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The 5E instructional model in the meaningful learning of science and technology

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The primary objective of the study was to determine the influence of the 5E instructional model on the meaningful learning of Science and Technology in the students of the El Amauta Pedagogical Research and Innovation Laboratory, belonging to the province of Pasco - Perú. The methodological process responds to the quantitative approach, applied with a pre-experimental design to a sample of 22 students selected intentionally, to whom the instructional model was applied for the development of learning. The application of the instrument and the results obtained through the Wilcoxon test showed 0.008 < 0.05. Therefore, the 5E instructional model influences the achievement of Science and Technology learning of the students of the aforementioned educational institution.

KEYWORDS

learning, science, competence, model, technology

Introduction

In the Peruvian context and specifically in the region and province of Pasco, science teachers lack formal teaching training and rely on empirical approaches based on their own experiences with students. Participating in workshops gives them the opportunity to explore various strategies to improve teaching, acquire skills as a trainer, and foster an open attitude. Towards technology and educational innovation.

In addition, the accelerated advancement of science and technology currently requires innovative educational strategies that promote meaningful learning in students. Under these premises, the results obtained in the 2022 sample evaluation were reviewed, which shows the performance of the students. Students of the second grade of secondary education, in the area of Science and Technology and in this it can be observed that at the regional level the results are at the beginning level of achievement; Therefore, there was no significant difference between the years 2019 and 2022 (MINEDU, 2022). For this reason, this study proposes to explore and analyze the effectiveness of an instructional model based on the 5 E's (Engage, Explore, Explain, Elaborate and Evaluate) in the field of teaching the curricular area of Science and Technology. This approach is supported by learning theories that propose the active construction of knowledge and coherently integrate the stages of the educational process from the initial capture of the student's attention to the critical evaluation of the acquired knowledge.

The 5E instructional model

According to Bybee et al. (2006), proposes the 5E model that responds to learning cycles and consists of five phases: *Engage*, aims to motivate when studying a particular topic by awakening curiosity and interest. *Explore*, allow you to question, make predictions, formulate hypotheses, record observations and discuss results among peers. *Explain* leads to discussing the findings. *Elaborate* allows you to establish relationships with other concepts so that they can be applied to new situations. *Evaluate* allows you to evaluate the knowledge achieved, the difficulties and how you worked as a group. Furthermore, this model seeks to capture attention, participate in activities in a timely manner, understand the central ideas of the topic, develop activities based on experiences and explain what happens, with the primary accompaniment of the teacher (Bybee, 2015).

The 5E instructional model allows students to acquire greater responsibility in the construction of their meaningful learning. The origin of the 5E model, as a strategy, was a proposal from the Biological Sciences Curriculum Study in 1980, this arises from the union of different models such as that of Herbart, Dewey, addressing even the Atkin-Karplus learning cycle (Bastida-Bastida, 2019).

This model is based on the constructivist paradigm, in which a person's ideas and prior knowledge serve as a basis for developing new knowledge, requiring the student to actively participate in the learning process, using strategies that allow the connection between new information with prior knowledge. Furthermore, through this model the student develops his own knowledge, understanding reality, instead of limiting himself to memorizing information without understanding it (Diaz et al., 2020).

According to Garcia i Grau et al. (2018), the phases of the 5E model are:

- Engage aims to stimulate students' interest in participating in their own learning, while; Teachers have the opportunity to connect new content with prior knowledge to make learning meaningful.
- Explore includes creating a variety of creative and hands-on activities that allows students to conduct guided experiments and explore similar activities.
- Explain, students explain in a simple way in their own words the concepts worked on, the knowledge acquired and share them with the rest of the class, as well; the teacher searches with accuracy and precision for scientific vocabulary, connecting the knowledge provided by the students with other abstract and conceptual terms.
- Elaborate, helps students apply acquired knowledge to new learning experiences.
- Evaluate, at this stage students can understand their own learning, in addition; This step is not done at the end of the process; can be done at any time of the 5 phases.

These steps are developed as a teaching and learning sequence with the purpose of promoting the adaptation and integration of scientific concepts and knowledge, the context in which these concepts and knowledge make sense, and the ways in which knowledge is constructed. This model proposes a method that serves as a guide to organize both declarative and procedural learning activities, with the aim of integrating them in an organic and relevant way, facilitating students to build their knowledge (Zárate-Moedano et al., 2023).

The 5E model is related to the learning cycle, in which concepts to be learned are created, modified and discarded, which is influenced by Piaget's ideas about the imbalance of thought structures and their process of adaptation and integration, culminating in a new balance (Lawson, 1994). This model emphasizes learning from a constructivist approach, therefore; assimilation and accommodation must be taken into consideration, according to Piaget; as well as social interaction and learning zones according to Vygotsky.

On the other hand, it is important to teach Science and Environment through the inquiry method based on experimentation, as presented in the 5E model (Cahuana and Limachi, 2016). This approach not only seeks to acquire knowledge, but also encourages students to build their knowledge through experimentation and verification of their own predictions (see Figure 1).

Significant learning

Learning is the acquisition of knowledge, skills, behaviors, values, aptitudes and attitudes (Beltrán, 1993); this is acquired as a result of cognitive processes intentionally through attention, observation and experiences achieved by the person in interaction with their context (Ausubel, 2002), which involves relating new information to the cognitive structure in a non-arbitrary and substantive way (Matienzo, 2020), highlighting the constructive integration of thoughts, feelings and actions, leading to human aggrandizement (Novak, 1988). This type of learning occurs when new information is combined with the prior knowledge that the learner has and that is relevant to the cognitive structure and development of the student.

Likewise, the pedagogical approach to meaningful learning seeks for students to understand and apply their cognitive and socio-emotional skills in real situations (Zamora et al., 2023), developing skills and competencies in students beyond just transmitting information, such as critical thinking, problem solving, creativity and collaboration (Posso, 2022); that contributes to the quality and relevance of education (Roa, 2021). Under this approach, learning becomes significant to the extent that other learning is adequately clear and functions as an anchor for new learning, as well; This differs from rote learning and prioritizes a deep and comprehensive understanding of the new learning and its application in various

FIGURE 1
5E learning cycle: engage, explore, explain, elaborate and evaluate. 5E model, in the teaching of initial education (Esquen, 2019).

situations, allowing students to acquire useful skills in their daily lives and in the future.

Teachers are knowledgeable and aware that meaningful learning is effective in motivating and engaging students in the learning process, which in turn leads to better academic outcomes and a greater desire to continue learning.

Therefore, applying the 5E teaching model helps to achieve meaningful, dynamic and interactive learning, where the student interprets objects and phenomena and internalizes the interpretation based on current experience. Additionally, it changes and improves understanding of its context, which often requires challenging existing knowledge and demonstrating that that knowledge is incomplete or inadequate.

The objective of the study was to determine the influence of the 5E instructional model on meaningful learning; for this, the processes of engaging, exploring, explaining, elaborating and evaluating had to be demonstrated in the learning of the Science and Technology curricular area of the students of the El Amauta Pedagogical Research and Innovation Laboratory. This research is important for the development of creative thinking and scientific skills of the student, using the steps of the 5E instructional model, with the aim of improving educational quality in the area of Science and Technology.

Methodology and methods

The approach of the research study is quantitative, because it is based on a hypothetical deductive system, where the scientific explanation is produced through inference, it is of an applied nature since the theories are used in the sequence of practices, with a methodological design experimental by manipulating the selected variables in which a group with a pre-experimental design intervenes.

The population was made up of 122 students from the El Amauta Pedagogical Innovation Research Laboratory, of which; For the sample, 22 students corresponding to the 2nd grade were considered, aged 13 to 15 years, between males and females; whose sampling was random, by decision of the researchers.

The scientific method was used, which allowed the identification of learning needs and the hypothetical approach with its respective contrast, while; As a specific method, the inductive-deductive method was used, which allowed the results to be generalized from the particular through the synthesis and analysis that led to obtaining the conclusions, in addition; through the applicative method that guided the application of the 5E model in student learning (see Figure 2)

The use of said model in class sessions didactically allowed the achievement of significant learning in the capabilities of the specific competence of the curricular area; besides; The use of this strategy allowed students to develop creative thinking and scientific skills, which allowed them to develop curricular competence, through the following process:

- *Engage*: The teacher organized work teams with the students and then presented novel images to be observed, which allowed the students' interest to be aroused. In this regard, this generated curiosity and allowed the development of critical thinking with provocative and challenging questions, which helped students generate diverse opinions, allowing the evaluation of prior knowledge through observation, description of images and the ability to analyze new information.
- *Explore*: The teacher delivered a learning module with the application of the ABC technique: I read carefully, I look for main ideas and I draw up my Conclusions. With which, it was sought that the students analyze the module with application of the technique, which allowed evaluating the registration and organization of the information to understand the topic discussed.
- *Explain*: A member of each work team presented the summary, the description of the procedures, the data obtained and the conclusions of the topic discussed, supported by the learning module. This allowed us to evaluate the clarity and coherence of the presentation, ensuring that the speaker communicates the concepts in a logical and organized manner, appropriately using scientific terms and formal language in the presentation.
- *Elaborate*: Each student wrote an essay based on their research, taking into account the introduction, statement of the problem and the relevance of the study. In this regard, the teacher evaluated the depth of the research, the clarity and coherence in the writing, the appropriate use of sources and the capacity for critical analysis.
- *Evaluate*: Students reviewed and reflected on the achievement and process of their learning and their understanding of the topic. Additionally, they offered their colleagues constructive feedback, highlighting strengths and suggesting improvements.

In order to verify the optimization in academic performance, it was carried out using the Likert Scale instrument, at the time of the pretest and posttest, structured by 6 items according to the dimensions of the variables and objectives of the study, which allowed collecting the information and measuring the performance of students in the classroom. For this, the instrument was validated by experts, who determined the viability and its reliability through Cronbach's Alpha through the pilot test, which was subsequently applied to the sample group.

The information processing was done through tabulation by frequencies and percentages of the responses obtained according to the study variables, with the support of descriptive statistics for the measures of central tendency, which helped us place it within the measurement scale, likewise; with inferential statistics that allowed us to validate the respective study with the use of SPSS version 25 statistical software.

Results

It is shown in accordance with the dimensions and moments of application of the instrument, with respect to the use of the 5E instructional model, with its respective stages: Engage, explore, explain, elaborate and evaluate.

In Figure 3, you can see the learning achievement according to the procedures of the 5E model, these being: engage 23%, explore 36%, explain 41%, elaborate 14% and evaluate 27%. These results show low student performance, taking into account that the assessment criterion is 100%.

In Figure 4, you can see the learning achievement according to the procedures of the 5E model, these being: engage 27%, explore 73%, explain 77%, elaborate 45% and evaluate 64%. These results show

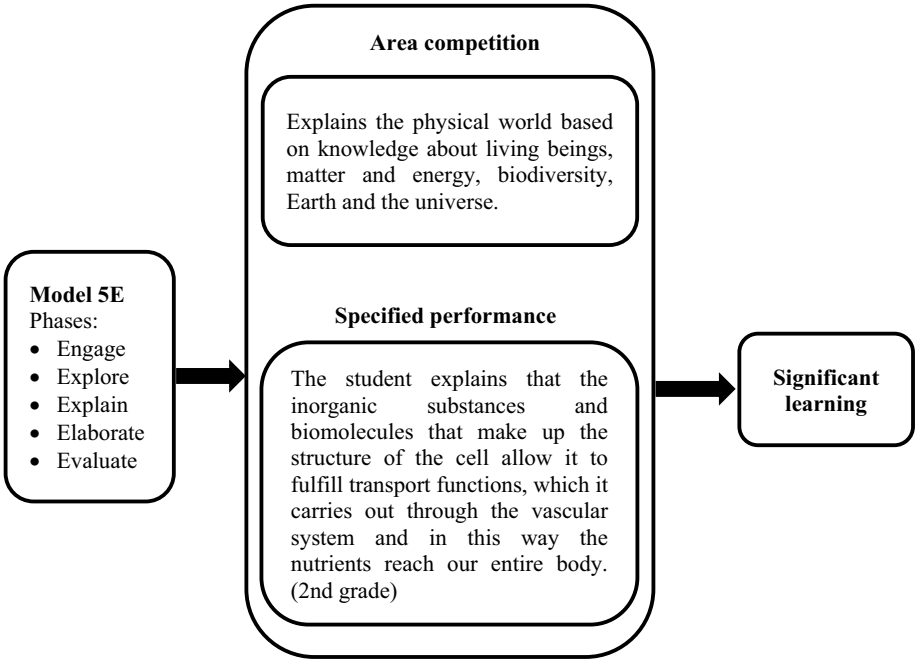

FIGURE 2
Adequacy of the 5E model in the development of competence in the curricular area of Science and Technology; to achieve meaningful learning. Prepared by researchers.

superior performance at the time of pretest, taking into account that the evaluation criterion is 100% (see Table 1).

The previous table shows the difference that exists between the data obtained, as well as in the pretest: Mean 15.27, Median 15.50, Dev. Deviation 2.567, Variance 6.589, Minimum 8, Maximum 19. Meanwhile, in the post-test, it was taken as: Mean 17.36, Median 18.00, Std. Deviation 2.216, Variance 4.909, Minimum 11 and Maximum 20. Therefore, in the post-test most of the data is superior to the pre-test, therefore; The 5E instructional model influences meaningful learning (see Table 2).

According to the Shapiro–Wilk test, the significance in the pretest is equal to 0.005 and in the posttest it is 0.001. At both times they are less than 0.05, which shows that it does not meet the normality test according to the data obtained.

Research verification

> *Alternative hypothesis (Ha)*: The 5E instructional model influences the significant learning of the Science and Technology curricular area of the students of the El Amauta Pedagogical Research and Innovation Laboratory.
>
> *Null hypothesis (Ho)*: The 5E instructional model does not influence the significant learning of the Science and Technology curricular area of the students of the El Amauta Pedagogical Research and Innovation Laboratory (see Tables 3, 4).

Significance level: $\alpha = 0.05$.
Statistical test: Wilcoxon.
Decision criterion:
If $p < 0.05$ (reject Ho and accept Ha).
If $p >= 0.05$ (accept Ho and reject Ha).
Results
Statistical conclusion
$\alpha = 0.05$ (5%).
If p value is $>= \alpha$ we reject Ho.
p value (asymptotic sig.) = 0.008.

Since the p value is $0.008 < 0.05$; Ha is accepted. Therefore, the 5E instructional model influences significant learning in the curricular area of Science and Technology of the students of the El Amauta Pedagogical Research and Innovation Laboratory.

Discussion

The 5E's facilitate the coherent organization of activities, improve learning and promote interaction between students (Zárate-Moedano et al., 2023), and are components of an instructional model that seeks to implement attractive activities related to cognitive processes to achieve learning objectives (Gálvez and Cobián, 2021). These results corroborate with the results of the research, since the 5E show a positive effect on the significant learning of students in the area of Science and Technology, which helps to improve the realization of activities by mobilizing creative thinking and scientist.

The 5E model helped teachers implement an active learning strategy (Garcia I Grau et al., 2021), and develop the lower and higher order cognitive process that had a positive effect on the students who studied using the mentioned model (Sotáková and Ganajová, 2023). These data also coincide with the results obtained in the study, since the 5E instructional model, with its respective processes, led to the development of creative thinking and scientific skills of the students, thus achieving significant learning in the curricular area. of Science and Technology.

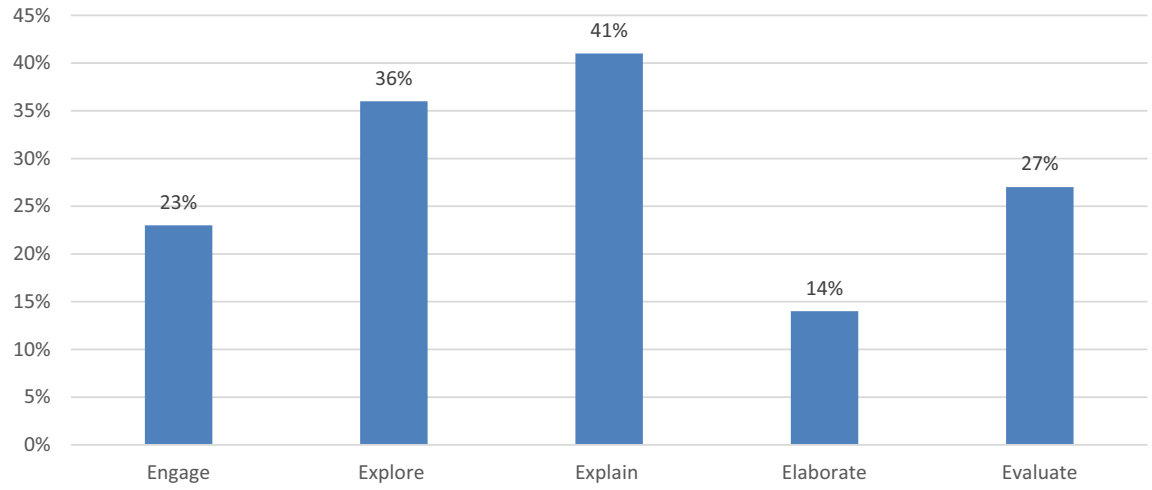

FIGURE 3
5E instructional model in meaningful learning—pretest. Result of the applicability of the instrument.

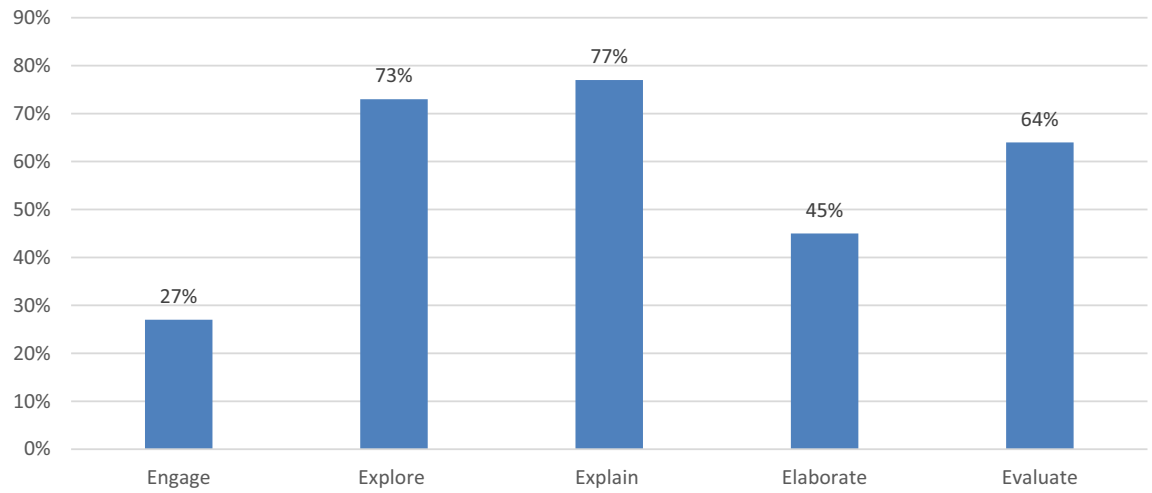

FIGURE 4
5E instructional model in meaningful learning—posttest. Result of the applicability of the instrument.

TABLE 1 Difference in results between the pretest and the posttest.

		Pretest	Posttest
N	Valid	22	22
	Lost	0	0
Half		15.27	17.36
Median		15.50	18.00
Dev. Deviation		2.567	2.216
Variance		6.589	4.909
Minimum		8	11
Maximum		19	20

Processed data from the instrument used.

TABLE 2 Normality tests.

	Shapiro–Wilk		
	Statistical	Gl	Sig.
Pretest	0.908	22	0.043
Posttest	0.866	22	0.007

Results according to inferential statistics.

Bastida-Bastida (2019) highlighted the effectiveness of the 5E model in didactic sequences that involve students in creative activities, motivating them to delve deeper into the topic and improve the teaching-learning process. This statement contrasts with the results obtained in the research due to the difference that exists: Average 15.27 to 17.36, Median 15.50 to 18.00, Minimum 8 to 11, and Maximum 19 to 20, these data show the difference from the pretest to the posttest, which confirms that the 5E model helps improve student learning and the skills of scientific thinking in the phases: engage, explore, explain, elaborate and evaluate, which implies; improve the

TABLE 3 Wilcoxon signed rank test.

		N	Average range	Sum of ranks
Pretest – Posttest	Negative ranges	15[a]	10.73	161.00
	Positive ranges	4[b]	7.25	29.00
	Ties	3[c]		
	Total	22		

[a]Pretest < Posttest.
[b]Pretest > Posttest.
[c]Pretest = Posttest.

TABLE 4 Test statistics[a].

	Pretest – Posttest
Z	−2.666[b]
Asymptotic sig. (bilateral)	0.008

Data processing results.
[a]Wilcoxon signed rank test.
[b]It is based on positive ranges.

level of observational stimulation to identify characteristics of the learning object, awakening the student's interest and motivation; the formulation of researchable questions and hypotheses identifying possible answers to the identified problem, analysis of the problematic situation allowing explanations to be issued with solid scientific arguments, registration, organization and acquisition of information to obtain conclusions, and the level of communication and dissemination of the knowledge acquired during his research of secondary education students in the province and region of Pasco – Perú.

Regarding the validation of the research, according to the Shapiro–Wilk test, the significance in the pretest and posttest were less than 0.05, which did not meet the normality test; Therefore, the Wilcoxon statistical test allowed us to validate the study since the *p* value was 0.008, being less than 0.05. Hence, the 5E instructional model influences the significant learning of the Science and Technology curricular area of the students of the El Amauta Pedagogical Research and Innovation Laboratory. In this way, the fulfillment of the proposed research objective is shown.

Conclusion

The implementation of the 5E instructional model showed a positive impact on the students' learning performance, since this model influences meaningful learning, thus allowing the student to achieve the competencies of the Science and Technology curricular area. As evident (Figure 4).

The process of engaging, exploring, explaining, developing and evaluating the 5E instructional model allows the achievement of learning in the curricular area of Science and Technology for the students of the El Amauta Pedagogical Research and Innovation Laboratory. As evidenced (Tables 1, 4).

Developing didactic activities, with well-structured processes such as the 5E model, favors learning, just as it occurred in the area of Science and Technology, it can occur in other curricular areas. Therefore, teachers should consider adapting this model 5E in the Peruvian context. Furthermore, this model for learning of Science and Technology can be applied globally, beyond the Peruvian educational setting.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

TM: Conceptualization, Investigation, Writing – original draft, Writing – review & editing, Formal analysis, Validation. LA: Conceptualization, Formal Analysis, Investigation, Writing – review & editing. AL: Formal analysis, Investigation, Methodology, Writing – review & editing. LF: Conceptualization, Formal analysis, Investigation, Validation, Writing – review & editing. MR: Conceptualization, Formal analysis, Investigation, Writing – review & editing. JL: Validation, Writing – review & editing. JC: Formal analysis, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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