THE CIU WHITE PAPERS SERIES

Coding in the Education System in Mexico

The Competitive Intelligence Unit

*The information and estimates of this analysis were obtained by The CIU
ABSTRACT

The Education System in Mexico comprises different education levels: initial education preschool, primary, secondary, upper middle school, and higher education under the terms established by the Political Constitution of the United Mexican States.

Meanwhile, coding and computational skills have increased their relevance in an increasing digital society facing incessant disruptions due to new technologies and digital goods and services. Thus, analyzing the teaching of computational skills in basic and secondary level in Mexico is pertinent and relevant as well as to draw some public policy recommendations. These recommendations aim to better prepare students for future jobs and challenges by developing soft skills for any type of job as well as hard skills for more specialized technological jobs.

Computational Thinking (CT) is a problem-solving method capable of improving knowledge acquisition in the Mexican education system.

Educational programs at a basic level in Mexico already consider many educational concepts that computational thinking requires, however, there are no adequate pedagogical approaches to permeate this educational style among students.

The educational principles established in computational thinking are logic, algorithms, decomposition, patterns, and abstraction. The pedagogical approaches necessary to achieve the acquisition of these concepts are tinkering, creating, debugging, persevering, and collaborating.

This white paper is intended to encourage the inclusion of coding and computational thinking in Mexican education curricula. Some education public policy recommendations based on this research are proposed below:

- Increase the number of public connectivity spots in the Public Sites Connectivity Program, particularly those that correspond to public schools without internet access.
  - To address the Information and Communications Technology access gap in economically lagging schools.
- Promote CT path on the primary school level. At this level, CT concept is not intended to directly teach coding but to create relevant logical and abstract thinking skills among students.
• Include the concept of Computational Thinking in the Mexican curriculum in primary, secondary, and upper middle education, as well as related concepts such as logic, algorithms, decomposition, patterns, and abstractions.
  o While some of these concepts are scattered all over the curricula, nevertheless, for secondary, and upper-middle levels purposes, they should be set in computational, computer, and coding environments, this is to create coding or coding-related courses.
• Include approaches and techniques in the curricula to promote CT among students, such as tinkering, creating, debugging, and preserving.
• Consider Computational Thinking (materialized on skills such as coding and software development) as necessary for the present or future development of innovative ventures and as a tool for workers to increase productivity and, therefore, income opportunities.
• To address Computational Thinking education aspects such as logical-mathematical thinking, promote a more experimental approach, like tinkering, at primary school levels.
  o This could be achieved by using tinkering-based experimentation and video games as learning tools, which would provide students with more coding-environment learning sessions.
  o With this approach, students would have a better understanding of coding concepts and could develop critical thinking and problem-solving skills.
• Implement direct coding sessions at the Secondary level always considering that students do not have previous coding experience. Topics can focus on teaching i) how codes work, ii) internet protocols, and iii) teaching how to write codes.
  o Teachers should ensure that this learning process must happen in a collaborative environment. Coding and computational thinking cannot be individual, they require a plurality of ideas and the ability to solve problems through teamwork.
• Provide vocational counseling at secondary schools aimed at promoting interest in coding and software development technical-level careers which are part of the next education level (upper-middle school).
• Focus coding subjects in the upper-middle level on developing hard skills such as using coding in specific languages, compiling, and executing programs, and developing object-oriented programming skills.

• Promote the importance of upper-middle school technical degrees among students and employers.

• Create “train the trainers” programs for computational thinking and coding at all levels of education.

• Provide relevant teacher’s training such as certified courses so that teachers can familiarize themselves with this pedagogical style and be able to transmit coding relevance to their students properly, as well as computational thinking.

• Promote programming and computing with a social approach:
  a. Free workshops and courses for the general population.
  b. Attractive coding and software development contests for students and the general population where for example, solutions to social problems or to meet SDG 2030 objectives are proposed.
  c. Execute advertising campaigns to inform about the benefits of learning to code, as well as information about the available educational offer.

• Promote the study of computational and coding careers, through the dissemination of their benefits in salaries and greater labor demand.

• Promote scholarships and financial support aimed exclusively at the study of careers related to computing and coding.

• Develop collaborative and problem-solving skills among students.

The above proposals can facilitate the introduction of computational thinking and coding into the Mexican educational system, all of them addressing problems and educational gaps, promoting a more coding-friendly educational ecosystem as well as helping to reduce the lack of specialized and innovative workforce in the country.
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1. **INTRODUCTION**

In Mexico education is recognized as a fundamental right guaranteed by the Constitution. Besides this, the provision of quality education services that respond to the present and future demands of society requires updating and periodic reviews of the educational system.

Therefore, this paper focuses on the relevance of computational thinking to develop coding skills for students since they are essential to face current and future economic and scientific challenges.

It briefly describes the structure of the national educational system, the different education levels to cover the scientific, industrial, nutritional, psycho-emotional, and technical needs of the students, among other aspects. Likewise, the paper explores some problems affecting the system.

This Working Paper explores the education curricula in Mexico and programming and how computational thinking is considered (or not) at basic (elementary) and medium (high school) school levels. These education levels are crucial for creating high-level human capital and for generating comprehensive digital inclusion in the future.

Finally, a survey on international practices delivers some guidelines for the national curricula to include coding as a subject in different school levels.
2. **National Educational System**

The education system in Mexico is grounded in Article 3 of the Constitution which establishes the National Educational System (NES) as the set of norms, principles, institutions, assets, and resources aimed at offering education services to the citizens. This article also provides structure to the NES by establishing school levels: basic, upper middle and higher education.

Article 3. Every person has the right to education. The Federation, States, Mexico City, and Municipalities will provide and guarantee initial education, preschool, primary, secondary, upper secondary, and higher education. Initial, preschool, primary, and secondary education are basic education (...)

This article also establishes basic education, middle and upper middle education as mandatory. Subsequently, includes a sequence of rights, obligations, guidelines, principles, and other aspects regarding teachers’ formation, and the National System for Continuous Improvement of Education, among other aspects.

The following sections review the composition of the NES at its different levels with particular emphasis on basic, middle, and upper middle school while providing to different educational modalities presents at those school levels, and discuss the challenges the NES faces, especially in basic, middle and upper middle education since the pandemic outbreak.

2.1. **National Education System Structure**

The General Education Law establishes the basic framework of the NES, definitions, and its basic principles. For example, it defines educational federalism, educational equity, the educational process, public and private education, among many other provisions.
The figure above depicts the NES according to the General Law of Education and other adjacent legal bodies, which can be considered as a staggered-model system that offers different educational options for citizens.

### 2.1.1. Primary Education

Primary education is a six grades level which serves 6 to 14 years old children. Unlike preschool, a certification is essential to advance to secondary education. Primary level is offered through general, Indigenous, and community modalities.

At this level, free textbooks (*libros de texto gratuito*) are introduced aiming at guaranteeing access to education contents for each subject and grade. This educational stage is where reading, writing, mathematical thinking, among other skills and competencies, must be consolidated.

In primary education there is enormous potential for Information and Communication Technologies (TIC) for teachers and students to use in the teaching learning process. In this level concepts considered as the basis for computational thinking are introduced such as information ordering, graphics reading, processes, language, among many others.
2.1.2. Secondary Education

Secondary education is a three-grade level and seeks to train students for upper middle education or to provide technical tools for citizens to join the labor force. In this level, it is possible to find a variety of modalities covering a wide age range. As it happens with other education levels, this also has state and federal level programs.

The general secondary school modality is intended for 12 to 16 years people. In addition to the basic curricular map, subjects such as foreign language, workshops, and technological activities are considered.

The modality for workers does not include physical education, workshops, or technological activities. This modality looks to close the educational gap among the adult population and provide education to young people participating in the workforce and cannot allocate the time for technical or general secondary school.

Tele secondary is a system of secondary education broadcasted on the television for remote communities, and it serves the population with no access to general or technical secondary schools, using electronic media and audiovisual communication. There is a teacher per group who facilitates and promotes learning and provides didactic support to students.

Technological modality follows a similar curricular map of the general modality, however more studying hours are dedicated to technical workshops. At the end of the three-year level, students are awarded a Diploma or Certificate that certifies that they attend workshops.

At this educational level, we find enormous potential for introducing technological and computational skills and coding in the workshops. This level is intended for developing a sophistication of logical-mathematical understanding, scientific, language, and processes knowledge, among other skills relevant for ICT use.
2.1.3 Upper Middle Education

Upper middle school education (baccalaureate) follows secondary education which constitutes a mandatory requirement for this level. This is also a three-year level and seeks to prepare students to access higher education or to become part of the labor force.

This level registers an important number of educational subsystems within the available modalities: general, technological, intercultural, and artistic baccalaureates, also technical bachelor professional modality, communitarian tele-baccalaureate, distance upper middle school, and technologist.

The general baccalaureate includes open and distance modalities, while technological baccalaureate prepares students for higher-level studies and technical professional education in various specialties.

In this level it is possible to find involvement from higher-level institutions, for example, schools under Universidad Nacional Autónoma de México (UNAM) and Instituto Politécnico Nacional (IPN) systems, as well as local universities systems. Other subsystems classified according to its operational and administrative structure (state or federal, centralized or decentralized, private, public or autonomous) are Colegio Nacional de Educación Profesional Técnica (CONALEP), Colegio de Bachilleres (COBACH), Dirección General de Educación Tecnológica Industrial y de Servicios (DGETI), etc.

Upper middle school level suggests a greater degree of knowledge sophistication and specialization while incorporating calculus, chemistry, physics, literature, and a greater involvement with the community and society.

Thus, this level:

i) Completes compulsory education.

ii) Encourages students to pursue further education.

iii) Prepares students for entry into the labor force.

iv) Develops socio-emotional skills.
Finally, this education level suggests the development of enough computational thinking and knowledge sophistication to promote coding in different language as part of the general curricula.

2.2. **Challenges and Problems of the National Educational System**

A fundamental education challenge in Mexico is, as in other economies with a similar degree of development, to provide a vast and efficient system that meets the education demand of the citizens. Mexico ranks 102 out of 137 in the Programme for International Student Assessment (PISA), a situation that exhibits structural deficiencies worsened during the pandemic crises.

In general, coverage, quality, management, resources, and dropout rates are the main challenges faced by the education system in Mexico. It has not been possible to consolidate an educational system that aligns with a national vision. Instead, efforts have been made to address the system's deficiencies in isolation, without measuring the impact on the overall system.

Unfortunately, the COVID-19 pandemic has exacerbated these challenges, resulting in mass dropouts at all levels due to economic, family, or health issues. According to statistics, 435,000 students were unable to complete the academic year due to COVID-19 related causes.

The digital divide was a significant factor contributing to the inefficiency of education services during the pandemic, particularly as classes were shifted to online learning, which required students to have access to reliable internet connectivity and necessary equipment such as computers or tablets.

The lack of connectivity and equipment created deficiencies in achieving school goals, as students were unable to access the necessary resources to fully participate in remote classes complete assignments or attend virtual meetings with teachers. This lack of participation made it challenging for teachers to accurately evaluate the progress and learning outcomes of their students. Without access to reliable connection, students were unable to demonstrate their full potential, and teacher evaluations could not fully capture their knowledge and skills.

In 2020, only 43.8% of households in Mexico had a computer at home, and 59.9% had an Internet connection. This lack of access to technology made it difficult for teachers to accurately
evaluate their students. As a result, students were allowed to advance to higher grades in the educational system, despite not having acquired the necessary skills and knowledge.

The Ministry of Education (SEP by its acronym in Spanish) identified, within the 2022 Public Sites Connectivity Program, 90,455 public sites to be connected. However only 16% of these sites are considered priority.

Despite this effort, Mexico's education system spending falls below the international standard of 4% of the Gross Domestic Product (GDP), which is the average percentage of OECD countries, leaving existing educational challenges unresolved even after the pandemic crisis.¹

In 2022, SEP presented a comprehensive proposal to reform the Curricular Framework and Study Plan considering epistemic, methodological, axiological, pedagogical, and structural transformations of the Curricula (Plan de Estudios). For example, introduced the concepts of training fields (instead of subjects) and learning phases (instead of grades). The proposal also emphasizes project-based learning and assessments which will connect the different training fields and provide a more holistic view of students' progress.

At the time of writing this document, the deployment of the pilot program of the proposed curricula has been suspended.

### Figure 2. National Educational System Summary

<table>
<thead>
<tr>
<th>Level</th>
<th>Goal</th>
<th>Modalities</th>
<th>Subsystems</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic school</strong></td>
<td>Foundation of the National Education System, seeks to introduce the basic notions of knowledge, care of children and induction of job skills</td>
<td>❖ General ❖ Indigenous ❖ Community Courses</td>
<td>❖ General ❖ Technological ❖ For workers ❖ Tele secondary</td>
<td>❖ Nutrition ❖ Desertion ❖ Educational Lag ❖ Evaluation</td>
</tr>
<tr>
<td>❖ Initial ❖ Primary ❖ Secondary</td>
<td>Last level of compulsory education, trains and induces to the labour market, propaedeutic function towards higher education</td>
<td>❖ General ❖ Technological ❖ Professional technical education</td>
<td>❖ Open ❖ Distance ❖ State or Federal ❖ Centralized or decentralized ❖ Private ❖ Autonomous</td>
<td>❖ Desertion ❖ Educational Lag</td>
</tr>
<tr>
<td><strong>Upper middle school</strong></td>
<td>Preparation of technicians and professionals who trigger the labour market, industry, scientific and national development.</td>
<td>❖ Higher university technician ❖ Bachelor ❖ Specialty, ❖ Master ❖ Doctorate</td>
<td>❖ Private ❖ Autonomous ❖ Technological ❖ State or Federal ❖ Normal</td>
<td>❖ Access</td>
</tr>
</tbody>
</table>

Source: Elaborated by The Competitive Intelligence Unit

However, it is crucial to redesign the educational structure with a focus on reconceptualizing fundamental and basic contents with concepts such as inclusion, integration of knowledge, interculturality, critical thinking, among others.
3. **IMPORTANCE OF CODING IN EDUCATION**

This section analyzes the formation and skills required to promote and stimulate computational and coding learning among students. From the theoretical point of view, this paper will analyze specific research that refers to skills or training needed to encourage computational thinking. Computational thinking is defined as a way to solve problems, design systems, understand human behavior, and contribute to fundamental concepts of computational science.

3.1. **SKILLS: A LITERATURE REVIEW**

Coding requires some skill development at initial stages of education. Djurdjevic-Pahl et al., affirm that skills related to computational thinking (CT) allow to understand, create, and manage future computerized environments, this is the case of coding and software development.

Authors propose to promote a path towards computational education through the promotion and the development of certain skills related to mathematics programs in primary schools. This thinking is not intended to directly teach coding but to create a key skill for future development in the computational world such as logical and abstract reasoning.

Computational thinking involves solving problems, designing systems, and understanding human behavior. The Computer Science Teachers Association (CSTA) and the International Society for Technology in Education (ISTE) suggested an operational definition of CT with three key dimensions that include:

- Concepts (such as sequences, loops, and conditionals)
- Practices (such as testing and reusing)
- Perspectives (such as questioning and expressing)

Through this dimensioning of computational thinking, the authors obtain a summary table where they describe the conceptual principles and approaches to achieve in the student the development of these skills, elements that will also allow to analyze Mexican curriculum for the case of basic and upper secondary education in the next section.
Among the main educational concepts to be developed for computational thinking in basic education are logic, algorithms, decomposition, patterns, and abstraction. Each of these concepts are closely related to computational thinking and specifically coding. Many times, these concepts are already incorporated into curricula indirectly or directly, especially in mathematics or mathematical reasoning study plans.

However, the most important fact is the educational approach of these concepts so that they are applicable and set in the computational, computer and coding environment that is sought to promote among Mexican students.

Special approaches are established such as tinkering. Children are stimulated through experiments and games which can be decisive for developing preferences to learn skills related to CT. This strategy is useful to guide children's future professional decisions towards technology and development of coding.

Skills such as creating (making and designing) is another important approach to coding because creativity and self-creation is promoted enabling students with capacity to propose innovative solutions to any problem.

Finally, debugging and persevering are approaches for basic educational levels because they represent qualities of significant importance for coding. Detection and correction of errors
coupled with persistence, patience, and effort encourage consistent analysis that allow detection and optimal solution for problems in any situation.

3.2. Some Benefits of Coding

Programming has become an indispensable process and skill to solve problems, challenges, and tasks in all branches of science and industry.

For this reason, coding and computational thinking have been introduced to the curriculum map around the globe. Also, learning computational skills such as programming contributes to the exercise of cognitive skills in other areas of knowledge.²

It is typically argued that computer science, and programming, engages in complex cognitive processes such as pattern abstraction and generalization, systematic information processing, symbol and representation systems, algorithmic thinking, problem decomposition, debugging, and systematic bug detection mistakes.

Programming involves several problem-solving phases that require the identification, decomposition, and representation of problems. These phases also enhance the ability to search and manage information, as well as evaluate solutions. Thus, coding is a powerful tool to expand the thinking horizons of its practitioners through the use of computational thinking. In other words, coding helps individuals develop a structured approach to problem-solving, which not only fosters technical skills but also encourages critical thinking and creativity.

4. CODING IN EDUCATION PROGRAMS IN MEXICO

The basic education system in Mexico does not have curricular subjects directly related to coding. However, these concepts are scattered all over the curricula that are indirectly and partially related to computational thinking and its principles. It is important to mention that such learning does not have the required approaches for the proper development of CT. They should be set in computational, computer, and coding environments. This will allow for the creation of coding or coding-related courses that are tailored to the appropriate level of education.

In basic education, this training field covers problem solving that requires knowledge of arithmetic, algebra, geometry, statistics, and probability knowledge. Likewise, through individual and collaborative work in class, students are encouraged to use mathematical thinking when formulating explanations, applying methods, implementing algorithms, developing strategies of generalization and particularization; but especially when facing the resolution of unfamiliar problems. It is through the learning of mathematics and the development of logical-mathematical reasoning skills that the educational foundations currently established in Mexico can facilitate the development of CT.

In addition, according to SEP educational programs, students need to understand how to justify and argue their approaches, as well as the importance of identifying patterns and relationships as a means to find the solution to a problem, identify errors as a source of learning. Through these programs, students are not only encouraged to persist in finding the solution to problems, but also through this action they gain self-confidence in their abilities, and could find that mathematics is useful and interesting, not only as school content.

The elements considered in the curriculum in Mexico at primary, secondary and upper middle levels are shown in this section (according to the programs established by the SEP). It is also described the state of the art of Mexican students (the maximum level students can achieve regarding the development of computational thinking and coding skills).

These elements prove to be helpful to provide guidelines to reform the curricula to promote the development of computational thinking among students.
4.1. **PRIMARY SCHOOL (ELEMENTARY)**

Primary education represents the foundations of education and the future development of computational thinking and coding. As that, it should promote not only mathematical reasoning and solid mathematical learning, but the approach to *tinkering* through experiments and games, especially in the early years that allow students to get interested in this type of situations and problems.

In the first grade, counting, comparing, equalizing and ordering numbers are skills that serve as pedagogical foundations of knowledge. Timely evaluation and feedback in the learning of logical-mathematical knowledge is desirable because they determine not only the future mathematical skills of the student but the taste and genuine interest in mathematics itself.

In second grade a very important development of coding related skills is performed among students: an increase in the numerical collection, identify patterns in numerical successions and order relationships, as well as basic problems about quantities that are iterated, a skill that undoubtedly establishes pedagogical basis for the future programmer.

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**Figure 4. Computational Thinking and Coding in the Primary Education System in Mexico**

<table>
<thead>
<tr>
<th>Degree</th>
<th>Topics</th>
<th>Practical Learning Related to Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Numbers and variation (1 to 100) -Natural Numbers</td>
<td>Diversify counting procedures, expand range of numerical succession (1 to 100)</td>
</tr>
<tr>
<td></td>
<td>-Addition and Subtraction -Shape, space and measures</td>
<td>-Situations of comparison and equalization</td>
</tr>
<tr>
<td></td>
<td>-Magnitudes and measurements -Data Analysis: Counting</td>
<td>-Order relations between numbers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Decompositions of numbers with calculator</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Collects data and makes personal records</td>
</tr>
<tr>
<td>2nd</td>
<td>Numbers and variation (1 to 1000) -Multiplication and Division</td>
<td>Organize a large numerical collection</td>
</tr>
<tr>
<td></td>
<td>-Shape, space and measures -Data Analysis: Tables</td>
<td>-Identification of regularities in written numerical succession and order relations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Calculator use and positional value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Problems about quantities that are iterated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Mental calculation and records of digit products</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Collects, records and reads data in tables</td>
</tr>
<tr>
<td>3rd</td>
<td>Numbers and variation (1 to 10,000) -Basic fractions</td>
<td>Part-everything relationship, distribution and measurement situations</td>
</tr>
<tr>
<td></td>
<td>-Shape, space and measures -Data Analysis: Simple pictograms</td>
<td>-Decompositions of numbers with calculator</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Use the conventional algorithm to subtract</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Calculate mentally with numbers up to three digits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Addition and subtraction with fractions of the same denominator</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Compare and sort the duration of different events</td>
</tr>
</tbody>
</table>
In the third grade of primary school, mental calculation and the introduction of fractions begin to embody a greater challenge for the students and to differentiate those with better learning skills.

In fourth and fifth grade, mathematics difficulties increase with bigger numbers and decimals, the introduction of fractions in operations and problem solving, as well as a growth in the practice and relevance of mental calculation. At the end of the fifth grade, students develop truly relevant concepts for computational thinking through the identification of probability situations and register the results of random experiments in frequency tables (relative and absolute).

Finally, in sixth year the student must handle numbers with any number of figures, fractions and decimal numbers. They will be able to make use and solve problems through the number line which will give them bases of the spatial and mathematical dimensioning (geometry, maps, location, trajectories) which are particularly essential elements for computational thinking and coding.

The most important conclusion is that in this educational level all these learning and logical-mathematical concepts should be accompanied by educational approaches necessary to
transform theory and isolated learning towards a computational and coding direction. Above all, it should function as an early level of stimulation, where interest and enthusiasm towards computational thinking and problem solving is promoted.

4.2. **SECONDARY SCHOOL**

During secondary education, the transformation of the students' personal and social life is radically modified. They register biological and mental changes that affect their ability to learn. In addition, students’ experiences provide them with a greater ability to develop the approaches of *creating, debugging, and persevering*, since they have more educational maturity helpful for developing computational thinking.

**Figure 5. Computational Thinking and Coding in the Secondary Education System in Mexico**

<table>
<thead>
<tr>
<th>Degree</th>
<th>Topics</th>
<th>Practical Learning Related to Coding</th>
</tr>
</thead>
</table>
| 1st    | -Numbers, algebra and variation  
- Proportionality  
- Equations  
- Functions  
- Patterns and equivalent expressions  
- Shape, space and measures  
- Magnitudes and measurements  
- Data Analysis: Central Trend Measures | - Convert decimal fractions to decimal notation  
- Calculate the perimeter of basic polygons and circle by developing and applying formulas  
- Calculates the volume of prisms  
- Uses and interprets the measures of central tendency (mode, arithmetic mean and median) and the range of a data set and decides which of them suits best in the analysis of the data in question |
| 2nd    | -Numbers, algebra and variation  
- Inverse proportionality  
- Equations: linear equation systems with two unknowns  
- Functions  
- Multiplication and Division  
- Shape, space and measures  
- Figures and geometric bodies  
- Data Analysis: histograms, frequency polygons, linear graphs | - Solve multiplication and division problems with negative numbers  
- Solves problems of direct and inverse proportionality and proportional distribution  
- Algebraic solution of systems of two linear equations with two unknowns  
- Analyzes and compares situations of linear variation and inverse proportionality  
- Collects, records and reads data in histograms, frequency polygons and line graphs  
- Determines the theoretical probability of an event in a random experiment |
| 3rd    | -Numbers, algebra and variation  
- Quadratic equations  
- Basic fractions  
- Functions: graphical and algebraic  
- Shape, space and measures  
- Pythagorean theorem  
- Data Analysis: Comparison of two data sets | - Determines and uses divisibility criteria and prime numbers  
- Use techniques to determine mcm and MCD  
- Algebraic solution of quadratic equations  
- Analyzes and compares various types of variation from their tabular, graphical and algebraic representations |
In the first year, students learn fractions and decimals as in the previous level (it is important to direct this knowledge through attractive and stimulating channels for the student). In addition, students develop and apply formulas for the calculation of volume of straight prisms and perimeters of polygons and circles. Another relevant learning is the use and interpretation of measures of central tendency (mode, mean, median) for the range of a data set, establishing which of the measures are appropriate considering the analyzed data.

All these skills promote mathematical and analytical thinking necessary for computational thinking, however it still lacks background when it comes to translating it to a computational or coding environment. It is important to introduce information technologies early into the learning process to stimulate students’ interest in acquiring these skills.

In the second year, a greater challenge is established in terms of concepts and practical application of mathematics with the introduction of negative numbers, problems of direct and inverse proportionality, proportional distribution problems and the formulation and solution of the first algebraic problems through the solution of a simple linear equation system, the analysis of situations of linear variation as well as the determination of the theoretical probability of an event in a random experiment.

These new learnings can establish an important starting point for preferences and liking for mathematics, as well as for skills related to CT.

It is important to identify those situations that make it difficult for students to learn adequately to solve the learning deficit and, at the same time, apply this knowledge to the computational and coding world.

The third grade of high school is probably the most important year for students and their possible interest on computing and coding. Students learn things such as solving problems through quadratic equations, divisibility criteria, analyzing diverse types of variation through
tabulation, draw graphics, algebra, and comparing trends of central measurement and dispersion in two data sets.

This knowledge represents an important expansion in the notion of knowledge in students, even in topics and perspectives such as the adoption of abstract concepts, patterns, and other learning relevant to the programmers’ thinking.

In addition, during this stage it is particularly important to promote the educational approach of collaborating because coding and computational thinking cannot be individual, it needs plurality of ideas and the ability to solve problems through teamwork.

When the student finishes secondary education between the ages of 14 and 16, they face an especially crucial decision for his educational and professional future since they choose among multiple options of upper middle school education.

### 4.3. Upper Middle School (Baccalaureate)

Before entering upper middle school education, the student must choose the type of education profile between technological and general baccalaureate, where the former is oriented to the development of learning and skills related to computational thinking and coding, delving into subjects such as: algebra, logic, geometry and trigonometry, analytical geometry, differential calculus, integral calculus, probability, and statistics.

Some of the most recognized institutions such as UNAM, the IPN, DGETI offer upper middle school degrees that include technical careers in coding or software development, although this offer is still limited and reserved for students with the best academic performances, even an admission exam must be taken to access any public school at this level in Mexico.

At this level, mathematical subjects and computational skills are considered an element, but not transcendental, because students usually prefer careers related to humanities, arts and other types of biological and industrial sciences not directly related to computational thinking and coding.
In the specific case of SEP, two types of curricula at the federal level are offered, one known: general baccalaureate and technological baccalaureate, where the first contemplates a few hours of curricular subjects whose objective is aligned with coding (18.6%), and the second which includes 42.2% of the total hours where students learn skills indirectly related to coding and software skills.

Students need to decide at the end of secondary education what type of upper middle school they are willing to pursue, either technical or professional. That is the relevance of creating a pedagogical mechanism intended for students to become interested in computer science and coding areas.
Educational Offer: Technician in Coding and Software Development in upper middle school level

The most remarkable case and with greater recognition is the Career of Technician in Coding offered by the IPN at the upper middle school level through the Center for Scientific and Technological Studies (CECyT) number 9, Juan de Dios Bátiz Paredes, where graduated coding technicians obtain skills such as technical support in analysis and design models, build codes, tests, code source maintenance of one or more software components, automatization of procedures and the creation of graphical user interfaces, as well as the development of interface prototypes.

Similarly, the UNAM, through its National Preparatory School where only 25% of its campuses offer the option of pursuing a professional technical career related to software processes.

DGETI offers in the 32 states of the country through its Educational Centers the option of studying the technical career in coding in 323 campuses throughout the country, in its various institutions (CBTis, CETis and CECyTES).

However, those institutions face difficulties regarding the integration of the graduated students into the labor market since their degree is not considered by employers as a professional degree.
5. **Best Coding Practices in Education and Learning**

Computational thinking can be used throughout the curricular map as a tool when solving problems, exercises, and other activities in all fields of knowledge. Using computational thinking, students exercise their technological skills, empathy, perseverance, imagination, efficiency, among others.

That is, teaching of computational thinking through programming provides skills such as handling a computer, keyboard, applications; encourages the application of values such as empathy or perseverance, and exercises logical-mathematical knowledge when making models, solving problems, and data analysis.

Therefore, we will review practical applications of computational thinking and programming teaching at international level, and we will propose public policy guidelines involving these knowledge and skills in the NES.

**5.1. Applications: International Cases**

In Ireland, some aspects of computational thinking related with language teaching were identified within the curricular map. In computational thinking we find algorithmic thinking, information systems, data, variables, functions, decomposition, control structures and programming. Of these, it was found that programming, decomposition, algorithmic thinking, and information systems are inserted in the teaching of the local languages.

For example, decomposition and algorithmic thinking can be taught as the identification and elaboration of narratives and ordered stories in sequences of events or objects. Programming and analysis by decomposition can be taught as the analysis and comparison of language structures.

In other words, through exercises and activities inserted in the teaching of the language (Gaelic and English), the Irish curricular map strengthens the computational thinking applied to the language.

It was found that through robotics clubs and workshops, students develop essential skills for computational thinking. In addition, the participation, teamwork, evaluation, competition,

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critical thinking, and other skills acquired in these activities encourage an adaptable, proactive, and future-oriented education\(^4\). For example, in Greece\(^5\) it was found that teaching programming languages through robotics facilitates learning, and that teaching using traditional methods that simulate a professional work environment can be counterproductive.

### 5.2. **Public Policy: Coding in the Educational System in Mexico**

The Mexico’s education system and its curricula promotes the principles established for computational thinking, nevertheless it lacks the educational approaches that end up consolidating and directing it towards computational and coding application that it seeks to promote.

The following table summarizes some current approaches of the educational system and computational and coding thinking, as well as public policy proposals to reform and promote the development of these educational skills applied to the coding ecosystem.

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## Figure 7. Public Policy Proposals for the Introduction of Computational Thinking and Coding in the National Educational System in Mexico

<table>
<thead>
<tr>
<th>Situation in Mexico</th>
<th>General Proposals</th>
</tr>
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<tbody>
<tr>
<td>• Teachers are not familiarized with the concepts of computational thinking and coding.</td>
<td>• Education about computational thinking to teachers through certifications and courses</td>
</tr>
<tr>
<td>• Poverty in Mexico prevents access to devices and information technologies.</td>
<td>• Conduct a program to address the gap in access to information technology in economically lagging schools.</td>
</tr>
<tr>
<td>• The world of coding is a little-known concept at a social level.</td>
<td>• Promote the study of computational and coding careers, through the dissemination of their benefits in salaries and greater labor demand.</td>
</tr>
<tr>
<td>• There is no adequate promotion of computational careers.</td>
<td>• Promote scholarships and financial support aimed exclusively at the study of careers related to computing and coding</td>
</tr>
<tr>
<td>• There are students who cannot continue with their studies due to economic deprivation</td>
<td></td>
</tr>
</tbody>
</table>

### Areas of Educational Opportunity

<table>
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<tr>
<th>Proposals for Educational Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Curricula in Mexico do not consider the educational approaches needed to translate computational thinking into computational applications.</td>
</tr>
<tr>
<td>• Placing computational thinking as the guiding axis of education at the federal level, is not about the use of computers but about mathematical and logical thinking related to the use of ICT’s for problems solution.</td>
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<tr>
<td>• It is important to start in a common coding language for all upper middle school level institutions</td>
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Source: Own elaboration, The Competitive Intelligence Unit

Teachers and professors are unfamiliar with the concepts of computational thinking and coding, so training is necessary to acquire the pedagogical background of computational thinking.
Similarly, regional poverty prevents access to devices and information technologies in some schools that limit computational learning in students with greater economic disadvantages.

A connectivity policy will help to reduce ICT access gap among schools, also it is necessary a policy of financial aid and scholarships aimed exclusively at the technical and professional study of careers related to coding and software development.

There is a need for promoting the potential benefits of studying these careers, since they represent an attractive opportunity for social mobility. Another way to promote coding is through public programs and contests that awaken the interest of the population.

Important modifications are required to the SEP curricula, it is important that the educational approaches of computational thinking become the educational backbone of the NES by considering in the curricula the concepts of tinker, creating, debugging, persevering, and collaborating.

Additionally, the development of free courses and workshops on computational skills and coding in public and private schools is desirable, as well as the creation of curricular subjects directly linked to coding for the upper middle educational level.

The above proposals together represent a way to introduce computational thinking and coding into the Mexican educational system, all of them attack problems and educational gaps in regarding computational thinking.
6. CONCLUSIONS AND POLICY RECOMMENDATIONS

The Education System in Mexico comprises different education levels: initial education preschool, primary, secondary, upper middle school, and higher education under the terms established by the Political Constitution of the United Mexican States.

Meanwhile, coding and computational skills have increased their relevance in an increasing digital society facing incessant disruptions due to new technologies and digital goods and services. Thus, analyzing the teaching of computational skills in basic and secondary level in Mexico is pertinent and relevant as well as to draw some public policy recommendations. These recommendations aim to better prepare students for future jobs and challenges by developing soft skills for any type of job as well as hard skills for more specialized technological jobs.

Computational Thinking (CT) is a problem-solving method capable of improving knowledge acquisition in the Mexican education system.

Educational programs at a basic level in Mexico already consider many educational concepts that computational thinking requires, however, there are no adequate pedagogical approaches to permeate this educational style among students.

The educational principles established in computational thinking are logic, algorithms, decomposition, patterns, and abstraction. The pedagogical approaches necessary to achieve the acquisition of these concepts are tinkering, creating, debugging, persevering, and collaborating.

This white paper is intended to encourage the inclusion of coding and computational thinking in Mexican education curricula. Some education public policy recommendations based on this research are proposed below:

- Increase the number of public connectivity spots in the Public Sites Connectivity Program, particularly those that correspond to public schools without internet access.
  - To address the Information and Communications Technology access gap in economically lagging schools.
- Promote CT path on the primary school level. At this level, CT concept is not intended to directly teach coding but to create relevant logical and abstract thinking skills among students.
• Include the concept of Computational Thinking in the Mexican curriculum in primary, secondary, and upper middle education, as well as related concepts such as logic, algorithms, decomposition, patterns, and abstractions.
  o While some of these concepts are scattered all over the curricula, nevertheless, for secondary, and upper-middle levels purposes, they should be set in computational, computer, and coding environments, this is to create coding or coding-related courses.
• Include approaches and techniques in the curricula to promote CT among students, such as tinkering, creating, debugging, and preserving.
• Consider Computational Thinking (materialized on skills such as coding and software development) as necessary for the present or future development of innovative ventures and as a tool for workers to increase productivity and, therefore, income opportunities.
• To address Computational Thinking education aspects such as logical-mathematical thinking, promote a more experimental approach, like tinkering, at primary school levels.
  o This could be achieved by using tinkering-based experimentation and video games as learning tools, which would provide students with more coding-environment learning sessions.
  o With this approach, students would have a better understanding of coding concepts and could develop critical thinking and problem-solving skills.
• Implement direct coding sessions at the Secondary level always considering that students do not have previous coding experience. Topics can focus on teaching i) how codes work, ii) internet protocols, and iii) teaching how to write codes.
  o Teachers should ensure that this learning process must happen in a collaborative environment. Coding and computational thinking cannot be individual, they require a plurality of ideas and the ability to solve problems through teamwork.
• Provide vocational counseling at secondary schools aimed at promoting interest in coding and software development technical-level careers which are part of the next education level (upper-middle school).
• Focus coding subjects in the upper-middle level on developing hard skills such as using coding in specific languages, compiling, and executing programs, and developing object-oriented programming skills.

• Promote the importance of upper-middle school technical degrees among students and employers.

• Create “train the trainers” programs for computational thinking and coding at all levels of education.

• Provide relevant teacher’s training such as certified courses so that teachers can familiarize themselves with this pedagogical style and be able to transmit coding relevance to their students properly, as well as computational thinking.

• Promote programming and computing with a social approach:
  d. Free workshops and courses for the general population.
  e. Attractive coding and software development contests for students and the general population where for example, solutions to social problems or to meet SDG 2030 objectives are proposed.
  f. Execute advertising campaigns to inform about the benefits of learning to code, as well as information about the available educational offer.

• Promote the study of computational and coding careers, through the dissemination of their benefits in salaries and greater labor demand.

• Promote scholarships and financial support aimed exclusively at the study of careers related to computing and coding.

• Develop collaborative and problem-solving skills among students.

The above proposals can facilitate the introduction of computational thinking and coding into the Mexican educational system, all of them addressing problems and educational gaps, promoting a more coding-friendly educational ecosystem as well as helping to reduce the lack of specialized and innovative workforce in the country.
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