blended learning, while Ibiloye (2024) applied instructional models through blended learning. Furthermore, Sheth's review in 2021 concluded that instructional models are functional in creating and designing online courses, positively impacting learning. Most instructional models are adapted and modified for improvement, such as the College Science Learning Model (CSLC), which emerged from the 5E instructional model, with elements derived from engagement, exploration, explanation, elaboration, and evaluation, as used by Withers (2016). Another modification derived from the 5E model is the 7E model developed by Eisenkraft in 2003. This model aims to add value by analyzing learners' prior understanding and making the transfer of learning more comprehensive. Byrne (2020) demonstrated the same principle in developing the 6P4C model, derived from instructional model frameworks like the ASSURE model, ADDIE instructional model, and SAMR model.

Different models provide distinct skills for development. Silva et al. (2012) developed a model aimed at enhancing students' academic and translational language required for engaging in science discourse. Ellis (2016) tested a model with the purpose of identifying and emphasizing creativity as a central component essential for developing higher-order thinking skills. Langkudi (2018) designed a model to foster the development of thinking skills. The cultivation of essential skills is intrinsic to 21st-century learning, often involving the refinement of critical thinking skills.

Saido (2015) asserts that the primary goal of science education is to nurture students' critical thinking through higher-order thinking skills. In a study conducted by Muhibbuddin et al. (2023), it was found that higher-order thinking skills, such as the ability to pose scientific questions,

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significantly enhanced critical thinking abilities. Post-test results revealed an improvement in mean scores, with the experimental group demonstrating a notable increase of 2.12, in contrast to the control group's mean score of 0.22.

In a comprehensive review, Santos (2017) observed that critical thinking is not fully facilitated in science education, attributing this deficiency to the uncritical application of critical thinking within the science curriculum. Saenab et al. (2020) emphasize the urgent need for an expanded approach to teaching, with a specific focus on models that underscore critical thinking in science education. Rogers (2023) further elaborates on critical thinking, identifying it as a persistent challenge in science education. The critical thinking as a guiding tool for teachers in making informed decisions, leading to the creation of diverse instructional models needed to the varying demographics of students.

The most prevalent instructional model associated with science education is the learning cycle in the inquiry method, such as 3E, 5E, 7E, and 9E. These models often align with the theory of constructivism, enabling the application of inquiry methods (Nicol et al., 2020). Bell (2014) expounded on the Next Generation Science Standards, which formulates the science curriculum. It articulated that there is no single or specific instructional model; rather, multiple models are necessary to implement learning goals in the science curriculum.

The purpose of this review and analysis of the development of instructional models in science is twofold: (1) to identify the categories or criteria that guide the development of instructional models in science and (2) to consolidate the procedures or methods used by studies, leading to the creation of a methodological framework specifically designed for science. This framework is intended for model developers, particularly those focused on science curriculum, including teachers, curriculum experts, and practitioners. Such a guide or methodological framework in development would clarify the rules and requirements in instructional model development in science education. This will serve as an avenue or gateway for an exchange of ideas among experts and scholars, contributing to the advancement of instructional model practices

METHODOLOGY

The study used databases such as ERIC, Google Scholar, and Emerald Insight as the initial process of providing relevant literature. Keywords such as "Instructional Model Development" and "Developing Instructional Design" were employed in looking for articles. The search criteria included the use of a database with specific filters. The inclusion criteria for the initial review of articles were that they should exist between the years 2014-2024 (covering a 10-year span), have open access, be written in the English language, and published in a journal. These criteria resulted in a total of 1046 articles.

A second screening was conducted, reviewing the abstracts and keywords of articles containing the term "development." A total of 100 articles were incorporated based on this screening. For quality screening of the abstracts and keywords, the researcher examined the methodology, specifically looking for details such as stages or phases, the process, and the approach of developing science instructional models. Articles that appeared in multiple databases were

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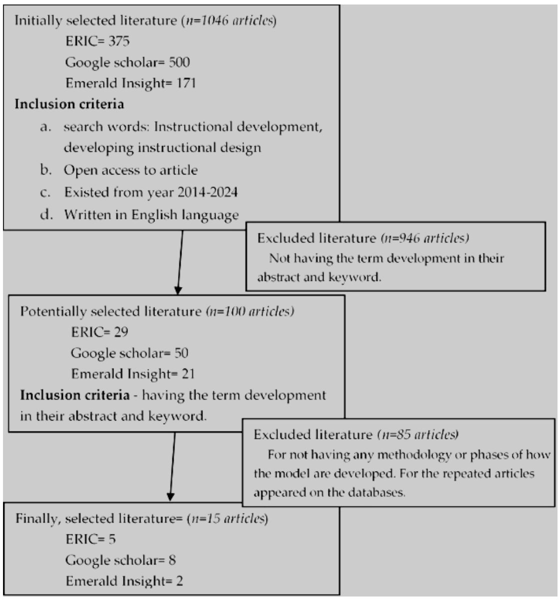
omitted, resulting in a final selection of 15 articles focused on the development of instructional models in science education. All inclusion criteria in selecting literature aimed at analyzing the methods used in developing instructional models intended for science education.

Figure 1 illustrates the flow of the literature selection process for the review.



Analyzing the literatures on Instructional model development in science education

After the final selection of papers to be included in the studies, the researcher coded the literature was coded and commenced analyzing the categories that set each instructional model apart from one another was commenced. During the review of literature or studies, the researcher scrutinized the features of models, the types of methods applied, and the phases undergone for their development were scrutinized. It emerged that each Instructional Model (IM) could be categorized according to three core aspects: (1) its development, including the ground of development; (2) the applied approach; and (3) the system of development.

Moreover, all literatures in terms of model development resulted in one purpose of their development. It can be reasoned out because of its served purpose for science education. The core purpose of model development in science education revolved around the scientific literacy in inquiry method combined with constructivist theory for 21st century skills such as critical thinking skills development thru higher order thinking skills. This purpose is common among all literature analysis which was anchored to the science process skills agenda.

Ground of model development

As further analysis was conducted on the selected literatures. The 'ground of model development' refers to the foundational basis upon which the model is created. This core aspect can be divided into two categories: literature-based and field-based grounds. In the context of this study, literature-based models are those grounded in a particular literature or theory related to the subject, such as science education. The review identified 8 eight papers categorized as literature-based models. On the other hand, field-based models are derived from direct phenomena experienced by the subjects, such as teachers. These models often stem from challenges encountered in the teaching and learning environment, becoming driving forces in their development. In total, 7 seven field-based models were identified in the selected literatures.

Approach applied in model development-Essential elements

The term 'approach applied' refers to the method implemented to develop a model. In the selected literature, various approaches were identified:

1. Design & and Development: This approach involves an investigation of design, development, and evaluation processes within an empirical basis for the development of instrumental and non-instrumental products, tools, and new or improved models. The progress is outlined through the necessary processes of describing, analyzing, and evaluating a product, such as a model or tool (Richey & Klein, 2008).
2. Research and Development: According to Gustiani (2019), this method purposefully validates educational products and is applied in educational practitioners' practices for designing instructional models. It is also employed by specific fields or organizations aiming to develop and improve their existing products or services with the ultimate goal of societal improvement.
3. Mixed Method: Gallant & Luthy (2020) explain that this is a systematic inquiry that collects and integrates several viewpoints using combined qualitative and quantitative data. The suggested stages include (a) initial model development based on experience, (b) applying Delphi-survey technique with experts (quantitative and qualitative data), (c) revising the model according to the results of the Delphi survey, (d) pilot testing (interviews with participants concerned in model development), and (e) revising the model.
4. Quantitative Phenomenology: Bonyadi (2023) stated that this method is applied in an educational context to explore the essence of a specific phenomenon from the perspective of individuals who have an in-depth understanding of it.
5. Instrumental Case Study: This approach is applied to gather insights into an issue, modify generalizations, or function to restructure a theory using an extension of experiences (Nolin, 2019).

In the literature review, three literatures used the design and development approach, two used mixed methods, five employed research and development, one used quantitative phenomenology, and two applied instrumental case study. Additionally, two literatures did not specify a particular approach in their model development. This varied approach in the literature review provides essential elements such as model prototype, implementation system, evaluation, revision, and gathering feedback.

Supreme guidelines in instructional model development

System of model development is related to the scheme of creation applied in the model. There are 2 two models of development used in selected literatures. First are the three literatures facilitating the Gall and Borg model of development, Sunyoto et al., (2020) explained that this model of development in educational context is used to develop and validate the product of education. Furthermore, its output is not relying only on existing products but in seeking answers to a problem upon using the product that serves as an evaluation tool. This system of model development is composed of four (4) main characteristics. (1) Working out with initial study to develop a product, (2) developing a product based on the result of initial study, (3) Field testing or pilot implementation of the product,

(4) evaluating the effectiveness of the product and revising it. Three literatures used the Plomp model of development. According to Rosmiati et al., (2016) wherein an adaptation of plomp model was implemented in the study it is composed of 5 major steps (1) Initial investigation, (2) design, (3) process of creating, (4) evaluation, (5) Implementation of the model. Likewise, a numerous number nine out of fifteen literatures appeared to be no system of model development is utilized. This system of model development can be combined to form a principal guideline that form ruling in developing IM (Instructional Model). The basic components such as (a) Initial investigation, which aims to find a phenomenon, theory, or literature about the model. ; (b) Model development, creating a model prototype or using an existing model. ; and (c) Carrying out the model, the deployment of the model either to a small scale or large-scale system.

System of development

The system of development critical core aspect refers to how model builders used, implement, combine, and put into practice the set of information obtained arriving in a model. The set of collected data can be arranged in multiple orientations according to a definite set of guideline analysis. As added by Lee & and Jang (2014) in their analysis scheme that data can be organized using their heuristic design and array of functions. As the data continues to organize a pattern of design will show up and the system for analysis will be visible. In this way, the builder of the model or developer gains a closer insight to further examine and relatively see information that later helps in developing the model. Furthermore, system development is able to produce design patterns in a heuristic manner that is reflected by the disposition of the developer, it begins in a simplest way headed to a more complex analysis.

Table 1 Combined core aspects for instructional model for science education (GES analysis)

Ground	Essential Elements	Supreme Guidelines
G1-literature base G2-Field Base G1+G2=Hybrid	E1-Literature or Theory E2- Field Experiences E1+E2-Combined Literature and field experiences E3-Creating New model E4-Using of Existing model E5-Applying model into learning material	S1- Initial Investigation S2-collection of information S3-Model development S4-carrying out model

Table 1 is a summary of a combination of core aspects for the instructional model for science education. The core aspects contain ground, essential elements, and supreme guidelines (GES). This pattern is utilized to establish a pattern or system function of development intended for science education.

Table 2 Integrated procedures for Science Instructional model development

System Model	Supreme Guidelines	Procedures
A. G1-E1-E3-E5 Using Literature base ground model in elements of literature or theory in IM. *Bandrun, et al., (2021)* *Syahri et al., (2021)* *Elwood and Jordan – 2022*	Initial Investigation	1. Finding literature or a theory about a particular science education related issue.
	Collection of information	2. Examining the related literature or theory about the science education related issue.
	Model development	3. Create a prototype model out of literature or theory, turning model using relationship among variables and representing it thru graph. forming a conceptual model.
	Carrying out the model	4. Applying model in teaching-learning materials.
B. G2-E2-E3-E5 Using field experiences ground model in element of field experiences in creating IM. *Novitra et al., (2021)* *Saido et al., (2018)* *Suastra et al., (2021)*	Initial Investigation	1. Finding relevant experiences about a particular science education related issue.
	Collection of information	2. Coding the experiences about a particular science education related issue.
	Model development	3. Creating a protype model out of field experiences using relationships among variables and representing it thru graph forming a conceptual model.
	Carrying out the model	4. Applying model in teaching-learning materials.
C. G1+G2-E1+E2-E3-E5 Using both literature and experience-based ground models in elements of both experience in creating IM. *Limatahu et al., (2018)* *Waluyo et al., (2021)* *Nonthamand (2020)*	Initial Investigation	1. Finding relevant literature and experiences about a particular science education related issue.
	Collection of information	2. Examining the related literature or theory and experiences about the science education related issue.
	Model development	3. Creating a prototype model out of literature or theory and field experiences using relationships among variables and representing it thru graph forming a conceptual model.
	Carrying out the model	4. Applying model in teaching-learning materials.

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System Model	Supreme Guidelines	Procedures
D. G1-E1-E4 Using literature ground model in element of literature in creating modified model. *Kim et al. - 2022 – Han & Shim (2019) Lee & Hong (2023)*	Initial Investigation	1. finding relevant literature about a particular science education related issue.
	Collection of information	2. Look for the developed model and its suitability to the issues being observed.
	Model development	3. Test its usability by employing a reliability test to the current situation. 4. Revised the model if needed in order to recreate it. Used the relationship among variables and represented it thru graph forming a conceptual model.
	Carrying out the model	5. Applying model in teaching-learning materials.
E. G2-E1-E4 Using field-based ground model in element of field experiences in creating modified IM. *Saenab et al. - 2020*	Initial Investigation	1. Finding relevant literature and experiences about a particular science education related issue.
	Collection of information	2. Look for a developed model and its suitability to the phenomenon being observed.
	Model development	3. Test its usability by employing a reliability test to current phenomenon. 4. Revised the model if needed to recreate it. Used the relationship among variables and represented it thru graph forming a conceptual model.
	Carrying out the model	5. Applying model in teaching-learning materials.
F. G1+G2-E1+E2-E4 Using field based and Literature based ground models in elements of field experiences and literature in creating modified IM. *Chaeruman et al. (2020) Clores and Nueva España (2023) Şen Akbulut and Hill (2020)*	Initial Investigation	1. Finding relevant experiences about a particular science education related issue.
	Collection of information	2. Look for a developed model and its suitability to the phenomenon and issues being observed.
	Model development	3. Test its usability by employing reliability tests to current phenomena. 4. Revised the model if needed to recreate it. Used the relationship among variables and represented it thru graph forming a conceptual model.
	Carrying out the model	5. Applying model in teaching-learning materials.

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RESULTS AND DISCUSSIONS

After a series of analyses conducted by the researcher on the selected literature pertaining to instructional models developed for science education, three core aspects and six integrated procedures were identified as the system for instructional model development in science. Following a thorough reflection on the findings, various discussions were derived.

The core aspects and system for instructional model development

The core aspects of the established system for instructional model development can be adopted by future instructional model developers for their projects or design studies. The first core aspect is the ground, which refers to the origin or foundation of creating the model. The second core aspect is the essential elements, encompassing the crucial features of each phase in the model that was analyzed, enabling developers to formulate their own models based on the literature used. The last core aspect is the supreme guidelines, rooted in the methodological approach employed by researchers and their developmental methods.

In the process of integration, understanding and processing the data require a structured development process to ensure the creation of a model grounded in evidence. Future researchers are free to choose a system that aligns with their expertise and data availability.

The Science Instructional model and its purpose

Furthermore, the data obtained must be carefully set and obliged to the community standards and ethical standards of conducting research. It is a must for data to be obtained reliably and valid. It will be a good and beneficial design if the gathered data and the model developed was addressed in such a way that it serves its purpose. Like science education, in analysis it states that all models for science education have a purpose of developing 21st century skills, the inquiry method, higher order thinking skills, and anchored to constructivist theory. With this a purpose of model development serves its differences among others.

In the Philippine context, the purpose of K-12 is to develop holistic learners who are job-ready and in the process of developing and applying 21st-century Century skills. Furthermore, to develop Filipino learners globally competitive with its neighboring ASEAN countries via standardized education (SEAMEO, 2020). Agnes et al. (2022) emphasized the importance of the instructional design model as a contributor to an effective teaching-learning situation. However, the analysis focuses on three emerging instructional design models: the nine events of the instructional model by Robert Gagne, the Instructional theory into practice model by Madeline Hunter, and 5E's learning model cycle by Rodger Bybee. The analysis revealed that the four instructional events are prominent in the learning plan: review, motivation, presentation, and assessment. Furthermore, there is no prevailing instructional design model that conforms to the utilization of the K-12 program. This implies how instructional events executed by teaching affect the sequence of learning patterns. Therefore, it is recommended to revisit the curriculum and provide an overview of the instructional design model's input to improve implementation.

The purpose of the curriculum reflects what it requires to achieve and

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to achieve this purpose, a systematic deployment to the learning and teaching process must be presented. An instructional model anchored to the purpose of the curriculum is essential. As the Philippines is continuously improving its curriculum lining up to globalization, it must look at its implementation and model to make a standardized education and effective and synchronized instruction available to learners. With this, a potential improvement and change in education might take place.

The validity of the model

In model validation, teachers' perceptions and problems can be variables that establish firmness. By looking at the teachers' experiences with the unique features and goals of a curriculum's implementation, its validation can be established. Further testing and observational tests should be considered when implementing curriculums. Furthermore, it is recommended to develop a curriculum with a goal driven to the development of an instructional design model particular to the needs of science instruction in the Philippines with its goal of accelerating science education in helping to steadfast the large-scale assessment helping the Filipinos to champion the future of the educational landscape. The literature shows that several validations are conducted upon implementing a model. It would be better if numerous studies were conducted to test the model's reliability and validity for a long time regarding the changing educational landscape.

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