



Research article

Factors influencing children's learning through their interest in STEM areas

Factores que influyen en el aprendizaje de los niños a través de su interés en las áreas STEM

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Abstract. – *This work explores the factors and indicators that influence the interest and motivation of children to pursue Science, Technology, and Mathematics (STEM) in basic education. The STEM interest, through the dimensions of Hands-on and Playful Learning, Technologies and Scientific Skills, Vocational Motivation towards Engineering, Creativity and Visual Learning, Adult Support and Guidance, and Curiosity and Motivation for discovery, was evaluated using data from a survey instrument administered to 165 elementary school children. Results showed that children exhibit enhanced interest in dynamic activities and technological devices, and highlight the relevance of factors such as family support and the practical experience in STEM skill development. These findings suggest the necessity of specific educational curricula in order to increase STEM interest from an early age, with targeted interventions to obtain better STEM competencies at the basic education stage.*

Keywords: STEM; Critical factors; Basic education; Science and Technology; Children learning.

Resumen. - *Este trabajo explora los factores e indicadores que influyen en el interés y la motivación de los niños para dedicarse a la Ciencia, Tecnología y Matemáticas (STEM) en la educación básica. El interés en STEM, a través de las dimensiones de Aprendizaje Práctico y Lúdico, Tecnologías y Habilidades Científicas, Motivación Vocacional hacia la Ingeniería, Creatividad y Aprendizaje Visual, Apoyo y Orientación del Adulto, y Curiosidad y Motivación por el Descubrimiento, fue evaluado a partir de datos obtenidos en un instrumento de encuesta aplicado a 165 niños de primaria. Los resultados mostraron que los niños exhiben un mayor interés en actividades dinámicas y dispositivos tecnológicos, y resaltan la relevancia de factores como el apoyo familiar y la experiencia práctica en el desarrollo de habilidades STEM. Estos hallazgos sugieren la necesidad de currículos educativos específicos para aumentar el interés en STEM desde una edad temprana, con intervenciones dirigidas a obtener mejores competencias STEM en la etapa de educación básica.*

Palabras clave: STEM; Factores críticos; Educación básica; Ciencia y Tecnología; Aprendizaje infantil.





1. Introduction

The manufacturing industry is one of the main economic drivers in Baja California, México, producing a high demand for skilled professionals in Science, Technology, Engineering and Mathematics (STEM). However, this demand is not reflected in the children's interest, as a consequence, STEM related academic programs have low enrollment compared with other programs, such as social or administrative sciences [1]. In Mexico, only 24% of bachelor students choose science and technology related careers, and 38% are women, this is evidence of the gender gap in the field [2], [3].

This issue originates in the early stages of education, where students at the basic education level in Mexico show limited confidence in their mathematical and scientific competencies, as well as a lack of motivation [4]. In response, there is a need to develop pedagogical strategies, such as the use of games and innovative methodologies, that promote interest from an early age [5], [6].

The objective of this study is to identify the key factors that children associate with STEM fields. This was achieved through a survey-based investigation applied to basic education students in the state of Baja California, aiming to identify their knowledge and learning approaches in Science, Technology, Engineering, and Mathematics. The results obtained will serve as a foundation for the future design of a didactic prototype that fosters interest in STEM from an early age.

2. Background

The development of interest in Science, Technology, Engineering and Mathematics (STEM) areas during childhood is a complex process that requires a combination of cognitive, motivational, social and technological factors. This study is based on a set of theories that explain the learning dynamics of childhood learning and their relation with STEM.

The Cognitive Development Theory from Piaget [7] establishes that childhood learning occurs through progressive states that determine how the kids process and acquire knowledge. Logical and abstract thinking start to develop in kids from 6 to 12 years old, but continue depending upon practical and manipulable experiences. This theoretical framework allows us to analyze how kids understand roles and professions related to STEM, which is reflected in activities such as the graphical representation of professional aspirations. These activities allow researchers to evaluate how children imagine the professional world and which elements capture their interest, an essential base for the design of educational tools that increase their STEM participation [8].

From the motivational perspective, the Self-Determination Theory [9] presents an integral approach about the basic psychological needs (autonomy, competence and relation) influence in the interest and persistence toward some learning areas. The competitive perception is particularly relevant in STEM, due to the children's need of feeling capable of interacting with technological concepts and tools. For example, evaluating the familiarity of electronic devices gives information about the level of confidence of kids in a technological environment, while a fun perception of science and technology directly relates to their intrinsic motivation [4].



The social environment also plays a crucial role in the interest to grow in STEM, as stated by the Theory of Social Learning by Bandura [10]. The children observe and imitate role models around them, as parents, teachers or public figures, to develop attitudes toward some disciplines. This aspect is particularly important in STEM, due to the exposition of positive role models that may inspire kids to visualize them in scientific, engineering or technological roles. The inclusion of questions about known professions by the kids and activities related to their family environment allow them to analyze how the close figures shape their aspirations [11].

The use of technology as an educational tool also has a significant impact in STEM learning. Diverse studies have shown that the interaction with electronic devices and digital platforms increase the exploration and critical thinking in children [12]. Evaluating the technological familiarity in this context can measure technological skills and the potential of these devices to motivate and facilitate the learning. The relation between technology and STEM is key to design games and activities that integrate these elements effectively.

Additionally, Vygotsky's Theory of Scaffolding [13] presents a perspective about the learning influence of external support from parents and other children. Children that receive guidance during their scientific and technological exploration process tend to overcome challenges. This observation reinforces the importance of the family and scholar environment in the interest development for STEM, a factor that is also analyzed in the applied survey [14].

Finally, the active and exploratory learning approach highlights the relevance of practical experiences and dynamics in the development of STEM skills. In [6], states that activities that allow children to build, experiment and solve problems are essentials to establish significant connections with scientific concepts. This approach, based on action, is particularly relevant when designing activities that evaluate creativity, collaboration and problem solving, which are pillars of STEM learning [15].

Together, these theories allow to understand how children perceive and relate with STEM disciplines from diverse dimensions: cognitive, motivational, social and technological. This conceptual framework guides the formulation of the survey questions and gives a solid base to interpret the results and propose educational tools that cover the needs and preferences of the children. Therefore, the didactic material and educational game based in STEM design can be founded in the theoretical framework that ensures their effectiveness and suitability.

3. Experimental

To understand student interest and vocational motivation toward engineering and STEM disciplines from basic education, it is essential to have valid and reliable data collection instruments. In this regard, a survey was designed to obtain information on students' motivation and attitudes toward STEM learning and careers related to engineering. This instrument seeks to capture both the cognitive and affective dimensions associated with children's engagement in these areas of knowledge. The methodology employed to develop and validate the data collection instrument is the same approach utilized to measure variables in social sciences using the psychometric method [16]. The methodology has been used as reference for researchers to develop and validate surveys [17], [18], [19]. The process to design and



validate the surveys was developed in 3 stages: 1) The construct and indicator definition and the variables operationalization, 2) Instrument design, 3) Implementation and analysis of preliminary results.

The methodological and statistical frameworks were grounded in an extensive literature review to justify the selected psychometric approach. This alignment ensures that the instrument adheres to established validity and reliability standards. Furthermore, integrating these theoretical foundations strengthens the study's rigor, ensuring that both data collection and result interpretation remain consistent with recognized social science practices.

The proposed methodology is shown in the following diagram.

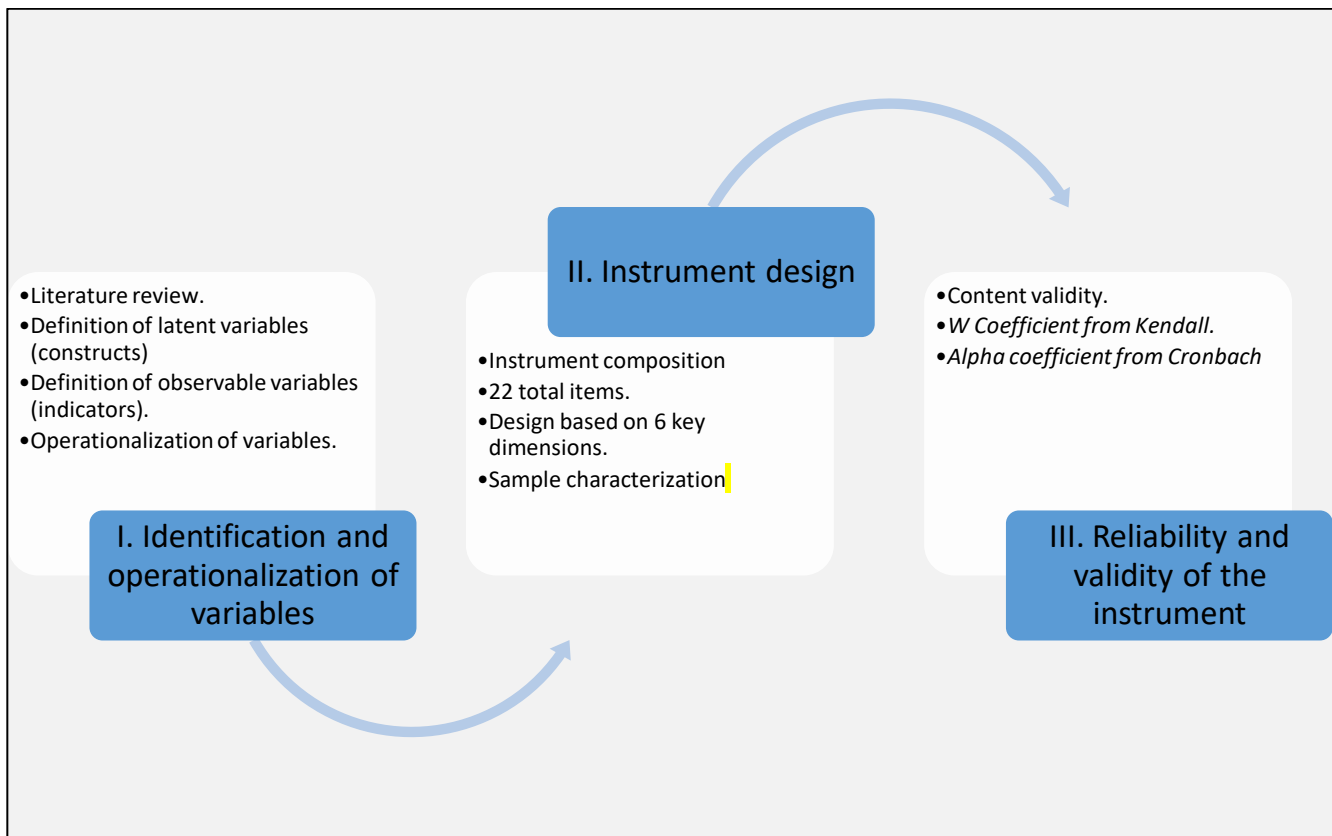


Figure 1. Methodological process of the study.

Stage 1: Identification and operationalization of variables

The first step of the instrument design is to identify the constructs that are going to be considered for the study, for this purpose, a comprehensive literature review using databases such as EBSCO Host, Elsevier, Emerald, Gale, IEEE, Springer, Wiley and Google scholar was performed. The screening criteria require publications from the last decade about vocational motivation toward engineering and STEM learning in basic education. Table 1 presents their constructs and conceptual definitions. The resulting factors are: practical and game-based learning, scientific and technological skills, vocational motivation toward engineering, creativity and visual learning, adult support and orientation, curiosity and motivation for discovery.



Table 1. Conceptual definition of the constructs from the children learning research focusing on their interest in STEM areas.

Construct	Description
Practical and game-based learning	This component highlights the student’s preference for learning by dynamic, game-based and experimentation-oriented activities. Literature has proven that practical and game-based approaches promote a higher knowledge retention, because children apply concepts in an active and significant way [20]. Furthermore, activities focused in science and technology through games have proven to be fundamentals to develop skills in STEM areas from early ages [21], [22].
Scientific and technological skills	Reveals the student preference for using electronic devices toward mathematical learning. Recent research has proven that technological devices enhance mathematical skills when offering interactive platforms and learning dynamics [23]. Furthermore, using technology in the classroom, allows students to learn more efficiently by giving access to calculation and simulation tools [24].
Vocational motivation toward engineering	Emphasizes the specific vocational interest toward engineering, which can be influenced by the growing demand of professionals in the STEM area and the promotion of these careers in educational environments. Recent research points out that early exposure to engineering and science concepts can awaken the vocational interest in children, because they offer a clear vision of how mathematical and scientific knowledge is applied in real-world scenarios [25].
Creativity and visual learning	The component highlights the importance of creative and visual learning in basic education. The usage of colors and imagination in educational activities promote a higher participation of children in the learning process. Studies have demonstrated that visual methods, as the use of colors, aid the children to improve their learning on complex concepts and reinforce memory [26], [27].
Adult support and orientation	The component points out the relevance of parents and teachers' support in the educational process of the children. Literature states that the adult involvement in the children's learning is key for their academic success, particularly in hard activities [28]. Children that receive support at home or school often have better academic results and show intrinsic motivation [29].
Curiosity and motivation for discovery	Learning based on curiosity and experimentation is one of the most effective ways of learning in childhood, due to the promotion of a higher emotional implication and a genuine interest for knowledge [30].

Note: The constructs of factors that influence the interest of children in STEM areas where defined and described by literature analysis.

The six factors represent the latent variables that are studied by means of the survey. These variables cannot be measured directly, therefore, it is necessary to operationalize them [31], [32], moreover, convert



the subjective variables into objective variables that are directly observables [33], [34]. In consequence, the final survey is the product of that operationalization. Then, it is necessary to start from the conceptual definitions in Table 1, after that, define indicators for each construct, and finally give at least an item that allows us to measure the indicator.

As an example of the operationalization process of the variables, Table 2 presents the constructs for example: of the practical and game-based learning, defined by 4 indicators: Recognition for dynamic activities, preferences for construction games, willingness for new activities and excitement of discovery. Each indicator is, in turn, followed by the items used to measure it. Thus, the indicator labeled as "Recognition for dynamic activities " is measured through item PGL1. Do you have fun playing and performing experiments? the indicator "preferences for construction games, needs," by item PGL2, the indicator "willingness for new activities " by item PGL3 and the indicator "excitement of discovery" by item PGL4.

Moreover, items corresponding to each indicator are given as well as how to measure them in Table 2.

Figure 2 proposes a model aimed at understanding and analyzing the latent factors that influence children's interest in STEM (Science, Technology, Engineering, and Mathematics). To this end, a statistical model is proposed that incorporates variables that are not directly observable but are manifested through responses to specific items within the measurement instrument. The proposed statistical model is based on the idea that the observable items in the questionnaire are indicators of underlying constructs, i.e., each set of questions is associated with a specific latent factor. These factors are not measured directly, but their presence can be inferred from response patterns [33].

This approach allows STEM interest to be interpreted not as a single variable, but as a combination of several dimensions that interact with each other.



Table 2. The operationalization of latent variables (constructs).

Construct	Indicator	Items
Practical and game-based learning (PGL)	Recognition for dynamic activities	PGL1. Do you have fun playing and performing experiments?
	Preferences for construction games	PGL2. Do you like to play games where you have to build things, as blocks?
	Willingness for new activities	PGL3. Do you enjoy doing new things?
	Excitement of discovery	PGL4. Are you excited by discovering new things?
Scientific and technological skills (STS)	Interest in Science and Technology	STS1. Do you think science and technology are fun?
	Technological Familiarity	STS2. Do you know how to use a phone or a tablet?
	Knowledge about the Engineering Profession	STS3. Do you know what an engineer does?
Vocational motivation toward engineering (VME)	Preference for Mathematics	VME1. Do you enjoy classes where you work with numbers, such as mathematics?
	Desire to Learn about Science	VME2. Would you like to learn more about science?
Adult support and orientation (ASO)	Problem-Solving Strategies	ASO1. Do you try different approaches when solving a problem?
	Family Support in Learning	ASO2. Do you ask your parents for help in order to make experiments or solve puzzles?
Curiosity and motivation for discovery (CMD)	External Motivation in STEM Activities	CMD1. Do your parents or teachers encourage you to do experiments or activities?
	Imagination during Experiments	CMD2. Do you imagine tales when doing experiments?
Creativity and visual learning (CVL)	Creativity and Visual Learning	CVL1. Do you enjoy activities where you can use a lot of colors?
	Career Aspirations	CVL2. Would you like to be an engineer when you grow up?

Note: Identification of indicators, items proposal and how the construct was measured.

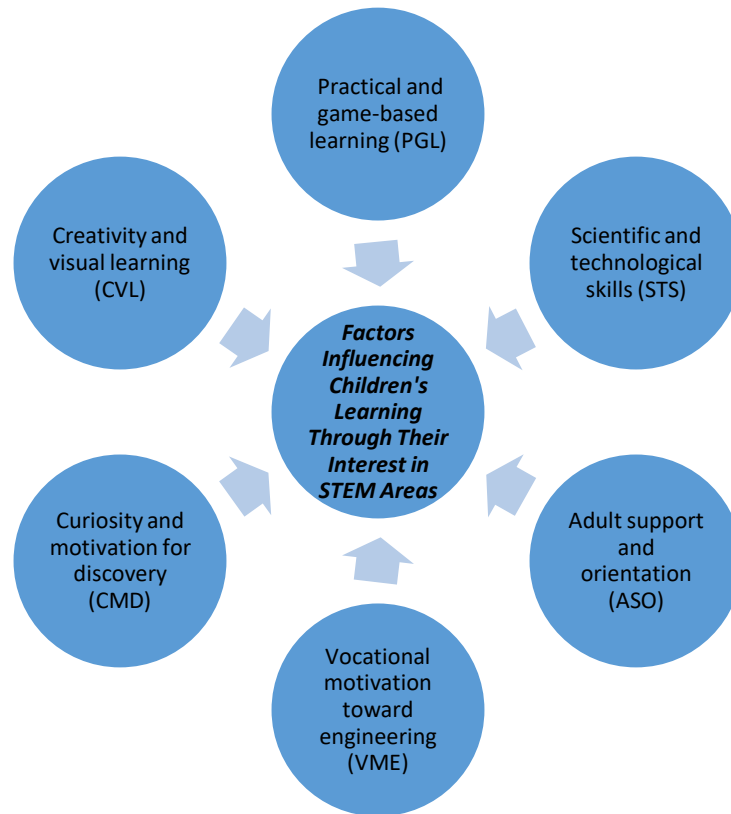


Figure 2. Model Statistical model of the study.

Stage 2. Instrument design

The instrument structure mixes 22 types of items, 16 closed-ended questions, 1 opened question, 2 activities based on drawings and 3 practical activities of Lego block building (see operationalization table in the appendix section).

The measurement instrument was designed based on the six key dimensions, each dimension aimed to obtain different interest approaches and willingness of the children toward STEM by a combination of types of test items:

Closed-ended questions: These questions allowed to measure specific interest aspects in learning and exploration activities. For example, items such as “I like to use electronic devices” and “Science, engineering and technology amuse me” were included. The questions use response options presented on a visual emoji scale that allow the children answer in an accessible format for their age.

Drawing: The respondents drew topics such as “What I want to be when I am an adult” and colored figures with their favorite colors. These activities allowed to evaluate personal preferences, vocational aspirations and helped the children to creatively express their interest without linguistic barriers.



Building with Legos: Teamwork practical activities were performed in order to evaluate creativity, collaboration and problem solving. These activities included using LEGO blocks to build houses, binoculars and airplanes, each of one was aimed to evaluate and specific skill. The building activity of the house measured creativity, whilst the binoculars and airplane evaluated the teamwork and problem-solving skills, respectively.

This combined approach addresses the need of adapting to cognitive and expressive capabilities found in the children's development. For example, open questions based on drawings enhance creativity and personal expression, while practical activities offer significant and tangible STEM concepts. These strategies are aligned with Piaget [7] recommendations, who clarify the importance of the direct manipulation and observation in the learning, and with Vygotsky [13], consider the learning as a social process regulated by collaborative activities and cultural tools.

The final survey was designed as a developmentally appropriate tool to assess children's interest and engagement in STEM. The final instrument is shown in the following figure 3:

RESEARCH ON VARIABLES THAT PROMOTE SCIENCE, TECHNOLOGY, AND ENGINEERING IN CHILDREN

We want to get to know you a little better and find out what things you like. This questionnaire doesn't have right or wrong answers—just tell us what you think and feel.

Some questions will ask you to draw, color or build something. Have fun doing it!

1. Draw what you would like to be when you grow up.

2. Do you know how to use a phone or a tablet?

3. Do you like classes where you see numbers, like math class?

4. Do you think science and technology are fun?

5. Do you have fun doing activities like games and experiments?

6. Do you ask your parents for help to do experiments or solve puzzles?

7. Do you try different ways when you have to solve a problem?

8. Do you ask an adult if you have questions about your homework or games?

9. Do you like playing with toys where you have to build things, like blocks?

10. What is your favorite game?

11. Do you like doing activities where you can use lots of colors?

12. Color the shape you like the most, and use your favorite color to do it!

13. Is it exciting to discover new things?

14. Do you like doing new things?

15. Do your parents or teachers encourage you to do experiments or activities?

16. Do you imagine tales when doing experiments?

17. Do you know what an engineer does?

18. Would you like to learn more about science?

19 - Get into groups and build binoculars using the available Lego blocks of different sizes and colors. Imagine how the characteristics of the blocks can improve the stability and functionality of the binoculars. How do you use the colors and sizes of blocks to make an attractive and unique binocular?

20 - Get into groups and build a house using the available Lego blocks of different sizes and colors. Imagine what kind of house you would like to build. Use different block sizes to obtain a solid structure and colors to make it more interesting or unique. What challenges will you face with the materials and how can you solve them in order to obtain a stable and creative house?

21 Get into groups and build an airplane using the available Lego blocks of different sizes and colors. Imagine what kind of airplane you would like to build (fighter, for transportation, etc.) and how the different size of blocks can contribute to represent the parts of it, such as wings, fuselage, wheels, etc. How will you solve the stability and functionality issues in the airplane? How are you going to set the colors in order to be more attractive?

22- Would you like to be an engineer when you grow up?

Figure 3. Measurement instrument.



A pilot study was conducted with a sample of 37 elementary school students in Tijuana, Baja California, to validate the questionnaire and assess the relevance and clarity of its items based on the participants' comprehension and responses. Prior to its administration, a formal written request was submitted to the principals of the participating schools to obtain the necessary institutional consent, thereby ensuring compliance with ethical principles in educational research.

Stage 3. Reliability and validity of the instrument.

Specific tests were conducted in order to ensure the validity and reliability of the designed questionnaire. These tests aim to ensure that the items are appropriate to measure the children's interest in science, technology and engineering [35], [36]. The evaluation included content validity analysis, agreement between evaluators and internal consistency of the instrument.

Content validity by Hernández Nieto Method

The instrument content validity was carried out by the Content Validity Coefficient (CVC), a method proposed by Hernández Nieto [37] that allows a quantitative evaluation of the clarity and pertinence of the items. This method uses a numeric index to classify the validity of the items in a scale from unacceptable to excellent, which facilitates an objective interpretation of the evaluation performed by experts. Furthermore, CVC stands out among other validation methods for its specific focus on the clarity and relevance of each item, being considered acceptable at a value of 0.80, which indicates significant match between experts [38].

In this work, items were revised by a multidisciplinary group of 5 experts in the field of psychology, preschooler education, social work and children development, ensuring an integral perspective. Each item was evaluated in three key aspects: appropriateness, clarity and composition, using Likert scale, where 1= Unacceptable, 2= Poor, 3= Fair, 4=Good and 5= Excellent. The assigned points were added to obtain a total score of each item, also, a space was dedicated to register comments and observations.

The CVC calculation obtained an average of 0.91, which scores as “good” according to the Hernandez Nieto proposed scale. This result indicates that the instrument items are clear and relevant to measure proposed dimensions, demonstrating significant match between experts.

Match between evaluator: W Coefficient from Kendall

W coefficient from Kendall was employed in order to evaluate match between evaluators, this is a robust technique that measures the agreement level between evaluators [39]. W coefficient from Kendall calculation was carried out using Minitab software. The obtained results allowed to determine the degree of match between evaluators and, in consequence, validate the items coherence. A significant value of this test confirms that the evaluators share a common perception about appropriateness, clarity and composition of items, which is essential to guarantee the instrument's consistency [40], [41].



Kendall appropriateness hypothesis

H₀: There is no association between evaluators scores.

H_a: There is a match between evaluators scores.

The results of Kendall appropriateness analysis yielded a value $p=0.0202$, lower than 0.05, rejecting the null hypothesis and confirming a significant match between evaluators in the item valuation, with a coefficient of $W=0.38341$ [40].

Reliability of the Instrument: Alpha coefficient from Cronbach

The internal consistency of the questionnaire was evaluated by the Alpha coefficient from Cronbach, which is considered as a stand for Likert scales [42]. In order to facilitate the children's understanding, the instrument utilizes expressive faces that represent a level of agreement, with the scale going from 1 (“I do not like at all”) to 4 (“I like it very much”) in the closed-ended questions from the measurement instrument. The pilot test applied to 37 kids in a community center of Tijuana, Baja California, obtained 0.841 in the Alpha coefficient from Cronbach, which indicated a high reliability, appropriate for a preliminary psychometric study [43], [44]. The sample size is in the recommended range to obtain preliminary estimation of reliability in psychometric studies. According to [44], between 30 and 50 participants are appropriate for pilot studies, because they give a reasonable basis to evaluate the internal consistency of the instrument. Moreover, [45] states that a sample of this size is enough for a first reliability evaluation, although he recommended a bigger sample in the final phase of the study to ensure a more robust and representative analysis. In a second round, the sample size was expanded to 167 children with the purpose of conducting a future factor analysis. Using these data, the behavior of Cronbach's alpha coefficient was analyzed again, obtaining a value of 0.78, which indicates good internal consistency among the items of the instrument.

The measurement instrument was applied by a qualified interviewer, who had experience in the instrument and skills for working with children. The interviewer read out loud every item in an environment such as a classroom of an elementary school or a community center, giving a brief description to ensure the sentence comprehension. Then, requested every kid to answer according to the type of item, by selecting a face that represents their response, making a drawing or participating in the building activity. Enough time was given to the participants to finish the activities.

4. Results and Discussion

The instrument was administered to a sample size of 165 students of basic education in order to perform a comprehensive analysis, which allowed to obtain solid data and ensure the precision in the reliability estimation of Alpha coefficient from Cronbach and other indicators of the study. The sample was selected by stratified sampling, gathering children from 6 to 12 years old in elementary schools from Tecate and Tijuana, Baja California, Mexico. In this analysis, a value of 0.7841 was obtained, which is superior to 0.70, indicating a proper reliability according to the conventional standard in social and educational research [46]. These results demonstrate the validity and reliability of the designed survey in order to measure the dimensions related with STEM learning in children from 6 to 12 years old.



Therefore, the results obtained so far are limited in scope to the region of Baja California. In subsequent stages, it is planned to extend the application of the instrument nationwide through stratified sampling by the states of the Mexican Republic, in order to obtain a representative sample and generalize the findings. This process will make it possible to strengthen the external validity of the instrument and to generate a broader overview of interest and vocational motivation toward STEM among the Mexican child population.

Gender Distribution

The 165 students' sample have a quasi-equal distribution between girls (50.9%) y boys (49.1%). This result is encouraging, because it indicates gender parity in basic education. Considering the low women enrollment in STEM undergraduate programs, it is fundamental to design specific strategies to enhance the girl's participation from an early age and challenge gender stereotypes associated with these disciplines. The investigation results act as a starting point to develop educational programs that promote gender equity and interest for science and technology in both genders.

Learning experiences in girls and boys

The survey results presented in Table 2 show a significant tendency toward activities that enhance the autonomous exploration and problem solving, with a high interest for the use of electronic devices and dynamic activities. This finding presents a natural affinity among children toward technology and environment interaction, which represent a key opportunity to introduce integrated learning experiences with technological tools. Likewise, the positive valuation toward science and technology is an opportunity to enhance scientific vocations from an early age. However, potential areas of development were observed. The difficulty of asking for help when facing challenges and the low perception of engineering as an attractive option indicates the need of strengthening the pedagogical support and the role modeling in these areas.

Due to the survey application time, only 81 answers were recovered regarding aspirational professions (item 1), favorite game (item 10) and favorite color (item 12). From 81 answers, 49.4% were boys and 50.6% were girls, results are presented next.

The highest level of favorable responses (98%) is associated with the use of mobile phones or tablets (Item 2, Mean: 3.6303). This finding is noteworthy, as it reflects children's natural affinity for technological devices and their engagement with interactive environments. Additionally, 95% of the participants reported excitement when discovering new things (Item 12, Mean: 3.5818). Enjoyment of hands-on activities, such as experiments and games, was reported by 87% of the children (Item 5, Mean: 3.3273), while 89% expressed enjoyment in trying new activities (Item 13, Mean: 3.4848). Overall, these results confirm that children demonstrate heightened interest when participating in dynamic and experiential learning activities.

Interest in engineering was notably low, with only 41% of respondents expressing a desire to become engineers as adults (Item 22, Mean: 2.2606). Furthermore, only 63% reported knowing what an engineer does (Item 17). These findings indicate the need to strengthen role modeling and improve the perception of engineering as an attractive career option.



Only 59% of children seek help from their parents for experiments or puzzles (Item 6, Mean: 2.6667). This relatively low proportion, together with the limited vocational perception, suggests the need to enhance pedagogical and family support.

Table 3. Learning indicators expectations in boys and girls.

Item #	Item indicator	Mean	Median	Mode	Std. Dev.	Favorable response
2	Do you know how to use a phone or a tablet?	3.6303	4	4	0.5206	98%
3	Do you enjoy classes where you work with numbers, such as mathematics?	3.0182	3	3	0.9271	76%
4	Do you think science and technology are fun?	3.097	3	3	0.8354	81%
5	Do you have fun making activities as experiments and games?	3.3273	3	4	0.7664	87%
6	Do you ask your parents for help in order to make experiments or solve puzzles?	2.6667	3	3	1.002	59%
7	Do you try different approaches when solving a problem?	3.297	3	3	0.726	52%
9	Do you ask an adult if you have questions about your homework or games?	3.1333	3	4	0.991	76%
11	Do you enjoy activities where you can use a lot of colors?	3.3333	4	4	0.8434	87%
12	Is it exciting to discover new things?	3.5818	4	4	0.6056	95%
13	Do you like to do new things?	3.4848	4	4	0.7539	89%
14	Do your parents or teachers encourage you to do experiments or activities?	3.2788	3	4	0.8008	85%
16	Do you imagine tales when doing experiments?	2.9273	3	3	0.9663	69%
17	Do you know what an engineer does?	2.7273	3	3	1.0143	63%
18	Would you like to learn more about science?	3.1152	3	3	0.8583	79%
22	Would you like to be an engineer when you grow up?	2.2606	2	2	1.0175	41%

Note: These items were evaluated using a scale represented by expressive faces, with scores from 1 to 4. On this scale, 1 represents “I do not like it at all” and 4 represents “I like it very much”.



Professional aspirations

Figure 4 presents the professional aspirations of 81 students, showing diverse interests, however traditional professions such as football player, artist or medic were majority chosen. It is seen that engineering is not a majority option. This finding is crucial because it reflects the low enrollment in academic programs related to STEM, a challenge identified in the introduction of the study, particularly in regions such as Baja California, where the manufacturing industry demands qualified professionals. These results suggest that, although natural curiosity for exploring different professional fields exists, it is necessary to implement specific strategies to enhance the interest for STEM careers from an early age. It is important to highlight that the STEM professional interest can be influenced by diverse factors, such as role model exposition, experience in STEM activities in school and the familiar environment.

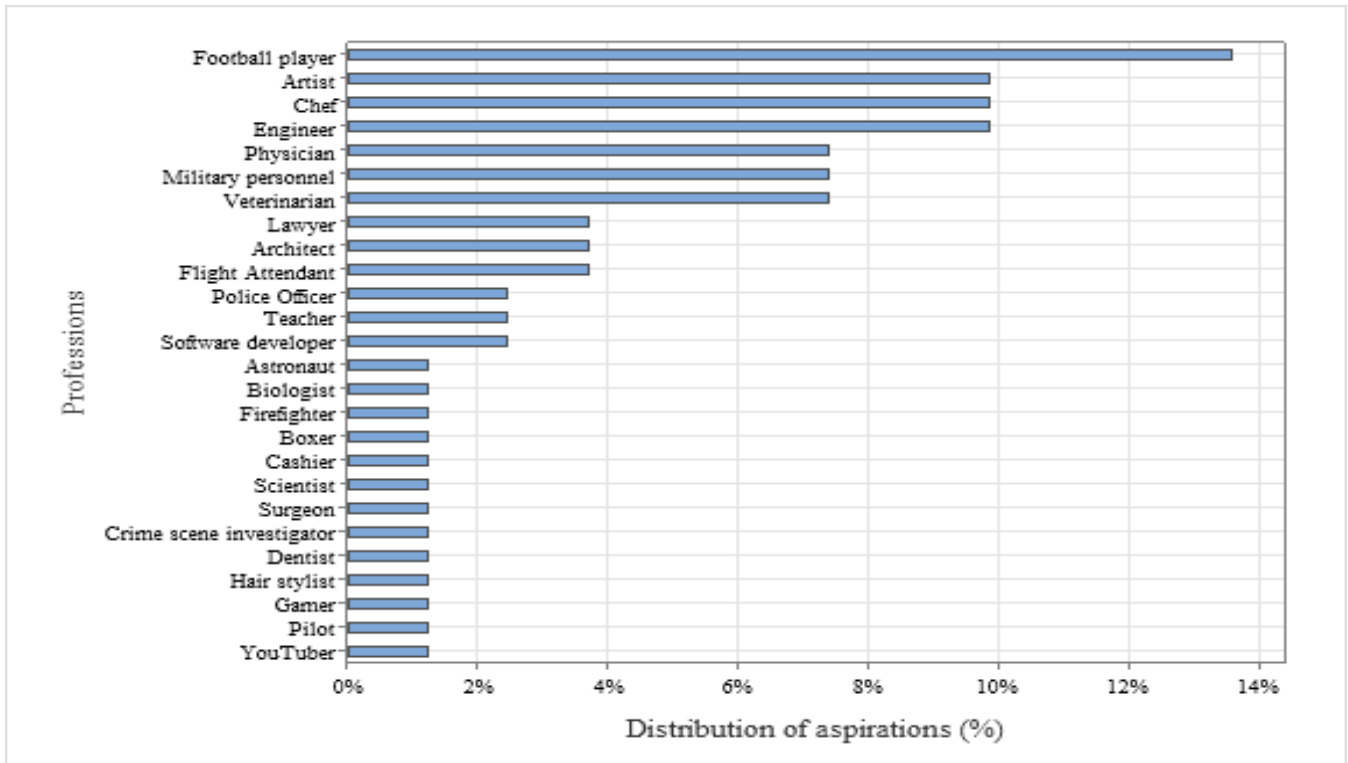


Figure 4. Distribution of children's career aspirations, based on survey responses.
Note: It is the first question of the survey (Item 1). "Can you draw what you would like to be when you grow up?"

Favorite game

Figure 5 shows a clear children preference for videogames, easily winning over other traditional games such as football. This result proves the growing influence of technology in children's free time and the attraction that videogames have as an entertainment option. Despite digital dominance, a diversity of interests remains, as other games such as basketball, hide-and-seek, or Chinese checkers were also mentioned. This aspect is crucial for the future development of the project (didactic prototype), since although technology (such as video games) is a powerful motivational tool, the study confirms that familiarity with electronic devices can enhance STEM skills when used appropriately. The survey results



also demonstrated a high level of technological familiarity (98% of children know how to use a phone or tablet, as shown in Table 3). Figure 5 further reinforces this technological affinity.

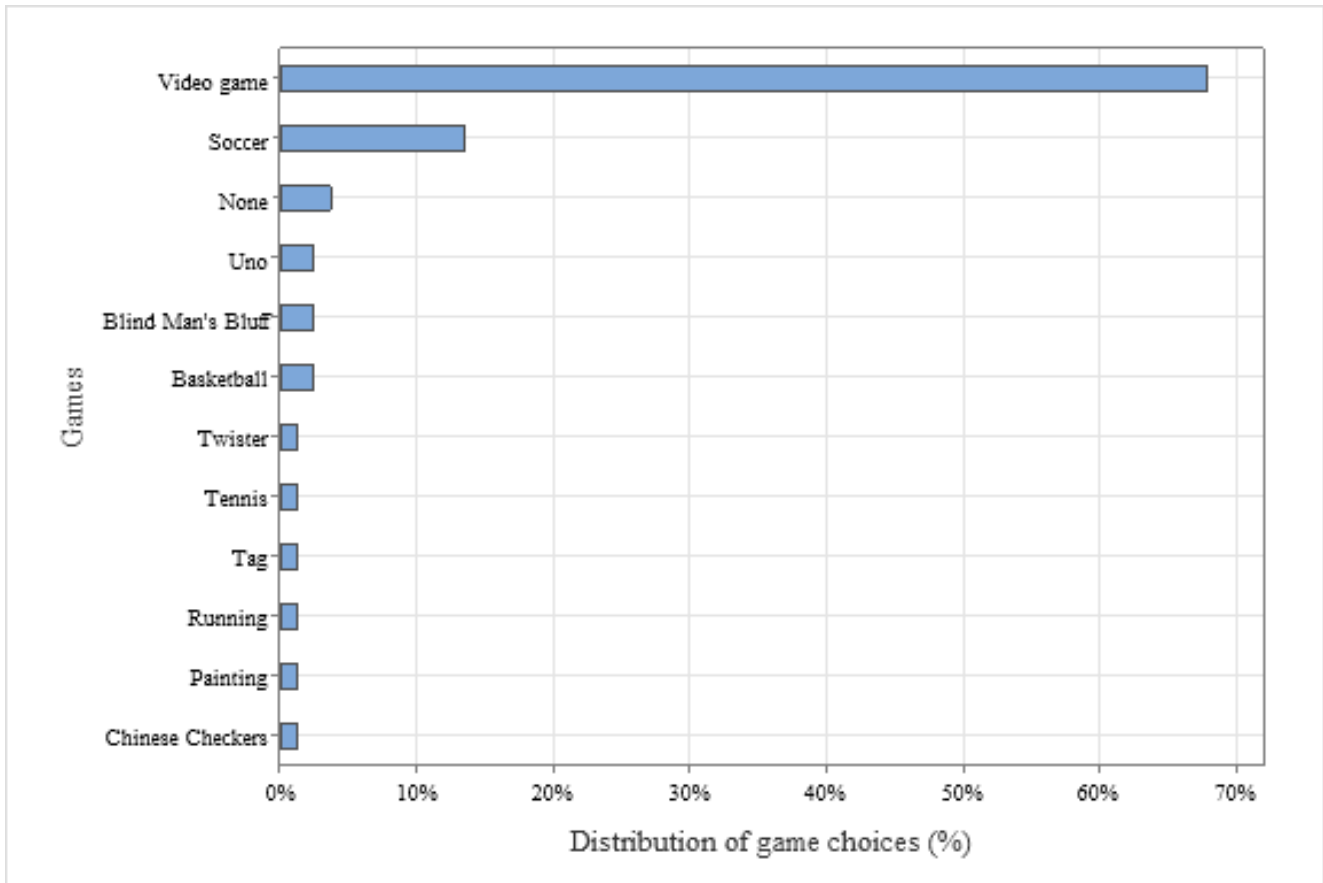


Figure 5. Distribution of children's game choices, based on survey responses. **Note:** It is the tenth question of the survey (Item 10), “What is your favorite game?”.

Favorite color and geometric shape

The color preference analysis with elementary school children revealed a clear choice for color blue, then purple and green. These results are consistent with previous studies that suggest an association between blue and tranquility, purple and green with creativity. The preference for cold colors can be influenced by nature exposure, because a lot of kids spend time outdoors and associate these colors to heaven, sea and vegetation. This finding has important implications for the Creativity and Visual Learning (CVL) dimension, as the appropriate selection of colors in instructional materials or educational spaces can enhance children’s concentration, relaxation, and learning. This is essential because the use of color and imagination fosters greater student engagement in the learning process, and visual methods help improve the understanding of complex concepts.

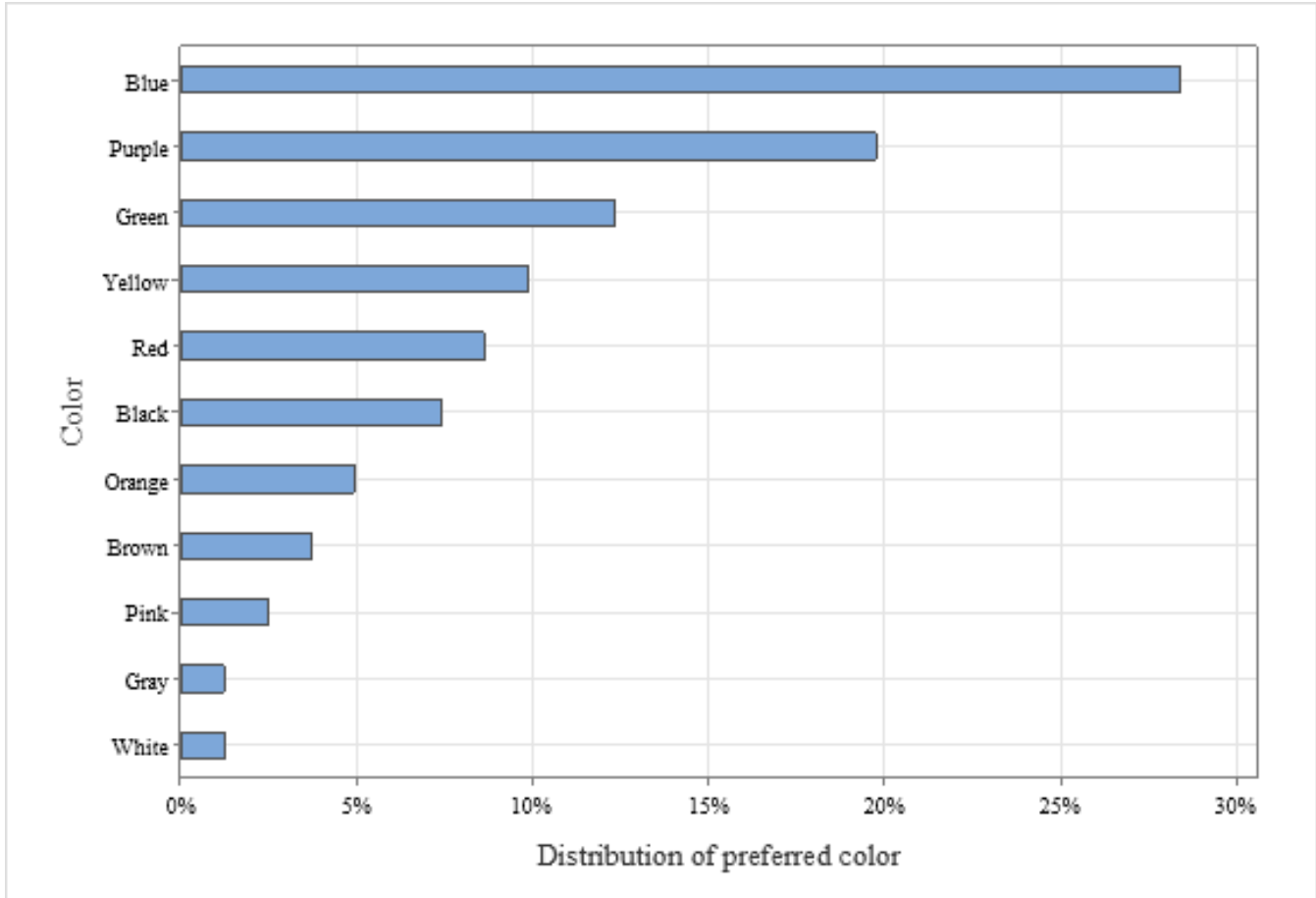


Figure 6. Distribution of children's preferred color, based on survey responses.

Regarding geometric figures, children show preference for triangle and circle, with 38% for each one, followed by the pentagon (15%) and the square (10%). These findings could be related to children's interaction with geometric figures from an early age. Previous research states that preference and comprehension of geometric figures in childhood depends on different factors, including the frequency of how they appear in their environment, their use in didactic material and structural complexity [47].

Project of building with blocks

In this section, the activity of building with Legos' blocks are presented, which was designed to evaluate creativity skills, teamwork and problem solving. Here, teams-built houses with blocks in order to evaluate their creativity, increasing the generation of original ideas and imagination. In the teamwork activity, children must build binoculars in a collaborative way, testing their ability to communicate and coordinate. Finally, problem solving skills were evaluated through the airplane construction activity, which requires logical thinking and the ability to overcome obstacles.

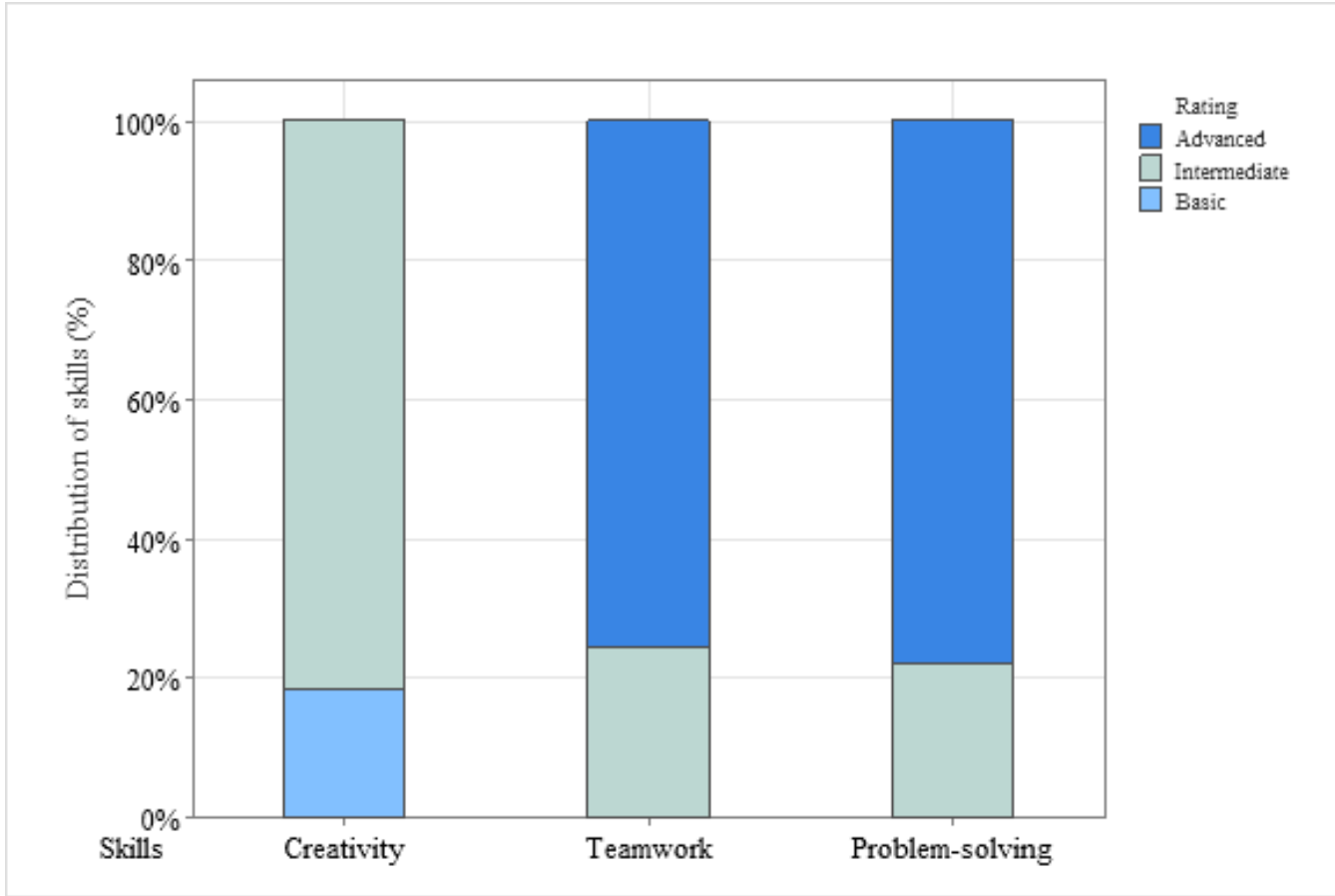


Figure 7. Distribution of children's self-assessment on STEM skills after the construction activity.

Figure 7, shows that participants obtained better results for teamwork level and problem solving, which is due to the collaborative nature of the assigned tasks and the need of finding a practical solution to build binoculars and the airplane. However, it is important to highlight that the house building, focused on creativity, obtained a score slightly lower, which could be attributed to the autonomy given in this activity, which can result in challenges for some children.

The creativity score, teamwork and problem solving, was measured by Lego's building activities in teams of 3 or 4 participants. The score was 15 points for excellent performance, 10 points for average performance and 5 points for regular performance. The construction of the binoculars model served to obtain information about teamwork, the house model for creativity and the airplane model for problem solving.

These results support a detailed proposal of the influence that practical and game-based learning, scientific and technological skills, vocational motivation toward engineering, creativity and visual learning, adult support and orientation, curiosity and motivation for discovery exert in the children's interest for science and technology. This statement differs from [48] work that highlights the influence of digital technology as only a motivational tool; our findings indicate that the combination of electronic devices with active learning activities and exploration results in an improved development of STEM skills.



On the other hand, [14] state that videogames and technological devices familiarity can enhance STEM skills if used properly. This study corroborates this conclusion by demonstrating that children with affinity for electronic devices also showed interest in activities related to science and mathematics.

Regarding intrinsic motivation, the results support [9] about the importance of learning motivation as in [49], which highlights the relevance of learning by discovering, the work suggests that practical and game-based approach can be key to enhancing the STEM interest.

The results of this study confirm previous research [4][5] regarding the need to strengthen children's interest in STEM fields. Therefore, there is a clear need for didactic and playful strategies that stimulate children's interest in these areas.

5. Conclusions

The study demonstrates that intrinsic motivation, active learning and familiar and teacher support are fundamental to enhancing the interest in STEM areas for basic education. The obtained results suggest that children that participate in practical and dynamical activities, and receive support from their environment, develop stronger preference toward science and technology, supporting theories as social learning from Bandura and the auto determination theory from Deci and Ryan, which emphasize the environmental role and the motivation during the learning process. Didactic materials and school curriculum should be improved in order to make STEM engaging and attractive to children. Children's preferences for practical activities and their professional aspirations highlight the need for educational programs that make science and technology more engaging and aligned with their interests. Workshops and guidance programs for parents and teachers is also a key action, their involvement can significantly enhance resilience, critical thinking and STEM interest.

In summary, the results of this study highlight the need for an inclusive and motivating educational approach that encourages STEM learning from an early age. It is possible to grow an early age interest in STEM by proper curriculum design, the use of didactic materials, technological attractive tools and collaboration between school and family. These findings provide a strong foundation for the development of educational intervention programs that prepare students for the challenges of a technology-driven and science-oriented environment.

The results obtained will serve as a basis for identifying key factors in the design—such as functionality and level of interactivity—that can influence children's interest and motivation in a STEM game that responds to their educational needs and expectations. This approach aims to inspire future generations in STEM fields and help reduce the existing gap between the manufacturing sector and the available professional education, thereby enhancing the economic competitiveness of Baja California.

Discussion

This section compares the findings of the present study with previous research on STEM education, particularly those focused on inquiry-based learning and active methodologies in basic education.

The results of this study show that children tend to prefer interactive, hands-on learning environments that incorporate technology. Furthermore, the study found that both adult guidance and curiosity-driven exploration significantly influence their interest in STEM fields. These findings are consistent with



previous studies conducted in the field of STEM education during the elementary school years. These findings are consistent with those reported by Casas and Muñoz (2022), who, following the implementation of inquiry-based learning units, developed digital teaching materials as a support guide for teachers, aimed at promoting the development of STEM competencies in students. This contribution highlights the importance of having practical and adaptable tools that facilitate the implementation of STEM strategies in the classroom [50].

Similarly, the results are consistent with studies on the use of educational games, which demonstrate that integrating playful strategies into STEM education significantly increases student motivation, engagement, and active participation [51]. Furthermore, these studies show that game-based learning fosters the development of essential 21st-century skills, such as critical thinking, problem-solving, and collaborative work, while also promoting hands-on learning that enables a deeper and more lasting understanding of scientific and mathematical concepts [51].

Furthermore, the integration of robotics into STEM education creates learning environments that foster not only the development of technical skills but also key social competencies. Various studies indicate that STEM projects focused on solving real-world problems promote collaboration, communication, and respect for others' ideas. Teamwork in these types of activities strengthens both academic learning and socio-emotional skills, such as active listening, emotion management, and cooperation to achieve common goals. In this sense, STEM education contributes to the development of resilient and competent students, capable of facing the challenges of today's world [52].

Finally, the results of our study highlight the importance of identifying the factors that influence children's interest in STEM fields, as these elements form a fundamental basis for designing educational games and interactive teaching materials that meet their needs, foster their motivation, and promote more meaningful learning.

Future work

As a future line of this research, the statistical analysis of the instrument will be expanded through exploratory and confirmatory factor analyses, with the aim of strengthening construct validity and more precisely determining the empirical weight of each latent variable. This extended analysis will allow a deeper examination of the factorial structure of the instrument and the relationships among the validated constructs. Based on these results, a didactic educational prototype in the form of a video game or interactive application (app) will be developed for primary school students. The prototype will integrate the validated variables identified as influential in children's interest in STEM, seeking to provide a playful and pedagogically grounded learning experience that complements the school curriculum and contributes to increasing students' engagement and interest in STEM areas from an early age.

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Yuridia Vega: Conceptualización; Ideas; Metodología; Análisis formal; Investigación; Análisis de datos; Borrador original; Administración de proyecto. *Eder German Lizárraga Medina:* Ideas; Investigación; Análisis de datos; Escritura; Revisión y edición. *Marina de la Vega Rodríguez:* Ideas; Metodología; Análisis formal; Investigación; Análisis de datos; Escritura; Borrador original; Revisión y edición;



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APPENDIX

Table of variables operationalization measured by scale.

Construct	Indicator	Items
Game-based learning	Appreciation for dynamic activities	Do you have fun doing activities such as games and experiments?
	Preference for building games	Do you like to play with toys where you have to build things, like building blocks?
	Engagement for new activities	Do you like to make new things?
	Excitement for discovery	Are you excited about discovering new things?
Scientific and technological skills	Interest in science and technology	Do you think science and technology are fun?
	Technological familiarity	Do you know how to use a cell phone or a tablet?
	Knowledge about engineering profession	Do you know what an engineer does?
	Technological familiarity	What is your favorite game?
Vocational motivation toward engineering	Mathematic preferences	Do you enjoy classes where you interact with numbers, such as mathematics?
	Desire for science learning	Would you like to learn more about science?
Adult support and orientation	Problem solving strategies	Do you try different approaches when solving a problem?
	Family support in learning	Do you ask your parents for help to make experiments or solve puzzles?
	Family support in learning	Do you ask for help when doing your homework or playing?
Curiosity and motivation for discovery	Building project (Creativity)	Get into groups and build binoculars using the available Lego blocks of different sizes and colors. Imagine how the characteristics of the blocks can improve the stability and functionality of the binoculars. How do you use the colors and sizes of blocks to make an attractive and unique binocular?
	Building project (Teamwork)	Get into groups and build a house using the available Lego blocks of different sizes and colors. Imagine what kind of house you would like to build. Use different block sizes to obtain a solid structure and colors to make it more interesting or unique. What challenges



		will you face with the materials and how can you solve them in order to obtain a stable and creative house?
	Construction project (Problem solving)	Get into groups and build an airplane using the available Lego blocks of different sizes and colors. Imagine what kind of airplane you would like to build (fighter, for transportation, etc.) and how the different sizes of blocks can contribute to represent the parts of it, such as wings, fuselage, wheels, etc. How will you solve the stability and functionality issues in the airplane? How are you going to set the colors in order to be more attractive?
	External motivation in STEM activities	Do your parents and teachers encourage you to do experiments or activities?
	Imagination during experiments	Do you imagine stories when doing experiments or activities?
Creativity and visual learning	Creativity and visual learning	Do you enjoy activities where you can use a lot of colors?
	Creativity and visual learning	Draw your favorite geometric figure using your favorite color.
	Professional aspiration	Would you like to be an engineer when you grow up?
	Professional aspiration	Draw what you would like to be when you grow up.

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